Response to Comments

Dated September 18, 1991

on

10 CFR Part 20.302 Application

submitted by

Dow U.S.A.

The Dow Chemical Company
Midland, Michigan 48674

for

Disposal of Magnesium-Thorium Slag Material

at the

Salzburg Landfill Disposal Facility

August, 1992

A/3

submitted by

DAMES & MOORE
ONE BLUE HILL PLAZA, SUITE 530
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ERRATA

LICENSE APPLICATION
ON-SITE THORIUM DISPOSAL AT THE SALZBURG LANDFILL,
MIDLAND, MICHIGAN

Errata

Page VII - Revise "MCi" to read "mCi".

Revise "PCi", "PCi/g", "PCi/l", and "PCi/m^3" to read "pCi", "pCi/g", "pCi/l", and "pCi/m^3", respectively

Page 4, last line, 3rd column in Table 1.2-1-Replace "25" with "a few mrem".

footnote 2 - Replace with "Based on NUREG 1101, vol. 2 limit for 10CFR 20.302 disposal".

Page 14, Table 3.1-2, Thorium Decay Scheme

Change the half-life of Radium 228 from "6.7 yr" to "5.8 yr".
Change the half-life of Polonium 212 from "10 sec." to "3 x 10^{-7} sec".

Page 20, Figure 3.7-2

Replace Figure 3.7-2 with the attached Figure 3.7-2 (Rev.1), entitled "Location of Magnesium/Thorium Storage Site (Bay City, Michigan)".

After Page 58

Attached Table 7.4-2 should be inserted at this point in the text.

Page, 60, Figure 7.4-2

Replace Figure 7.4-2 with the attached Figure 7.4-2 (Rev.1), entitled "Salzburg Landfill Monitoring Wells Location Map"

Page 86, second paragraph

Replace the paragraph with the following:
"the migration of the daughter products of Th-232 would also be inhibited because of the slow transport of water through the liner and chemical retardation of the elements in clay. These factors, combined with the relatively short half-lives of the Th-232 daughters, would result in limited movement of these constituents from the cell into the liner or cap before they decayed".

Page 98, First sentence of next to last paragraph

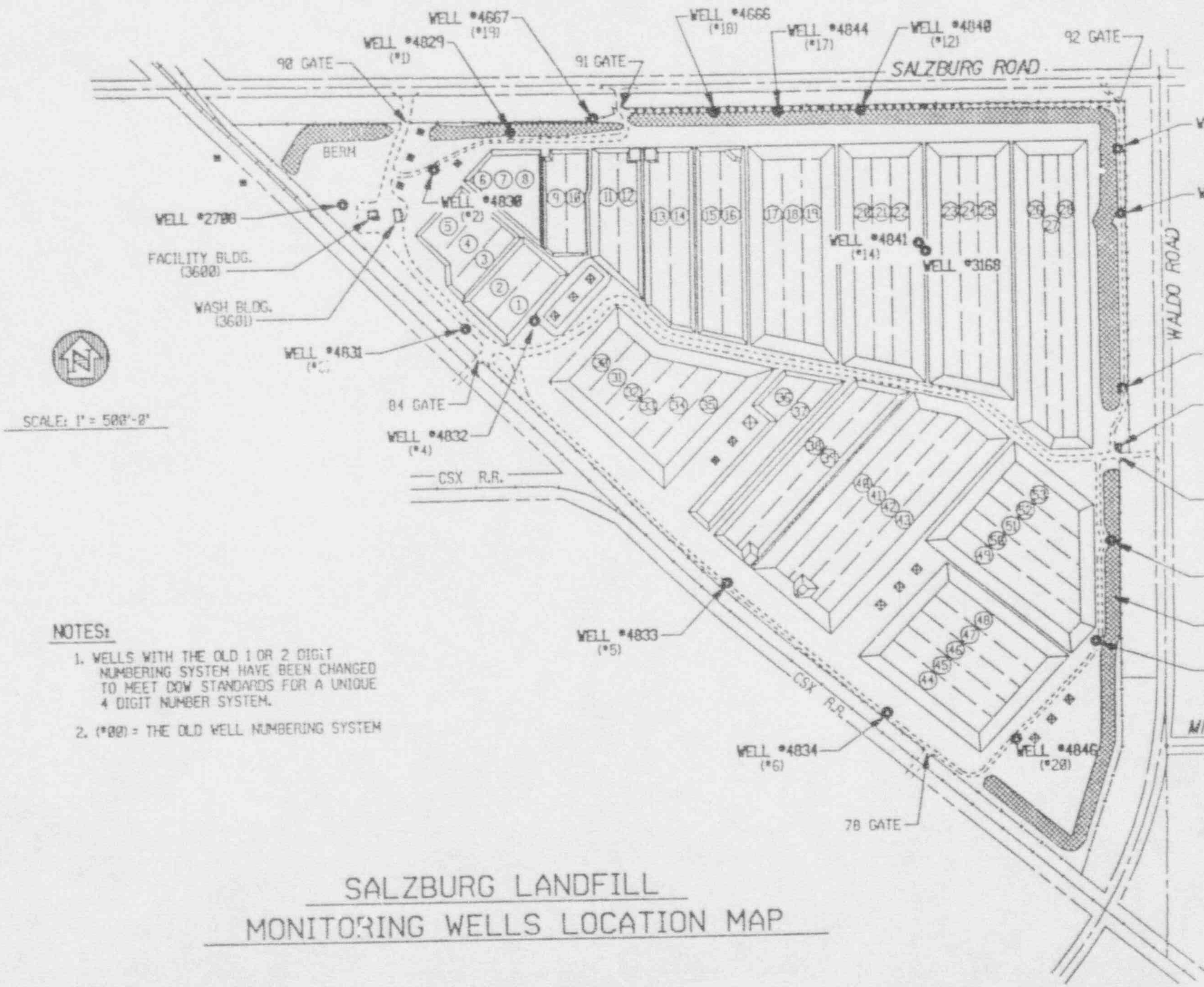
Revise the sentence as follows:
"Smoking, drinking, eating or other activities that would enhance the transfer of radionuclides into the human body will be prohibited in the contamination and contamination reduction zones".

Appendix I Insert the attached Table I2.0 after Table I1.0 in the text.
Appendix I Add the attached list of "References" at the end of Appendix I.

TABLE 7.4-2

RESULTS OF PRIVATE WELL SURVEY (1984)

MAP LOCATION	OWNER NAME	WELL DEPTH	GENERAL COMMENTS
	Louis F. Bober	35'	Well is a "dug well", approx. 30" in diameter and located right outside the basement wall in back of the house. Well has perhaps 10 ft of masonry at the top in back of the house. Well has perhaps 10 ft of masonry at the top. Below is an uncased and unscreened open hole. The well dries up sometimes in the summer, and the owner has to use bottled water. Well is 37 years old.
(Removed)	Kenneth Hutfilz	106'	They had a dug well, but that went dry in the summer, so in the early sixties this deep well was drilled.
36-11	James Trout	40' to 60'	Have had problems with their well. Water smells bad. Had an analysis done which said it was high in sulfur. Water at time of this survey has an H S odor.
36-8	John Hochstetler (Dow)	134'	Have a water softener. Water has a brine taste, and do not use it for drinking or cooking. Bring in water for those purposes. Log in Appendix C.
Removed	Frank May	?	Has [illegible] of water. Previous owner sold water to homes on Waldo from Salz[illegible] Milner Roads. Owner believes pipeline is still in because Mr. Trout hit an underground line in his yard last year and Mr. May lost pressure in his water system until the line was capped.
36-7	J. Lewis Formerly Spencer	65'	Water quality is not adequate. Have trouble when neighbors make prolonged use of their well. Reported that many neighbors do their wash outside because water supply is not adequate. Log in Appendix C.
36-5	Charles Witherspoon	160'	Well is 6" in diameter, but only yields 2 gals/min. Were out of water frequently until he lowered the drop-pipe. Water smells and has a lot of rust sediment in it. In 1973 drilled 232' in an attempt to develop a new well Log of this abandoned well in Appendix C.
36-9	Dow (Formerly Gutchak)	98'	Water is salty and has a "fishy" smell sometimes.
(Removed)	Frank Baker	141'	Owner reports plenty of good quality water. No problems with bad smell or taste.



NOTES:

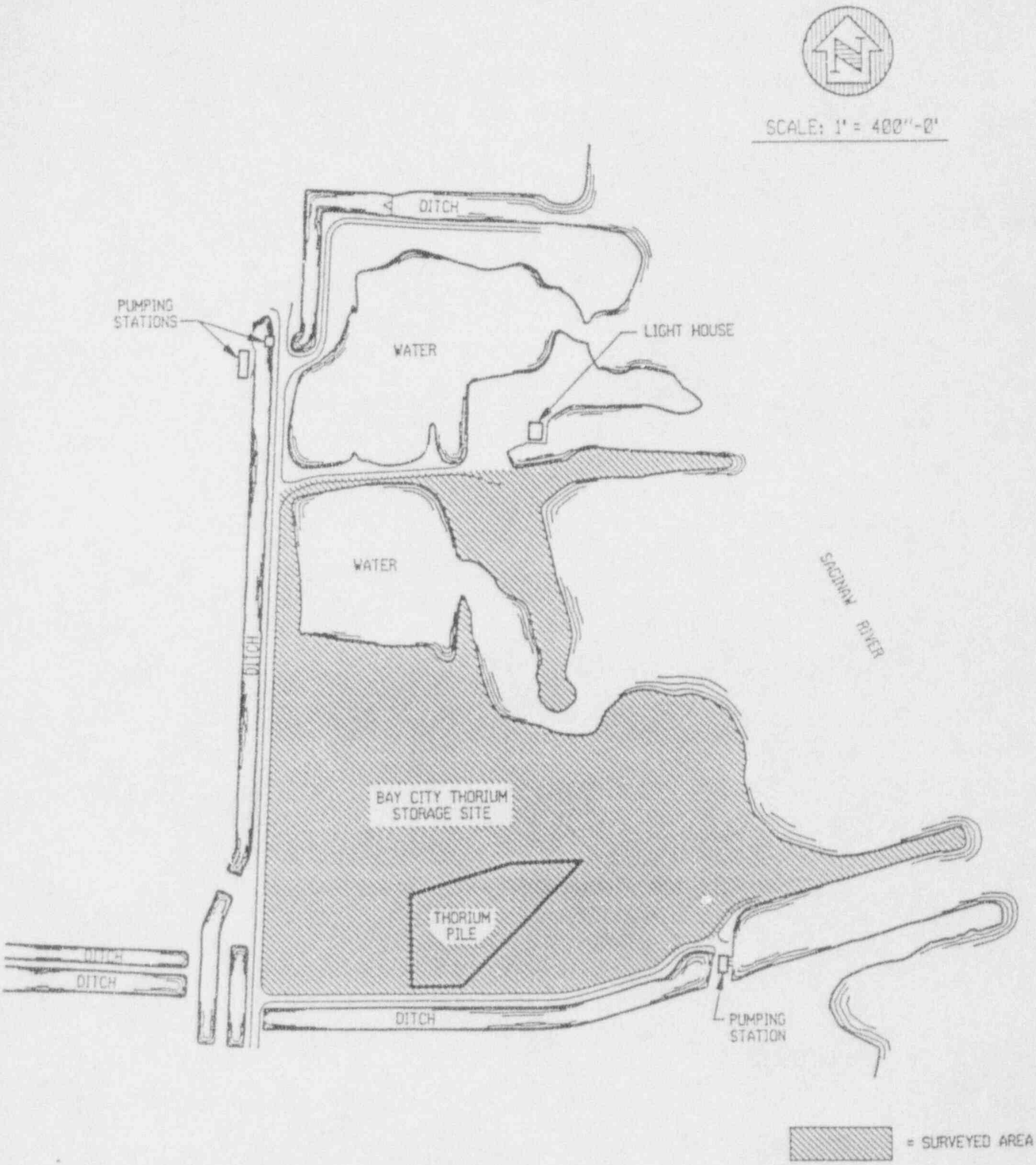
1. WELLS WITH THE OLD 1 OR 2 DIGIT NUMBERING SYSTEM HAVE BEEN CHANGED TO MEET DOW STANDARDS FOR A UNIQUE 4 DIGIT NUMBER SYSTEM.
2. (#00) = THE OLD WELL NUMBERING SYSTEM

SALZBURG LANDFILL

MONITORING WELLS LOCATION MAP

Figure 7.4-2

REV. 1
2/27/92



LOCATION OF MAGNESIUM/THORIUM STORAGE SITE
(BAY CITY, MICHIGAN)

11/25/91

Dames & Moore
Figure 3.7-2
Rev. 1
11/25/91

Table I-2.0

Occupational Air Particulate Dose

(A) Bay City Material

Activity	Total Exposure Time (hrs)	Total Dose (mrem/activity)		Maximally Exposed Individual (mrem)
(1) Excavation of material and movement to staging area	1000	WB	3.7	0.37
		L	114	11.4
		BM	174	17.4
(2) Emplacement and cover of material at Salzburg.	500	WB	1.9	0.31
		L	57	9.5
		BM	87	14.5
(3) Health Physics Monitoring Support				
(a) at Source	200	WB	0.7	0.4
		L	23	11.5
		BM	35	17.5
(b) at Salzburg	1000	WB	3.7	2.9
		L	114	57
		BM	174	87

(B) Midland Material

Activity	Total Exposure Time (hrs)	Total Dose (mrem/activity)		Maximally Exposed Individual (mrem)
(1) Excavation of material and movement to staging area.	300	WB	0.2	0.02
		L	5.3	0.5
		BM	8.2	0.8
(2) Emplacement and cover of material at Salzburg.	150	WB	0.1	0.01
		L	2.7	0.5
		BM	4.1	0.7
(3) Health Physics Monitoring Support				
(a) at Source	60	WB	0.04	0.02
		L	1.1	0.6
		BM	1.6	0.8
(b) at Salzburg	300	WB	0.2	0.1
		L	5.3	2.7
		BM	8.2	4.1

REFERENCES

(DOE-86) U.S. DOE, Draft Environmental Impact Statement, Remedial Actions at the Former Climax Uranium Company Uranium Mill Site, Grand Junction, Mesa County, Colorado: DOE/EIS-0126-D, 1986.

(DOE-87) U.S. DOE, Environmental Assessment of Remedial Action at the Grand Junction Projects Office Facility (Draft): Grand Junctions Project Office, CO, 1987.

(EI-1973) M. Eisenbud, "Environmental Radioactivity", second edition, Academic Press, 1973.

(NRC-80) U.N. NRC, "Final Generic Environmental Impact Statement on Uranium Milling", NUREG-0706, 1980.

TRANSDOS Dames & Moore, "TRANSDOS, A Computer Program for Calculation of Radiation Doses to Individuals Along the Shipping Route of Gamma Emitting Materials, 1981.

RESPONSE TO COMMENTS

RESPONSE TO COMMENTS DATED SEPTEMBER 18, 1991
ON 10 CFR PART 20.302 APPLICATION
SUBMITTED BY DOW CHEMICAL FOR
DISPOSAL OF MAGNESIUM-THORIUM SLAG MATERIAL AT THE
SALZBURG LANDFILL, MICHIGAN DISPOSAL FACILITY

COMMENT (1)

Page VII "MCi = millicurie = 10^{-3} Ci" should be mCi and "PCi = picocurie = 10^{-12} Ci" should be pCi. The capital M refers to mega = 10^{6}, while the capital P refers to peta = 10^{18}.

RESPONSE

See attached errata sheet for corrections

COMMENT (2)

Section 1.1 The licensee needs to clearly state that the ultimate goal of this activity is to terminate NRC source material license number STB-527.

RESPONSE

Upon completion of the slag material removal operations at Midland and Bay City, and validation by Dow and the NRC that residual radioactivity levels are within allowable limits, Dow intends to apply for termination of license STB-527.

COMMENT (3)

Section 1.1 Is it DOW's plan to make the Salzburg Landfill available for the magnesium/thorium slag wastes now in the Kawkawlin landfill?

RESPONSE

As discussed in the meeting of December 4, 1991 between NRC and DOW, DOW will consider disposing of the pile of thoriated material on the surface of the MDNR property at the Kawkawlin landfill in Cells 36 & 37 at the Salzburg Landfill in conjunction with the comparable Midland and Bay City material. Prior to DOW assuming this responsibility, the NRC will have to have the material characterized to assure that is compatible with the Midland and Bay City material, validate that the volume of material will not exceed the remaining capacity of Cells 36 & 37, and assume liability for any future impacts from disposing of the Kawkawlin material. DOW would intend to pick up the material in conjunction with the Bay City material, truck it to the Salzburg Landfill, and emplace it in Cells 36 & 37 with the Midland and Bay City material prior to cell closure.

COMMENT (4)

Section 1.1 The application indicated that if Cells 36 & 37 were not filled by the material from the two sites, Bay City and Midland, that earth material would be added to complete the cell. Information should be provided on these other materials, where they are generated, what, if any, contaminants are in these soils, etc.

COMMENT (5)

Section 1.1 It is suggested that the licensee not put anything in the cell besides the licensed material. If non-licensed must be put into the cell, describe the non-licensed material and investigate the possibility that it may increase the solubility of the magnesium/thorium slag.

RESPONSE TO (4) AND (5)

Cells 36 & 37 will only be filled with licensed material from the 2 thorium sites. No other material will be used in these cells.

COMMENT (6)

Section 1.1 The current NRC soil clean-up standard for thorium is the Branch Technical Position on burial or on-site storage of uranium and thorium waste (46 FR 52061). The licensee must show that the proposed thorium (and daughter) concentration of material to be left in-place will not give a dose over a few mrem/yr total effective dose equivalent (TEDE).

RESPONSE

It is intended to remove thorium contamination to residual levels below 10 pCi/g total thorium. Since daughters are assumed to be in equilibrium with the parent Th-232, the cleanup criteria can be translated to 5 pCi/g Th-232 above background. All calculations assume the presence of Th-232 and all daughter in equilibrium at 5 pCi/g. Even if equilibrium has been disturbed by process or environmental action the short lived daughters of Th-232 will return to equilibrium in about 30 years, or will be produced at the equivalent rate by the decay of Th-232. Therefore, for the important intruder pathways of direct radiation, dusting, and agriculture, analysis over 50 years will produce the same results as a 10,000 year analysis.

In response to the comments herein, and discussions with NRC personnel, calculations have been performed of TEDE for an intruder scenario with the hypothetical condition of no soil layer over the residual material. Both the MAXI and RESRAD models were used to perform these analyses. In reality clean soil will be emplaced over the residual material to restore the site. The postulated scenario of loss of this cover due to long-term erosion taken together with the consideration that institutional control over the site will be eventually lost permitting intrusion to the residual material makes it essentially impossible to achieve a TEDE of less than "a few mrem/yr" (see below). This unrealistic combination of factors would require reduction of residual concentrations to less than 1 pCi/g Th-232 above background at the site (and any other site containing thorium). As discussed below, the more realistic assumption of the maintenance of a minimal clean fill of 10" over the residual material would reduce long-term total dose to about 10 mrem/yr; or, the presumption of continued control over site access would eliminate the presence of the intruder.

3 months ?

Calculation of direct radiation exposure to an intruder from a released site depends on the assumed duration of exposure and the protection offered by a structure such as a residence. The code MAXI uses a default duration of 2000 hours/year. For the material in question, and the postulated scenario of the residual material being directly on the surface, this yields an estimate of 24 mrem/yr direct exposure. An additional 18

8760 hr/yr

mrem/yr of exposure is received through dietary pathways and inhalation. Similar results are obtained from RESRAD except that a factor of 0.6 is used to correct for annual direct exposure, as opposed to the factor of 0.23 (2000/8760) used by MAXI. This accounts for almost all the difference between MAXI and the RESRAD results of 64 mrem/yr from direct and 18 mrem/yr from other water-independent pathways. The RESRAD results are taken at T=100 years when the code has reached equilibrium.

These results are considered to be highly conservative and unrealistic. It is unlikely that a person could grow an entire diet on a 1900 m^2 plot such as the Midland site or the 8400 m^2 available at Bay City. Time spent off-site and shielding would produce lower exposures than suggested by the 0.6 direct exposure factor used by RESRAD.

Doses will actually be well below those calculated by the code due to several factors. Though not intended as a radiation protection mechanism, the fill that will be used to level and grade the excavated sites at Midland and Bay City after slag excavation will function as an effective shield. As shown in Figure 1 25 cm of dirt (10 inches) would reduce the total dose from all pathways to about 10 mrem/yr (the peak at about 2000 years is from leaching and groundwater transport-see the response to Comment No. 43, 44). Actual doses will also be even lower since residual radioactivity will be a maximum of 5 pCi/g Th-232, and will be lower throughout most of the site because additional soil will be removed to fill Cells 36 & 37. Also, the 1 meter thick layer of residual contamination is a conservative modeling assumption. Thorium does not leach readily, and prior experience shows soil contamination to commonly be limited to the top 15 cm (6 inches).

The related RESRAD and MAXI runs supporting the above discussed results are included in Appendix A.

The TEDE to a member of the off-site public (outside the site boundary) or to a non-nuclear worker in a on-site building from the covered or uncovered residual material at the 5 pCi/g level would be inconsequential (<<1 mrem/yr) because of the distance to the receptor from the source and the lack of any dietary pathways.

COMMENT (7)

Section 1.1. Please include the dry bulk density of the thorium slag and the glacial till.

RESPONSE

The average dry bulk density of the thorium slag is 66 lb/ft^3 (as measured for the same material in the Madison, Illinois site) and of the glacial till is 135 lb/ft^3. The bulk density of the slag is highly variable.

COMMENT (8)

Table 1.2-1 The regulatory limits for non-nuclear workers and general public, including inadvertent intruders, should be "a few mrem/yr" for a 10 CFR 20.302 disposal (see NUREG-1101, Volume 2). The low-level waste management regulation, 10 CFR Part 61, does not apply to a 10 CFR 20.302 disposal.

RESPONSE

See attached errata sheet for corrections

COMMENT (9)

Section 2.0, Appendix A and Appendix I The application discusses six possible alternative dispositions for the thorium wastes. However, in the case of the three viable alternatives, namely; 1) disposal at an existing LLW site, 2) on-site temporary storage followed by off-site disposal at a future LLW site, and 3) on-site disposal under 10 CFR Part 20.302, incomplete cost estimates and radiological impacts analysis are given. What is required is cost estimate information on alternatives 2 and 3 above. Also, radiological impact information on alternatives 1 and 2 above need to be determined. In addition, cost estimates and a radiological impact analysis for shipment by bulk to an existing or proposed bulk disposal site (e.g., Envirocare of Utah or Dawn Mining of Washington State) need to be included in the application.

RESPONSE

In order to provide a basis for evaluating comparative costs for the "viable" remedial alternatives, complete cost estimates are provided in Appendix B. The cost estimates have been updated since the original estimates are over 2 years old. In summary, the estimated costs for these alternatives are;

	Remedial Alternatives	Estimated Cost ($)
(1)	On-site disposal at the Salzburg Landfill under CFR 20.302	4,978,000
(2)	Disposal at an existing LLW site (Beatty, NV)	325,728,000
(3)	On-site temporary storage followed by off-site disposal at a future LLW (i.e., Compact) site.	392,187,000
(4)	Disposal at the Envirocare facility in Clive, Utah	28,224,000

Thus, in addition to the comparative advantages and disadvantages discussed in Section 2.0 of the License Application, the considerably lower cost of the on-site disposal alternative is another factor in favor of this alternative.

Comparative radiological impacts can be weighed by considering the analyses in Appendix I of the License Application for the on-site disposal option at the Salzburg Landfill, and comparing parameters in the other alternatives that would tend to change these doses.

The radiological impacts associated with the off-site disposal options for excavation, vehicle loading and unloading, emplacement of the material at the disposal site, cell closure and post-closure are essentially comparable to the Salzburg Landfill disposal option. The primary variations are: (1) exposure to truck driver transporting the material and; (2) the total population exposure along the transport routes. These variations result from the difference in transport distance to each disposal location. The total population exposures along the transport routes have been calculated using the IMPACTS-BRC Version 2 Code. The exposures for each disposal alternative are compared in Table 1 for these transport exposures. All other exposures are essentially comparable.

It should be noted that the long-term post-closure exposures from the thoriated material to an inadvertent intruder at any of the potential disposal locations for the worst case hypothetical scenario of loss of institutional control in conjunction with erosion of the cover would be essentially the same. In fact, the excellent containment capabilities of the proposed composite cover at the Salzburg Landfill would permit material isolation for at least as long as that projected for the future compact site, and likely longer than for the other sites. Nor is the current sparse population or land use at the Clive and Beatty sites a basis for projecting that an intruder scenario is not feasible at those sites in the future since demographics and land use change. It is therefore suggested that the exposure for this hypothetical scenario is not a basis for evaluating the suitability of these disposal locations for the Midland and Bay City material. (Also see response to Comment No. 6 and 41).

COMMENT (10)

Section 2.2 There is no current prohibition to disposal of high volume, low activity material at commercial disposal facilities. In addition, the discussion of radium contaminated material in this section are inapplicable to this case as the thorium wastes are licensable source material.

COMMENT (11)

Section 2.4 The NRC is unaware of any concentrated thorium waste that would be unacceptable for disposal at a commercial low-level waste disposal facility. All thorium waste material would be a class A waste regardless of its concentration.

RESPONSE TO (10) AND (11)

The statement relative to disposal of high volume, low activity material at commercial disposal facilities was not intended to imply a prohibition, but to reflect negative attitudes then conveyed (1989) to Dow in conversations with disposal facility management as to accepting this type of material in preference to higher activity material from out of state sources. We recognize that disposal of this Class A thorium waste at a commercial disposal facility is a viable alternative at this time, and have reflected the disposal costs and special fees (surcharges) associated with disposal of the material in 1992 into the cost estimates in response to Comment No. (9).

The discussion of problems associated with shipping radium-contaminated waste to a commercial disposal site was not intended to apply directly to the thorium wastes. We recognize that as licensable material, the thorium waste would be considered in a different manner than radium material. The intent of citing the examples of difficulties in disposing of radium material was to emphasize the then-existing problems associated with disposal of high volume, low-activity bulk material from out of state remediation projects.

COMMENT (12)

Section 2.6 Another disadvantage would be possible state or compact restrictions, under the Low-Level Radioactive Waste Policy Amendments Act, that would prohibit disposal of the low wastes at the Salzburg Landfill regardless of NRC approval of the 10 CFR 20.302 disposal.

RESPONSE

This subject was discussed with the appropriate State personnel prior to submittal of the application. We are not aware of any restrictions relative to the Compact that would prohibit disposal of this thorium material at the Salzburg Landfill.

COMMENT (13)

Section 3.0 The application did not contain detailed soil removal/closure/remedial action plans or citations for plans to ensure all contaminated material is adequately removed when site restoration occurs. These details need to be cited or provided.

RESPONSE

The application has been prepared to be responsive to the requirements of 10 CFR 20.302 as amplified by NUREG 1101. The detailed plans and procedures requested in this comment and in other comments that relate to the implementation of the remediation process are appropriate for inclusion in a work plan. The plan will be prepared and submitted for NRC and agency review subsequent to this response to the comments on the license application. An outline of the contents of the work plan is provided in Table 2.0. It is our understanding that the NRC will proceed with the review and approval of the license application pending receipt of the Work Plan.

COMMENT (14)

Table 3.1-2 There are incorrect values given for the half-lives of two of the nuclides. The correct values should be Po-212 = 3×10^{-7} seconds and Ra-228 = 5.7 years.

RESPONSE

See attached errata sheet for corrections. Since there is some variation concerning the half-lives provided in various publications, the corrected values have been obtained from Table 3.0 (page 43) of the UNSCEAR publication "Sources and Effects of Ionizing Radiation" of 1977.

COMMENT (15)

At the Bay City site, soil samples were taken until natural soil was reached. At the Midland site, cores were taken until the thorium concentration was less than 5 pCi/g on two consecutive samples. Some soil samples should have been taken down to the water table and groundwater samples taken and analyzed for evidence of leachate.

RESPONSE

The difference in approach to characterizing the 2 sites reflects the variation in available data at the time. The more detailed characterization of the soil at Bay City was required because the extent and variability of the thorium material were not clearly known, and a thorough mapping was required to determine volumetric contamination and distribution. At Midland, source and deposition records gave a better indication of the locations and distribution of the thorium material and showed it to be considerably smaller and more intact than at Bay City. Thus, the conservative approach of using 2 consecutive measurements of less than 5 pCi/g Th-232 was acceptable to validate the intact nature of the "pile".

Appendix C contains the following drawings which provide details of the characterization programs conducted at the 2 sites:

- Thorium Limits Site Plan - Midland Plant - Shows boring locations, depth of contamination (above 5 pCi/g level), and lateral extent of contamination;
- Thorium Site Cross Sections - Midland Plant;
- Bay City Plant - Thorium Delineation Site - Shows boring and survey locations, elevated readings, and contamination boundaries for entire area and for Sections A1-A4 and B1-B4; and
- Bay City Plant - Soil Analysis Boring Locations.

Appendix C also contains a map showing the sampling wells (Figure C-13) and the radionuclide sample analysis for constituents of the thorium and uranium decay chains from wells located around the Bay City thorium pile from the last 4 sampling periods for which results are available. There is no indication of any migration of leachate to the groundwater under the Bay City pile. While there is some variability (solids/salt content of the groundwater is high) the constituent concentrations are essentially at or near background levels. Only well No. 9 shows any significant elevation in Ra-228 levels and this is likely due to high solid content of the samples.

As discussed in the application, sampling and measurements program to be conducted during material removal will carefully validate that the residual Th-232 concentration is less than the standard of 5 pCi/g above background.

COMMENT (16)

Section 3.4 Cleanup of the piles is proposed to be to the 10 pCi/g level. An ALARA analysis should be required to evaluate the cost/benefits of cleaning to an optimum level lower than the proposed level. Since thorium is relatively immobile, cleanup to background may be possible at reasonable cost.

RESPONSE

It is proposed to remove thorium slag & soil material until residual concentrations at the regulatory criteria of less than 10 pCi/g of Th-232 plus Th-228 above background are achieved. There is no regulatory requirement to achieve background levels in removing the material, and it is suggested that this would establish an inappropriate and unsupported precedent. Further, the current characterization of the Bay City and Midland sites does not provide sufficient data to show where background levels are achieved, and a costly and time consuming sampling and analysis effort would be required to obtain this data for use in a predictive analysis.

Since, as was noted in the comment, the thorium is relatively immobile it is likely that the boundary between the slag and the uncontaminated soil is relatively distinct in most peripheral locations around the "piles". It is therefore probable that, when the material removal achieves the regulatory limit, concentrations below this value will also occur. Furthermore, since Dow intends to continue to remove soil from Bay City and Midland sites to fill Cells 36 & 37 (see response to Comment Nos. 4 and 5) additional concentration reductions approaching background will be achieved.

COMMENT (17)

Section 3.5 The application suggests that there are limited amounts of construction debris mixed with the soil-like slag materials that consists primarily of masonry with limited amounts of wood. The application should contain additional information that estimates the total amount of construction debris in the waste material.

RESPONSE

There is or' a small volume of construction debris mixed with the slag material, generally about 1% of the total volume. The debris typically lies close to the surface.

COMMENT (18)

Section 3.6 Identify the types of chelating agents considered in this section.

RESPONSE

Chelating agents include chemical solvents and cleaners that contain hydroxides and carbonates in the acid ranges. No materials of this type are known to be present in the thoriated slag. While there is indication of some carbonates in the clay media at the Salzburg Landfill (See response to Comment No. 29), the presence of these constituents would not change the solubility and mobility of the thorium sufficiently to effect the groundwater (See response to Comment No. 43, 44).

COMMENT (19)

Section 3.8 and Figure 3.7-2 Figure 3.7-2 shows, by cross hatching, the location of the contaminated area at Bay City. This cross-hatched area stops at the fenceline to the east of the slag pile shown in the figure. This is inconsistent with the text in Section 3.8 that states that contamination exists outside of the fence to the east. The application should clarify this discrepancy by either correcting the text and/or figure appropriately, or by explaining why surveying will not be conducted to the east of the fenceline where contamination is known to exist.

RESPONSE

The map in Figure 3.7-2A will replace Figure 3.7-2 in the text (see errata). It shows the extent of the region now surveyed at Bay City and reflects the results of an extensive survey of the site. There are discrete areas of elevated thorium that have been located outside of the fence. The results of the survey will be used as the starting point for the excavation, with all elevated material inside and outside the fence removed to the required cleanup levels.

COMMENT (20)

Section 38.1 and 38.2 The two existing sites are near flowing water and may have been flooded in recent years. No details were provided on sampling the cover and canal sediments for accumulations due to surface runoff.

RESPONSE

The Midland site is not within the 100 or 500 year flood boundaries as shown on the FEMA map in Appendix D. To the best of Dow's knowledge the site has never been flooded. All surface runoff from this site is collected in the Dow plant stormwater collection system which discharges into Dow's wastewater treatment plant.

At Bay City, the sediments in the waters immediately adjacent to the storage site will be sampled in the near-term to assess whether runoff has transported any contamination into these water bodies. Any elevated sediments will be excavated as part of the Bay City material removal program.

COMMENT (21)

Section 3.9 The specific instrumentation used in site characterization or for final surveys should be identified.

RESPONSE

The specific instruments to be used in the in-process and final surveys used in the monitoring programs will be identified as part of the detailed procedures in the Work Plan. The following types of instruments will be used in these programs;

- Portable pressurized ion chamber
- Portable ratemeter scaler and ratemeter scaler
- Alpha scintillation probe
- G-M probe
- 2" x 2" NaI Gamma scintillation probe
- Alpha tray counter
- Air Sampler
- Micro R meter

COMMENT (22)

Section 3.9.2 The application states "it is assumed that the Th-232 daughters are in equilibrium" (page 13). However, the application proposes to not remove contaminated material if the concentration of only Th-232 is below 10 pCi/gm (page 23). The licensee should include the Th-228 daughters in the total thorium activity determination.

RESPONSE

The statement on page 23 is not complete. Dow intends to remove slag and soil until a residual concentration of ≤ 10 pCi/g Th-232 plus Th-228 is achieved. For the purpose of predictive dose analysis it is assumed that Th-232 is in equilibrium with its daughters in the decay chain (See also the response to Comment No. 6).

COMMENT (23)

Section 3.9.2 Sufficient details were not provided on proposed surface and subsurface sampling after the bulk of the thorium is removed to evaluate the adequacy of the proposed plans.

RESPONSE

The information provided in Sections 3.9.1 and 3.9.2 was intended to be a summary description of the in-process, final survey, and sampling programs to validate the removal of the thoriated material to cleanup standards. The detailed survey and sampling plan will be provided as part of the follow on Work Plan (see response to Comment No. 13).

COMMENT (24)

Section 3.9.2 If significant amounts of contaminated material at the 10 pCi/g level are to be left at the Bay City and/or Midland sites then a dose assessment will need to be performed for that site. If such a situation arises, site characterization and characterization of residual contamination at that site will need to be performed in order to do a dose assessment.

RESPONSE

The analyses performed in response to Comment No. 6 assessed the doses as a function of residual contamination levels at Midland and Bay City.

COMMENT (25)

Section 4.0 Describe how Department of Transportation requirements will be met.

RESPONSE

Relevant DOE requirements for transportation of radioactive materials, as defined in 49CFR Parts 171-173 and 177-178, will be strictly adhered to.

Standard 25 yd^3 trucks will be used to transport the material from Midland and Bay City to the Salzburg Landfill. The trucks will be covered with tarpaulins affixed in a manner that prevents material release during transport. The truck tailgates will have pressurized gaskets to also prevent material release. Fugitive dust will be washed from the exterior of the truck and tires prior to leaving the site. Radiation surveys will then be conducted on each vehicle exterior and in the cab to validate that regulatory limits are achieved, and the results recorded. The trucks will be placarded as appropriate for the thoriated material being transported.

Transport papers and Dow's internal manifest system will be used to assure that all shipment and receipt of material is accounted for at each stage in the operation and all records generated will be maintained. The documentation will provide material characterization, records of radiation surveys, routing information, in addition to accountability data. Drivers and material handlers will be given radiation health and safety training prior to starting the job. All personnel will be monitored to ensure that personnel exposures are maintained ALARA. Drivers will be provided with written standards and emergency procedures and in-vehicle communication equipment.

The background radiation levels along the transport route from Bay City and Midland to the Salzburg Landfill have been measured and are provided in the Dames & Moore report entitled "Background Radiological Survey, Bay City/Midland, Michigan of October 11-13, 1989", excerpts of which are included in Appendix E. Radiation levels along the route will be validated to remain at or near background through periodic surveys and post transport survey and sampling.

COMMENT (26)

Section 5.0 Detailed closure and post-closure plans for the Salzburg Landfill were not included or cited in the application.

RESPONSE

Detailed closure and post-closure plans for the Salzburg Landfill (Cells 36 & 37) will be provided in the Work Plan. See response to Comment No. 13.

COMMENT (27)

Section 5.3.1 Figure 5.3-2 indicates that the "Generalized Development Plan" calls for this land to be designated as industrial. The text also states that the "Midland Township Zoning Ordinance has the property adjacent to the site zoned residential [but that this] should only be considered a temporary zoning designation, since the Township Master Plan proposes this property be developed as industrial in the future." It is also indicated that this information was current in 1984. The application should contain the most recent information on the zoning designations for the lands adjacent in all directions to the Salzburg Landfill. Also, the application should contain additional information on the actions that will be taken to implement either the "Generalized Development Plan" or the "Township Master Plan" that will lead to an industrial zoning designation for the lands east of the Salzburg Landfill.

RESPONSE

Appendix F contains drawings No. B2-042-884040 and B2-043-884040-Sheets 1 and 2 titled "Cells 36 & 37 Surrounding Land Uses Map" which show the current zoning designation for the area surrounding the Salzburg Landfill.

Dow continues to purchase the residential property east of the Salzburg Landfill adjoining Waldo Road and Milner Road. Currently the only residences not owned by Dow are the Trout and Bober residences, as shown in the property ownership sketch of Figure 2.0. Dow continues to pursue the purchase of these properties as they become available and conversion of the zoning of all the existing residential property to industrial.

COMMENT (28)

Section 5.3.3 The proposed disposal site is close to a river. Information is needed on the elevation of the site above any water table and above the river's 500 year flood plain.

RESPONSE

The figure in Appendix G shows Cells 36 & 37 elevation in relation to the 100 and 500 year flood elevations of the Tittabawassee River. The location of Cells 36 & 37 is approximately 100 feet above the highest level of the regional aquifer (See response to Comment No. 29 for more detail).

COMMENT (29)

Section 7.2 The geophysical log of the well nearest the proposed disposal cell, well 2396, appears to have the poorest quality clay of the logs furnished. The application should include data from the nearest soil borings which were continuously split-spoon sampled, including blow counts, and geotechnical, geochemical, and hydrogeological testing performed on the samples and the well bores, especially any mineralogical testing of the clays obtained.

RESPONSE

According to the closest soil borings on the northwest (S.B. #3421) and the southeast (S.B. #3398 and 3399) sides of the proposed thorium Cells 36 & 37 at the Salzburg Landfill, the glacial till below 600' USGS datum does contain some thin layers of clayey sand and silt (see boring location map in Figure H-1 and boring logs in Appendix H). These sand and silt layers are historically one-quarter to one-half inch in thickness, and are poor hydraulic conductors due to the fine-grained sediment and extreme compaction. Previous construction at the Salzburg Landfill has shown even the thicker (four to six inches) layers to be isolated from aquifers by rapid dewatering during construction with little or no subsequent seepage occurring. Also, the engineered composite liner, including compacted clay, provides an even more impermeable barrier to flow than the natural clays. Where the sand and silt seams are found, they are horizontal in trend, providing only limited horizontal flow over the short distance they exist. The clay above and below the sand and silt seams inhibit vertical flow through the till.

Sixty-three silt and clay samples from the Lakebed Clay unit were collected at the Salzburg Landfill and analyzed for permeability, Atterberg limits, pH, and particle size. Laboratory permeability ranged from 3.1×10^{-6} to 1.4×10^{-8} cm/sec, with eighty-six percent less than 1.0×10^{-7} cm/sec. Clay particles (<5 microns) comprise a significant fraction of all samples, ranging from 23.4 to 96.2 percent, with an average of 56.3 percent. The liquid limit ranged from 13.0 to 56.5 percent, and averaged 36.2 percent. The plastic index ranged from non-plastic to 35.8, and averaged 16.6. The pH ranged from 7.3 to 8.9. Using the Unified Soil Classification, the unit is predominantly a CL clay with subordinate amounts of CH, SC, SC-SM, ML-CL, and ML soils.

The matrix material of the Glacial Till is predominantly highly compacted sand and silt, with a clay fraction that averages thirty percent (as compared to the Lakebed Clay, averaging greater than fifty percent). Twelve samples from this unit were analyzed for permeability, Atterberg limits, pH, and particle size. Permeability ranged from 1.2×10^{-7} to 2.5×10^{-8} cm/sec, with eighty-two percent less than 1.0×10^{-7} cm/sec. The liquid limit and plastic index averaged 20.4 and 8.4, respectively, which are notably lower than for the Lakebed Clay unit. The pH ranged from 8.0 to 9.0, and the unit is a mix between the SM, SC, SC-SM, CL-ML, and CL Unified classes.

Eight split-spoon samples were taken from soil boring 3421 (250' north of the proposed thorium Cell) and analyzed for sediment characteristics in April, 1985. The results are listed in Table 3.0.

Samples of the Lakebed Clay and Glacial Till from the Salzburg Landfill were analyzed by Dr. Glass of the Illinois Institute of Natural Resources in 1981 for clay mineralogy. X-ray diffraction analyses indicated that 62 to 64% of the clay in both units is illite; 17 to 25% is chlorite plus kaolinite; and 11 to 20% is expandable clays, which in these samples, are alteration products of chlorite. The cation exchange capacity measured low in all samples, ranging from 6.2 to 14 milliequivalents (meq) per 100 grams.

The structure of illite is characterized by "fixed" potassium ions between two planes of oxygen atoms. This forms a very rigid crystalline unit that impedes water penetration between crystal layers. Because of this rigid structure, only limited swelling occurs when saturated. The low cation exchange capacity is due to the high percentage of illite, in which the potassium ions between successive crystal layers are "fixed" or non-exchangeable.

Calcite ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$) were also found in the clay samples, although no quantitative measures were made. The presence of these minerals contributes to the buffering of the clay, preventing the alkaline pH of the clay from being easily lowered. The alkaline pH of the clay reduces the likelihood of dissolution of metals in contact with the natural Salzburg clay, and also the acidification of any groundwater contained or in contact with the clays.

COMMENT (30)

Section 7.3.3 More detail should be provided on how radioactive leachates will be collected, evaluated and treated and on what controls will be placed on the release of radioactively contaminated materials. Under unrestricted release conditions, no leachate treatment should be necessary. As stated in the application, the leachate will be tested to ensure 10 CFR Part 20, Appendix B limits will be met. These limits apply to licensed operations and are based on a 500 mrem/yr dose objective. For unrestricted release, doses should not exceed a few mrem/yr. Dow needs to demonstrate that leachate radioactivity concentrations will not produce doses in excess of a few mrem/yr.

RESPONSE

The Cells 36 & 37 leachate collection system (LCS) which is to be built equivalent to the other Landfill cells is shown in the schematic cross section of the cell in Figure I-1.0 of Appendix I. It is placed below the waste and consists of a 12 inch thick layer of sand over the geotextile and polyethylene (PE) liner at the bottom of the cells, with a 2% slope to assure drainage to 4 inch diameter perforated PE collection pipes located at the low points in the cell. The sidewall leachate collection system, consisting of geotextile and geonet layers over a PE liner, is tied into the cell bottom leachate collection system. Details of the leachate collection pipe and sidewall system are shown in Figures I-2.0 and I-3.0. The piping and monitoring system connecting the collection pipe to the 10 foot diameter PE lift stations No. 26 and 27 is shown in plan and isometric views in Figures I-4.0 and I-5.0. The lift stations have a total capacity of greater than 27000 gallons. In fact experience has shown that the isolation capability of the cell is such as to essentially eliminate leachate generation within 18 months after cell closure.

The leachate collected in the lift stations will be monitored for radionuclide concentrations prior to transport to the Dow wastewater treatment facility and subsequent release. No release will be made if concentrations exceed appropriate State and Federal environmental release standards. Any leachate having concentrations exceeding these limits will be treated prior to release. This approach is more conservative than basing the permissible radioactivity concentrations in the leachate on an exposure level of "a few mrem/yr" at the receptor (drinking water intake).

COMMENT (31)

Table 7.4-2 This table is missing

RESPONSE

Table 7.4-2 was inadvertently omitted from the License Application. It is now included with the errata to the Application.

COMMENT (32)

Section 7.4.2 The I.D. numbers for the well locations shown in Figure 7.4-2 are either illegible or missing.

RESPONSE

Figure 7.4-2(A), titled "Salzburg Landfill Monitoring Wells Location Map" shows the monitoring wells with their I.D. numbers. It is included with the text corrections in the errata.

COMMENT (33)

Sections 7.4.2, 7.7.2 and 7.7.4 The primary danger to groundwater would be the existence of any unplugged soil borings or abandoned well bores underlying or adjacent to the cells used. If such a boring existed, it would act as a conduit and would have caused at least some lateral disturbance of the bedded sediments resulting in an increase in permeability and porosity, thereby allowing possible migration of the contaminants. The application should indicate if previous borings were made near the cell and how these borings were plugged. The application should also include the Stiff diagrams, pump tests, and recovery rates of the monitor wells.

RESPONSE

No borings or wells within Dow's documented usage of the site have been located within the boundaries of Cells 36 & 37. No borings or wells previous to Dow's usage of the site have been found during previous investigations that were located on or near the proposed thorium cell site. As far as can be determined from a search of the Salzburg Landfill records, a pump test has not been performed on any of the monitoring wells. Recovery times average about one day for all the wells except #20, which takes greater than three days to recover.

COMMENT (34)

Section 7.5 Provide up-to-date water level data if available.

RESPONSE

Water level data for the 19 Salzburg Landfill monitoring wells for 1990 and 1991 is provided in Table 4.0.

COMMENT (35)

Section 7.6 Please provide data on the yearly average rain and snowmelt runoff, snow pack accumulation, and vegetative cover in the area between the proposed cell location and the Tittabawassee River, as well as a description of the land surface (surface roughness).

RESPONSE

The following information has been extracted from the Salzburg Landfill RCRA Part B Application Revision 30 - February 14, 1986 submittal, and updates the data in Section 7.0 of the 20.302 License Application.

> " The following climatological summary is based on data derived from the weather station at the City of Midland Wastewater Treatment Plant approximately two miles northwest of the landfill site.
>
> The lake influence, so noticeable in many areas of Michigan, is minimal at Midland, since it is partially sheltered by the higher plateau region to the northwest. The continental-type climate of the Midland area is characterized by greater daily, monthly and annual temperature ranges than experienced in other areas at the same latitude but nearer to the Great Lakes.
>
> Normal daily temperatures in January range from a normal maximum of 30.4 F to a daily normal minimum of 16.0 F, the average temperature being 23.2 F. In July, the daily normal maximum temperature is approximately 82.7 F and the daily minimum low is 60.2 F, the average daily temperature being 71.4 F. Summers are dominated by moderately warm temperatures, with an average of 10 days exceeding the 90 F mark. The lake influence is reflected by milder minimum temperatures with an average of six days between November and March experiencing zero temperatures.
>
> Precipitation is well distributed throughout the year, with the growing season (May through October, averaging 143 days) receiving an average of 17.06 inches, or 58% of the average annual total.
>
> The normal annual precipitation is 29.28 inches. The record maximum monthly amount of precipitation received was in August, 1975, with a total of 12.76 inches. Minimum monthly precipitation was recorded in September, 1979, with only a trace received for the month. The mean total annual snowfall is 36.3 inches, with the maximum monthly amount being received in February, 1949, which totaled 29.4 inches. The average date for Midland's first 1-inch snow depth is November 29; first 3-inch snow depth, December 20; and first 6-inch snow depth, January 8. The average date of the last freezing temperature in spring is May 12, while the average day of the first freezing temperature is October 2.
>
> Prevailing winds are generally from the southwest. Strongest winds occur in late fall and early spring, with the strongest being recorded in May, 1956 at 81 miles per hour. The mean annual hourly wind speed is approximately ten miles per hour."

The following information has been extracted from the Waste Storage Area I Act 64 Reapplication Revision 40 of January 29, 1987.

"The flora of the entire site is typical of industrial locations. Trees and brush have been removed. Nuisance weeds are located throughout the site. Small areas of grass and ornamental plantings are scattered through out the site mainly concentrated around administrative and research buildings. To the south and east of the entire site, at a distance of approximately two miles, active agriculture is occurring with corn being the predominant type. No active agriculture is present on the site itself.

The flora of the Tittabawassee River is typical of waterways in this region. Industrial activity has resulted in tree and brush removal from the river bank areas. Flora consists of noxious weeds, quack grass, milk weed, cat tails, willow, sumac, poison ivy, and other vegetation.

The site is generally flat. Localized highs and lows are present with the highest ground at the norther portion of the total site. The Tittabawassee River intersects the total site with the majority of the site being north of the river."

COMMENT (36)

Section 7.7.4 Qualitatively show the similarities in the water quality between the till aquifer and the regional aquifer (i.e. provide the Stiff diagrams and the geochemical data).

COMMENT (37)

Section 7.7 Sufficiently detailed geochemical, geotechnical, and hydrogeological data was not provided to assess migration pathways. The data from the closest wells to the proposed cell is not provided. A hazardous waste site has many monitor wells and is continually doing assessments in these wells; yet, the data provided are several years old.

RESPONSE TO (36) AND (37)

The results of the constituent analyses of the Salzburg Landfill monitoring wells for the second quarter 1990, fourth quarter 1990, and second quarter 1991 sampling events are provided in Appendix J. In addition, the response to Comment No. 38 discusses the locations of the wells with respect to the regional or till aquifers. Stiff diagrams based on the April 16 and 17, 1991, sampling of the Salzburg Landfill monitoring wells are also provided in Appendix J.

COMMENT (38)

Section 7.7.2 A groundwater contour (piezometric) map using the most recent monitoring data displayed on a landfill area map rather than a regional map should be furnished.

RESPONSE

The monitoring wells at the Salzburg Landfill can be grouped by depth into four elevation zones (see drawings in Appendix K). The very shallow wells, Well 3 and 4 (Figure K1.0), are only 30' deep. Because they are located only 1,080 feet apart, contouring these two wells would not provide area-wide usable data. Secondly, three data points are required to provide a contour of directional flow. Thirdly, the latest data for which analyses have been completed does not contain a static water level datum for Well 3, because it was dry.

The next deeper zone contains those monitoring wells screened 43 to 44 feet below grade (Figure K2.0). This zone of wells is the only group of wells in consistent sediments (i.e., clay Glacial Till) that can be contoured and provide reasonably realistic gradients. The general flow is toward the west, with a southerly flow at the southeast corner of the landfill.

The last Glacial Till zone includes those monitoring wells screened from 63 to 70 feet below grade (Figure K-3.0). Wells 8 and 9 must be excluded from contouring this zone, because they are screened in a Till Sand that does not reflect the general head within the Glacial Till. Wells 17 through 19 all lie on about the same east-west line, with only Well 14 to give a two-dimensional component. A contour can be approximated for the northern quarter of the landfill, but is not extendable to the rest of the site.

The deepest four wells at the Salzburg Landfill are screened at elevations between 114 and 143 feet below grade (Figure K-4.0). Two of the wells may be in the same formation: Wells 2708 and 3011. These two wells are believed to be screened in parts of the Regional Aquifer, a dendritic, wide-spread local aquifer. However, Well 3168 is screened in a local Till Sand that may be connected to the Regional Aquifer via interconnecting sand seams. A direct connection is unlikely, due to the discrepancy in hydraulic heads. Well 20, although 123' deep, is screened in clay Glacial Till, and has very low flow with poor quality water. Since only two of the wells are in consistent formation, Wells 2708 and 3011, these could possibly be contoured. However, the static water level in the wells is only 0.45" apart, indicating an extremely slow flow to the east. Also, without a third component to the data set, a two-dimensional contour could not be accurately portrayed.

COMMENT (39)

Section 7.11 Dow should include a discussion of the possible short-term and long-term interactions of the hazardous chemicals, in the other disposal cells, with the thorium wastes. A list of hazardous chemicals disposed in the other cells should be provided.

RESPONSE

There are no hazardous materials, as defined by the State of Michigan (and EPA) regulations, in Cells 38 & 39 that are adjacent to the proposed Cells 36 & 37. The nearest hazardous materials are in Cells 15 & 16 and 17 to 19 which are approximately 190 and 65 feet respectively at their closest point to the berm at the north end of Cells 36 & 37. Cells 20 to 22 and 30 to 35 are not yet constructed. Table 5.0 present a listing of the materials, volumes and hazardous waste codes, emplaced in Cells 15 & 16 and 17 to 19.

There are a number of factors which individually will prevent interaction between the thorium material in Cells 36 & 37 and the hazardous materials in the other disposal cells both in the short and long-term. These include:

- The highly insoluble nature of the thorium in the slag as emplaced in Cells 36 & 37;

- The absence of any other waste material as fill in the cell;

- Emplacement and compaction of the slag material in the cell in a manner that prevents void formation, cap subsidence, and infiltration, with followup QC and inspection to assure continued cap and liner integrity;

- Monitoring of groundwater to determine whether constituents are migrating from any of the cells so that measures can be instituted to stop the migration;

- The multi-barrier design of the cell cap and liners to prevent infiltration and subsequent leachate migration;

- The use of a high capacity leachate collection and treatment system coupled with the operational data to show that there is essentially no leachate production within 18 months of cell closure;

- Monitoring of leachate as an early indicator of Cells 36 & 37 thorium mobilization;

- The extensive travel time through low permeability clay between cells;

- The surface water management program at the facility is designed to minimize any inflow in the cells; and

- The extensive experience and sophistication of the facility managers and operators in handling, disposing of, and managing hazardous materials.

COMMENT (40)

Section 7.12.2 The text states that the source term assumed for the thorium-bearing material is 2.4×10^8 pCi/m^3. The application should contain an explanation of the derivation of this source term number. The explanation should justify that this number is a conservative assumption for determining the impacts to an intruder considering the variation in concentrations of the material that will be disposed of in Cells 36 & 37.

RESPONSE

The value of 2.4×10^8 pCi/m^3 corresponds to an average concentration of 151 pCi/g with a material assumed to have an average density of 1.6 g/cm^3. This was the weighted average of the Midland (29 pCi/g, 9200 m^3) and Bay City (188 pCi/g, 30,600 m^3) materials.

COMMENT (41)

Section 7.12.2 and Table 7.12-3 Dose calculations should assume that the site is released for unrestricted use and that the thorium slag is uncovered and exposed at the surface. If a dose assessment code is used, then all of the assumptions for the data input into the code should be justified.

RESPONSE

The comment indicates that a dose assessment should be interpreted in the context of a site intended for unrestricted release, and the models should be developed accordingly.

The Salzburg Landfill is not intended for unrestricted release. Since the rest of the site is permitted as a RCRA disposal facility, the entire facility will be subjected to restrictive covenants, approved closure and post-closure plans, financial assurance, and long-term institutional control. Furthermore, additional restrictive covenants have been proposed relative to Cells 36 & 37 to prevent in perpetuity any actions that would impair the integrity of the Cells. (See response to Comment No. 72, etc.)

In response to Comment No. 41, cases have been evaluated using the RESRAD code developed for the Department of Energy. Figure 3.0 shows the time varying dose as a function of cover thickness. Default values are used for all parameters except the radioactive inventory. The peak dose at 2300 years is a result of the lower distribution coefficient for radium relative to thorium. This effect is an artifice of the code methodology, and does not represent a realistic estimate of potential impacts, as described in the response to Comment No. 44. The rapid increase in dose rate starting at about 300 years for the 0.5 m cover case, and proportionally later for the thicker covers, results from the erosion of the cover and subsequently the waste material, assumed to occur at a default rate of 0.001 m/y. The combination of exposed waste and groundwater contamination results in a peak dose rate of 3350 mrem/y.

The components of the radiation exposure are shown in Figures 4.0 and 5.0 for a model assuming no cover at all and a reduced erosion rate to allow examination of the contributions from the various pathways. Direct exposure to an on-site resident (intruder) is the major factor, representing about 2000 mrem/yr out of 2500 mrem/yr from water independent pathways.

Figure 6.0 shows the dose rate profile if a 1 meter cover is emplaced and assumed to erode slower (10^{-6} m/y) than the default value. In this case only groundwater produces a radiation exposure. However, as discussed above, the groundwater dose is an artifice of the methodology. If a more realistic groundwater model is employed, the dose drops to below 1 mrem/yr, as shown in Figure 7.0. This is the most realistic scenario since the engineered cap is thicker than the assumed 1 meter and much more substantial, including geotextile and polyethylene liners.

RESRAD results are included in Appendix L.

COMMENT (42)

Section 7.12.2 Because of the long half-life of thorium, the dose assessment should be carried out to a least 1000 years, taking into account doses from ingrowth of thorium daughters.

RESPONSE

The RESRAD model includes the impacts from all Th-232 daughters attributed to the parent present at time of emplacement. This is consistent with the decay of any short-lived isotopes and the presence of such short-lived daughters in the future only because the parent was originally present (See also the response to Comment No. 6).

COMMENT (43)

Section 7.12.3 NUREG-1101, Volume 1, On-site Disposal of Radioactive Waste Guidance for Disposal by Subsurface Burial, identifies the critical pathway as the drinking water pathway with the source of exposure as a contaminated well located on the disposal site. An analysis of this pathway was not provided nor was sufficient geochemical and geotechnical data provided to indicate that this pathway could be ignored.

COMMENT (44)

Section 7.12.3 Show that the assumed lack of groundwater transport is a valid assumption, i.e., perform groundwater transport modeling out to 1000 years or until the peak concentration at the receptor point is reached. Assume that both the bottom and top engineered barriers completely degrade at a reasonable point in the future. A groundwater analysis is needed since the thorium will remain long after the disposal cell has ceased to be effective. This analysis should consider the potential chelating and solubilizing affects of the natural carbonates that are in the groundwater and the hazardous chemicals disposed in the other cells at the landfill.

RESPONSE TO (43) AND (44)

The response to Comment No. (29) discusses the characteristics of the natural soil material that serves to inhibit potential leachate dispersion.

Several comments, including No. (44) address the possibility of release of contaminants to the groundwater and subsequent uptake through water wells. This scenario involves failure of the cap, percolation of liquid into the cell, leaching of contaminant, and failure of the cell liner. The leachate then penetrates the natural clays and travels to a well from where it is ingested.

Impacts from groundwater contamination depend on the distance to the well where uptake occurs and the rate at which the contamination travels to that well. Transport is element-specific due to the chemical behavior during leaching and retardation by the soil. Thorium is relatively insoluble, with a low leaching fraction and high retardation coefficient. The radium 228 daughter travels much quicker through the groundwater, but also has a much shorter half-life and therefore decays between release and uptake at a receptor. The key factor in the groundwater pathway is therefore the transport of the only long-lived isotope, Th-232.

The available computer codes analyze the situation in a simpler manner then discussed above. RESRAD, developed for the Department of Energy, calculates radioactive ingrowth and decay in the cell, but does not decay the contaminant during transport. This radioactive underestimates the time to breakthrough of the contaminant and the duration of the plume, producing much higher doses over the supposed impact time period. This situation is shown in the attached plots. Figure 8.0 shows that the peak dose and its time of occurrence are dependent on the distribution coefficient (Kd). For this case, the Kd for radium is taken at the default value of 70 cm^3/g and that for thorium as 60,000 cm^3/g. Varying the thorium Kd does not effect the results, but a sensitivity analysis on Kd for radium in the saturated zone shows the direct proportionality of the time to peak dose rate and the elemental Kd. If account is taken of radioactive decay of the traveling contaminants, then it is appropriate to assume that the short-lived daughters are traveling with the long-lived parent. This is modeled in RESRAD by setting the Kd of the daughter (radium) equal to that of the parent (thorium). When the Kd is set to the thorium default of 60,000 cm^3/g, the breakthrough time exceeds the code time limit of 100,000 years.

As noted above, the RESRAD default Kd of 60,000 cm^3/g for thorium was used in the calculations. This Kd value was chosen to compensate for any reduction that might occur due to chelating effects of the Landfill clays. A tabulation of thorium Kd values in "Radiological Assessment: a textbook on Environmental Dose Analysis", ORNL, NUREG/CR-3332, September, 1983 shows Kd values from 160,000 to 400,000 cm^3/g for clay based soils with pH levels at 6.5. The thorium Kd values for the alkaline clays at the Salzburg Landfill would be at the higher end of this range. Thus the 60,000 cm^3/g used in the analysis represents a conservative approach. A further discussion of the effect of pH on thorium chelation is provided in the literature study in Appendix V. An implication of the data is that the clay in the Landfill will have a stronger ionic adsorption effect then a mobility-reducing chelation effect.

Figure 9.0 then shows the results when the Kd's for radium and thorium are set to 250 cm^3/g, an arbitrary and extremely low value well below that which would occur for chelated thorium for the Landfill clays. (This value was chosen to demonstrate the impact on the model of varying the kd, and has no basis in physical reality). Even at this extreme, the peak dose is pushed out past 10,000 years, and includes contributions from the thorium well as radium. The more realistic values for reduced Kd's for chelated material described above yield lower dose rates at a more distant time.

The plots refer to "Water Independent" and "Water Dependent" pathways. "Water Dependent" pathways are those related to groundwater contamination, such as wells, "Independent" pathways include direct radiation exposure dusting and agriculture.

It should be noted that the RESRAD code includes consequences of erosion of the cover and contaminated zone. Taking the default erosion rate of 0.001 meters/year for both the cover and waste zone produces the dose impacts shown in Figure 10.0. First the cover erodes, then the waste is dispersed, leaving no contamination to be leached into the groundwater. The significant dose is to intruders from direct radiation and airborne dust. The doses shown in Figures 8.0 and 9.0 assume very slow erosion rates in order to examine potential groundwater impacts.

The above results indicate that groundwater contamination is not a significant concern relative to the Salzburg Landfill site. When realistic retardation conditions are considered using Kd's as low as 60,000 cm^3/g, the breakthrough time to an on-site well is longer than the 100,000 years analyzed by the code. Even in the extreme case, with an arbitrary kd for the thorium (250 vs. the default value of 60,000 cm^3/g) the peak dose rate is delayed past 10,000 years. The supporting RESRAD analyses are provided in Appendix M.

COMMENT (45)

Section 7.12.3.1 Evaluate a scenario where the cap is removed but the bottom engineered barriers remain intact and the leachate collection system is disrupted. As part of this scenario, estimate the time for bathtubbing to occur and the amount of, and thorium concentration in, the leachate when the cell bathtubs, and the expected impacts from the release.

RESPONSE

Potential bathtubbing at the Salzburg Landfill has been identified as a possible exposure mechanism. This scenario would involve failure of the cap, allowing precipitation into the cell, while the liner remains intact. Water would fill the cells, leaching radioactive material from the waste.

Bathtubbing occurs after failure, if the cap allows precipitation into the cell. The intact liner holds the liquid until it overflows the cell sides. The time to fill the cell is determined by the height of the cell divided by the annual contribution. This simplistic and conservative analysis suggest that it would take 34 years to fill the 7 meter deep cell at the rate of 8.07 inches (20.5 cm) per year. The fill rate is determined from the water balance contained on pages 51-52 of the original License Application.

Overflow volume will be the amount displaced by the annual contribution once the cell has failed, or 20.5 cm of depth over 5700 m^2, or 1170 m^3/year of leachate overflow.

It is assumed that the leachate is saturated with contaminants as a result of a sufficiently long contact time.

During the period of institutional control, any leachate in the cell will be collected and treated prior to release. After institutional control ceases it is assumed for this bathtubbing scenario that any leachate that forms will eventually overflow the cell, producing a surface water pathway for exposure of off-site public.

This scenario was analyzed for the Salzburg Landfill using the IMPACTS-BRC, Version 2.0 code developed for the Nuclear Regulatory Commission. Default environmental parameters were used for a humid, highly populated northeastern site.

Radioactive decay does not affect the source inventory in the cell since Th-232, the parent, is extremely long-lived with a half-life of 1.4 x 1010 y. The much shorter lived daughters reach equilibrium in about 30 years. However, contaminant transport is element specific, depending on the chemical behavior. Short-lived isotopes would decay between the time of leaching and reaching the point of uptake. Therefore, impacts from bathtubbing are only considered for the longer lived isotopes: Th-232, Ra-228, and Th-228.

Impacts to an individual from overflow of the cell at Salzburg Landfill after cessation of institutional control are:

Isotope	Dose (mrem/y)
Th-232	1.21
Ra-228	0.58
Th-228	0.12
TOTAL	1.91

(Printout from IMPACTS-BRC code is included in Appendix N)

It should be noted that the overflow would be diluted by the watershed area flowing to the surface water (in this case, the Tittabawassee River) as well as the flow of the river itself. Thus the dose would be reduced to essentially background levels.

COMMENT (46)

Section 7.12.3.1 Note that thoron is a gas and would be released directly to the environment if the thorium waste was on the surface. The statement that thorium daughters would migrate for a limited distance is therefore not entirely correct.

COMMENT (47)

Section 7.12.3.1 The sum of thorium daughter half-lives has no real meaning. This statement should be deleted or modified.

RESPONSE TO (46) AND (47)

It was not intended that the reference to the sum of Th-232 daughter half-lives should be used in assessing migration potential, but to only make the point that the individual daughter half-lives are sufficiently short so that, taken with the retardation characteristics of the media, they would decay to negligible levels within a limited distance from the source. We agree that the wording is awkward and have modified the language (see below and errata sheet).

With regards to Comment No. (46), the discussion in this paragraph (and the rest of Section 7.12.3.1) relates to potential groundwater impacts. It is true that some thoron gas would be released to the air from the slag if it were on the surface, however the statement referred to does not treat this scenario but presumes the presence of some overlying cover material. The release of thoron from the bare and covered slag has been assessed in the response to Comment No. (58).

Paragraph 2 on Page 86 of the license application is therefore modified as follows:

> "The migration of the daughter products of Th-232 would also be inhibited because of the slow transport of water through the liner and chemical retardation of the elements in clay. These factors, combined with the relatively short half-lives of the Th-232 daughters, would result in limited movement of these constituents from the cell into the liner or cap before they decayed."

COMMENT (48)

Section 7.12.3.2 The discussion states that thorium can have high retardation coefficients. Note that carbonates can substantially reduce retardation coefficients as can the chemicals that may be present in the other disposal cells. The effects of natural carbonate and the other chemicals in the disposal cells need to be considered (e.g., determine site specific retardation coefficients and leachability of the magnesium/thorium waste).

RESPONSE

As discussed in the response to Comment No. (4), and No. (39) no other material aside from the slag and soil at the Bay City and Midland sites will be put into Cells 36 & 37; nor is the interaction between the material in Cells 36 & 37 and nearby cells at the Salzburg Landfill a feasible scenario because of the design of the cells, the material used as barriers and between cells, and the rigorous monitoring to detect and then remove any leachate formed in the cells.

While it is not anticipated that the carbonates in the clay would substantially affect the dispersion characteristics of the thorium in groundwater, the highly conservative assumption of reduced Kd values were investigated to assess the potential for increased mobility resulting from chelating. The results of these analyses are provided in response to Comment No. (44).

In addition leaching of metals results from contact with acidic waters. Subsequent interaction with alkaline material (i.e., clay carbonates) would neutralize the groundwater and precipitate dissolved metals such as thorium, inhibiting migration of these constituents (See also the response to Comment No. 29).

COMMENT (49)

Section 7.12.3.2 We must assume that the sand lens under the landfill could be used as a drinking water source because for a 10 CFR 20.302 burial and site decommissioning we must assume that the site is released for unrestricted use with no administrative control.

RESPONSE

The only usable drinking water source near the proposed thorium Cell, assuming uncontrolled site usage in the distant future, would be the two small aquifers along the east edge of the landfill and under Monitoring Well 3168, and the Regional Aquifer sand channels monitored by Wells 2706 and 3011, on the far west and far northeast edges of the landfill and probably under Monitoring Well 3168. The small sand body identified in soil boring 2388 does not appear to be extensive enough to support a well, even for domestic usage, and would quickly be dewatered. A pump test applied to a well set into this sand lens would be required to obtain more comprehensive data to evaluate the possibility of this sand body connecting to a more substantial aquifer.

Furthermore, it is at least 700 feet laterally from the edge of the nearest defined intra-till sands (lens) to the periphery of Cells 36 & 37. The material separating Cells 36 & 37 from this sand lens is highly impermeable lakebed clay and glacial till. As a result of the long pathway, low-solubility of the thorium in the slag, isolation capability of the engineered cell, and retardation capabilities of the clay and glacial till, migration of thorium in the leachate to the lens is not a viable scenario.

COMMENTS (50)

Section 7.12.3.2 Comparison of concentrations with 10 CFR 20, Appendix B is inappropriate since Appendix B applies to licensed operations and not for conditions of unrestricted release.

RESPONSE

The comment is correct if the site was intended to be released for unrestricted access. However, in the unlikely event that the site is released for unrestricted use at some time in the foreseeable future after closure the factors discussed in Section 7.12.3.2 and noted in the response to Comment No. (49) and others would prevent groundwater from being contaminated to levels that would prevent its use.

COMMENT (51)

Section 7.12.4 It is stated in this section that the solubility of the waste material is low. The application should include data and/or other information on the solubility of the thorium-magnesium slag that supports the contention that the solubility is low enough to prevent potentially adverse consequences should bathtubbing occur. The solubility determination should take into account the fact that the carbonate contained in the clay, which will be used to line the disposal cell, has the potential to chelate the thorium.

RESPONSE

Solubility data on the thorium in the slag in water of varying pH levels was provided on page 88 of the License Application. This data shows the solubility at all pH values to be very low. A conservative analysis for the hypothetical bathtubbing scenario was provided in response to Comment No. (45) which showed exposures to any potential receptor to be negligible.

COMMENT (52)

Section 7.12.4 The most probable failure mode of the disposal cell would seem to be "bathtubbing" which would cause the release of Th-232 via a surface water pathway or shallow groundwater pathway (within the overlaying sand layer), or a combination of both. To help evaluate this scenario, please supply the standard U.S. Geological Survey map (7.5 min. quadrangle) of the site area so that an evaluation of the overland flow characteristics can be made.

RESPONSE

Enclosed in Appendix O are Dow drawings B2-040-884040 and B2-041-884040 which show the existing topographic features and surface contours for the Salzburg Landfill and the surrounding region. The topography and contours are shown to a distance of approximately 1000 feet beyond the fence line.

The potential "bathtubbing" scenario has been evaluated in response to Comment No. (45).

COMMENT (53)

Section 8.0 The application states that trucks "will be covered with tarpaulins to minimize fugitive dust during transport (page 90). The application should include an analysis of material loss during transport and projected health effects.

RESPONSE

The radiological impacts analyses in Appendix I of the License Application includes an assessment of exposures to the public from direct radiation from the thoriated material along the transport routes from Midland and Bay City. The exposure levels are negligibly small (6.8×10^{-5} mrem for transport of the Bay City material to the Salzburg Landfill). The analysis in Appendix P further consider potential releases of fugitive dust during transport and the doses resulting from these releases.

Release of fugitive dust material from the trucks will be controlled by truck covers, which should effectively eliminate any dusting. However, as a conservative estimate of possible impacts, material remaining airborne due to releases from the truck during transport were considered to be the equivalent of a truck bottom dump, dispersed into a volume 10m on each side of the truck to a height of 3m. This was assumed to be constant along the length of the route.

Since the concentration is assumed to be constant during the period of exposure, and the calculation is for the maximally exposed individual, the result is applicable for each possible disposal alternative. The dose from dusting calculated for that maximally exposed individual is 0.12 mrem for the transportation of the Bay City material to the Salzburg Landfill.

COMMENT (54)

Section 8.1 No details were provided on compatibility or long-term performance of the liners, the cover systems, the leachate piping and holding tanks, or the pumps with which the radioactive material may be in contact. Assurance of long-term performance requires supporting data and test results on the proposed materials, based on in-service performance records and testing that meets accepted codes and standards.

RESPONSE

The man-made materials to be used in Cells 36 & 37, consisting of the geotextiles and geonets, PE liners, PE piping, and PE lift stations, have been developed for application to hazardous and radioactive waste disposal units. They are used in the other cells at the Salzburg Landfill and nationally in landfills and impoundments containing similar type wastes without indication of premature deterioration or failure resulting from compatibility problem. Manufacturers data is available on these materials from both laboratory testing and field applications which demonstrate long-term performance.

The clay liner material and emplacement meet an exacting set of Dow standards which are summarized as follows:

- Primary = 5' thick & Secondary = 3' thick
- Clay Specification
  - Minimum of 25% of particles .5 Microns
  - CL or CH (Unified Soil Classification System)
  - Liner permeability no greater than 1×10^{-7} cm/sec
- Spread in 9" loose lifts
- Broken up with disc to reduce clod size
- All stones and debris> 2" removed
- Compaction
  - Vibratory padfoot roller compactor
  - Minimum of 90% max dry density
  - Within 0% to +5% optimum moisture content
- Scarify top of each lift 1" to 2"
- "Stepped" back of secondary clay liner
  - Eliminates slip plane
  - Enhances long-term dike stability

- Final lift
  - Shaped to 2% slope to collection lines
  - Primary liner - no abrupt deviations > 1/2"

- CQA
  - Soils testing during clay placement
  - Survey for elevations and slopes

The construction quality assurance (CQA) testing program for the clay, 2NS sand, and peastone are summarized in Table 6.0.

COMMENT (55)

Section 8.1 The application states "The localized water bearing sand units are depleted during construction" (page 92). The application should state if the localized units are recharged following construction and supply any recharge data from the monitoring wells completed in these units. The presence of perched water tables should be determined as well as the possibility that the localized water bearing sand units may be used as groundwater/drinking water sources.

RESPONSE

See the responses to Comments No. 33, 37, 38, and 49.

COMMENT (56)

Section 8.1 The specifications and capabilities of each piece of construction equipment to be used in the construction and operation of the disposal facility should be provided. Procedures should be established to monitor and decontaminate equipment before release of the equipment for other uses.

RESPONSE

The types and required capabilities of the construction equipment will be provided in the cell construction, emplacement, and closure procedures to be included in the Work Plan (see response to Comment No. 13). As discussed in Section 9.2.4 of the license application, a contamination monitoring and decontamination program will be established at Midland, Bay City, and the Salzburg Landfill covering, among other areas, construction equipment decontamination. This program will also be defined in the Work Plan.

COMMENT (57)

Section 8.3 This section of the application provides a brief description of how the material will be emplaced in the disposal cell. The application should include more detail on the emplacement procedures, including how lifting and compaction will be accomplished, and how compaction will be accomplished around and including the construction debris that is part of the waste material. Descriptions of the equipment that will be used should be included in this additional information.

RESPONSE

Detailed material and fill emplacement procedures and equipment descriptions will be provided in the Work Plan. The emplacement steps are summarized as follows:

The thorium material will be moved from both the Midland and Bay City sites to the Salzburg Landfill Cells 36 & 37 in single trailer dump trucks. Each truck has an approximate capacity of 25 cubic yards. This size truck will allow sufficient maneuverability within the limited space of the cell.

All equipment will enter and leave the cell via one or more earthen ramps constructed at the northerly end of the cell. The ramp(s) will be composed of clean fill material excavated during construction of the cell. The emplacement process will start at the bottom of the ramp(s), extend over the full width of the cell bottom and proceed generally from north to south.

The first layer of thoriated material will be placed on top of the leachate collection system sand. This lift will be a minimum of three feet thick to protect the underlying geomembrane from damage during the emplacement process. All equipment will work on the layers of thoriated material only; no equipment will work directly on the leachate collection system sand. Successive layers will be 18 inches to 24 inches thick.

The thoriated material will be spread using bulldozers, front-end loaders or similar equipment. compaction equipment, such as padfoot rollers, Cat 815 extended foot rollers or similar may also be used if it is seen that the spreading equipment is not performing an adequate job of compaction.

At the end of each working day the thoriated material will be covered with 4 inches to 6 inches of clean soil or a substitute daily cover such as ConCover* (see Table 7). The daily cover material will be maintained at all times to prevent wind dispersal of particulate matter.

As noted in the response to Comment No. (17), the construction debris amounts to less than 1% of the total volume of material. Large pieces of the debris will be removed prior to transport to the Salzburg Landfill, decontaminated, and disposed of as non-hazardous waste. Small pieces will be left with the slag and soil and disposal of at the Salzburg Landfill. This will not effect the material compaction procedure in Cells 36 & 37.

* Trademark of Newastecon, Inc.

COMMENT (58)

<u>Section 8.6</u> The application states "After Cells 36 & 37 is closed, a survey to measure thoron levels will be performed at a height of 1 meter above the release ducts from the cell and at the closest disposal perimeter fence downward of the cell. A release standard of 0.5 pCi/L of thoron (above background) in air will be adhered to" (page 96). The sampling 1 meter above the release ducts may not provide any degree of sampling reproducibility considering wind, and variations in wind speed. The application should specify the method, frequency, and duration of sampling. The application should also include a calculation of the expected thoron emanation from this material with time and indicate what engineering controls are to be used to limit emanations of thoron to 0.5 pCi/L of air.

RESPONSE

The vent pipes (release ducts) in Cells 36 & 37 will be equipped with gas release control systems to slow-down the gas emission from the cells. It is not anticipated that measureable thoron concentrations (above background) will be experienced at on-site receptor locations from release from these vents. However, the survey referred to in Section 8.6 will be conducted after closure of the Cells at several heights above the release points to assess thoron levels. The details of this sampling program will be described in the Work Plan (See the response to Comment No. 13).

The only other pathway for release of the thoron from the slag would be diffusion through the multi-layered cap. The diffusion of thoron collected in the pore spaces of the soil will be inhibited by the dense clay cover, the long travel distance to the surface, and the natural moisture content of the cap. Taken with the short half-life of thoron (55 seconds), these factors cause the reduction in thoron concentration from release at the slag to the surface to be substantial. It would therefore be expected that thoron emanation from the surface of the cap would be negligible.

In order to assess the anticipated thoron emanation from the slag, as covered at the end of each workday, and when the final cover is emplaced, an analysis has been performed using the appropriate diffusion model (see Appendix Q). The flux at the surface of the cover material was calculated for varying cover thicknesses of clay and natural soil cover (Table Q-1). As can be seen a 2 foot cover of clay reduces the surface flux to the insignificant value of 3.0×10^{-30} pCi/m^2 sec. Thus the cap of 3 feet of clean compacted clay, 2 feet of top soil, and synthetic materials should reduce the flux to immeasurable levels. An average 5 inch layer of soil emplaced over the slag at the end of each work day would reduce the flux to approximately 1 pCi/m^2-sec. Even if the highly conservative assumption of a 1:1 ratio between surface flux and surface concentration is made, concentrations above the surface of the final cap would be negligible.

As stated in the Application, baseline thoron concentrations and levels during emplacement and after cell closure will be measured. The aforementioned survey performed after closure to validate the predicted negligible thoron concentrations will also be made at varying heights up to 1 meter above the cap surface and at the closest downwind site perimeter location. A release standard from the site of 0.5 pCi/L will be adhered to. Based on the flux calculations and experience at other sites containing thorium it is not anticipated that any additional engineering controls will be required to meet the standard.

In referencing the use of the Kusnetz method in the Application, the intent was to use a measurement technique similar to the modified Kusnetz method described in "Radiation Monitoring" by R.C. Rock and R.P Beckman, U.S. Department of Labor. In the period since preparation of the Application improvements in measurement techniques have been made that may permit use of other techniques more appropriate for this field application. We are investigating the use of a continuous monitor that gives readings in the field, or the use of approaches involving collection on charcoal with subsequent laboratory analysis or field adaptation of a continuous flow chamber. The approach to be applied at the Salzburg Landfill will be defined in the EHSP provided with the Work Plan (See response to Comment No. 13).

COMMENT (59)

Section 8.6 How will initial thoron and thorium air sampling be performed? How will air samples be taken downwind of work areas? Where will air samplers be located and what type will be used?

RESPONSE

See the response to Comment No. (58) for discussion of thoron measurement techniques and to Comment No. (69) for discussion of use of air samplers.

COMMENT (60)

Section 8.6 The application states "Thoron concentrations will be analyzed using the Kusnetz method, and the filter samples from the air pumps will be analyzed for thorium concentrations on the dust (particulates) using neutron activation techniques" (page 96). A review of the Kusnetz method reveals that this is a method specifically designed for measurement of Rn-222 and not Rn-220 (thoron). Subsequent methods by Rock (1975), and Khan and Phillips (1986) incorporate the simultaneous measurements of Rn-222 and Rn-220, but are not specific for Rn-220. A "modified Kusnetz" procedure, or a "modified" procedure of some other writer, or writers, may be proposed for the analysis of thoron concentrations. However, the Kusnetz method as described in the literature, is inappropriately cited.

RESPONSE

See response to Comment No. (58)

COMMENT (61)

Section 8.6 How long are the long-term trends mentioned in the second paragraph, page 96?

RESPONSE

Samples from the monitoring wells at the Salzburg Landfill are collected and analyzed on a quarterly basis. This program, incorporating radiological and non-radiological constituents analysis, will be continued for as long as Dow maintains ownership of the site.

COMMENT (62)

Section 9.0 The Environmental Health and Safety Plan (EHSP) was not provided for review. We have on file only a draft EHSP for this facility.

RESPONSE

The EHSP will be provided in conjunction with the Work Plan for the performance of the remedial program (See response to Comment No. 13).

COMMENT (63)

Section 9.1.1 CFR Title 10 Part 19 topics should be covered in the training plan.

RESPONSE

Title 10 Part 19 topics will be covered in the formal worker training program. The training program will be described in detail in the EHSP. Topics covered will include health protection problems associated with exposure to thoriated material, precautions and procedures to minimize exposure, purposes and functions of any protective devices used on-site, applicable NRC regulations and standards relating to protection from radiation exposure, employees responsibilities relative to reporting unsafe conditions, and appropriate response to warnings as to malfunction or occurrences that may cause exposure to the thoriated material.

COMMENT (64)

Section 9.1.2 Smoking, eating and drinking should be prohibited in the contamination reduction zone as well as in the contamination zone.

RESPONSE

Smoking, eating and drinking will also be prohibited in the contamination reduction zone. (See errata sheet for revision to text).

COMMENT (65)

Section 9.1.2 The application should contain procedures to minimize further contamination of the environment during operations. The collection, monitoring and appropriate disposal of the runoff water from the truck wash stations at the Bay City, Midland, and Salzburg sites should be specifically addressed as well as the collection, monitoring, and appropriate disposal of water potentially draining from the trucks.

RESPONSE

All vehicles that enter Cells 36 & 37 will have their tires/tracks and undercarriage washed visually clean immediately after exiting the cells. This will be accomplished at a vehicle wash building which will be constructed adjacent to the cells. The vehicle will enter the wash building, all doors will be closed and vehicle wash personnel will wash the vehicle tires/tracks and undercarriage using pressurized water. A visual inspection and a check using radiation monitoring instruments will be performed by the vehicle wash personnel. If both of the inspections are successfully completed, the vehicle will then be allowed to leave the facility. If either of the inspections fail, the vehicle will be rewashed and reinspected. This process will continue until both inspections are successfully completed.

Vehicle and equipment decontamination stations will also be established at the Bay City and Midland sites that will be designed and operated in a manner that prevents any release of contaminated water. Similar inspection and monitoring procedures will be followed.

All wash water at each location will be collected, filtered and retained until it has been tested for thorium content to determine that it is acceptable for transfer to the NPDES licensed Michigan Division waste water treatment plant. If the water is not acceptable, it will either be refiltered or pumped into tank trucks and transported to another appropriately licensed treatment facility. Filtered and dewatered solids will be collected at the vehicle wash building. The solids and filter media will be placed in the cells.

The vehicle wash building and wash stations will also be inspected and decontaminated. All material from the decontamination operation will be placed in the cells before the first layer of clay cap is completely installed.

No trucks will be permitted to leave any location with contaminated water draining from the interior. At Bay City and Midland, tarpaulins will be fixed over the top of the loaded trucks to prevent infiltration of precipitation.

The above-described approach and those discussed in Section 9.1.2 of the application, will be elaborated on in decontamination procedures to be included in the Work Plan (See response to Comment No. (13)).

COMMENT (66)

Section 9.2 No detail was provided on emergency procedures to be followed when severe weather (e.g., tornados, high winds, rainstorms, etc.) effect the excavation or disposal sites. Emergency procedures should also be established regarding transportation incidents, including accidents, tire changes, tarpaulin loss, etc.

RESPONSE

No operations will be conducted at the excavations at Bay City and Midland or at Cells 36 & 37 at the Salzburg Landfill when severe weather threatens or occurs. All equipment will be secured and personnel removed from the sites when severe weather is predicted.

Emergency procedures will be provided to each truck driver, consistent with DOT requirements for transporting radioactive material, covering actions to be taken should any unplanned incident arise, including a list of emergency phone numbers.

COMMENT (67)

Section 9.2.1 Dosimetry should '.e required for entry into the contamination reduction zone.

RESPONSE

Dosimetry will be required for entry into the contamination zone and the contamination reduction zone.

COMMENT (68)

Section 9.2.1 The dosimetry to be used during operations should be specified in the application. The dosimetry could include direct-reading dosimeters, film or TLD badges, and personal air samplers. Consideration should also be given to having the dosimetry analyzed by a third party.

RESPONSE

On-site worker will be issued individual TLD's to monitor their external exposure as appropriate. The TLD's will be read by a third party vendor to verify analysis performed by Dow. In addition to the continuous operation of the PIC referred to in Section 9.2.1, periodic gamma exposure rate surveys, using hand-held detectors, will be conducted in the immediate area where personnel will be working. The detailed dosimetry program will be provided in the EHSP.

COMMENT (69)

Section 9.2.2 Explain why high volume air samplers are being used instead of continuous low volume. Will high volume samplers be run during the entire excavation work or will grab samples be collected? If thoron is to be measured using the Kusnetz method then only grab samples are proposed. If thoron is estimated to be a significant contribution to dose, licensee could estimate thoron production based on thorium concentration and initial thoron source term. Off-site dose could be calculated based on maximum concentration of thorium at sites. Is thoron included in dose calculations?

RESPONSE

High volume air samplers have been successfully used at the Salzburg Landfill since its opening to monitor airborne particulate concentration. No operational problems have been encountered nor has dust loading proven to be sufficient to impair the sampler operation or accuracy of the analyses. To provide more flexibility during excavation and removal operations at Midland and Bay City to handle a range of dusting conditions, air sampling pumps capable of pulling air through an open face 47 in^3 dosimeter glass fiber filter at a rate of 60 liters per minute (intermediate volume) will be used. The air samplers at the excavation sites will be located in the immediate vicinity of the work being performed in the downwind direction. At the Salzburg Landfill they will be operated in the vicinity of and downwind of Cells 36 & 37 and at the current fixed locations. The vicinity air samplers will be operated continuously whenever work activities result in uncontrolled dust generation.

See the response to Comment No. (58) for discussion of thoron measurements, calculations of thoron emanation from Cells 36 & 37, and discussion of resultant doses.

A conservative estimate of thoron doses to the lung was provided in Section 1.3 of Appendix I of the Application. The calculated lung dose to a postulated full-time resident at the site boundary at Bay City was 0.70 mrem and 0.20 mrem at Midland for the material excavation and removal period. The calculated lung dose to an individual working in a building on-site was 0.24 mrem at Bay City and 0.06 mrem at Midland for the same period. Remediation worker exposures to all releases will be carefully monitored and controlled to maintain exposures at ALARA levels.

COMMENT (70)

Section 9.2.2 Specify the airborne dust concentration that will trigger the initiation of dust suppression techniques.

RESPONSE

Airborne dust suppression techniques will be employed at any time invasive activities (i.e., digging, boring) are undertaken at Bay City and Midland, during vehicle loading, and during emplacement and compaction in Cells 36 & 37 at the Salzburg Landfill. The primary dust suppression techniques will involve the use of aqueous sprays to wet the surface of the material and form a surface crust.

COMMENT (71)

Section 9.2.4 Will protective clothing be removed upon exit from the contaminated zone or upon exit from the site? What will be the worker decontamination criteria for personnel leaving the site? What unrestricted release criteria will be applied to contaminated equipment?

RESPONSE

Any protective clothing worn by on-site workers will be removed upon exit from the contaminated zone and placed in a designated contaminated clothing container. Personnel leaving the contaminated zone showing readings above background on the skin will be required to wash the contaminated areas and have the area re-surveyed and the results of the re-survey approved by the RSO (or his designee). Unrestricted release criteria for removable and total surface levels for equipment will be based upon the requirements in U.S. NRC Regulatory Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors" of 1974. Equipment will be decontaminated to levels that are ALARA, but below the applicable release criteria in all cases (as determined from Reg. Guide 1.86 standards) for Th-232 (and daughters). The decontamination procedures, including surface contamination measurements for total and removable alpha contamination, will be detailed in the EHSP. In brief the procedures will require:

1. Recording equipment item identity on a survey form;
2. Complete scan of potentially contaminated surface areas with an alpha probe and ratemeter. Maximum and average total alpha levels will be measured and recorded;
3. Wipe tests will be conducted. A biased sample(s) will be taken from areas judged or measured (from scan) to have the highest potential for contamination and highest potential for removal of material;
4. If results of wipe test or surface scan for total alpha activity indicate activity approaching the limits, additional measurements may be required to assure that the release criteria are met; and
5. Decontamination of the surface will be performed if required and alpha scan and wipe tests repeated to validate that levels are below the release criteria.

COMMENT (73)

Section 10.3 The Text states that "Records of the disposal activities will be maintained in conjunction with those of the hazardous waste facility" but there is no further explanation of how these records will be maintained.

COMMENT (74)

Section 10.3 This section describes what information about the disposal cell will be included in the "records of the Salzburg Landfill," but it is not clear whether these records are the same as the records referred to in Section 10.2 and/or how they will be maintained.

RESPONSE TO (73) AND (74)

All facility disposal records will be maintained in locked fire resistant file cabinets located in the on-site facility building (3600 Bldg) at the Salzburg Landfill. This building is locked at all times the facility is not in operation. In addition, all disposal records will be microfiched and stored in two other separate locations within the Michigan Division. Records retention for the facility disposal records will be permanent.

COMMENT (75)

Section 10.3 The text says that the cell used for the disposal of the thorium wastes will be identified with the radiation symbol. The application should contain additional information on where these symbols will be displayed, and a description of the materials the signs will be manufactured with and how they will be installed at the disposal facility.

RESPONSE

Concrete markers will be emplaced at the side of Cells 36 & 37 on which stainless steel (or other suitable material) signs containing the appropriate radiation symbols will be mounted. Additionally, information relating data on the waste content of the cell to the detailed file records maintained at the Salzburg Landfill will be provided on the markers.

COMMENT (72)

Sections 10 and 11 and Appendix B NRC staff does not object to covenants in deed, records, fences and placards restricting use of the property. However, since the objective in our review is for unrestricted release, we can give no credit for these restrictions. Nevertheless, we are interested in how the restrictions will be applied.

COMMENT (76)

Section 11.2 It is mentioned that further covenants will be included on the landfill deed to the effect that radioactive material has been disposed on the site. The application should include additional information on the specific details that will be included in this restrictive covenant.

COMMENT (77)

Appendix B On page 2 of the "Declaration of Restrictive Covenant," it is explained that the restrictive covenants will be lifted after 15 years following completion of "all landfill activity." The application should clarify whether this means 15 years after disposal of the last wastes and final covering, or 15 years after the cessation of all monitoring and surveillance that could be considered "landfill activities".

COMMENT (78)

Appendix B The application should include information on, and the content of the additional restrictive covenants that will be placed on the property after the current ones shown are lifted. In addressing this question, the application should describe the requirements for future restrictive covenants that will be imposed on the Salzburg Landfill as a result of the permitted burial of hazardous material at the facility.

RESPONSE TO (72), (76), (77) AND (78)

Additional proposed restrictive covenants, relevant to Cells 36 & 37, have been prepared and are provided in Appendix W. These covenants, which are in addition to those currently on record affecting the Landfill, are intended to ensure long-term institutional control at the facility, and to prevent any future action that would impair the integrity of Cells 36 & 37. They "shall run with the land in perpetuity and shall be binding upon Dow, its successors and assigns." For completeness, a copy of the existing Declaration of Restrictive Covenants provided with the 1989 License Application (including the previously omitted signature page) is also included in Appendix W.

COMMENT (79)

Appendix B Please supply a copy of the RCRA Part B Application and permit for the Salzburg site. A copy of the RCRA Part B Application and permit for the Salzburg site, which contains section background site characterization information, will be helpful in preparing the dose assessment.

RESPONSE

A copy of the Table of Contents of the RCRA Part B Application is provided in Appendix B. Copies of specific material in this voluminous application will be furnished upon request.

COMMENT (80)

Appendix G Please provide a cell construction diagram showing the relation of the geologic/lithologic units around the cell to the cell construction.

RESPONSE

Figure S1.0 in Appendix S shows a typical cell excavation plan at the Salzburg Landfill as it relates to the geologic profile under the landfill.

COMMENT (81)

Appendix G. The reduced copies of the construction drawings in the application were hard to read. Please supply the full scale versions of these drawings.

RESPONSE

A set of full scale construction drawings B2-001-884040 through B2-021-884040 is included as attached Appendix T to this response. These drawings, which provide accurate details of the proposed Cells 36 & 37 design, replace the reduced copies in Appendix G of the license application. (Please note that there is no drawing B2-019).

COMMENT (82)

Appendix I A reference list should be provided for this Appendix.

RESPONSE

The reference list was inadvertently omitted from Appendix I. It is provided in the Errata.

In addition to the radiological impacts analysis provided in Appendix I for the removal, transport and disposal of the thoriated material, a NESHAPS Compliance Assessment for the current site status (no action case) and for the removal and disposal at the Salzburg Landfill was performed in December, 1990 using the COMPLY Code at Level 4 (most site specific). The Report presenting the results of this analysis is provided in Appendix O. In summary, the results of the analysis are;

Current Status:	
Maximum Dose (EDE)* to nearest resident at Bay City	- 0.1 mrem/yr
Maximum Dose (EDE) to nearest resident at Midland	- 0.008 mrem/yr
Excavation and Removal	
Maximum EDE to nearest resident at Bay City	- 0.32 mrem/yr
Maximum EDE to nearest resident at Midland	- 0.031 mrem/yr
Emplacement at the Salzburg Landfill	
Maximum EDE to nearest resident	- 0.44 mrem/yr

* Effective Dose Equivalent

COMMENT (83)

Appendix I, Section 1.2.0 What is the basis for assuming dust burdens and specific activities equal to uranium mill tailings? What are the units for specific activity of dust?

RESPONSE

Dust burden and specific activities equal to uranium mill tailings were assumed to provide highly conservative results. Actual dust burdens at the site will be less than the value used. The units for specific activity used in the analysis are pCi/g; the value 2.4 is a dimensionless ratio.

COMMENT (84)

Appendix I Table 2.0 This table is missing.

RESPONSE

Table I.2.0 was inadvertently omitted from the text. It is now provided in the Errata to the License Application.

TABLE 1

COMPARISON OF EXPOSURE DURING TRANSPORT
FOR POTENTIAL REMEDIAL ALTERNATIVES

	Exposures for Potential Disposal Facility (Person-mrem/activity)			
Population Affected	Salzburg Landfill, MI	Beatty, NV	Michigan Compact Site	Clive, UT
Truck Drivers (Total Exposure)	7,920[1]	863,300	39,600	704,900
Population Along Route [2]	600	64,500	3,000	52,700

(1) Based on calculations in Section 1.1.1 of Appendix I to License Application. Highly conservative assumptions were used to estimate doses (i.e., no reduction in dose is assumed for effect of distance or shielding from the truck and driver assumed to remain at 1 meter from truck exterior at all times). All assumptions are comparable for each disposal location so that exposures vary with distance traveled.

(2) Based on average population density of 60 people/mi^2, and a truck velocity of 40 mph, calculated from IMPACTS-BRC Version 2 code.

TABLE 2

OUTLINE OF WORK PLAN FOR
IMPLEMENTATION OF DISPOSAL OF SLAG MATERIAL AT SALZBURG LANDFILL

1.0 INTRODUCTION

- 1.1 Summary of Database Characterizing the Bay City and Midland Slag and Surrounding Media
- 1.2 Salzburg Landfill Disposal Site (location, operational history, management approach, land use and demographics, topography, hydrogeology, etc.)
- 1.3 Cells 36 & 37 Design and Construction
- 1.4 Remedial Program Objectives

2.0 REMEDIAL PROGRAM

- 2.1 Program Management (organization, lines of authority and communication)
- 2.2 Phase/Task Description of Work
- 2.3 Schedules and Milestones
- 2.4 Labor and Estimated Cost Per Task
- 2.5 Equipment and Material to be Used

3.0 PLANS AND PROCEDURES

- 3.1 Slag/Soil Excavation and Removal Procedures
- 3.2 Slag/Soil Survey and Sampling Protocols, Analytic Procedures, and Release Standards for Remediated Sites
- 3.3 Slag/Soil Emplacement Procedures in Cells 36 & 37
- 3.4 Cells 36 & 37 Closure Plan and Procedures
- 3.5 Post-Closure Plans and Procedures (monitoring, maintenance, etc.)
- 3.6 Equipment and Vehicle Decontamination Standards and Procedures
- 3.7 Slag/Soil Truck Loading, and Hauling Procedures
- 3.8 Recordkeeping and Reporting Plan
- 3.9 Quality Assurance Plan

4.0 ENVIRONMENTAL HEALTH & SAFETY PLAN

- 4.1 ALARA Program
- 4.2 Health & Safety Organization
- 4.3 Site(s) Access Control Procedures
- 4.4 Worker Training and Indoctrination
- 4.5 Personnel Monitoring and Dosimetry Program
- 4.6 Environmental Monitoring Program
- 4.7 Personnel Contamination Control Procedures (controlled areas, monitoring, decontamination, prohibitions for restricted areas)
- 4.8 Sample Control, Handling, Packaging, and Shipping Procedures
- 4.9 Emergency and Contingency Procedures (during handling and transport)

5.0 AGENCY AND COMMUNITY INFORMATION PLAN

TABLE 3

DOW CHEMICAL MIDLAND PLANT, SALZBURG LANDFILL
SOIL BORING 3421 SEDIMENT ANALYSES
APRIL, 1985

Sample Identifier	B	C	D	E	F	G	H	I
Elev. of Sample (USGS Datum)	602.9	597.9	592.9	587.9	582.9	577.9	572.9	567.9
% Moisture	13.0	8.0	9.0	7.0	9.0	6.0	9.0	8.0
Unit Weight (PCF)	141		140				148	
Liquid Limit	19.1	18.4	17.7	16.1	15.7	12.6	15.7	13.2
Plastic Limit	12.4	12.3	13.3	10.7	10.3	11.6	10.0	10.5
Plasticity Index	6.7	6.1	6.4	5.4	5.4	1.0	5.7	2.7
Unified Soil Classification	CL-ML	SM-SC	CL-ML	SM-SC	SM-SC	SM	SM-SC	SM
Permeability		1.2×10^{-8}		2.2×10^{-8}		6.2×10^{-7}		5.4×10^{-7}
% Passing # 200 Sieve	65	48	50	46	41	32	39	32
% > or = .00	38	18	29	17	15	7	13	7

TABLE 4

WATER LEVELS FOR SALZBURG MONITORING WELLS

Water level data taken before purging and sampling of the nineteen Salzburg monitoring wells in the Operating License is as follows:

Well #	2nd Qtr 1990	4th Qtr 1990	2nd Qtr 1991
4829	617.07	615.68	616.66
4830	620.02	619.96	619.61
4831	609.21	610.28	NOT SAMPLED
4832	620.33	620.16	619.17
4833	620.54	620.72	620.38
4834	617.62	618.14	617.60
4836	608.72	608.69	610.52
4837	609.38	608.64	610.77
4838	623.99	624.00	624.88
4839	622.96	623.30	623.53
4840	621.22	621.37	622.19
4841	620.59	619.85	621.34
4844	620.28	605.91	620.68
4666	612.10	615.11	619.31
4667	619.60	618.92	619.37
4846	567.48	591.62	602.88
2708*	625.00	623.00	625.72
3011	624.43	622.96	625.27
3168	623.13	621.83	623.91

* NOTE: Water level readings on Well 2708 are taken from the 3600 Building computer.

TABLE 5

HAZARDOUS MATERIAL IN CELLS 15 & 16 AND 17 to 19

Material	Volume (yd^3)	RCRA/MI Act 64 Waste Code
incinerator ash	34,032	001T
secondary WWTP solids	23,500	005T
primary WWTP solids	18,157	003T
soil containing benzene	1,695	U019
soil characteristic for benzene	880	D018
waste containing > 0.7 mg/l 1,1-dichloroethene	370	D029
waste containing chromium	350	D007
waste containing copper	232	001D
soil containing leachate	220	F039
soil characteristic for chlorobenzene	100	U037
soil containing toluene	75	U220
waste containing 2,4-D	47	D016
soil containing xylene	20	F003
waste containing lead	12	D008
soil containing tertiary pond waste water	10	F001
soil containing methylene chloride	10	F002
waste containing barium	7	D005
waste containing zinc	1	003D
waste containing mercury	1	D009
waste containing silvex	1	D017
soil with 2,4-D waste water	1	F039
chromic fluoride	< 1	D002

TABLE 6

SCHEDULE FOR
CONSTRUCTION QUALITY ASSURANCE TESTING OF SOILS USED IN CELL CONSTRUCTION

CELL COMPONENT	TEST METHOD	PROPERTY EVALUATED	MINIMUM FREQUENCY
Clay for primary and secondary liners	ASTM* D2487	Classification of soils	Every 5,000 cubic yards (CY)
	ASTM D422	Particle size analysis	Every 5,000 CY
	ASTM D4318	Liquid limit, plastic limit and plasticity index determination	Every 5,000 CY
	ASTM D1557	Mositure-density relationship	Every 5,000 CY
	ASTM D2922	Density of soils by nuclear methods	Every 1,000 CY
	EM 1110-2-1906**	Permeability test	Every 10,000 CY
	Field Survey	Minimum thickness determination & elevation checks	Every 100 feet in longitudinal direction of cell and at the centerline and all grade breaks in tranverse direction of cell
2NS sand for liner failure detection & leachate collection systems	ASTM C136	Gradation determination	Every 5,000 CY
	ASTM D2434	Permeability test	Every 5,000 CY
	Field Survey	Minimum thickness determination & elevation checks	Every 100 feet in longitudinal direction of cell and at the centerline and all grade breaks in transverse direction of cell
Pea stone for liner failure failure detection & leachate collection systems	ASTM C136	Gradation determination	Every 500 CY (2 minimum)

* ASTM = American Society for Testing and Materials
**EM1110-2-1906 is a Corps of Engineers Test Method

Table 7

Specifications of Con Cover™

ConCover™

ENVIRONMENTAL CONTROL FOR LANDFILLS

TECHNICAL BULLETIN

Product Description

A spray applied temporary cover for use to minimize infiltration of precipitation, to control blowing litter and particulate matter, to control air emissions of volatile materials and odors. The system consists of two components that are nontoxic Part A that is a binding agent and part B a treated recycled cellulose fiber to provide structural integrity. When cured these two components form a 1/8" - 1/4" crust for normal application.

Specifications Blended ConCover

Property	Specification		
Appearance, 25º C	-Slurry of a consistent nature -dark green color with solids fully suspended in solution.		
pH, slurry	-9.5 max. -8.0 min.		
Flash Point, T.C.C.	-None		
Water Solubility	-100% soluble (binder components only)		
D.O.T. Shipping Class	-N/A		
D.O.T. Hazard Class	-N/A		
Typical US E.P.A. Toxicity Ext' Procedure (SW846)	Units	Results	Detection Limit
EP Arsenic	mg/L	<0.04	0.04
EP Barium	mg/L	< 4	4
EP Cadmium	mg/L	<0.1	0.1
EP Chromium	mg/L	<0.2	0.2
EP Copper	mg/L	<0.2	0.2
EP Lead	mg/L	<0.2	0.2
EP Mercury	mg/L	<0.004	0.004
EP Selenium	mg/L	<0.04	0.04
EP Silver	mg/L	<0.2	0.2
EP Zinc	mg/L	.27	0.2

SS-4/90

Newastecon believes all information in this document to be true and reliable to the best of its knowledge. No guarantee, warranty, or representation is made as to the suitability of this sales specification. The user should conduct his own investigation as to the suitability of this product for his own use.

Total Dose to Intruders from Residual Radioactivity as a Function of Soil Cover Thickness

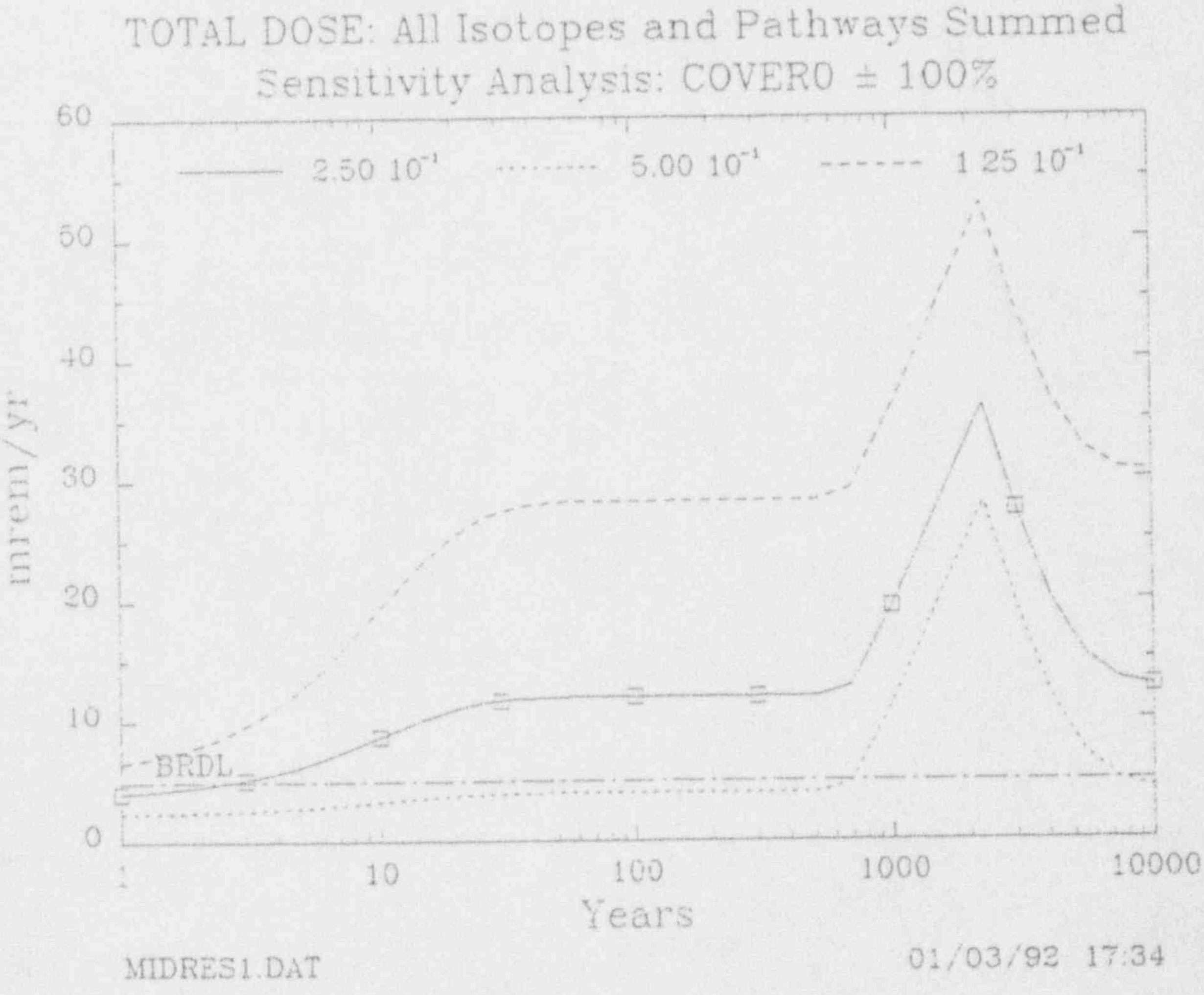
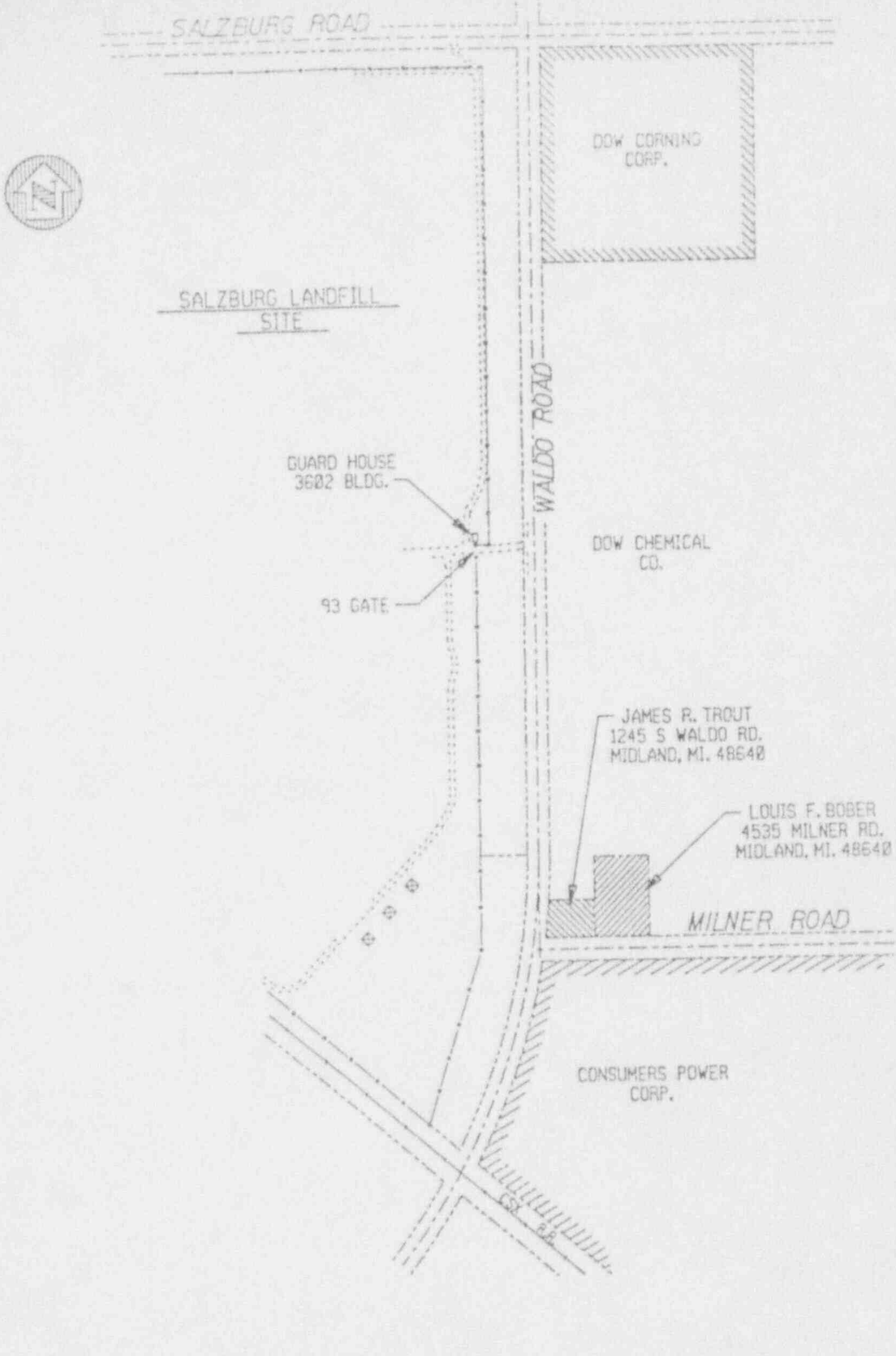


Figure 1



PROPERTY OWNERSHIP
EAST SIDE OF WALDO ROAD
ACROSS FROM SALZBURG LANDFILL

Figure 2

Time Varying Dose to an Intruder at Salzburg
as a Function of Cover Thickness

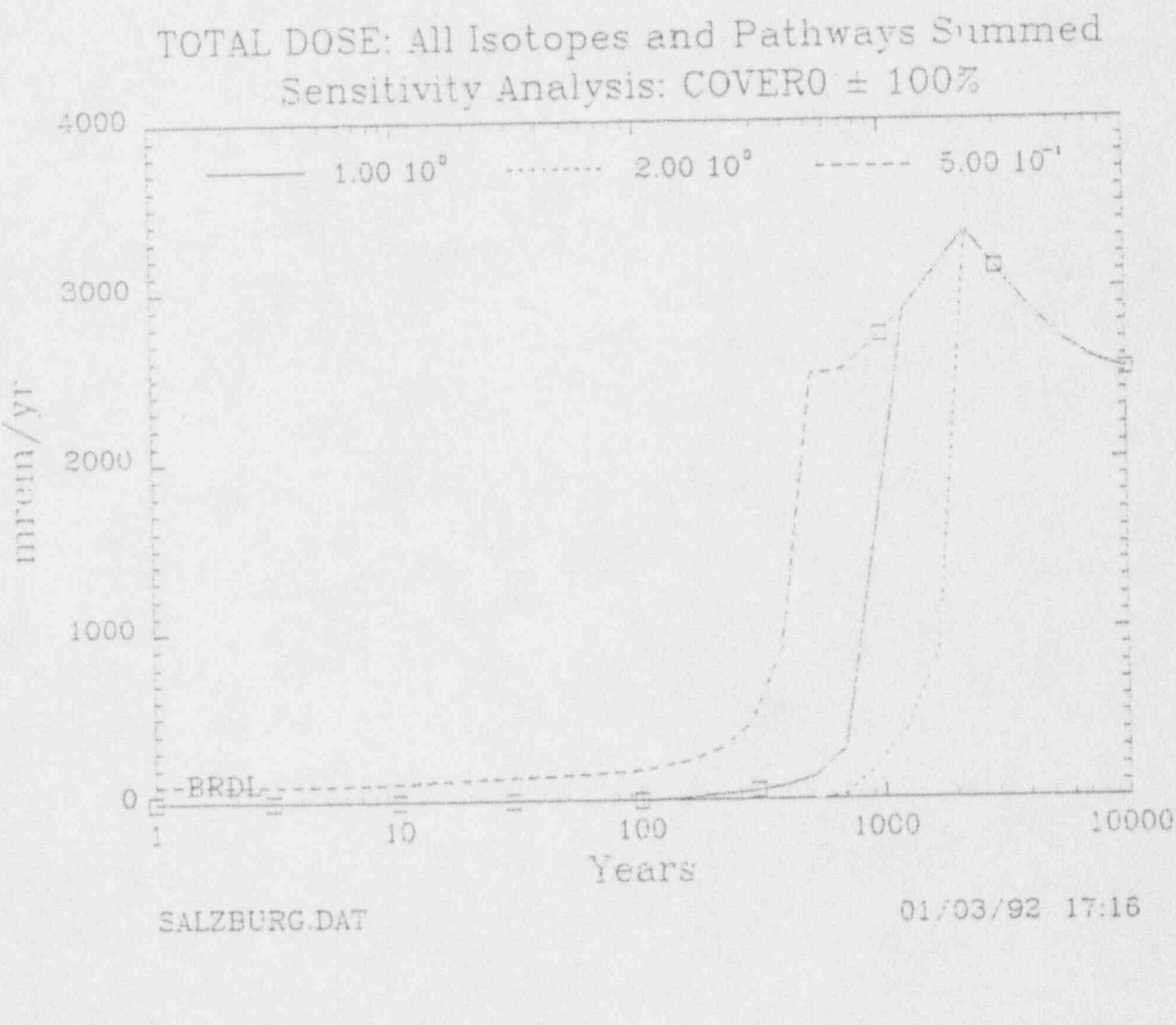


Figure 3

Time Varying Dose to an Intruder at Salzburg with No Cover

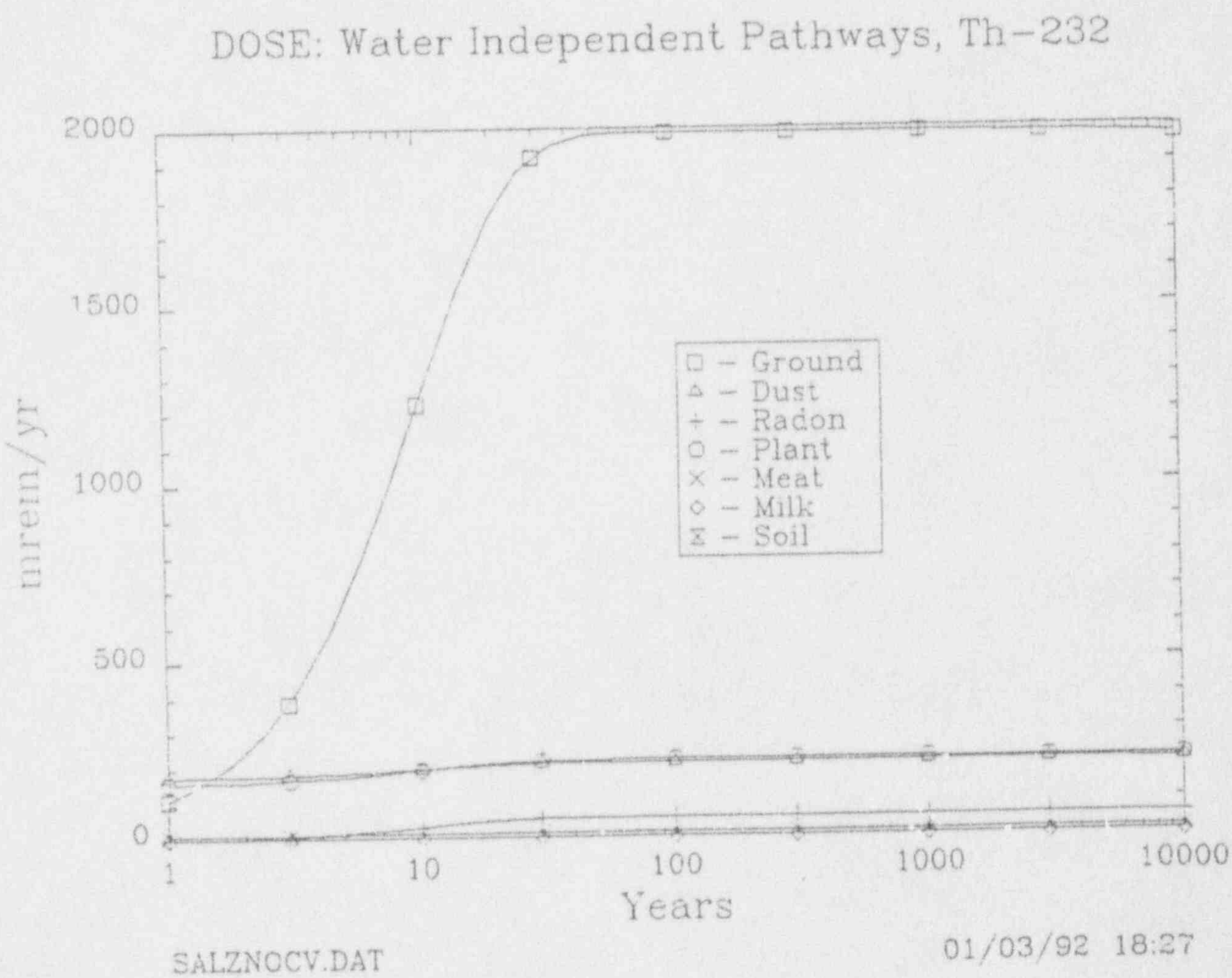


Figure 4

Time Varying Dose to an Intruder at Salzburg with No Cover

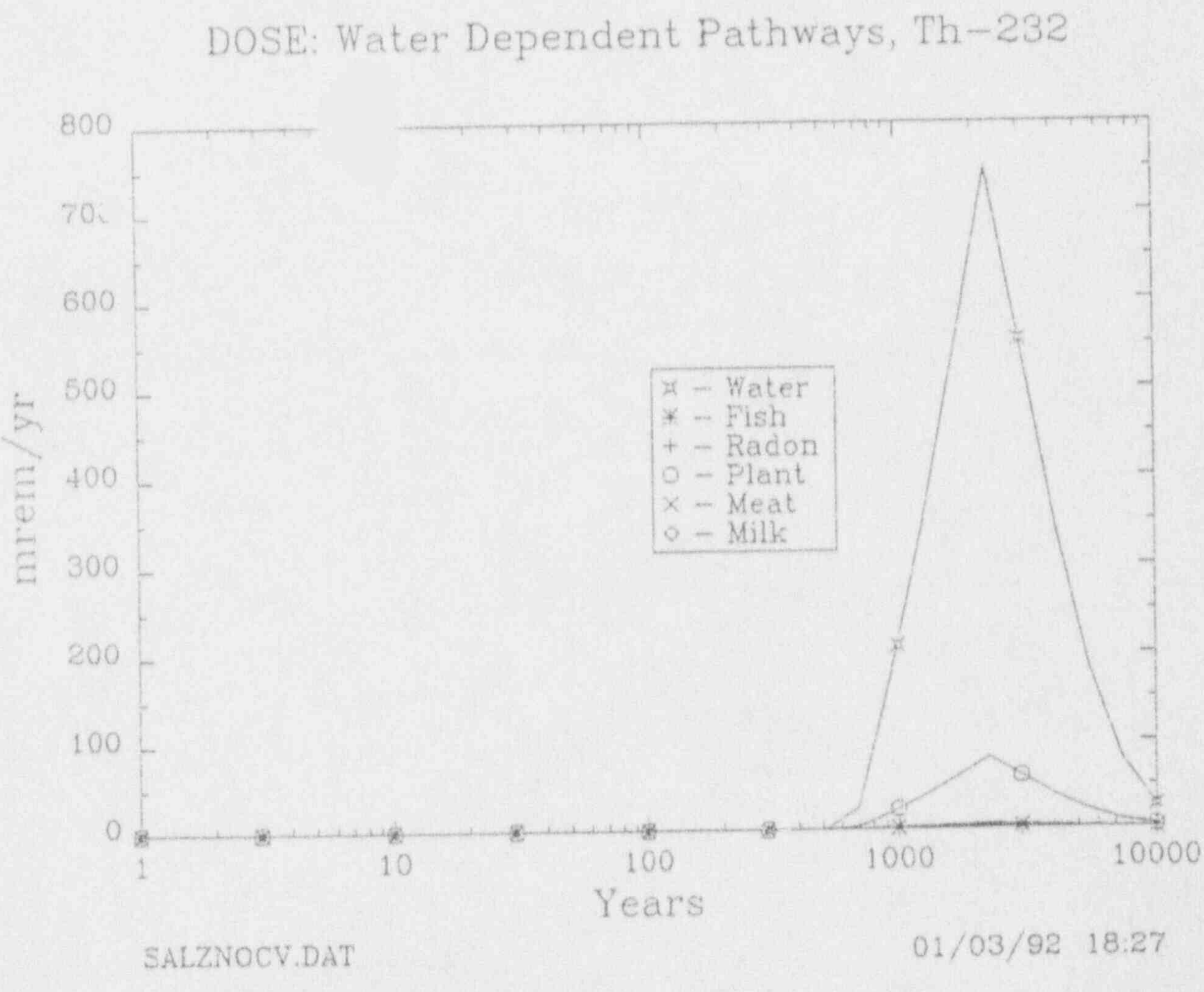


Figure 5

Time Varying Dose to an Intruder at Salzburg
with No Cover -10 $^{-6}$ m/y Erosin Rates

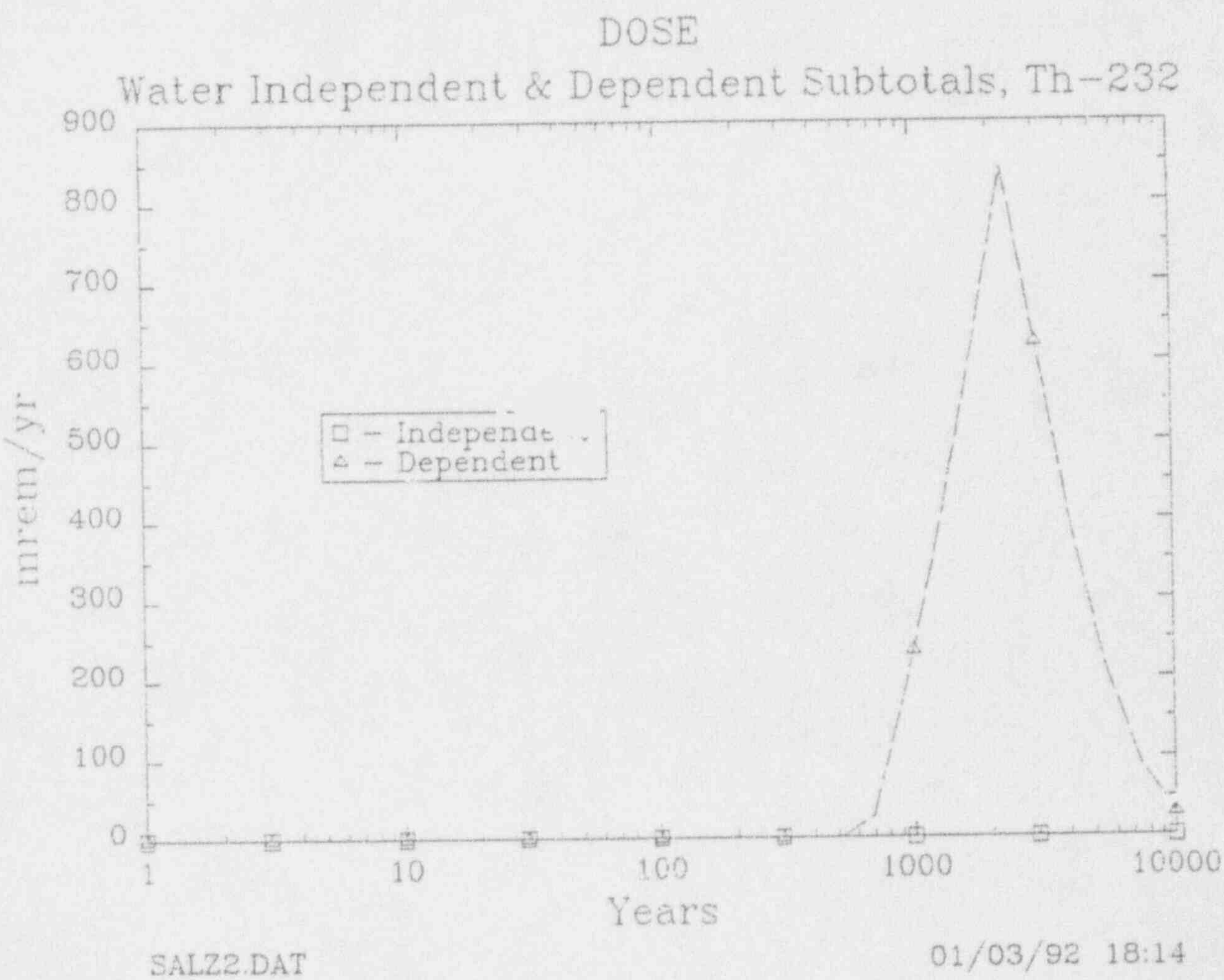


Figure 6

Time Varying Dose to an Intruder at Salzburg
Using Realistic Groundwater Model

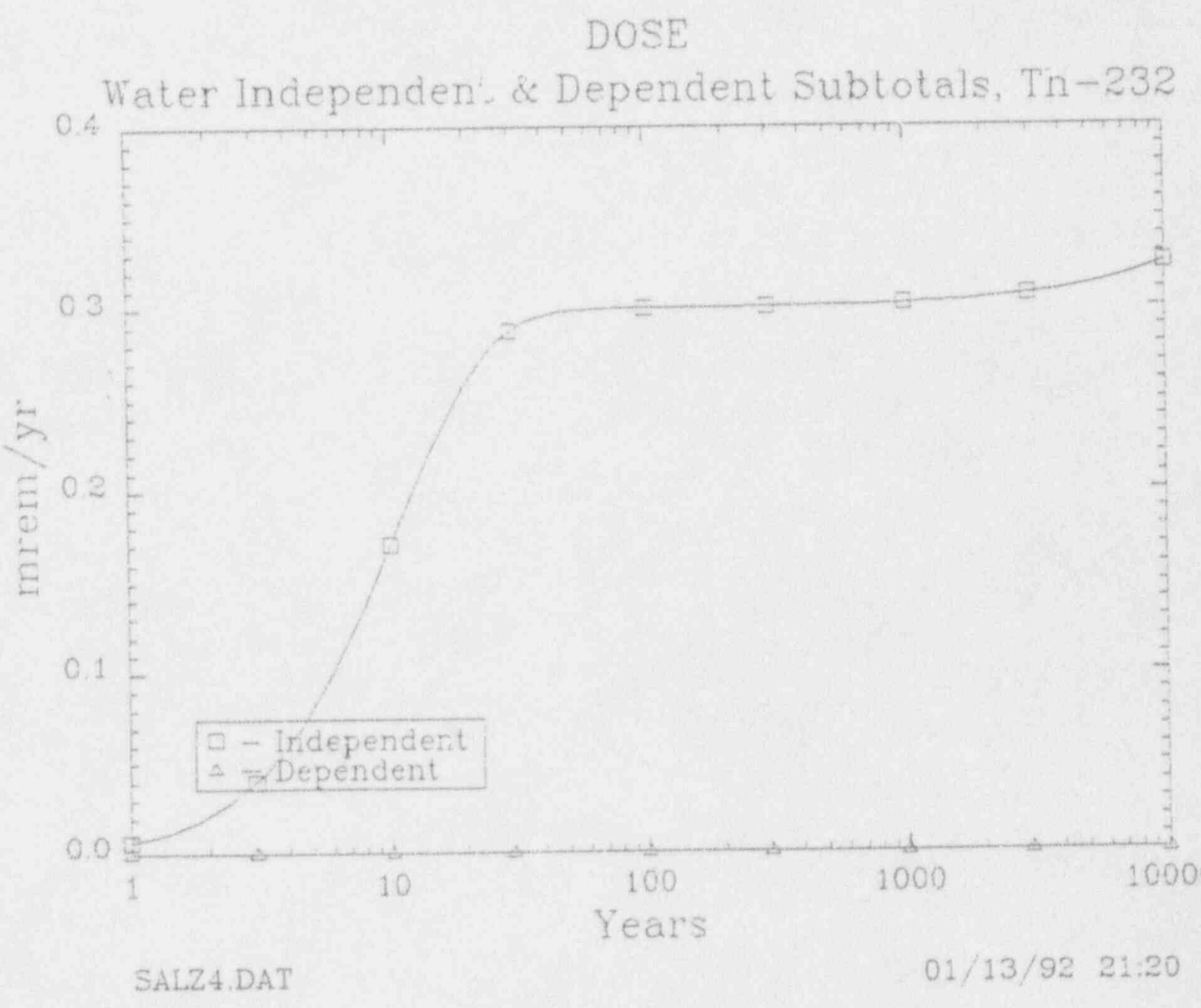


Figure 7

Parametric Study of Effect on Dose of Varying Radium K_d

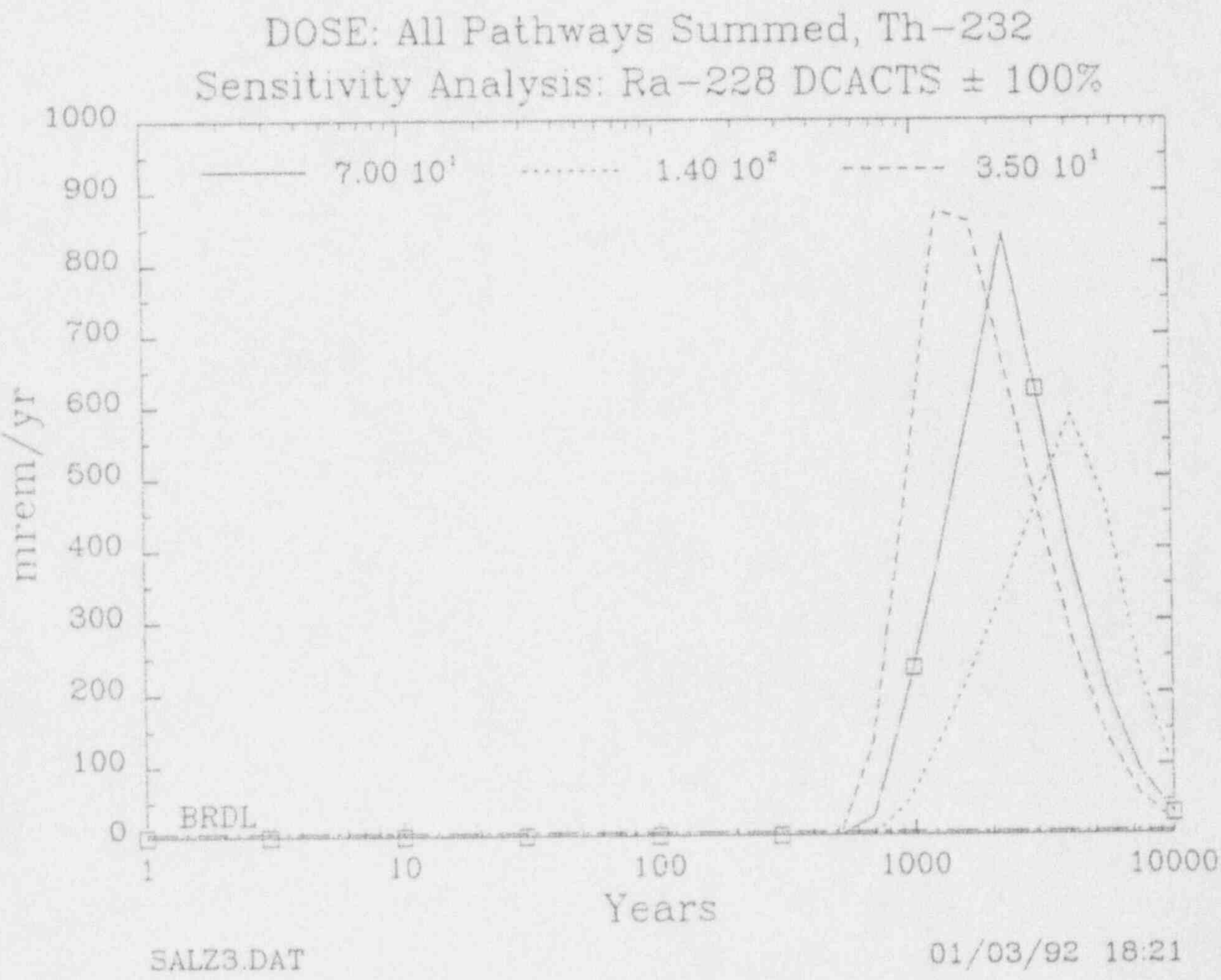


Figure 8

Time Varying Dose with no Cover Erosion
Assume Radium K_d =Thorium K_d=250 cm^3/g (very Low)

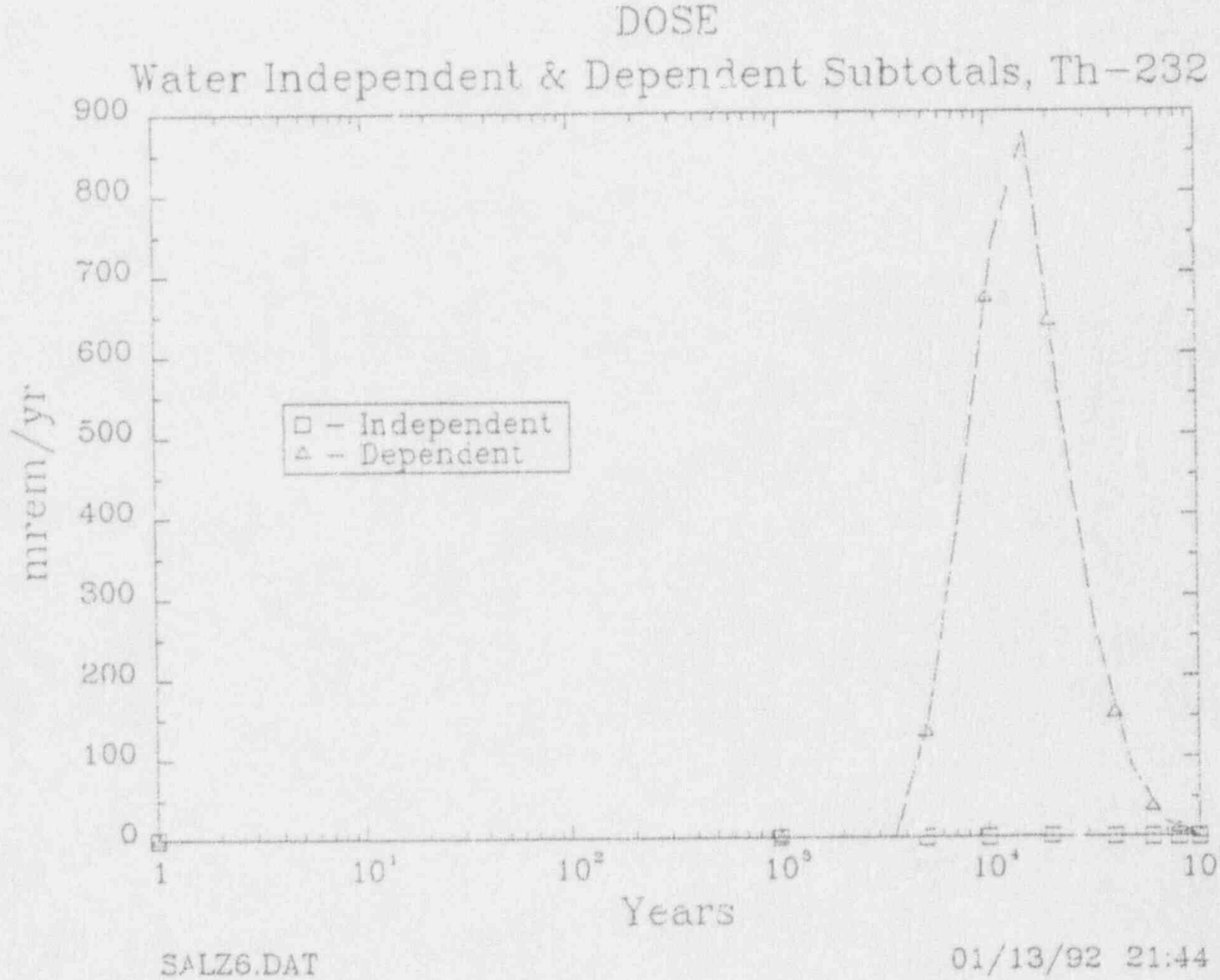


Figure 9

Time Varying Dose Profile
Resulting from Erosion of Cover and Contaminated Zone

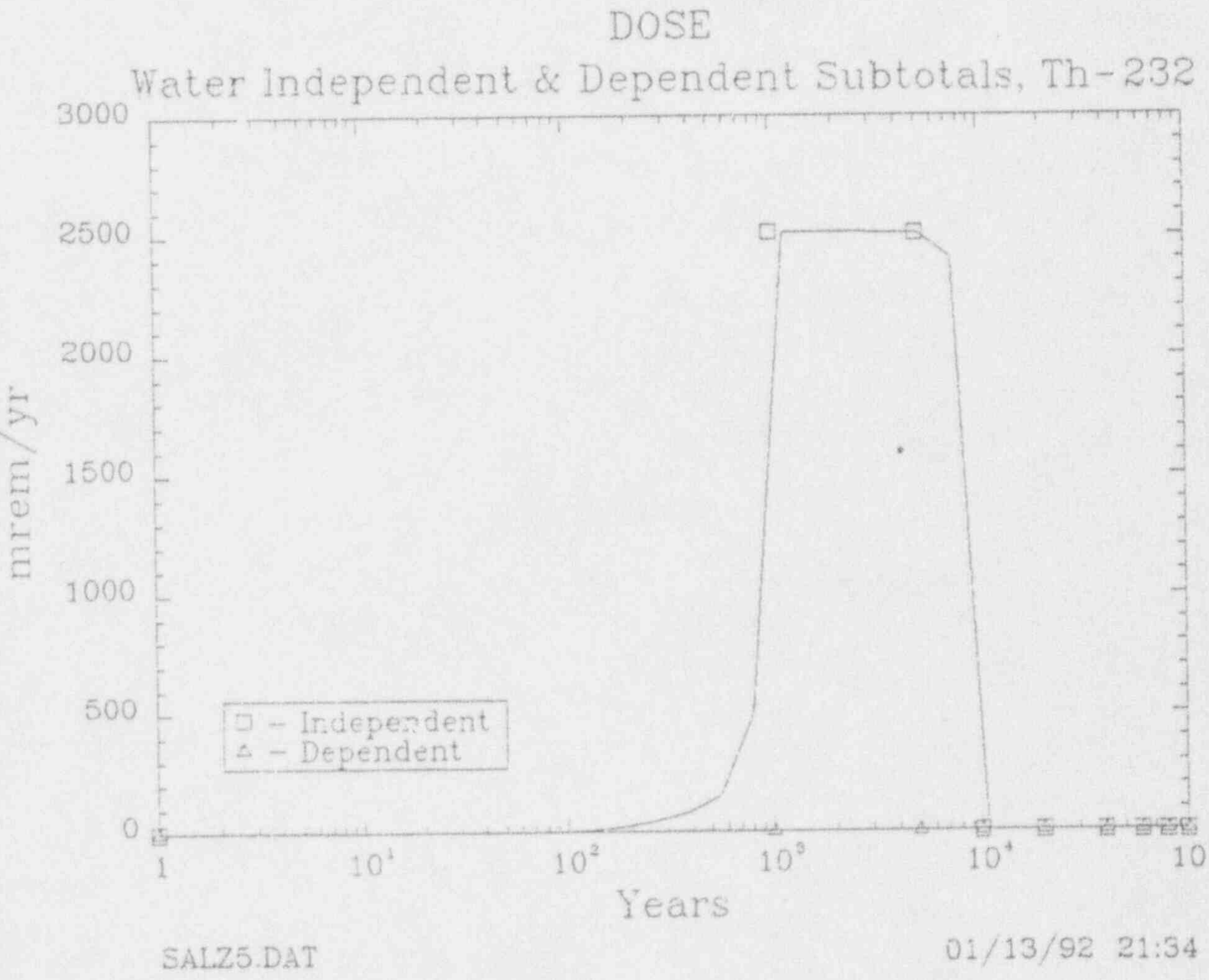


Figure 10

APPENDIX A

MAXI and RESRAD Model Calculations
for Exposure to Residual Materials

Table of Contents

Part I: Mixture Sums and Single Radionuclide Guidelines

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	1.000E+04	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	1.000E+00	1.000E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	1.000E+02	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	5.000E+00	1.000E+02	---	BRLD
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	1.000E+01	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+02	1.000E+01	---	T(4)
R011	Times for calculations (yr)	5.000E+02	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+03	1.000E+02	---	T(6)
R011	Times for calculations (yr)	5.000E+03	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+04	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	3.000E+03	---	T(9)
R011	Times for calculations (yr)	not used	1.000E+04	---	T(10)
R012	Initial principal radionuclide (pCi/g): Ra-228	5.000E+00	0.000E+00	---	S(1)
R012	Initial principal radionuclide (pCi/g): Th-228	5.000E+00	0.000E+00	---	S(2)
R012	Initial principal radionuclide (pCi/g): Th-232	5.000E+00	0.000E+00	---	S(3)
R012	Concentration in groundwater (pCi/L): Ra-228	not used	0.000E+00	---	W(1)
R012	Concentration in groundwater (pCi/L): Th-228	not used	0.000E+00	---	W(2)
R012	Concentration in groundwater (pCi/L): Th-232	not used	0.000E+00	---	W(3)
R013	Cover depth (m)	0.000E+00	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.600E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.600E+00	1.600E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-07	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	4.000E-01	4.000E-01	---	TPCZ
R013	Contaminated zone effective porosity	2.000E-01	2.000E-01	---	EPCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	1.000E+01	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	5.300E+00	5.300E+00	---	BCZ
R013	Evapotranspiration coefficient	6.000E-01	6.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	1.000E+00	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	2.000E-01	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	1.000E+06	1.000E+06	---	WAREA
R014	Density of saturated zone (g/cm**3)	1.600E+00	1.600E+00	---	DENSAQ
R014	Saturated zone total porosity	4.000E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	2.000E-01	2.000E-01	---	EPSZ
R014	Saturated zone hydraulic conductivity (m/yr)	1.000E+02	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	2.000E-02	2.000E-02	---	HGWT
R014	Saturated zone b parameter	5.300E+00	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	1.000E-03	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	1.000E+01	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	---	MODEL
R014	Individual's use of groundwater (m**3/yr)	not used	1.500E+02	---	UW
R015	Number of unsaturated zone strata	1	1	---	NS

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R015	Unsat. zone 1, thickness (m)	4.000E+00	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	1.600E+00	1.600E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	4.000E-01	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	2.000E-01	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	5.300E+00	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	1.000E+02	1.000E+02	---	HCUZ(1)
R016	Distribution coefficients for Ra-228				
R016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCACTC(1)
R016	Unsaturated zone 1 (cm**3/g)	7.000E+01	7.000E+01	---	DCACTU(1,1)
R016	Saturated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCACTS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	3.561E-03	RLEACH(1)
R016	Distribution coefficients for Th-228				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCACTC(2)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCACTU(2,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCACTS(2)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	4.167E-06	RLEACH(2)
R016	Distribution coefficients for Th-232				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCACTC(3)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCACTU(3,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCACTS(3)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	4.167E-06	RLEACH(3)
R017	Inhalation rate (m**3/yr)	8.400E+03	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	2.000E-04	2.000E-04	---	MLINH
R017	Dilution length for airborne dust, inhalation (m)	3.000E+00	3.000E+00	---	LM
R017	Occupancy factor, inhalation	4.500E-01	4.500E-01	---	FO3
R017	Occupancy and shielding factor, external gamma	6.000E-01	6.000E-01	---	FO1
R017	Shape factor, external gamma	1.000E+00	1.000E+00	---	FS1
R017	Fractions of annular areas within AREA:				
R017	Outer annular radius (m) = √(1/π)	not used	1.000E+00	---	FRACA(1)
R017	Outer annular radius (m) = √(10/π)	not used	1.000E+00	---	FRACA(2)
R017	Outer annular radius (m) = √(20/π)	not used	1.000E+00	---	FRACA(3)
R017	Outer annular radius (m) = √(50/π)	not used	1.000E+00	---	FRACA(4)
R017	Outer annular radius (m) = √(100/π)	not used	1.000E+00	---	FRACA(5)
R017	Outer annular radius (m) = √(200/π)	not used	1.000E+00	---	FRACA(6)
R017	Outer annular radius (m) = √(500/π)	not used	1.000E+00	---	FRACA(7)
R017	Outer annular radius (m) = √(1000/π)	not used	1.000E+00	---	FRACA(8)
R017	Outer annular radius (m) = √(5000/π)	not used	1.000E+00	---	FRACA(9)
R017	Outer annular radius (m) = √(1.E+04/π)	not used	1.000E+00	---	FRACA(10)
R017	Outer annular radius (m) = √(1.E+05/π)	not used	0.000E+00	---	FRACA(11)
R017	Outer annular radius (m) = √(1.E+06/π)	not used	0.000E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	1.600E+02	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	1.400E+01	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	9.200E+01	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	6.300E+01	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	5.400E+00	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	9.000E-01	9.000E-01	---	DIET(6)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R018	Soil ingestion rate (g/yr)	3.650E+01	0.000E+00	---	SOIL
R018	Drinking water intake (L/yr)	4.100E+02	4.100E+02	---	DWI
R018	Fraction of drinking water from site	1.000E+00	1.000E+00	---	FDW
R019	Livestock fodder intake for meat (kg/day)	6.800E+01	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	5.500E+01	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	5.000E+01	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	1.600E+02	1.600E+02	---	LWI6
R019	Mass loading for foliar deposition (g/m**3)	1.000E-04	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	9.000E-01	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Livestock water fraction from ground water	1.000E+00	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	1.000E+00	1.000E+00	---	FGWIR
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	1.000E-01	1.000E-01	---	TPFL
R021	Volumetric water content of the cover material	not used	5.000E-02	---	PH2OCV
R021	Volumetric water content of the foundation	1.000E-02	1.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.000E-06	---	DIFCV
R021	in foundation material	2.000E-08	2.000E-08	---	DIFFL
R021	in contaminated zone soil	2.000E-06	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	2.000E+00	2.000E+00	---	HMIX
R021	Average annual wind speed (m/sec)	2.000E+00	2.000E+00	---	WIND
R021	Average building air exchange rate (1/hr)	1.000E+00	1.000E+00	---	REXG
R021	Height of the building (room) (m)	2.500E+00	2.500E+00	---	HRM
R021	Building interior area factor	1.000E+00	1.000E+00	---	FAI
R021	Bulk density of building foundation (g/cm**3)	2.400E+00	2.400E+00	---	DENSFL
R021	Thickness of building foundation (m)	1.500E-01	1.500E-01	---	FLOOR
R021	Building depth below ground surface (m)	1.000E+00	1.000E+00	---	DMFL
R021	Fraction of time spent indoors	5.000E-01	5.000E-01	---	FIND
R021	Fraction of time spent outdoors (on site)	2.500E-01	2.500E-01	---	FOTD
R021	Emanating power of Rn-222 gas	not used	2.000E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	1.000E-01	1.000E-01	---	EMANA(2)

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	active
2 -- inhalation	active
3 -- plant ingestion	active
4 -- meat ingestion	active
5 -- milk ingestion	active
6 -- aquatic foods	active
7 -- drinking water	active
8 -- radon	active
9 -- soil ingestion	active

Contaminated Zone Dimensions	
Area:	10000.00 square meters
Thickness:	1.00 meters
Cover Depth:	0.00 meters

Initial Soil Concentrations, pCi/g	
Ra-228	5.000E+00
Th-228	5.000E+00
Th-232	5.000E+00

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 5 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	1.000E+01	1.000E+02	5.000E+02	1.000E+03	5.000E+03	1.000E+04
TDOSE(t):	8.414E+01	8.402E+01	8.284E+01	8.203E+01	8.189E+01	8.692E+01	8.037E+01	7.872E+01
M(t):	1.683E+01	1.680E+01	1.657E+01	1.641E+01	1.638E+01	1.738E+01	1.607E+01	1.574E+01

Maximum TDOSE(t): 8.920E+01 mrem/yr at t = 2055.5 ± 0.6 years

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 2055.5 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	6.363E+01	0.7133	6.933E+00	0.0777	2.239E+00	0.0251	7.109E+00	0.0797	8.095E-01	0.0091	4.642E-03	0.0001	6.370E-01	0.0071
Total	6.363E+01	0.7133	6.933E+00	0.0777	2.239E+00	0.0251	7.109E+00	0.0797	8.095E-01	0.0091	4.642E-03	0.0001	6.370E-01	0.0071

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 2055.5 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	6.908E+00	0.0774	4.170E-02	0.0005	0.000E+00	0.0000	7.577E-01	0.0085	9.181E-02	0.0010	4.044E-02	0.0005	8.920E+01	1.0000
Total	6.908E+00	0.0774	4.170E-02	0.0005	0.000E+00	0.0000	7.577E-01	0.0085	9.181E-02	0.0010	4.044E-02	0.0005	8.920E+01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Independent Pathways

Radio-Nuclide	Ground mrem/yr	Ground fract.	Dust mrem/yr	Dust fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Ra-228	2.512E+01	0.2986	1.651E-02	0.0002	0.000E+00	0.0000	7.344E-01	0.0087	1.817E-02	0.0002	4.335E-03	0.0001	1.643E-01	0.0020
Th-228	4.095E+01	0.4867	1.138E+00	0.0135	2.325E+00	0.0276	1.373E+00	0.0163	1.698E-01	0.0020	1.003E-04	0.0000	1.027E-01	0.0012
Th-232	3.545E-03	0.0000	5.872E+00	0.0698	0.000E+00	0.0000	5.124E+00	0.0609	6.339E-01	0.0075	3.744E-04	0.0000	3.832E-01	0.0046
Total	6.608E+01	0.7854	7.026E+00	0.0835	2.325E+00	0.0276	7.231E+00	0.0859	8.219E-01	0.0098	4.810E-03	0.0001	6.502E-01	0.0077

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0 0000	0.000E+00	0.0000	2.606E+01	0.3097
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.606E+01	0.5474
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.202E+01	0.1428
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.414E+01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	3.386E+01	0.4030	3.386E-01	0.0040	6.621E-01	0.0079	1.040E+00	0.0124	6.441E-02	0.0008	3.858E-03	0.0000	1.743E-01	0.0021
Th-228	2.850E+01	0.3392	7.919E-01	0.0094	1.618E+00	0.0193	9.553E-01	0.0114	1.182E-01	0.0014	6.980E-05	0.0000	7.145E-02	0.0009
Th-232	3.608E+00	0.0429	5.895E+00	0.0702	4.322E-02	0.0005	5.233E+00	0.0623	6.391E-01	0.0076	8.669E-04	0.0000	4.037E-01	0.0048
Total	6.597E+01	0.7851	7.025E+00	0.0836	2.324E+00	0.0277	7.228E+00	0.0860	8.217E-01	0.0098	4.795E-03	0.0001	6.495E-01	0.0077

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.614E+01	0.4301
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.206E+01	0.3816
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.582E+01	0.1883
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.402E+01	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	2.364E+01	0.2854	4.594E-01	0.0055	9.292E-01	0.0112	7.612E-01	0.0092	7.312E-02	0.0009	1.296E-03	0.0000	8.860E-02	0.0011
Th-228	1.093E+00	0.0132	3.037E-02	0.0004	6.207E-02	0.0007	3.[illegible]64E-02	0.0004	4.533E-03	0.0001	2.677E-06	0.0000	2.741E-03	0.0000
Th-232	4.015E+01	0.4847	6.517E+00	0.0787	1.295E+00	0.0156	6.395E+00	0.0772	7.410E-01	0.0089	3.421E-03	0.0000	5.537E-01	0.0067
Total	6.489E+01	0.7833	7.007E+00	0.0846	2.287E+00	0.0276	7.193E+00	0.0868	8.187E-01	0.0099	4.719E-03	0.0001	6.451E-01	0.0078

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.596E+01	0.3133
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.230E+00	0.0148
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.566E+01	0.6718
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.284E+01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	3.634E-04	0.0000	7.261E-06	0.0000	1.470E-05	0.0000	1.173E-05	0.0000	1.149E-06	0.0000	1.867E-08	0.0000	1.332E-06	0.0000
Th-228	7.532E-15	0.0000	2.092E-16	0.0000	4.276E-16	0.0000	2.524E-16	0.0000	3.123E-17	0.0000	1.844E-20	0.0000	1.888E-17	0.0000
Th-232	6.415E+01	0.7821	6.990E+00	0.0852	2.257E+00	0.0275	7.167E+00	0.0874	8.161E-01	0.0099	4.680E-03	0.0001	6.422E-01	0.0078
Total	6.415E+01	0.7821	6.990E+00	0.0852	2.257E+00	0.0275	7.167E+00	0.0874	8.161E-01	0.0099	4.680E-03	0.0001	6.422E-01	0.0078

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.996E-04	0.0000
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.471E-15	0.0000
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.203E+01	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.203E+01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+02 years

Water Independent Pathways

Radio-Nuclide	Ground mrem/yr	Ground fract.	Dust mrem/yr	Dust fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Ra-228	1.089E-25	0.0000	2.175E-27	0.0000	4.403E-27	0.0000	3.514E-27	0.0000	3.442E-28	0.0000	5.592E-30	0.0000	3.991E-28	0.0000
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	6.405E+01	0.7821	6.978E+00	0.0852	2.254E+00	0.0275	7.156E+00	0.0874	8.148E-01	0.0099	4.672E-03	0.0001	6.412E-01	0.0078
Total	6.405E+01	0.7821	6.978E+00	0.0852	2.254E+00	0.0275	7.156E+00	0.0874	8.148E-01	0.0099	4.672E-03	0.0001	6.412E-01	0.0078

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+02 years

Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.197E-25	0.0000
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.189E+01	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.189E+01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	6.391E+01	0.7353	6.964E+00	0.0801	2.249E+00	0.0259	7.141E+00	0.0821	8.131E-01	0.0094	4.663E-03	0.0001	6.398E-01	0.0074
Total	6.391E+01	0.7353	6.964E+00	0.0801	2.249E+00	0.0259	7.141E+00	0.0821	8.131E-01	0.0094	4.663E-03	0.0001	6.398E-01	0.0074

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	4.583E+00	0.0527	2.767E-02	0.0003	0.000E+00	0.0000	5.027E-01	0.0058	6.091E-02	0.0007	2.683E-02	0.0003	8.692E+01	1.0000
Total	4.583E+00	0.0527	2.767E-02	0.0003	0.000E+00	0.0000	5.027E-01	0.0058	6.091E-02	0.0007	2.683E-02	0.0003	8.692E+01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+03 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	6.286E+01	0.7820	6.849E+00	0.0852	2.212E+00	0.0275	7.023E+00	0.0874	7.997E-01	0.0099	4.586E-03	0.0001	6.292E-01	0.0078
Total	6.286E+01	0.7820	6.849E+00	0.0852	2.212E+00	0.0275	7.023E+00	0.0874	7.997E-01	0.0099	4.586E-03	0.0001	6.292E-01	0.0078

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+03 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	1.720E-03	0.0000	1.038E-05	0.0000	0.000E+00	0.0000	1.886E-04	0.0000	2.286E-05	0.0000	1.007E-05	0.0000	8.037E+01	1.0000
Total	1.720E-03	0.0000	1.038E-05	0.0000	0.000E+00	0.0000	1.886E-04	0.0000	2.286E-05	0.0000	1.007E-05	0.0000	8.037E+01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+04 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	6.156E+01	0.7821	6.708E+00	0.0852	2.166E+00	0.0275	6.878E+00	0.0874	7.832E-01	0.0099	4.491E-03	0.0001	6.163E-01	0.0078
Total	6.156E+01	0.7821	6.708E+00	0.0852	2.166E+00	0.0275	6.878E+00	0.0874	7.832E-01	0.0099	4.491E-03	0.0001	6.163E-01	0.0078

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+04 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	3.866E-10	0.0000	2.334E-12	0.0000	0.000E+00	0.0000	4.241E-11	0.0000	5.138E-12	0.0000	2.263E-12	0.0000	7.872E+01	1.0000
Total	3.866E-10	0.0000	2.334E-12	0.0000	0.000E+00	0.0000	4.241E-11	0.0000	5.138E-12	0.0000	2.263E-12	0.0000	7.872E+01	1.0000

*Sum of all water independent and dependent pathways.

Dose/Source Ratios Summed Over All Pathways, (mrem/yr)/(pCi/g)

Nuclide (i)	t= 0.000E+00	1.000E+00	1.000E+01	1.000E+02	5.000E+02	1.000E+03	5.000E+03	1.000E+04
Ra-228	5.212E+00	7.228E+00	5.191E+00	7.992E-05	2.394E-26	0.000E+00	0.000E+00	0.000E+00
Th-228	9.212E+00	6.412E+00	2.459E-01	1.694E-15	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Th-232	2.403E+00	3.165E+00	1.113E+01	1.641E+01	1.638E+01	1.738E+01	1.607E+01	1.574E+01

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 5 mrem/yr

Nuclide (i)	t= 0.000E+00	1.000E+00	1.000E+01	1.000E+02	5.000E+02	1.000E+03	5.000E+03	1.000E+04
Ra-228	9.593E-01	6.918E-01	9.632E-01	6.256E+04	*2.721E+14	*2.721E+14	*2.721E+14	*2.721E+14
Th-228	5.428E-01	7.798E-01	2.033E+01	*8.192E+14	*8.192E+14	*8.192E+14	*8.192E+14	*8.192E+14
Th-232	2.080E+00	1.580E+00	4.492E-01	3.048E-01	3.053E-01	2.876E-01	3.110E-01	3.176E-01

*At specific activity limit

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
at tmin = time of minimum single radionuclide soil guideline
and at tmax = time of maximum total dose = 2055.5 ± 0.6 years

Nuclide (i)	Initial pCi/g	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Ra-228	5.000E+00	3.1733 ± 0.0010	8.532E+00	5.860E-01	0.000E+00	*2.721E+14
Th-228	5.000E+00	0.000E+00	9.212E+00	5.428E-01	0.000E+00	*8.192E+14
Th-232	5.000E+00	2055.1 ± 0.6	1.784E+01	2.803E-01	1.784E+01	2.803E-0[illegible]

*At specific activity limit

ICRP-2 and ICRP-26/30 Maximum Annual Dose Calculation
(MAXI Version IBM 1.12 19-May-87)

Case title: MIDLAND RESIDUAL - AGRICULTURE

Executed on: 12/ 2/1991 at 9:55:19

PATHWAYS/OPTIONS CONSIDERED:
- External exposure to surface contamination modeled as a plane source
- Inhalation of resuspended material
- Farm product ingestion
- Committed effective dose equivalent (CEDE) calculation

TITLES OF LIBRARY FILES ACCESSED:

10: RMDLIB - Radionuclide Master Library (21-Nov-86 H3 & C14 [W] RAP)
11: ORGAN DATA LIBRARY UPDATED BY RA PELOQUIN 8-Jul-86
12: FOOD TRANSFER COEFFICIENT LIBRARY (RAP/WTF 04-APR-86 Cl update)
13: Committed Dose Equivalents (Sv/Bq) ICRP Publication 30 (22-Nov-86 RAP)
22: OVERBURDEN: 0.0M, SOURCE: 0.15 M (DEN: CONCRETE/1.8): MR/HR 8-Jul-86 RAP
23: DACRIN (DIFDOS) DOSE INCREMENT FILE ONSITE/MAXI 20-Apr-87 RAP

NUMBER OF YEARS AFTER WASTE IS DISPOSED THAT:

Scenario begins:	1
Scenario ends:	50

INVENTORY:

Release Term Input units: (1-pCi 2-uCi 3-mCi 4-Ci)	1 pCi
Soil source units: (0- m**2 1- m**3 2- kg)	1
Number of radionuclides in inventory:	3

Release Terms	Soil Source (per m**3)	Irrigation /Aquatic (per L)	Drinking Water (per L)	Atmospheric Release (per yr)
TH232	8.0E+06	.0E+00	.0E+00	.0E+00
RA228	8.0E+06	.0E+00	.0E+00	.0E+00
AC228	.0E+00	.0E+00	.0E+00	.0E+00
TH228	8.0E+06	.0E+00	.0E+00	.0E+00
RA224	.0E+00	.0E+00	.0E+00	.0E+00
PB212	.0E+00	.0E+00	.0E+00	.0E+00
BI212	.0E+00	.0E+00	.0E+00	.0E+00

INVENTORY MODIFICATION FACTORS: (multipliers)

Surface inventory dilution factor:	1.
Irrigation/aquatic inventory modification factor:	1.
Size of site (fractional ha):	1.0E+00
Fraction of total diet grown on site:	1.

EXTERNAL/INHALATION EXPOSURE:

Hours of external exposure to contamination (h/yr):	2.0E+03
Hours of inhalation of airborne contamination (h/yr):	2.0E+03
Breathing rate (cm**3/sec):	2.7E+02

RESUSPENSION PARAMETERS:

Model used:	Mass Loading
Soil density (g/m**3):	1.6E+06
Mass loading factor (g/m**3):	1.0E-04

AGRICULTURAL PARAMETERS:

Fraction of roots in upper soil:	1.00
Fraction of roots in deeply buried waste:	.000
Ratio of ext. contamination in surface/subsurface soil:	1.00
Months per year irrigated:	6
Irrigation rate (L/m**2/mo):	1.5E+02
Years of irrigation w/ contaminated water prior to the beginning of the dose calculation period:	0
Number of food types:	10

FOOD TYPE INDEX	FOOD TYPE	GROWING PERIOD (days)	YIELD (kg/m**3)	HOLDUP (days)	CONSUMPTION (kg/yr)	TRANSLOCATION FACTOR
1	LEAFY VEG.	90.	1.50	1.	9.5	1.00
2	O.A.G.VEG.	60.	.70	1.	9.5	.10
4	OT.RT.VEG.	90.	4.00	10.	76.0	.10
7	ORCH.FRUIT	90.	2.00	10.	42.0	.10
9	OT.GRAIN	90.	1.00	1.	51.0	.10
10	EGGS	90.	.84	1.	19.0	.10
11	MILK	30.	1.30	1.	110.0	1.00
12	BEEF	90.	.84	15.	39.0	.10
13	PORK	90.	.84	15.	29.0	.10
14	POULTRY	90.	.84	1.	6.5	.10

Input prepared by: ____________________ Date: __________

Input checked by: ____________________ Date: __________

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*******PLEASE NOTE ANY SPECIAL CONSIDERATIONS IN THIS SPACE*******
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CALCULATED VALUES:

Ingestion area correction factor:	1.0
External/inhalation area correction factor:	1.0
Inhalation exposure modification factor:	.23
External exposure modification factor:	.23

SOIL, AIR, AND WATER CONCENTRATION SUMMARY FOR YEAR: 1

Radio-nuclide	Surface Soil pCi/m2	Deep Soil pCi/m3	Air pCi/m3	Irrigation pCi/L	Drink Water pCi/L
TH 232	1.2E+06	.0E+00	5.0E-04	.0E+00	.0E+00
RA 228	1.2E+06	.0E+00	5.0E-04	.0E+00	.0E+00
AC 228	1.2E+06	.0E+00	5.0E-04	.0E+00	.0E+00
TH 228	1.2E+06	.0E+00	5.0E-04	.0E+00	.0E+00
RA 224	1.2E+06	.0E+00	5.0E-04	.0E+00	.0E+00
PB 212	1.2E+06	.0E+00	5.0E-04	.0E+00	.0E+00
BI 212	1.2E+06	.0E+00	5.0E-04	.0E+00	.0E+00

SOIL, AIR, AND WATER CONCENTRATION SUMMARY FOR YEAR: 50

Radio-nuclide	Surface Soil pCi/m2	Deep Soil pCi/m3	Air pCi/m3	Irrigation pCi/L	Drink Water pCi/L
TH 232	1.2E+06	.0E+00	5.0E-04	.0E+00	.0E+00
RA 228	1.2E+06	.0E+00	5.0E-04	.0E+00	.0E+00
AC 228	1.2E+06	.0E+00	5.0E-04	.0E+00	.0E+00
TH 228	1.2E+06	.0E+00	5.0E-04	.0E+00	.0E+00
RA 224	1.2E+06	.0E+00	5.0E-04	.0E+00	.0E+00
PB 212	1.2E+06	.0E+00	5.0E-04	.0E+00	.0E+00
BI 212	1.2E+06	.0E+00	5.0E-04	.0E+00	.0E+00

Annual Effective Dose Equivalent (AEDE): 4.2E-02

Maximum Annual Dose (ICRP-2):

To Organ: TOTAL BODY	at Year 50	2.0E-01 rem
To Organ: BONE	at Year 50	2.0E-01 rem
To Organ: LUNGS	at Year 28	2.6E-02 rem
To Organ: THYROID	at Year 21	2.4E-02 rem
To Organ: LLI	at Year 21	2.8E-02 rem

DOSES FROM 1 YEAR OF EXPOSURE (REM)

Organ	Committed Dose Equivalent	Weighting Factors	Weighted Dose Equivalent
Gonads	8.5E-04	2.5E-01	2.1E-04
Breast	8.5E-04	1.5E-01	1.3E-04
R Marrow	3.4E-02	1.2E-01	4.0E-03
Lungs	6.7E-03	1.2E-01	8.1E-04
Thyroid	.0E+00	3.0E-02	.0E+00
Bone Surf	4.1E-01	3.0E-02	1.2E-02
LLI Wall	2.6E-03	6.0E-02	1.5E-04
Liver	4.3E-04	6.0E-02	2.6E-05
ULI Wall	3.4E-04	6.0E-02	2.0E-05
Kidneys	2.2E-04	6.0E-02	1.3E-05
SI Wall	2.5E-07	6.0E-02	1.5E-08
Effective Dose Equivalent			1.8E-02
External Dose			2.4E-02
Annual Effective Dose Equivalent			4.2E-02

MAXIMUM ANNUAL DOSE SUMMARY FOR THE YEAR 50 FOR TOTAL BODY

RADIO- NUCLIDE	INGESTION REM	%	INHALATION REM	%	EXTERNAL REM	%	AQUATIC FOOD REM	%	DRINK WATER REM	%
TH232	3.4E-04	0	3.1E-05	22	1.2E-05	0	.0E+00	0	.0E+00	0
RA228	1.7E-01	99	1.0E-04	74	1.0E-10	0	.0E+00	0	.0E+00	0
AC228	3.8E-10	0	2.1E-10	0	4.6E-03	19	.0E+00	0	.0E+00	0
TH228	7.6E-05	0	3.0E-06	2	4.0E-06	0	.0E+00	0	.0E+00	0
RA224	1.9E-04	0	1.9E-07	0	4.0E-05	0	.0E+00	0	.0E+00	0
PB212	1.6E-05	0	1.2E-08	0	4.6E-04	1	.0E+00	0	.0E+00	0
BI212	1.4E-13	0	2.0E-10	0	1.9E-02	78	.0E+00	0	.0E+00	0
TOTAL	INGESTION		INHALATION		EXTERNAL		AQUATIC FOOD		DRINK WATER	
2.0E-01	1.8E-01	87	1.4E-04	0	2.4E-02	12	.0E+00	0	.0E+00	0

MAXIMUM ANNUAL DOSE SUMMARY FOR THE YEAR 50 FOR BONE

RADIO- NUCLIDE	INGESTION REM	%	INHALATION REM	%	EXTERNAL REM	%	AQUATIC FOOD REM	%	DRINK WATER REM	%
TH232	9.6E-03	5	8.9E-04	83	1.2E-05	0	.0E+00	0	.0E+00	0
RA228	1.6E-01	92	9.4E-05	8	1.0E-10	0	.0E+00	0	.0E+00	0
AC228	4.8E-09	0	2.7E-09	0	4.6E-03	19	.0E+00	0	.0E+00	0
TH228	2.2E-03	1	8.7E-05	8	4.0E-06	0	.0E+00	0	.0E+00	0
RA224	9.4E-04	0	9.3E-07	0	4.0E-05	0	.0E+00	0	.0E+00	0
PB212	2.0E-04	0	1.7E-07	0	4.6E-04	1	.0E+00	0	.0E+00	0
BI212	2.1E-13	0	3.0E-10	0	1.9E-02	79	.0E+00	0	.0E+00	0
TOTAL	INGESTION		INHALATION		EXTERNAL		AQUATIC FOOD		DRINK WATER	
2.0E-01	1.7E-01	87	1.1E-03	0	2.4E-02	12	.0E+00	0	.0E+00	0

MAXIMUM ANNUAL DOSE SUMMARY FOR THE YEAR 28 FOR LUNGS

RADIO-NUCLIDE	INGESTION REM	%	INHALATION REM	%	EXTERNAL REM	%	AQUATIC FOOD REM	%	DRINK WATER REM	%
TH232	.0E+00	0	5.0E-04	28	1.2E-05	0	.0E+00	0	.0E+00	0
RA228	.0E+00	0	1.9E-05	1	1.0E-10	0	.0E+00	0	.0E+00	0
AC228	.0E+00	0	9.7E-07	0	4.6E-03	19	.0E+00	0	.0E+00	0
TH228	.0E+00	0	1.2E-03	69	4.0E-06	0	.0E+00	0	.0E+00	0
RA224	.0E+00	0	2.0E-05	1	4.0E-05	0	.0E+00	0	.0E+00	0
PB212	.0E+00	0	5.5E-07	0	4.6E-04	1	.0E+00	0	.0E+00	0
BI212	.0E+00	0	1.0E-07	0	1.9E-02	78	.0E+00	0	.0E+00	0
TOTAL 2.6E-02	INGESTION .0E+00	0	INHALATION 1.8E-03	6	EXTERNAL 2.4E-02	93	AQUATIC FOOD .0E+00	0	DRINK WATER .0E+00	0

MAXIMUM ANNUAL DOSE SUMMARY FOR THE YEAR 21 FOR THYROID

RADIO-NUCLIDE	INGESTION REM	%	INHALATION REM	%	EXTERNAL REM	%	AQUATIC FOOD REM	%	DRINK WATER REM	%
TH232	.0E+00	0	.0E+00	0	1.2E-05	0	.0E+00	0	.0E+00	0
RA228	.0E+00	0	.0E+00	0	1.0E-10	0	.0E+00	0	.0E+00	0
AC228	.0E+00	0	.0E+00	0	4.6E-03	19	.0E+00	0	.0E+00	0
TH228	.0E+00	0	.0E+00	0	4.0E-06	0	.0E+00	0	.0E+00	0
RA224	.0E+00	0	.0E+00	0	4.0E-05	0	.0E+00	0	.0E+00	0
PB212	.0E+00	0	.0E+00	0	4.6E-04	1	.0E+00	0	.0E+00	0
BI212	.0E+00	0	.0E+00	0	1.9E-02	78	.0E+00	0	.0E+00	0
TOTAL 2.4E-02	INGESTION .0E+00	0	INHALATION .0E+00	0	EXTERNAL 2.4E-02	100	AQUATIC FOOD .0E+00	0	DRINK WATER .0E+00	0

MAXIMUM ANNUAL DOSE SUMMARY FOR THE YEAR 21 FOR LLI

RADIO-NUCLIDE	INGESTION REM	%	INHALATION	%	EXTERNAL REM	%	AQUATIC FOOD REM	%	DRINK WATER REM	%
TH232	2.6E-04	7	3.0E-08	6	1.2E-05	0	.0E+00	0	.0E+00	0
RA228	9.0E-05	2	3.0E-08	5	1.0E-10	0	.0E+00	0	.0E+00	0
AC228	1.3E-06	0	3.4E-09	0	4.6E-03	19	.0E+00	0	.0E+00	0
TH228	2.8E-03	81	3.1E-07	61	4.0E-06	0	.0E+00	0	.0E+00	0
RA224	2.2E-04	6	1.3E-07	25	4.0E-05	0	.0E+00	0	.0E+00	0
PB212	6.6E-05	1	1.7E-09	0	[illegible]6E-04	1	.0E+00	0	.0E+00	0
BI212	1.2E-13	0	1.1E-12	0	[illegible]-02	78	.0E+00	0	.0E+00	0
TOTAL	INGESTION		INHALATION		EXTERNAL		AQUATIC FOOD		DRINK WATER	
2.8E-02	3.5E-03	12	5.0E-07	0	2.4E-02	87	.0E+00	0	.0E+00	0

APPENDIX B

Cost Estimates
For Remedial and Disposal Alternatives

1. On-site disposal at the Salzburg Landfill
2. Disposal at an existing LLW site
3. Disposal at a future LLW Compact Site
4. Disposal at the Envirocare Facility In Clive Utah

TABLE B-1

ESTIMATED COST FOR ON-SITE DISPOSAL
AT THE SALZBURG LANDFILL

	COST ITEM	AMOUNT ($)
1.	Preparation of Work Plan and EHSP	50,000
2.	HP and Environmental Monitoring Program During Remediation	300,000
3.	Post-Closure Monitoring (One Year)	90,000
4.	Cells 36 & 37 Excavation, Construction and Closure	1,513,000
5.	Third Party QA/QC for Cells 36 & 37	184,000
6.	Security (Cells 36 & 37 and Cap)	53,000
7.	Excavate and Haul from Bay City Site (60,000 Cy)(1)	755,000
8.	Excavate and Haul from Midland Site (12,000 Cy)	100,000
9.	Decommission Both Sites to Residual Levels (includes radiation surveys, soil analysis and certification)	630,000
10.	Truck Wash and Decontamination Facilities	525,000
11.	Wrap-Up Insurance (4% of Items 4-10)	150,000
12.	Engineering (10% of Items 4-10)	376,000
13.	Contingencies (6% of Items 1-10)	252,000
	Estimated Total Project Cost	$4,978,000

Note: This estimate assumes cell construction in 1992 and 1993 with the thorium excavation, haul and site decommissioning along with the capping to be performed in 1993.

(1) 60,000 cy volume estimate used here and in other alternative cost estimates to accommodate additional material to be excavated beyond required residual concentration to fill Cells 36 & 37.

TABLE B-2

ESTIMATED COST FOR DISPOSAL
AT THE ENVIROCARE FACILITY IN CLIVE, UTAH

	COST ITEM	AMOUNT ($)
1.	Preparation of Work Plan and EHSP	45,000
2.	HP and Environmental Monitoring Program During Remediation	250,000
3.	Post-Closure Monitoring (One Year)	70,000
4.	Excavation at Bay City (60,000 Cy @ $6.50/Cy)	390,000
5.	Excavation at Midland (12,000 Cy @ $6.50/Cy)	78,000
6.	Decommission Both Sites to Residual Levels (includes radiation surveys, soil analysis and certification)	636,000
7.	Truck Wash and Decontamination Facilities	350,000
8.	Transport Bay City and Midland Material to Clive, Utah ($2/Truck - mile)(1)	10,252,000
9.	Disposal at Envirocare Facility (@ $220/Cy)(1)	15,840,000
10.	Wrap-Up Insurance (4% of Items 4-7)	58,000
11.	Engineering (10% of Items 4-7)	145,000
12.	Contingencies (6% of Items 1-7)	109,000
	Estimated Total Project Cost	$28,224,000

Note: This estimate assumes excavation, shipment and disposal of the material in 1992.

(1) Unit truck transport and disposal costs are based on recent informal quotes.

TABLE B-3

ESTIMATED COST FOR DISPOSAL AT THE
BEATTY NEVADA LLW BURIAL SITE

	COST ITEM	AMOUNT ($)
1.	Preparation of Work Plan and EHSP	45,000
2.	HP and Environmental Monitoring Program During Remediation	250,000
3.	Post-Closure Monitoring (One Year)	70,000
4.	Excavation at Bay City (60,000 Cy @ $6.50/Cy)	390,000
5.	Excavation at Midland (12,000 Cy @ $6.50/Cy)	78,000
6.	Decommission Both Sites to Residual Levels (includes radiation surveys, soil analysis and certification)	636,000
7.	Truck Wash and Decontamination Facilities	350,000
8.	Transport Bay City and Midland Material to Beatty, Nevada (@ $2/Truck - mile)(1)	12,557,000
9.	Disposal at Beatty (@ $160/Cf)(1)	311,040,000
10.	Wrap-Up Insurance (4% of Items 4-7)	58,000
11.	Engineering (10% of Items 4-7)	145,000
12.	Contingencies (6% of Items 1-7)	109,000
	Estimated Total Project Cost	$325,728,000

Note: This estimate assumes excavation, shipment and disposal of the material in 1992.

(1) Unit transport cost is based on recent informal quote; unit disposal cost at Beatty is based on a $40/cf base charge with a $120/cf surcharge for 1992.

TABLE B-4

ESTIMATED COST FOR DISPOSAL AT A
FUTURE LLW COMPACT SITE IN MICHIGAN

	COST ITEM	AMOUNT ($)
1.	Preparation of Work Plan and EHSP	56,000
2.	HP and Environmental Monitoring Program During Remediation	313,000
3.	Post-Closure Monitoring (One Year)	88,000
4.	Excavation at Bay City (60,000 Cy @ $8.15/Cy)	489,000
5.	Excavation at Midland (12,000 Cy @ $8.15/Cy)	98,000
6.	Decommission Both Sites to Residual Levels (includes radiation surveys, soil analysis and certification)	795,000
7.	Truck Wash and Decontamination Facilities	438,000
8.	Transport Bay City and Midland Material to Future LLW Compact Site (@ $2.50/Truck - mile for 100 miles)	720,000
9.	Disposal at Future LLW Compact Site (@ $200/Cf)(1)	388,800,000
10.	Wrap-Up Insurance (4% of Items 4-7)	73,000
11.	Engineering (10% of Items 4-7)	181,000
12.	Contingencies (6% of Items 1-7)	136,000
	Estimated Total Project Cost	$392,187,000

Note: This estimate presumes availability of the future LLW compact site in 1997 with the material to be excavated, shipped and disposed of that year. Unit costs for all items except for Item 9 reflect a 25% projected increase over 1992 costs.

(1) Unit disposal cost is based on preliminary internal Dames & Moore projections for other compact sites since there are no projections available for a potential Michigan Compact Site.

APPENDIX C

Midland/Bay City Site Characterization Program,
and Groundwater Analysis From Bay City Site

See Figure Binder for

TABLE C-1

RADIONUCLIDE CONCENTRATIONS IN GROUNDWATER AT BAY CITY SITE
(Page 1 of 2)

THORIUM DECAY CHAIN

THORIUM-232

	Concentration in Wells (pCi/l)									
Collection Date	1	2	3	4	5	6	7	8	9	10
5/22/90	<0.6	<0.6	<0.6	<0.6	<0.6	0.7±0.5	0.8±0.6	<0.6	<0.6	<0.6
11/16/90	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	5.5±1.3	<0.6	1.9±0.8	<0.6
4/23/91	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
10/17, 11/12/91	—	-.0007±0.03	-0.02±0.03	-0.01±0.02	0.02±0.04	0.0±0.03	0.01±0.04	0.05±0.10	0.0±0.02	-0.03±0.02

THORIUM-228

	Concentration in Wells (pCi/l)									
Collection Date	1	2	3	4	5	6	7	8	9	10
5/22/90	<0.6	<0.6	<0.6	<0.6	<0.6	0.8±0.5	1.1±0.7	<0.6	<0.6	<0.6
11/16/90	<0.6	<0.6	1.2±0.9	5.7±3.0	1.3±1.0	1.9±1.1	9.8±1.8	<0.6	4.8±1.4	<0.6
4/23/91	<0.2	<0.2	<0.1	<0.1	0.3±0.2	<0.2	<0.1	<0.1	0.6±0.4	<0.1
10/17, 11/12/91	—	0.2±0.08	0.24±0.12	0±0.09	0.22±0.15	0.09±0.12	0.06±0.12	0.23±0.23	0.39±0.18	0.31±0.14

RADIUM-228

	Concentration in Wells (pCi/l)									
Collection Date	1	2	3	4	5	6	7	8	9	10
4/23/91	0±2	0±3	0±1	0±2	0±1	0±1	0±3	2.3±2.1	23.9±3.3	0±1
[illegible]	—	0±2	0±2	0±2	0±2	0±2	0±1	0±2	8.9±2.5	0±2

TABLE C-1

RADIONUCLIDE CONCENTRATIONS IN GROUNDWATER AT BAY CITY SITE
(Page 2 of 2)

URANIUM DECAY CHAIN

THORIUM-230

	Concentration in Wells (pCi/l)									
Collection Date	1	2	3	4	5	6	7	8	9	10
5/22/90	<0.6	<0.6	<0.6	<0.6	<0.6	1.1±0.6	1.2±0.7	<0.6	<0.6	<0.6
11/16/90	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	1.4±0.7	<0.6	<0.6	<0.6
4/23/91	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
10/17, 11/12/91	—	0±0.06	-0.03±0.05	-0.02±0.04	0.07±0.09	-0.04±0.05	-0.02±0.04	-0.05±0.05	-0.06±0.02	-0.02±0.04

RADIUM-226

	Concentration in Wells (pCi/l)									
Collection Date	1	2	3	4	5	6	7	8	9	10
4/23/91	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
10/17, 11/12/91	–	0±1	0±1	0±1	1.1±0.8	0±1	0±1	0±1	0±1	0±1

TOTAL RADIUM-(RA226 + 228)

	Concentration in Wells (pCi/l)									
Collection Date	1	2	3	4	5	6	7	8	9	10
5/22/90	2±1	6±2	2±1	2±1	2±1	3±1	3±1	4±1	5±1	2±1
11/16/90	5±2	5±2	4±2	<1	5±2	5±2	5±2	5±2	15±4	2±1

Note: 5/22/90 and 11/16/90 samples were analyzed by Controls for Environmental Pollution, Inc. (CEP).
4/23/91 samples were analyzed by TMA/Norcal.

CEP reported large amounts of solids in 5/22/90 and 11/16/90 samples. TMA/Norcal reported large amounts of dissolved salts and smaller than normal aliquots for majority of samples taken on 4/23/91 and 11/12/91.

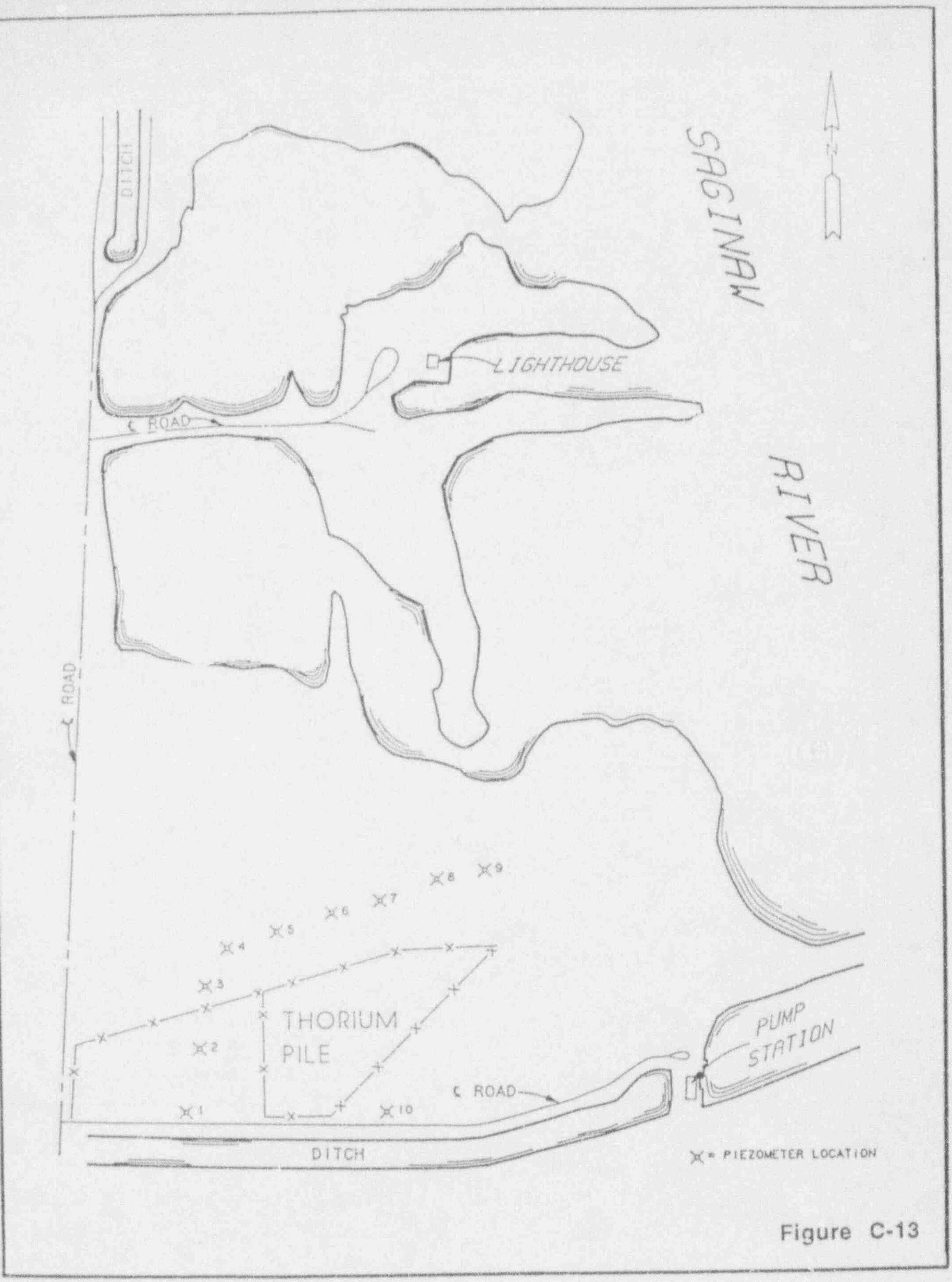


Figure C-13

BAY CITY PLANT
THORIUM STORAGE AREA

APPENDIX D

FEMA Map
Showing Relationship of the Midland Site to
100 and 500 Year Flood Plain Boundaries

See Figure Binder for

Figure D-1 FEMA Map of Midland Site

APPENDIX E

Background Characterization of Transport Routes
From Bay Cityand Midland Sites
To Salzburg Landfill

See Figure Binder for

Figure 6 Bay City Thorium Site, Locations of Gamma Measurements and Soil Samples
Figure 9 Soil Sample Locations

TABLE OF CONTENTS

BACKGROUND RADIOLOGICAL SURVEY OF TRANSPORT ROUTES FROM BAY CITY/MIDLAND SITES TO SALZBURG LANDFILL, MIDLAND, MICHIGAN

1.0 INTRODUCTION

1.1 HISTORY OF STUDY AREA

The areas involved in the study include the counties of Bay and Midland located in the east-central part of the lower peninsula of Michigan (Figure 1). Bay County is bordered on the south by Saginaw County, on the west by Midland and Gladwin Counties, on the north by Arenac County, and on the east by Saginaw Bay and Tuscola County. It has an area of approximately 288,640 acres. The major town in Bay County located near the study area is Bay City, one of Michigan's major ports located along the shore of Saginaw Bay.

Historically, the area once served as a fur trading center for the French. Agriculture and lumbering were the earliest enterprises in the county with lumbering peaking in the mid 1880's. As it declined, agriculture and other industries began to thrive. Today, a fair number of industries manufacture various items including automobile parts and accessories, aerospace equipment, metal castings, magnesium products, and cement.

Midland County has a total area of approximately 332,800 acres and is bounded on the north by Gladwin County, on the east by Bay and Saginaw Counties, on the south by Saginaw and Gratiot Counties, and on the west by Isabella County. The major town included in the study is Midland, the county seat and main commercial center.

The major employer in the county of Midland is the chemical industry. Farming is another major industry with the major crops being corn, beans, wheat, and sugar beets. Small industries are located throughout the county.

Three railroads run through the counties as well as one interstate highway, 2 U.S. highways and five state highways (Figure 2).

1.2 SITE CHARACTERISTICS

1.2.1 Meteorological

The Bay City and Midland areas on October 11-13, 1989 were characterized by moderate winds predominantly from the southwest, an average daytime temperature of 61 degrees Fahrenheit, an average relative humidity of 53 percent, and an average barometric pressure of 30 inches of mercury.

1.2.2 Soil Types

1.2.2.1 Bay City

The soil types found in Bay County in the areas surveyed include the following soil groups:

- Tappan
- Tappan-Belleville
- Condo-Tappan
- Tappan-Condo
- Wixom-Pipestone-Tappan

These are nearly level, slightly to poorly drained soils, formed in loamy and/or sandy material (See Figure-3).

1.2.2.2 Midland

The soil types found in Midland County in the areas surveyed include the following soil groups:

- Belleville-Wixom
- Parkhill-Condo

These are nearly level and gently sloping soils, formed in glacial till or lake deposits. (See Figure-4).

1.3 RADIONUCLIDES OF CONCERN

1.3.1 Isotopic Content of Transport Material

The material which will be transported along the routes surveyed originally consisted of magnesium with up to two percent thorium. Portions of this process slag have been mixed with soil or limited amounts of construction debris. As a results of this mixing, the thorium concentrations, as determined by Dow soil sampling, vary from 2-7000 pCi/g at the Bay City Site, and from 2-2000 pCi/g at the Midland site. A total activity of 9.7 Ci of Th-232 is distributed throughout approximately 52,000 cubic yards of slag, soil, and construction debris. Table-1 summarizes the Th-232 activity and concentrations. Since the thorium bearing material has been in place for over 20 years, it is assumed that the Th-232 daughters have achieved equilibrium.

Table 1
Thorium-232 Activity and Concentrations

	Bay City	Midland
Total Activity (Ci)	9.2	0.46
Volume (Cubic yards)	40,000	12,000
Average Concentration (pCi/g)	188	29
Maximum Concentration (pCi/g)	7000	2000

1.3.2 Sources of Radionuclides in the Study Area

1.3.2.1 Naturally - Occurring

Th-232 is a naturally - occurring radionuclide and is the first member of the thorium decay series. The concentration of Th-232 in soil throughout the United States varies by geographic location. Background radiation levels across the United States have been measured in 1975-1979 by the "Off-Site Pollutant Measurements Group of the Health & Safety Research Division" at Oak Ridge National Laboratory (ORNL) as part of a radiological surveillance program involving inactive uranium mines and sites formally utilized during the Manhattan Projects. The "off-site" data was collected to provide a comparison with the "on-site" radiological data. Tables 2 and 3, respectively, give the background external gamma rate measurements using a glass-walled Geiger-Mueller (G-M) tube and soil concentrations for Th-232 for various states. (Note: gamma measurements were not taken in the states of Alaska, Michigan, or New York). Radionuclide concentrations of Th-232, Ra-226, U-238 in surface soil samples for the state of Michigan are given in Table 4. It must be noted that the average background levels in each state are highly dependent on sample size, as well as the randomness of the sample, since neither were controlled adequately in the measurement program. In addition, local variability in soil types and geologic conditions as well as climatic, hydrological and agricultural history can result in a wide range of "background" values for any particular area. Therefore, the use of mean state values for comparative purposes must be exercised with caution, as the reported values in Table 4 may not adequately characterize the state as a whole. MI-4 & MI-5 (Figure 1) are sample locations near Bay City, and Midland, Michigan indicating surface soil concentrations of Th-232 on the order of 0.39 ± 0.02 (pCi/g) and 0.51 ± 0.02 pCi/g respectively. Levin, using a calibrated portable Scintillation Counter has reported an average external gamma reading of 7.8 ± 1.3 µrem/hour for the State of Michigan[5]. Sources of naturally -occurring gamma radiation include cosmic radiation and naturally-occurring radionuclides found in the earth's crust. Aside from the daughter products of Th-232 (Table 5), which is the most abundant of all naturally-occurring radioisotopes, other naturally-occurring radionuclides likely to contribute to the gamma exposure rate include the daughter products of the Uranium Series (Table 6) and such radionuclides as K-40 and others as indicated in Table 7. The surface soil concentrations of U-238 of Bay City and Midland,as determined by the ORNL study, were 0.49 pCi/g and o.50 pCi/g respectively. Of the many radionuclides produced through nuclear reactions between cosmic rays and soil, as indicated in Table 8, only a few are present at any given location in detectable concentrations.

1.3.2.2 Other Sources

Sources of technologically enhanced, naturally-occurring radionuclides in soil includes the use of fertilizers, which in agricultural areas such as central Michigan, can significantly affect radionuclide concentrations. For example, K-40 concentrations can be increased due to the use of potassium fertilizers. Other fertilizers have relatively high concentrations of other naturally occurring radionuclides, particularly the isotopes of radium. Man-made sources of radionuclides in the soils of the area surveyed include atmospheric weapons testing resulting in variable concentrations of such radionuclides as CS-137, which is the major source of long-lived gamma radiation from fallout.

2.0 OBJECTIVE

Dow Chemical U.S.A., an operating unit of the Dow Chemical Company, is seeking the permission of the United States Nuclear Regulatory Commission (NRC) to dispose of limited quantities of radioactive material at a Dow facility in Midland, Michigan. Dow is applying under the provision of 10 CFR Part 20.302 to dispose of the material at a Dow owned and operated disposal area, the Salzburg Landfill. Materials to be disposed of are currently located at two nearby facilities, referred to as the Bay City and Midland sites. The transfer of the material from these sites to the Salzburg landfill will involve the transportation of radioactive material along established roads.

The purpose of this survey is to establish background external gamma exposure levels and thorium isotopic concentrations in soil along the transport routes (Figure-9) used to transport material from Bay City and Midland, Michigan, to the Salzburg Landfill. This will serve to establish the preoperational baseline of background levels in the event of any contamination of the area due to accidental releases of radioactivity during transport.

3.0 SAMPLING PLAN

3.1 GENERAL INFORMATION

On October 11-13, 1989, a background radiological survey was conducted by Dames & Moore for Dow Chemical, U.S.A. The survey involved overland gamma radiation measurements and the collection of soil samples at the following Dow facilities and routes which will be involved in the transportation of the thorium material:

Bay City Site (Figure -6):

- Entrance to thorium storage area along Roadway No. 1 - approximately 0.25 miles.
- Main entrance gate of thorium storage area along Street C to 9th Street- approximately 0.5 miles.
- Along 9th Street to F Street - approximately 0.5 miles.
- F Street to Wilder Road - approximately 0.1 miles.

Alternative Route

- Corner of 9th Street to Wilder Road - 0.10 miles.
- Wilder Road to F Street - approximately 0.5 miles.

Midland Site (Figure 7):

- 11th and J streets to Saginaw Road (23 Gate) - approximately 0.5 miles.

Salzburg Landfill (Figure 8)

- Gate 93 to Cells 36/37-approximately 0.03 miles

Transportation Routes (Figure 9):

- Wilder Road to M-13-approximately 5 miles.
- M-13 to I-75 (South)-approximately 1 mile
- I-75 (South) to US-10 (West)-approximately 1 mile
- US 10 (West) to M-47 -approximately 10 miles
- M-47 to Salzburg Road -approximately 1 mile.
- Salzburg Road to Waldo Road-approximately 2.5 miles.
- Waldo Road to Salzburg Landfill (93 Gate)-approximately 0.3 miles.

3.2 GAMMA RADIATION SURVEY

An overland gamma radiation survey in accordance with Dames & Moore Environmental Procedure EM/01, "Low-Level Radiation Survey" (attached as Appendix A), was conducted from the shoulder of the transport routes at a distance from the centerline of the route that an observer may typically stand (approximately 10 to 15 feet). Direct measurements were made using a calibrated survey meter. The parameters of the radiological survey were essentially based on the Dames & Moore proposal of August 21, 1989, (Appendix C). The readings were made and recorded at approximately every 0.25 miles along the side of the route that the loaded truck will travel. Additional measurements were made and recorded on the opposite side at approximately every 1.25 miles. The gamma radiation levels were measured at each point at a height of one meter (approximately waist height) and at one centimeter above the surface of the ground."Off-site" background readings were made at the neighboring towns of Saginaw and Kawkawlin, Michigan.

The distances of each measurement point were approximated using an odometer. Continuous readings were made from a vehicle along the edge of the roadway (approximately 3 feet from the surface) when speed and traffic conditions permitted.

3.2.1 Survey Equipment

The external radiation exposure data was collected using a Bicron Corporation microRem survey meter. This device uses a tissue equivalent plastic scintillator as the detector device medium to provide accurate dose rate information to biological tissue. It had been calibrated using a Cs-137 source (See attachment D for calibration certificate and instrument specifications) in accordance with 10 CFR 34. An instrument operability check, which included a battery and source check, was performed prior to use to assure proper instrument operation while performing the survey.

3.3 SOIL SAMPLING

Near surface samples of the top horizon at a depth of 0-15 cm (Figure 5) were taken along the transportation routes at approximately one mile intervals. Additional samples were taken at the Bay City and Midland Storage Sites and the Salzburg Landfill and a "off-site" composite background sample was taken along I-75 (South) as a quality control sample and analyzed for equivalent constituents as the "on-site" samples. The following information was recorded in a field log book for each sample:

- Location of Sampling
- Description of Sample
- Method of Collection
- Volume of Sample
- Date and Time of Collection
- Sample Identification Number
- Field Measurements
- Name of Collector

The sampling was conducted in accordance with EPA Procedure SW-846 using Dames & Moore Environmental Monitoring Procedure-02, "Near Surface Soil Sampling" (attached as Appendix B).Three (3) separate unbiased (random) soil samples of approximately 600 to 800 cubic centimeters were collected at each sampling point as close to the shoulder of the roadway as possible (approximately 5 feet) and placed in plastic bags. Gamma exposure rate levels were also measured at each sample location at a height of 1 meter and 1 centimeter from the ground surface prior to sampling. Each sample was homogenized and a composite sample was created by combining approximately 1/2 (by volume) of each individual sample collected. The composite aliquotes were placed in wide-mouth paper containers, sealed to prevent and detect unauthorized tampering, and shipped to International Technology Corporation, Oak Ridge, Tennessee, along with the appropriate documentation (Sample labels, Request for Analysis, Chain of Custody Forms which can be found in Appendix E) for analysis. The remaining samples were archived and labeled for future analysis if needed.

All collected samples were analyzed using gamma spectroscopy for thorium isotopic content (Th-228, Th-230, Th-232) and the following radionuclides: K-40, Ra-22, Ra-226, Ra-228, Cs-137, Bi-212, Pb-212.

3.3.1 Soil Sampling Equipment

Soil sampling equipment included a 3 in diameter soil sample, heavy duty one gallon plastic bags and cleaning and wiping supplies. A uniform decontamination procedure was used on all equipment before sampling and between samples.

4.0 DATA ANALYSIS

The results of the external gamma-ray measurements and surface soil sample analyses are given in Tables 12, 13, 14 and Table 19 respectively. The data includes the external gamma rates at 1 centimeter and 1 meter above the surface and the concentration in pCi/g of ^{228}Th, ^{230}Th, ^{232}Th, and other radionuclides (^{40}K, ^{224}Ra, ^{226}Ra, ^{228}Ra, ^{137}Cs, ^{212}Pb) in surface soil samples (0 to 15 centimeters) at each sample location. Table 17 provides a brief description of the soil sampling locations. A total of 24 soil samples were analyzed from the storage sites, landfill, and along the established transportation routes along with an "off-site" composite background soil sample.

The results in Table 19 which are based on the Laboratory report from International Technology Corporation, give the concentration (pCi/g) of each radionuclide analyzed. The standard deviations given in Table 19 for the soil analysis represent only the errors associated with the individual sample counting statistics and are given at the 2σ (95%) confidence interval. The propagation of errors from sampling methods, sample preparation, and system calibration are not included. The soil concentrations (pCi/gr) and the external exposure measurements (μrem/hr) were averaged for the storage sites, landfill and individual roadways along the established transportation route. A summary of the statistics for the external gamma measurements are given in Table 9 and soil concentrations for the Thorium Series,Uranium Series, and Natural and Man-Made Sources are given in Tables 10, 11, and 12 respectively. The standard deviations for single measurements reflect only the counting error while more than one measurement reflects the sampling error.

4.1 RESULTS

4.1.1 External Gamma Results

The external gamma measurements at 1 meter ranged from 1μrem/hr to 8 μrem/hour with an average reading over the survey area (excluding the area outside of the Bay City Site Thorium storage area) of 3.0 ± 1.0 (at 2σ). A reading of 8 μrem/hr at the top of the dike at the Bay City Site was elevated due to the higher exposure rate typically associated with igneous rock. "Off-Site" background readings at 1 meter ranged from 3.3 ± 1.6 (2σ) μrem/hour in Bay City to 5.2 ± 1.8 (2σ) at Saginaw, Michigan. These values are within the range typical of external gamma background levels for the mid western portion of the United States using an instrument with the sensitivity of the Bicron, a tissue equivalent plastic scintillator, which measures x-ray and gamma energies in the 40 kev to 1.2 Mev range.

4.1.2 Soil Sampling Results

The characterization of average background levels throughout the state is highly dependent upon sample size, as well as the randomness of the sample. In addition, local variability in soil types, geologic condition, as well as hydrological and agricultural history, can result in a wide range of "background" values for any particular area. The soil concentrations over the area surveyed in pCi/g for ^{232}Th, the predominant radionuclide in the soil to be transported, range from 0.11 pCi/g to 0.56 pCi/g with a mean of 0.33 ± 0.22 (at 2σ). This is within the range expected for natural ^{232}Th within the central portion of Michigan. Figure 10 shows the equilibrium concentration of natural Th-232 and its daughters based on the arithmetic means. The highest concentration of 0.99 pCi/g was found outside of the Bay City Thorium storage area at the front gate (Figure 6.0). The average concentration and variability of the radionuclide to be transported as well as its daughter products and those of the naturally occurring uranium decay series (U-238) and other radionuclides such as K-40 and Cs-137 are given in Tables 10, 11 and 12. These results establish the preoperational base line of background concentrations in the Bay City and Midland areas prior to the transport of the thorium material from the Dow facilities to the Salzburg landfill.

Note:

The margin of error for the survey is a function of the measurement interval and number of soil samples. The smaller the external gamma measurement interval and the greater the number of soil samples, the smaller the margin of error and the more representative the results would be of the survey area.

4.2 DISTRIBUTION ANALYSIS

Tables 9, 10, 11 and 12 include the number of measurements of soil samples taken as well as the arithmetic mean, standard deviations and range of values at the storage sites, landfill and transportation routes. A distribution analysis of the transportation route data was also performed to obtain the geometric means and geometric standard deviations (Table 13) since environmental samples are often represented by a log normal distribution. Most media background concentrations have a geometric standard deviation near two. Values greater than two typically denote the presence of a source-related concentration distribution.Figures 11, 12, and 13 give the cumulative frequency plot of the radionuclides included in the analysis. The linearity of the data (correlation coefficient greater than 0.9) indicate the adherence of the data to a log normal distribution typical of environmental surveillance data.

TABLE 2

SUMMARY OF STATE BACKGROUND EXTERNAL GAMMA FXPOSURE RATE MEASUREMENTS[a]

State	Number of measurements taken	Range of values (μR/h)	Arithmetic mean and standard deviation[b] (μR/h)	Geometric mean and standard deviation[c] (μR/h)
Alabama	8	3.0 - 7.8	4.8 ± 3.5	4.5 : 1.4
Alaska	*d*	*d*	*d*	*d*
Arizona	6	5.3 - 12	9.3 ± 5.4	8.9 : 1.4
Arkansas	1	11	11[e]	11[e]
California	3	9.0 - 11	10 ± 2.3	10 : 1.1
Colorado	32	6.3 - 34	14 ± 10	14 : 1.4
Delaware	2	5.0 - 6.9	6.0 ± 2.6	5.9 : 1.3
Florida	11	<1.0 - 7.4	4.0 ± 3.2	3.6 : 1.7
Georgia	9	1.9 - 9.0	5.1 ± 4.2	4.7 : 1.6
Idaho	13	11 - 16	12 ± 3.2	12 : 1.1
Illinois	8	7.2 - 11	8.1 ± 2.5	8.0 : 1.2
Indiana	2	6.0 - 7.1	6.6 ± 1.5	6.5 : 1.1
Kansas	6	6.6 - 14	10 ± 5.2	9.8 : 1.3
Kentucky	12	3.9 - 11	7.4 ± 4.6	7.0 : 1.4
Louisiana	3	3.5 - 6.0	5.1 ± 2.7	4.9 : 1.4
Maryland	5	4.5 - 8.8	6.6 ± 3.2	6.4 : 1.3
Michigan	*d*	*d*	*d*	*d*
Mississippi	3	4.3 - 11	8.0 ± 6.7	7.4 : 1.6
Missouri	10	4.6 - 10	6.8 ± 3.2	6.6 : 1.3
Nevada	6	11 - 19	14 ± 5.7	14 : 1.2
New Jersey	23	2.3 - 13	6.1 ± 4.8	5.7 : 1.5
New Mexico	13	6.8 - 16	10 ± 5.4	9.7 : 1.3
New York	*d*	*d*	*d*	*d*
North Carolina	8	3.2 - 13	8.2 ± 6.5	7.6 : 1.6
Ohio	11	2.8 - 11	6.9 ± 5.0	6.4 : 1.5
Oregon	9	8.2 - 19	11 ± 6.6	11 : 1.3
Pennsylvania	32	2.5 - 14	6.7 ± 5.0	6.2 : 1.5
Tennessee	12	2.9 - 11	6.4 ± 4.8	5.9 : 1.5
Texas	10	1.4 - 5.6	3.3 ± 3.0	3.0 : 1.6
Utah	32	5.0 - 14	8.7 ± 4.5	8.4 : 1.3
Virginia	13	3.9 - 13	7.4 ± 5.8	6.9 : 1.5
West Virginia	11	4.6 - 11	7.7 ± 3.9	7.4 : 1.3
Wyoming	13	10 - 20	14 ± 5.2	13 : 1.2
U. S. Average	327	<1.0 - 34	8.5 ± 4.1	7.5 : 1.7

[a]Summary of data contained in Tables 1-33 for individual states.

[b]Standard deviation of arithmetic mean is the 2σ value.

[c]The geometric standard deviation is a multiplicative parameter to the geometric mean containing 68% (1σ) of the frequency values.

[d]No data on external gamma exposure rates available for the state.

[e]Values for standard deviation cannot be computed.

SOURCE

STATE BACKGROUND RADIATION LEVELS
RESULTS OF MEASUREMENTS TAKEN
DURING 1975-1979
T.E. MYRICK, B.A. BERVEN, F.F. HAYWOOD
ORNL TM-7343

TABLE 3

SUMMARY OF STATE BACKGROUND CONCENTRATIONS OF ^{232}Th IN SURFACE SOIL[a]

State	Number of samples analyzed	Range of values (pCi/g)	Arithmetic mean and standard deviation[b] (pCi/g)	Geometric mean and standard deviation[c] (pCi/g)
Alabama	8	0.36 - 1.5	0.77 ± 0.71	0.70 : 1.6
Alaska	7	0.19 - 2.3	0.87 ± 1.4	0.67 : 2.2
Arizona	6	0.20 - 1.3	0.63 ± 0.83	0.52 : 2.0
Arkansas	1	1.6	1.6[d]	1.6[d]
California	3	0.30 - 0.76	0.54 ± 0.45	0.50 : 1.6
Colorado	20	0.10 - 3.1	1.3 ± 1.4	1.1 : 2.1
Delaware	2	1.2	1.2 ± 0.04	1.2[d]
Florida	10	0.12 - 0.37	0.24 ± 0.13	0.23 : 1.3
Georgia	9	0.28 - 3.4	1.1 ± 1.9	0.85 : 2.1
Idaho	13	0.42 - 1.9	1.2 ± 0.73	1.1 : 1.5
Illinois	8	0.49 - 1.2	0.96 ± 0.43	0.93 : 1.3
Indiana	2	1.1 - 1.2	1.2 ± 0.14	1.2 : 1.1
Kansas	4	0.32 - 1.6	1.3 ± 1.2	1.1 : 2.2
Kentucky	12	0.88 - 1.5	1.2 ± 0.39	1.2 : 1.2
Louisiana	2	0.60 - 0.72	0.66 ± 0.17	0.66 : 1.1
Maryland	6	0.48 - 0.86	0.70 ± 0.28	0.69 : 1.2
Michigan	10	0.24 - 0.82	0.56 ± 0.35	0.53 : 1.5
Mississippi	3	0.81 - 1.7	1.1 ± 0.50	1.1 : 1.5
Missouri	10	0.32 - 1.3	1.0 ± 0.56	0.95 : 1.5
Nevada	6	0.62 - 3.0	1.5 ± 1.6	1.4 : 1.7
New Jersey	23	0.31 - 1.5	0.90 ± 0.66	0.82 : 1.6
New Mexico	13	0.48 - 1.8	0.95 ± 0.73	0.89 : 1.5
New York	6	0.40 - 1.1	0.71 ± 0.52	0.67 : 1.5
North Carolina	8	0.42 - 1.5	0.92 ± 0.83	0.83 : 1.6
Ohio	12	0.71 - 1.5	1.0 ± 0.50	1.0 : 1.3
Oregon	9	0.43 - 1.5	0.72 ± 0.66	0.66 : 1.5
Pennsylvania	33	0.38 - 1.7	1.1 ± 0.53	1.1 : 1.3
Tennessee	11	0.66 - 1.5	0.95 ± 0.50	0.92 : 1.3
Texas	10	0.40 - 1.1	0.73 ± 0.40	0.70 : 1.4
Utah	28	0.20 - 2.3	1.1 ± 0.92	0.97 : 1.7
Virginia	13	0.42 - 1.4	0.86 ± 0.47	0.83 : 1.4
West Virginia	11	1.1 - 1.6	1.4 ± 0.35	1.3 : 1.2
Wyoming	12	0.59 - 1.8	1.1 ± 0.68	1.0 : 1.4
U. S. Average	331	0.10 - 3.4	0.98 ± 0.46	0.87 : 1.7

[a] Summary of data contained in Tables 1-33 for individual states.

[b] Standard deviation of arithmetic mean is the 2σ value.

[c] The geometric standard deviation is a multiplicative parameter to the geometric mean containing 68% (1σ) of the frequency values.

[d] Values for standard deviation cannot be computed.

SOURCE

STATE BACKGROUND RADIATION LEVELS
RESULTS OF MEASUREMENTS TAKEN
DURING 1975-1979
T.E. MYRICK, B.A. BERVEN, F.F. HAYWOOD
ORNL ITM-7343

TABLE 4

BACKGROUND RADIATION LEVELS AND NUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES IN THE STATE OF MICHIGAN

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
MI-1	E side of Hwy 23 at the Michigan-Ohio border, just N of Toledo, Ohio	[c]	0.99 ± 0.10	0.54 ± 0.04	0.78
MI-2	N of Hwy 71, just E of Corunna, Michigan	[c]	0.79 ± 0.08	0.76 ± 0.02	0.65
MI-3	W side of Gratiot County road, ~3.2 km SW of Edgewood, Michigan, next to Bad Creek	[c]	0.46 ± 0.04	0.24 ± 0.04	0.34
MI-4	Approx. 2 km E of Mt. Pleasant, Michigan, on S side of Hwy 20 in Isabella Indian Reservation	[c]	0.51 ± 0.02	0.39 ± 0.02	0.49
MI-5	Approx. 2 km S of Midland, Michigan, on Midland County road between Midland and Poseyville, Michigan	[c]	0.69 ± 0.06	0.51 ± 0.02	0.50
MI-6	Approx. 11 km of St. Johns, Michigan, on W side of road at intersection with county road	[c]	0.86 ± 0.10	0.66 ± 0.12	0.57
MI-7	Approx. 6.4 km E of Adrian, Michigan, at the intersection of Deerfield Rd and Wellsville Hwy	[c]	2.0 ± 0.12	0.41 ± 0.28	1.0
MI-8	Approx. 6 km N of Adrian, Michigan, at the intersection of Shepard Rd. and Bent Oak Hwy	[c]	1.5 ± 0.12	0.82 ± 0.08	1.1
MI-9	S side of Hwy 223, ~11 km W of Adrian, Michigan	[c]	1.5 ± 2.0	0.69 ± 0.04	1.2
MI-10	Approx. 1.6 km E of Hwy 52, on E. Gorman Rd., about 8 km S of Adrian, Michigan	[c]	1.2 ± 0.14	0.54 ± 0.12	0.70

[a]Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b]Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are $\leq 5\%$ (2σ).

[c]No data obtained.

TABLE 5

THORIUM DECAY SCHEME

Element	Atomic Weight	Half-life	Radiation
Thorium	232	1.4×10^{10} yr	α
Radium	228	6.7 yr	β
Actinium	228	6.13 hr	β, γ
Thorium	228	1.9 yr	α, γ
Radium	224	3.64 days	α, γ
Radon	220	54.5 sec.	α, γ
Polonium	216	0.14 sec.	α
Lead	212	10.6 hrs.	β, γ
Bismuth	212	60.5 min.	α, β
Polonium	212	10 sec.	α
Thallium	208	3.1 min.	β, γ
Lead	208	Stable	

TABLE 6

URANIUM DECAY SERIES

Element	Atomic Weight	Half-life	Radiation
Uranium	238	4.51×10^{9}y	α
Thorium	234	24.1d	β, γ
Protactinium	234m	1.17m	β, γ
Protactinium	234	6.75h	β, γ
Uranium	234	2.47×10^{3}y	α, γ
Thorium	230	8.0×10^{4}	α, γ
Radium	226	1602y	α, γ
Radon	222	3.823d	α, γ
Polonium	218	3.05m	α, β
Lead	214	26.8	β, γ
Astatine	218	~2s	α, β
Bismuth	214	19.7m	α, β, γ
Polonium	214	164μs	α, γ
Thallium	210	1.3m	β, γ
Lead	210	21y	α, β, γ
Bismuth	210	5.01d	α, β
Polonium	210	138.4d	α, γ
Thallium	206	4.19m	β
Lead	206	Stable	

Source: Radiation Health, U.S. Department of Health Education and Welfare, January, 1970

TABLE 7
PRIMORDIAL RADIONUCLIDES

Nuclide	Half-life (years)	% isotopic abundance	Emissions decay	Energy primary emission (MeV)	Specific activity (Ci/g) element)
^{40}K	1.3×10^{-9}	0.0118	β, γ, ε	1.32	8.3×10^{-10}
^{50}V	$\sim 6 \times 10^{-14}$	0.24	β, γ, ε	—	$\sim 2.8 \times 10^{-14}$
^{87}Rb	4.7×10^{-10}	27.85	β	0.27	2.5×10^{-8}
^{115}In	6×10^{-14}	95.72	β	0.6	5.0×10^{-12}
^{138}La	1.1×10^{11}	0.089	β, γ, ε	0.205	2.1×10^{-12}
^{142}Ce	5×10^{-15}	11.07	α	1.5	5.7×10^{-14}
^{144}Nd	$\sim 5 \times 10^{-15}$	23.85	α	1.8	$\sim 1.2 \times 10^{-13}$
^{147}Sm	1.6×10^{11}	14.97	α	2.24	3.38×10^{-9}
^{148}Sm	1.2×10^{13}	11.24	α	2.14	2.24×10^{-11}
^{149}Sm	$\sim 4 \times 10^{-14}$	13.83	α	1.84	$\sim 8.2 \times 10^{-13}$
^{152}Gd	1.1×10^{14}	0.200	α	2.15	4.15×10^{-12}
^{174}Hf	4.3×10^{15}	0.18	α	2.5	8.4×10^{-14}
^{176}Lu	3.6×10^{10}	2.59	β, γ	0.42	1.47×10^{-10}
^{187}Re	7×10^{10}	62.93	β	<0.008	1.73×10^{-8}
^{190}Pt	7×10^{11}	0.0127	α	3.11	3.33×10^{-13}
^{192}Pt	$\sim 10^{15}$	0.78	α	2.6	$\sim 1.4 \times 10^{-14}$
^{204}Pb	1.4×10^{17}	1.48	α	2.6	1.83×10^{-16}
^{238}U (series)					
^{235}U (series)					
^{232}Th (series)					

Source: From Klement, A.W., Jr., in Radioactive Fallout, Soils, Plants, Foods, Man, Fowler, E.B., Ed., Elsevier, Amersterdam, 1965, 113.

TABLE 8
MAJOR COSMIC-RAY-ACTIVATED RADONUCLIDES

Nuclide	Half-life	Emission, decay	Energy of primary emission (MeV)	Production rate (atom/cm^2-sec)
^{3}H	12.26 years	β	0.0181	0.12 -1.3
^{7}Be	53 days	ε, γ	___	0.021 - 0.035
^{10}Be	2.7×10^{6} years	β	0.56	0.04 - 0.1
^{14}C	5760 years	β	0.156	2 -2.6
^{22}Na	2.[illegible] years	β^{+} ε, γ	0.54	–
^{32}Si	~700 years	β	0.1 (to ^{32}P)	2×10^{-4}
^{32}P	14.3 days	β	1.71	1×10^{-4}
^{33}P	25 days	β	0.25	1×10^{-4}
^{35}S	86.7 days	β	0.168	2×10^{-4}
^{36}Cl	3×10^{5} years	β, ε	0.71	–
^{39}Cl	55 min	β, γ	1.91, 2.18, 3.43	–

Source: From Klement, A.W., Jr., in Radioactive Fallout, Soils, Plants, Foods, Man, Fowler, E. B., Ed., Elsevier, Amsterdam, 1965, 113.

TABLE 9

STATISTICAL SUMMARY - EXTERNAL GAMMA READINGS OF SURVEY AREAS (µrem/hr)

Location	Number of Measurements	External Gamma (at 1 Meter)		
		Mean	Variance	Confidence Interval (at 95%)
Bay City				
Near Thorium Storage Area	9	16	37.2	3.8 -28.2
Outside Thorium Storage Area	10	4.1	6.7	–1.1 -9.3
Alternative Route	11	2.4	0.64	1.6 -3.2
E. Wilder	23	2.9	0.81	1.1 -4.7
Route 13 South	4	2.5	0.25	1.5 -3.5
Interstate 75 South	4	2.8	0.36	1.6 -4.0
Route 10 West	43	3.2	0.36	2.0 -4.4
Route 47 South	5	3.3	0.49	1.9 -4.7
Salzburg Road	16	3.3	1	1.3 -5.3
Waldo Road	6	3.4	1	1.4 -5.4
Saginaw Road	5	3.2	0.81	1.4 -5.0
Midland Site	27	3.3	0.81	1.5 -5.1
Salzburg Landfill	15	2.5	0.22	1.6 -3.3

TABLE 10

STATISTICAL SUMMARY - SOIL CONCENTRATIONS OF SURVEY AREAS (pCi/g)

THORIUM SERIES (4n)

Location	Number of Soil Samples	Soil Concentrations of 232th			Number of Soil Samples	Soil Concentrations of 228Ra		
		Mean	Variance	Confidence Interval (at 95%)		Mean	Variance	Confidence Interval (at 95%)
Bay City								
Near Thorium Storage Area	1	0.99	0.01	0.78 -1.20	1	0.62	0.003	0.51 - 0.73
Outside Thorium Storage Area	1	0.23	0.004	0.11 -0.35	1	0.26	0.0009	0.20 -0.32
E. Wilder	2	0.36	0.00005	0.35 -0.38	2	0.32	0.005	0.15 -0.49
Route 13 South	1	0.11	0.0016	0.03 -0.19	1	0.24	0.001	0.17 -0.31
Interstate 75 South	2	0.28	0.0072	0.11 -0.45	1	0.29	0.001	0.22 -0.36
Route 10 West	8	0.38	0.009	0.19 -0.56	7	0.36	0.02	0.084 -0.636
Route 47 South	1	0.30	0.002	0.20 -0.40	1	0.19	0.001	0.12 -0.26
Salzburg Road	2	0.26	0.02	0.041 -0.55	1	0.21	0.0009	0.15 -0.27
Waldo Road	2	0.24	0	0.24	1	0.22	0.0009	0.16 -0.28
Saginaw Road	1	0.44	0.01	0.27 -0.61	1	0.28	0.002	0.20 - 0.36
Midland Site	1	0.34	0.004	0.21 -0.47	1	0.38	0.002	0.30 -0.46
Salzburg Landfill	1	0.13	C.002	0.05 -0.21	1	0.27	0.002	0.19 -0.35
Transportation Routes	19	0.32	0.01	0.11 -0.53	15	0.30	0.01	0.08 -0.52

TABLE 10

STATISTICAL SUMMARY - SOIL CONCENTRATIONS OF SURVEY AREAS (pCi/g)

THORIUM SERIES (4n)

Location	Number of Soil Samples	Soil Concentrations of 232th			Number of Soil Samples	Soil Concentrations of 228Ra		
		Mean	Variance	Confidence Interval (at 95%)		Mean	Variance	Confidence Interval (at 95%)
Bay City								
Near Thorium Storage Area	1	0.7	0.007	0.53 -0.87	1	0.66	0.003	0.55 - 0.77
Outside Thorium Storage Area	1	0.11	0.002	0.02 -0.20	1	0.21	0.0004	0.17 -0.25
E. Wilder	1	0.3	0.004	0.17 -0.43	1	0.32	0.002	0.22 -0.42
Route 13 South	1	0.2	0.002	0.10 -0.30	0	–	–	– –
Interstate 75 South	2	0.39	0.0008	0.33 -0.45	2	0.28	0	0.28
Route 10 West	8	0.32	0.004	0.19 -0.45	8	0.35	0.02	0.08 -0.61
Route 47 South	1	0.29	0.002	0.19 -0.39	1	0.23	0.0009	0.14 -0.32
Salzburg Road	2	0.14	0.004	0.02 -0.27	2	0.18	0.01	–0.02 –0.38
Waldo Road	2	0.22	0.004	0.09 -0.34	2	0.25	0	0.25
Saginaw Road	1	0.35	0.006	0.20 -0.50	1	0.26	0.0009	0.20 - 0.32
Midland Site	2	0.29	0.02	0.021 -0.601	2	0.28	0.08	–0.27 -0.84
Salzburg Landfill	1	0.21	0.002	0.12 -0.30	1	0.22	0.0006	0.17 -0.27
Transportation Routes	18	0.29	0.008	0.11 -0.47	18	0.29	0.01	0.07 -0.51

TABLE 10

STATISTICAL SUMMARY - SOIL CONCENTRATIONS OF SURVEY AREAS (pCi/g)

THORIUM SERIES (4n)

Location	Number of Soil Samples	Soil Concentrations of 232th			Number of Soil Samples	Soil Concentrations of 228Ra		
		Mean	Variance	Confidence Interval (at 95%)		Mean	Variance	Confidence Interval (at 95%)
Bay City								
Near Thorium Storage Area	1	0.68	0.004	0.56 -0.80	1	0.45	0.01	0.21 - 0.69
Outside Tho.ium Storage Area	1	0.21	0.0004	0.17 -0.25	1	0.12	0.003	0.01 -0.23
E. Wilder	2	0.31	0.005	0.17 -0.48	2	0.28	0.008	0.09 -0.46
Route 13 South	1	0.20	0.0004	0.16 -0.24	0	–	–	– –
Interstate 75 South	2	0.28	0.00005	0.26 -0.29	1	0.24	0.01	0.02 -0.4
Route 10 West	8	0.34	0.016	0.08 -0.59	1	0.21	0.009	0.02 -0.40
Route 47 South	1	0.22	0.0009	0.16 -0.28	0	–	–	– –
Salzburg Road	2	0.18	0.01	–0.037 –0.39	1	0.20	0.004	0.07 -0.33
Waldo Road	2	0.24	0.00005	0.23 -0.26	1	0.19	0.004	0.06 -0.32
Saginaw Road	1	0.25	0.0009	0.19 -0.31	0	–	–	– –
Midland Site	2	0.28	0.07	–0.25 –0.80	0	–	–	– –
Salzburg Landfill	1	0.22	0.0006	0.17 -0.27	0	–	–	– –
Transportation Routes	20	0.28	0.01	0.08 -0.48	8	0.23	0.003	0.13 -0.33

TABLE 11

STATISTICAL SUMMARY - SOIL CONCENTRATIONS OF SURVEY AREAS (pCi/g)

URANIUM SERIES (4n+2)

Location	Number of Soil Samples	Soil Concentrations of 234Th			Number of Soil Samples	Soil Concentrations of 230Th			Number of Soil Samples	Soil Concentrations of 226Ra		
		Mean	Variance	Confidence Interval (at 95%)		Mean	Variance	Confidence Interval (at 95%)		Mean	Variance	Confidence Interval (at 95%)
Bay City												
Near Thorium Storage Area	1	0.52	0.01	0.31 - 0.73	1	3.82	0.08	3.25 - 4.39	1	0.43	0.0009	0.37 - 0.49
Outside Thorium Storage Area	0	–	–	– –	1	0.74	0.01	0.53 - 0.85	1	0.45	0.0006	0.40 - 0.50
E. Wilder	0	–	–	– –	2	0.53	0.02	0.28 - 0.78	2	0.43	0.0002	0.4 - 0.46
Route 13 South	0	–	–	– –	1	0.21	0.002	0.11 - 0.31	0	–	–	– –
Interstate 75 South	1	0.40	0.007	0.23 - 0.57	1	0.50	0.004	0.37 - 0.63	2	0.28	0.0004	0.24 - 033
Route 10 West	4	0.56	0.01	0.33 - 0.79	8	0.68	0.09	0.09 - 1.28	6	0.43	0.06	-0.042 - 0.90
Route 47 South	0	–	–	– –	1	0.34	0.003	0.23 - 0.45	1	0.18	0.0004	0.14 - 0.22
Salzburg Road	1	0.33	0.01	0.14 - 0.52	2	0.67	0.002	0.58 - 0.76	2	0.36	0.008	0.18 - 0.55
Waldo Road	1	0.30	0.02	0.03 - 0.57	2	0.46	0.0008	0.40 - 0.52	1	0.30	0.05	0.25 - 0.35
Saginaw Road	0	–	–	– –	1	0.83	0.01	0.60 - 1.06	1	0.33	0.0009	0.27 - 0.39
Midland Site	1	0.56	0.01	0.38 - 0.74	2	0.62	0.04	0.22 - 1.035	2	0.68	0.0004	0.64 - 0.73
Salzburg Landfill	1	0.46	0.01	0.26 - 0.66	1	0.60	0.006	0.44 - 0.56	1	0.22	0.0004	0.18 - 0.26
Transportation Routes	8	0.48	0.02	0.20 - 0.76	18	0.58	0.06	0.1 - 1.06	15	0.37	0.03	0.02 - 0.70

TABLE 12

STATISTICAL SUMMARY - SOIL CONCENTRATIONS OF SURVEY AREAS (pCi/g)

NATURAL-OCCURRING (K-40); MAN-MADE (GS-137

Location	Number of Soil Samples	Soil Concentrations of 40K			Number of Soil Samples	Soil Concentrations of 137Cs		
		Mean	Variance	Confidence Interval (at 95%)		Mean	Variance	Confidence Interval (at 95%)
Bay City								
Near Thorium Storage Area	1	9.61	0.69	7.95 - 11.27	1	0.12	0.0002	0.09 - 0.15
Outside Thorium Storage Area	1	4.67	0.14	3.91 - 5.43	0	–	–	– –
E. Wilder	2	7.72	0.29	6.65 - 8.79	1	0.07	0.0006	0.02 - 0.12
Route 13 South	0	–	–	– –	2	0.34	0.04	-0.065 - 0.76
Interstate 75 South	2	5.38	0.24	4.4 - 6.36	8	0.35	0.02	-0.0522 - 0.66
Route 10 West	8	9.77	3.72	5.91 - 13.63	1	0.18	0.0004	0.14 - 0.22
Route 47 South	1	11.0	0.81	9.8 - 12.8	1	0.05	0.0002	0.02 - 0.08
Salzburg Road	2	5.68	17.05	-2.58 - 13.94	2	0.05	0	0.05
Waldo Road	2	11.5	0.32	10.3 - 12.64	1	0.07	0.0002	0.04 - 0.10
Saginaw Road	1	9.02	0.57	7.51 - 10.53	0	–	–	– –
Midland Site	2	4.8	29.33	-6.08 - 15.64	0	–	–	– –
Salzburg Landfill	1	12.00	1	10.00 - 14.00				
Transportation Routes	17	9.11	6.34	4.07 - 14.14	18	0.26	0.04	0.06 - 0.46

TABLE 13

DISTRIBUTION ANALYSIS
GEOMETRIC MEANS AND GEOMETRIC STANDARD
DEVIATIONS OF TRANPORTATION ROUTES

	Geometric Mean	Geometric Standard Deviation
Thorium Series		
Th-232	0.39	1.5
Ra-228	0.43	1.4
Th-228	0.34	1.3
Ra-224	0.30	1.5
Pb-212	0.33	1.4
Bi-212	0.44	1.5
Uranium Series		
Th-230	0.69	1.6
Th-234	0.63	1.7
Ra-226	0.44	1.3
Others		
Cs-137	0.42	1.9
K-40	10	1.6

TABLE 14

RADIOLOGICAL SURVEY - EXTERNAL GAMMA
BAY CITY SITE

Bay City Storage Site
A. Proposed Routes

Number	External Gamma Readings at 1 Meter (μrem/hr)	External Gamma Readings at 1 Centimeter (μrem/hr)	Roadway
THORIUM STORAGE AREA:			
1	20.0	20.0	Roadway No. 1
Location: 3 feet from center of gate to thorium storage area			
2	20.0	20.0	Roadway No. 1
Location: At edge of gate to thorium storage area			
The following measurements were made at approximately 150 foot intervals along shoulder in direction of travel:			
3	20.0	20.0	Roadway No. 1
4	15.0	15.0	Roadway No. 1
5	25.0	20.0	Roadway No. 1
6	20.0	20.0	Roadway No. 1
7	15.0	15.0	Roadway No. 1
8	10.0	10.0	Roadway No. 1
9	10.0	10.0	
Location: At entrance to main gate in direction of travel			
Arithmetic Mean and Standard Deviation:	16 ± 12.2	15.5 ± 10.4	
OUTSIDE OF THORIUM STORAGE AREA:			
10	5.0	5.0	
Location: Directly across from No. 9, on shoulder of Street C			
11	5.0	5.0	
Location: Base of Dike			
12	5.0	5.0	
Location: Top of Dike			
13	10	5.0	C Street
14	8.0	8.0	
*Top of Dike, in line with No. 13			
The following measurements were made at 0.25 mile intervals:			
15A	2.5	2.5	Corner of 9th and C Street
B	2.5	3.0	Corner of 9th and C Street
16A	3.5	2.5	9th Street (near pond)
*Continuous reading = 2.5 (average)			
17A	2.5	2.0	Corner of 9th and F Street
B	2.0	3.0	
18A	2.0	2.0	F Street
B	1.5	2.0	
Location directly across from #17			
*5 feet from shoulder			
*Continuous reading = 2.5 (average)			
19	5.0	5.0	
*At Guard gate			
*Continuous reading = 2.0 (average)			
Arithmetic Mean and Standard Deviation:	4.1 ± 5.2	3.8 ± 3.6	
20	4.0	3.5	
Location: corner of Bay City Site and Wilder Road			

TABLE 14

RADIOLOGICAL SURVEY - . 'TERNAL GAMMA
BAY CITY SITE

Bay City Storage Site
B. Alternative Route

Number	External Gamma Readings at 1 Meter (μrem/hr)	External Gamma Readings at 1 Centimeter (μrem/hr)
B.1 STORAGE SITE SIDE OF ALTERNATIVE ROUTE GATE:		
21	3.0	2.5
Location: Base of utility pole		
22	2.0	3.0
Location: Approximately 10 feet from utility pole		
23	1.0	2.0
Location: Approximately 10 feet past guard house		
B.2 WILDER ROAD SIDE OF ALTERNATIVE ROUTE GATE:		
The following measurements were made along the gate:		
24	2.0	2.0
Location: Edge of gate on side being traveled.		
25	1.0	2.0
Location: Center of Gate		
26	2.0	1.5
Location: Edge of gate, opposite side		
The following measurements were taken at approximately 30 foot intervals from the gate along truck side unless otherwise indicated:		
27	3.0	2.5
28	3.0	3.0
29	3.0	3.0
30	3.5	2.0
31	2.0	2.0
32	3.0	3.0
Location: Opposite side of road from measurement No. 30		
*Continuous reading = 3.0		
Arithmetic Mean and Standard Deviation:	2.4 ± 1.6	2.4 ± 1.0

Note: - "A" measurements were made at shoulder of road.
- "B" measurements were made approximately 5 feet from the shoulder.

All measurements were made along should of the road

TABLE 15

RADIOLOGICAL SURVEY EXTERNAL GAMMA
MIDLAND SITE

Number	External Gamma Readings at 1 Meter (μrem/hr)	External Gamma Readings at 1 Centimeter (μrem/hr)
1A	4.5	5.0
Location: Base of utility pole		
The following measurements were taken at approximately 10 feet intervals from Utility Pole in front of Thorium Storage Area:		
2A	3.0	2.5
3A	3.0	3.0
4A	3.0	4.0
4B	4.0	3.5
5A	3.0	2.0
6A	3.0	2.0
7A	4.0	2.0
8A	4.0	3.0
9A	2.0	1.0
10A	1.5	1.0
11A	3.0	2.5
12A	3.5	3.5
13	6.0	
Location: Fence edge		
14A	3.0	2.5
15A	3.0	3.5
16A	3.5	4.0
B	3.0	6.0
17A	3.0	2.0
18A	1.5	1.0
19A	2.5	2.0
B	5.0	5.0
20A	3.5	2.0
B	2.5	3.0
21A	4.0	3.0
B	3.5	3.0
22A	4.0	3.0
B	3.5	3.0
23A	2.0	3.0
B	4.0	6.0
The following measurements were made at entrance to Building 1304:		
24A	3.0	5.0
Location: Front of Building, Center		
25A	2.0	1.5
Location: Front of Building, Northern edge		
26A	4.0	4.0
Location: Front of Building, Southern edge *Continuous reading = 3.0		
27A	4.0	5.0
Location: 35 feet from center of building *Continous reading = 3.5		
Arithmetic Mean and Standard Deviation:	3.3 ± 1.8	3.0 ± 2.6

Note:

- "A" measurements were made approxiamtely 5 feet from the shoulder of road.
- "B" measurements were made approximately 5 feet from "A" measurements toward thorium Storage Area.
- Standard deviations are given as the 2σ value.

TABLE 16

RADIOLOGICAL SURVEY EXTERNAL GAMMA
SALZBURG LANDFILL

Number	External Gamma Readings at 1meter (µrem/hr)	External Gamma Reading at 1 centimeter (µrem/hr)
The following measurements were made along a gravel road in front of cells 17 through 20 at approximately 30 foot intervals		
1A	4.0	3.0
2A	3.5	4.0
3A	5.0	4.0
4A	4.0	3.0
5A	2.0	2.0
6A	3.5	5.0
7A	4.0	2.0
8A	4.0	3.0
Location: Middle of road		
Along road in front of cells future cell #36, at approximately 30 foot intervals.		
9A	4.5	4.0
10A	4.5	3.5
11A	2.0	2.0
12A	1.0	1.0
13A	0.5	1.0
14A	1.0	2.0
15A	3.5	4.5
Arithmetic Mean & Standard Deviation:	2.5 ± 0.94	2.6 ± 1.1

*Continuous walk at one meter to end of cell #39 was approximately 1.0 µrem/hour.

- "A" measurements were made approximately 5 feet from road
- Standard deviations are given at the 2 value

TABLE 17

RADIOLOGICAL SURVEY - EXTERNAL GAMMA
TRANSPORTATION ROUTES

Number	External Gamma Readings at 1 Meter (μrem/hr)	External Gamma Readings at 1 Centimeter (μrem/hr)
1.0 Wilder Road		
The following measurements were made at approximately 0.25 mile intervals:		
1A	2.0	1.0
B	(pond)	(pond)
Location: Front of DOW Plastic Lined Pipe Plant		
2A	3.0	2.5
B	2.0	3.0
3A	3.0	2.0
B	4.0	3.0
Location: Opposite side of road from measurement No. 2		
4A	2.0	3.0
B	2.0	2.0
5A	2.5	
Location: Intersection with Patterson Ave.		
6A	2.0	2.0
B	2.5	3.0
* Continuous readings = 1.5 (average)		
7A	2.0	2.0
7O	5.0	5.0
8B	3.0	4.0
Location: Opposite side of road from measurement No. 7		
9A	3.0	1.0
9B	3.0	2.0
Location: Entrance to Consumer Power's Co./Great Lakes Junior College		
10B	3.0	4.0
10B	2.5	3.0
11B	2.0	3.0
12B	1.0	2.0
13B	3.0	4.0
Location: Opposite site of road from measurement No. 12B		
14A		
Location: Euclid and Wilder (Intersection)		
15A	3.0	3.0
B	2.5	2.0
16A	2.5	4.0
B	3.0	4.0
17B	5.0	4.0
18B	3.0	3.0
Location: Opposite side of road from measurement No. 17		
*Continuous reading = 2.5 mrem/hr (average)		
19A	3.0	3.0
B	3.0	4.0
Opposite side of road from, opposite measurement No. 20		
20A	4.0	3.0
B	4.5	4.5
21A	4.0	3.0
B	4.0	4.0
Arithmetic Mean and Standard Deviation:	2.9 ± 1.8	3.0 ± 2.0

Number	External Gamma Readings at 1 Meter (µrem/hr)	External Gamma Readings at 1 Centimeter (µrem/hr)
2.0 M-13		
The following measurements were made at approximately 0.25 mile intervals:		
24A	2.5	2.5
B	3.0	2.0
25A	3.0	3.0
B	2.5	3.0
Location: Opposite side of road from measurement No. 24		
26A	2.0	2.0
B	2.0	2.0
27A	3.0	2.5
B	2.0	3.0
Arithmetic Mean & Standard Deviation	2.5 ± 1.0	2.5 ± 0.8
3.0 Interstate 75 (South)		
28B	2.0	3.0
29B	3.0	4.0
30B	2.5	3.0
31B	3.5	5.0
Arithmetic Mean & Standard Deviation:	2.8 ± 1.2	3.8 ± 2.0
4.0 Route 10 (West)		
32A	3.0	3.0
B	4.0	3.0
33A	3.5	3.0
B	4.0	3.5
34A	3.0	2.5
B	3.0	3.0
35A	2.0	2.0
B	1.5	3.0
36A	2.0	2.0
B	2.0	2.5
*Opposite side of road from measurement No. 36		
37A	4.5	4.5
B	3.0	3.5
38A	2.0	2.5
B	3.0	3.0
39A	2.5	3.0
B	3.0	3.0
40A	3.5	3.0
B	4.0	3.5
*Opposite side of road from measurement No. 40		
41A	2.5	2.5
B	3.0	4.0
C	4.0	4.0
D	3.5	3.0

TABLE 17

RADIOLOGICAL - EXTERNAL GAMMA
TRANSPORTATION ROUTES

Number	External Gamma Readings at 1 Meter (μrem/hr)	External Gamma Readings at 1 Centimeter (μrem/hr)
4.0 Route 10 (West) (Continued)		
42A	2.0	3.0
B	4.0	3.5
43A	3.0	3.5
B	4.0	4.5
44A	4.0	3.5
B	2.0	2.0
45A	3.0	3.0
B	4.0	3.5
*Opposite side of road from measurement No. 45		
46A	3.0	3.5
B	1.0	2.0
C	4.0	3.5
D	2.0	2.0
47A	4.0	3.5
B	4.5	3.5
48A	3.5	3.0
B	5.0	3.0
49A	2.0	3.5
B	4.0	4.0
50A	3.0	3.5
B	3.0	2.5
*Opposite side of road from measurement No. 49		
51A	4.0	2.0
B	4.5	2.5
C	3.5	2.5
D	4.0	3.0
52A	3.0	3.0
B	3.5	3.0
53A	3.0	4.0
B	3.5	3.0
54A	3.0	3.0
B	3.0	2.0
55A	3.0	3.0
B	5.0	4.0
*Opposite side of road from measurement No. 54		
56A	1.0	2.5
B	4.0	3.0
C	4.0	2.5
D	4.0	3.0
57A	3.0	3.5
B	3.5	4.0
58A	3.0	3.5
B	2.5	3.0
59A	4.0	2.0
B	3.0	5.0
60A	4.0	3.5
B	4.0	4.0
*Opposite side of road from measurement No. 59		
61A	1.0	3.5
B	4.0	4.0
C	3.0	3.5
D	4.0	3.5
62A	2.0	3.0
B	3.0	4.0
63A	3.0	2.0
B	3.0	4.0

Number	External Gamma Readings at 1 Meter (μrem/hr)	External Gamma Readings at 1 Centimeter (μrem/hr)
4.0 Route 10 (West) (Continued)		
64A	3.5	4.0
B	3.5	5.0
65A	3.0	3.5
B	4.0	5.0
*Opposite side of road from measurement No. 65		
66A	2.0	3.5
B	4.0	4.0
C	3.0	3.5
D	4.0	3.5
67A	3.0	3.0
B	3.0	3.0
68A	3.0	4.0
B	3.5	4.0
69A	3.5	2.0
B	3.0	3.5
70A	3.0	3.0
B	2.5	3.0
*Opposite side of road from measurement No. 70		
71A	2.0	3.0
B	3.0	3.0
C	2.0	1.5
D	4.0	3.0
72A	3.5	2.0
B	3.0	3.5
73A	3.0	3.5
B	3.5	3.5
74A	4.0	4.0
B	4.5	4.5
75A	3.5	4.0
B	3.0	3.5
*Opposite side of road		
Arithmetic Mean and Standard Deviation:	3.2 ± 1.2	3.4 ± 1.6
5.0 Route 47 South		
76A	3.0	2.0
Location: Intersection of Route 10 West and Route 47 (South)		
The following measurements were made at approximately 0.25 mile intervals:		
77A	3.0	3.0
B	3.0	3.0
78A	3.0	*
79A	3.5	3.0
B	4.0	3.5
C	2.0	3.0
D	4.0	3.5
80A	4.0	3.0
B	3.0	3.5
Arithmetic Mean and Standard Deviation:	3.3 ± 1.4	3.2 ± 0.6
6.0 Salzburg (From 47-S to Salzburg Landfill)		
81A	4.0	4.0
B	3.0	3.5
Location: Intersection of 47 [illegible] and Salzburg		
The following measurements w[illegible] made at approximately 0.25 mile intervals:		
82A	2.0	3.5
B	4.0	4.0
83A	3.0	3.5
B		3.5

TABLE 17

RADIOLOGICAL - EXTERNAL GAMMA
TRANSPORTATION ROUTES

Number	External Gamma Readings at 1 Meter (μrem/hr)	External Gamma Readings at 1 Centimeter (μrem/hr)
6.0 Salzburg (From 47(S) to Salzburg Landfill) continued:		
84A	3.5	2.0
B	2.5	3.0
85A	4.0	3.5
B	6.0	4.0
86A	2.0	3.0
B	3.0	3.0
87A	3.0	2.0
B	3.5	2.5
88A	2.0	1.5
B	4.0	3.0
89A	2.5	1.0
B	3.5	3.0
90A	4.0	3.5
B	2.0	3.0
Location: Intersection of Salzburg and Waldo		
91A	2.5	2.0
B	2.5	4.0
Location: Opposite side of road Intersection of Salzburg and Waldo		
92A	4.0	3.5
B	3.0	3.5
Location: Waldo		
93A	4.0	4.5
B	4.0	3.5
Location: Opposite side of road across from Guard House (3602)		
94A	2.0	2.0
Location: East of gate 93		
95A	2.0	2.0
Location: West of gate 93		
96A	3.5	4.5
B	4.5	4.0
Location: Approximately 0.2 from disposal cells No. 38		
Arithmetic Mean and Standard Deviation	3.3 ± 2.0	3.0 ± 1.8
7.0 From Midland site, along Saginaw to intersection of Salzburg and Waldo		
97A	2.0	2.0
B	4.0	4.0
Location: Intersection of Saginaw and Salzburg		
The following measurements were made at approximately 0.25 mile intervals:		
98A	3.5	4.5
B	3.5	3.0
Location: Center, front of Gate 90		
99A	3.5	3.0
B	1.0	2.0
Location: Opposite front of Gate 90		
100A	3.5	3.0
B	4.0	3.0
101A	4.0	3.0
B	3.0	2.5
Arithmetic Mean and Standard Deviation	3.2 ± 1.8	3.0 ± 1.6

Note: The following measurements were made at 0.25 mile intervals.
- "A" measurements were made as close to the shoulder of the road as possible.
- "B" measurements were made 10 to 15 feet (unless otherwise stated) from the "A" measurement pending on the nature of the side of the road.
- Measurements "C" through "D" were made at 10 foot intervals starting with "B" in a westward direction along route 10.
- * Not taken due to hazards
- Standard deviations are given as the 2σ value

TABLE 17

RADIOLOGICAL - EXTERNAL GAMMA
TRANSPORTATION ROUTES

Number	External Gamma Readings at 1 Meter (µrem/hr)	External Gamma Readings at 1 Centimeter (µrem/hr)
8.0 Waldo Road		
120A	3.0	3.0
B	4.0	4.0
103A	4.0	4.0
B	4.0	5.0
104A	4.0	3.0
B	4.0	4.0
105A	3.0	3.0
B	2.5	2.5
106A	2.5	2.0
B	2.5	4.0

Mean and standard deviation: 3.5 ± 1.3 3.4 ± 1.8

Location: Measurements were made outside of Dow Gate 93 at 30 foot intervals from fire hydrant in a northward direction along Waldo F ad.

TABLE 18

OFF-SITE BACKGROUND
EXTERNAL GAMMA

Number	External Gamma Readings at 1 Meter (μrem/hr)	External Gamma Readings at 1 Centimeter (μrem/hr)	Location
1	5.0	5.0	Holland Road
	5.0	5.0	Near Quality
	4.5	4.5	Farm and Fleet
	4.0	6.5	Saginaw, Michigan
	6.5	7.0	
	6.0	8.0	
Arithmetic Mean And Standard Deviation:	5.2 ± 1.8	6 ± 2.8	
2	4.5	5.0	Off Pine Street
	4.5	5.5	Kawkawlin, Michigan
	4.5	3.5	
	4.5	4.5	
	4.5	3.0	
	4.0	4.0	
Arithmetic Mean and Standard Deviation:	4.4 ± 0.4	4.25 ± 1.8	
3	2.0	2.5	Off E. Wilder Road
	4.0	3.0	Bay City, Michigan
	3.0	4.0	
	3.0	3.5	
	4.0	4.5	
	4.0	5.0	
Arithmetic Mean and Standard Deviation:	3.3 ± 1.6	3.7 ± 1.8	

• Standard deviations are given at the 2σ value

TABLE 19

Radiological Survey
Soil Sampling Location/Soil Type

Number	Location	Soil Type
1	In front center of Gate to Thorium Storage area, Bay City Site.	Brown humus (1)
2	Base of dike across street from main gate to thorium storage area, near utility pole.	Brown humus
3	Corner of Wilder Road and entrance to Bay City Site, on truck side.	Brown humus
4	15 feet from East Wilder Road on vacant lot owned by Gary Steadman.	Brown humus
5	5 feet from Intersection of Route 13 South and E. Wilder Road, on truck side.	Brown humus
6	Along Interstate 75 South, 5 feet from shoulder of road, 200 feet from edge of billboard.	Brown humus
7	Along Interstate 75, 5 feet from shoulder of road, 75 feet from 160 mile marker.	Brown humus
8	Route 10 West, approximately 1 mile from Intersate 75-S, on truck side.	Brown humus
9	Route 10 West, near first merge line, approximately 0.5 miles past Delta College sign.	Brown humus
10	Route 10 West, 1 mile west of Mackinaw Road, 5 feet from shoulder.	Brown humus

(1) All soils are top 6" cores

TABLE 19

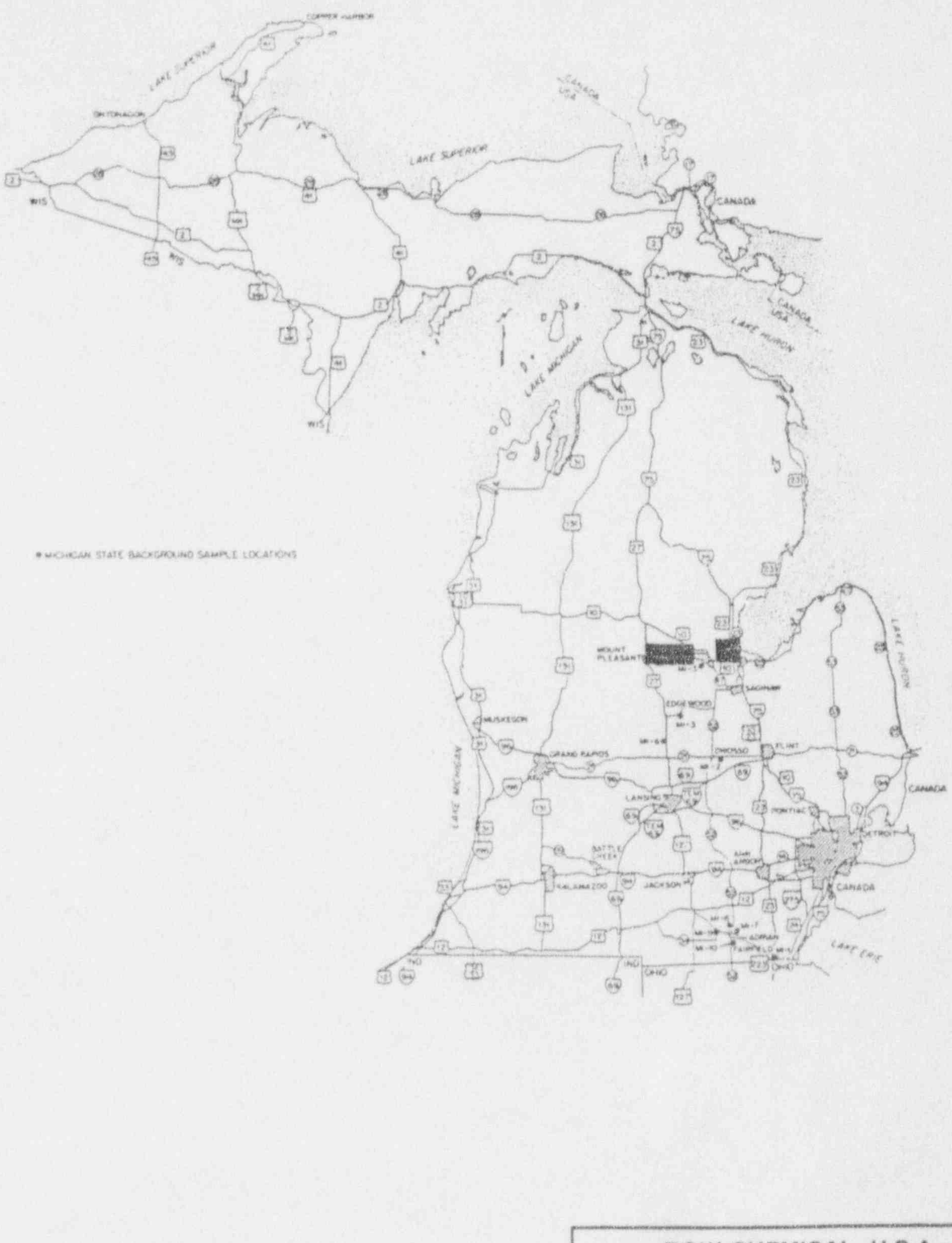
Radiological Survey
Soil Sampling Location/Soil Type

Number	Location	Soil Type
11	Route 10 West, directly across from Makinaw Road exit sign in open field, 5 feet from shoulder.	Brown humus
12	Route 10 West, approximately 1000 feet from Auburn Exit Sign, 5 feet from shoulder.	Brown humus
13	Route 10 West approximately 1000 feet west of Garfield Road Exit, approximately 1000 feet from Motel 8, 5 feet from shoulder.	Brown humus
14	On Route 10 West, approximately 1000 feet (west) from overpast, near Blue Water Tower, 5 feet from shoulder.	Brown humus
15	On Route 10 West, front of Dow Corning, approximately 1500 feet from Route 47 Exit(s).	Sandy Soil
16	On Route 47 West, approximately 0.25 from Salzburg Road Exit sign.	Sandy Soil
17	Opposite Intersection of Salzburg and Currie Road.	Sandy Soil
18	Salzburg Road, near Red and White Tower, approximately 200 feet from Yellow Gate, Right corner of dirt road, 5 feet from shoulder.	Sandy Soil
19	Across from Intersection of Waldo and Salzburg, truck side, 5 feet from shoulder.	Sandy, Gravelly Soil
20	Outside of Dow Gate #93, near fire hydrant, 5 feet from shoulder.	Brown Humus

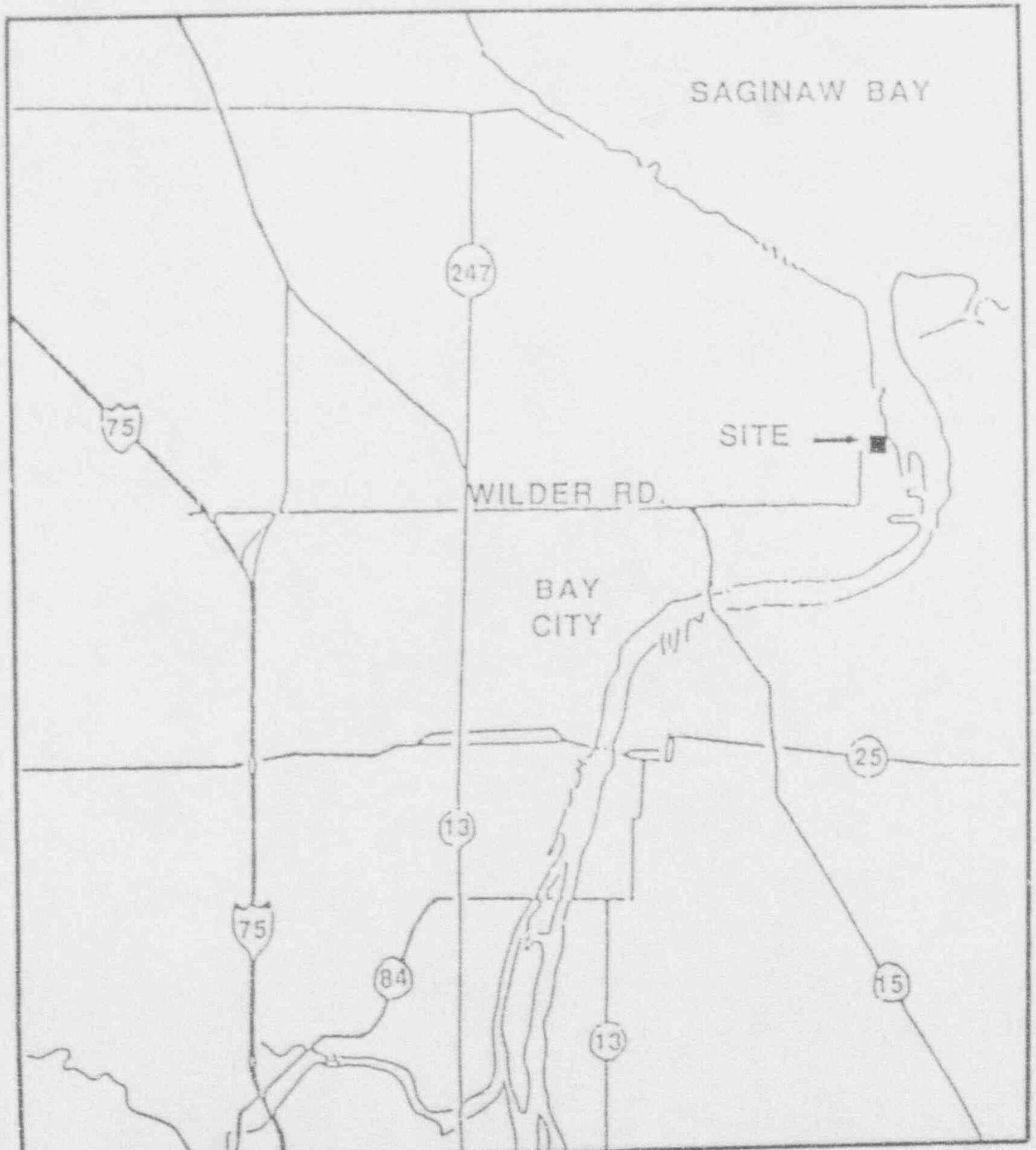
TABLE 19

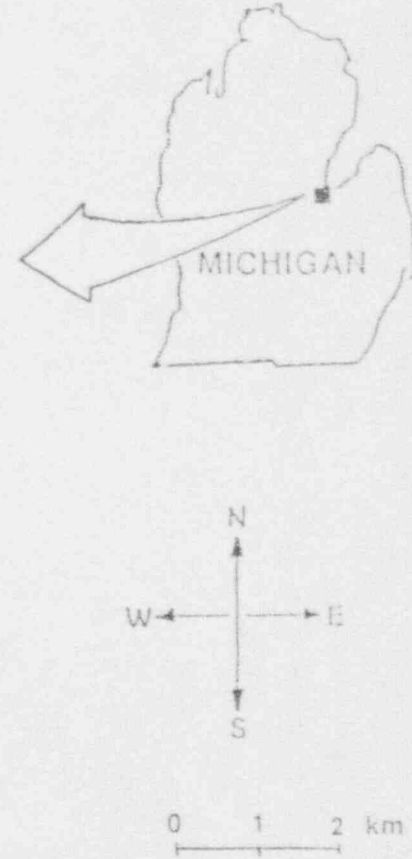
Radiological Survey
Soil Sampling Location/Soil Type

Number	Location	Soil Type
21	Across from Midland site, thorium storage area, 5 feet from 11th street, near Safety Shower (at Dow's Request).	Rocky Crushed Limestone
22	Salzburg landfill, in front of cell #37.	Sandy Soil
23	Midland Site, 6 feet in front of Building 1304.	Sand, crushed limestone
24	Saginaw road, 3 feet from shoulder of road, front of gate 25-5 near building 2510.	Brown Humus
25	Composite, "off-site" background of 4 samples taken at 1 mile intervals on Interstate 75 south of Route 10 West.	Brown/Sandy Soil



DOW CHEMICAL U.S.A.		
MIDLAND/BAY CITY, MICHIGAN		
LOCATION OF BACKGROUND SAMPLES AND EXTERNAL GAMMA-RAY EXPOSURE RATE MEASUREMENTS IN MICHIGAN		
DATE: 12/1/89	JOB NO. 01097-065	FIGURE
Dames & Moore PEARL RIVER, NEW YORK		1



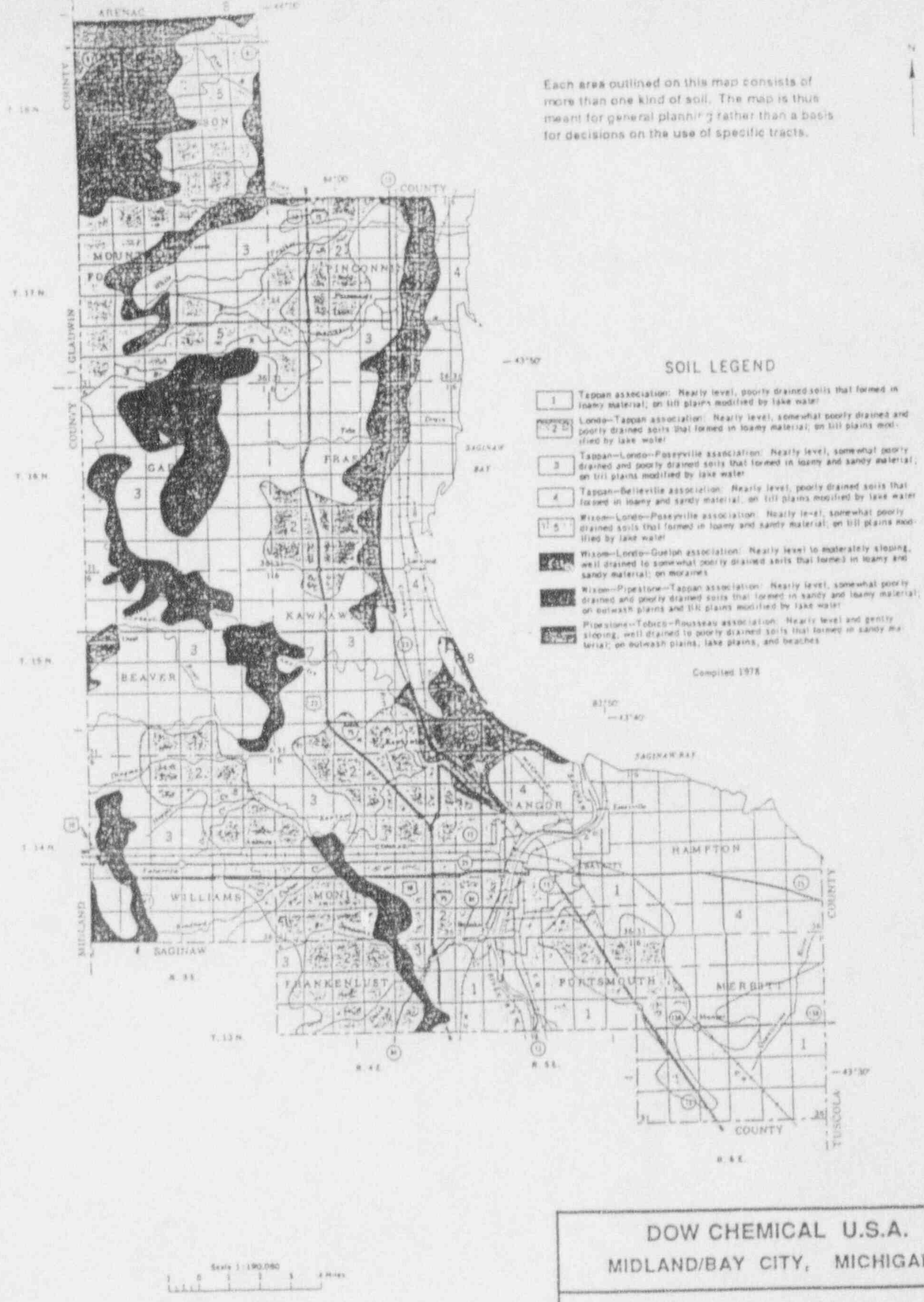


DOW CHEMICAL U.S.A.
BAY CITY, MICHIGAN

MAP OF BAY CITY

DATE: 12/1/89	JOB NO. 01097-065	FIGURE 2

Dames & Moore
PEARL RIVER, NEW YORK

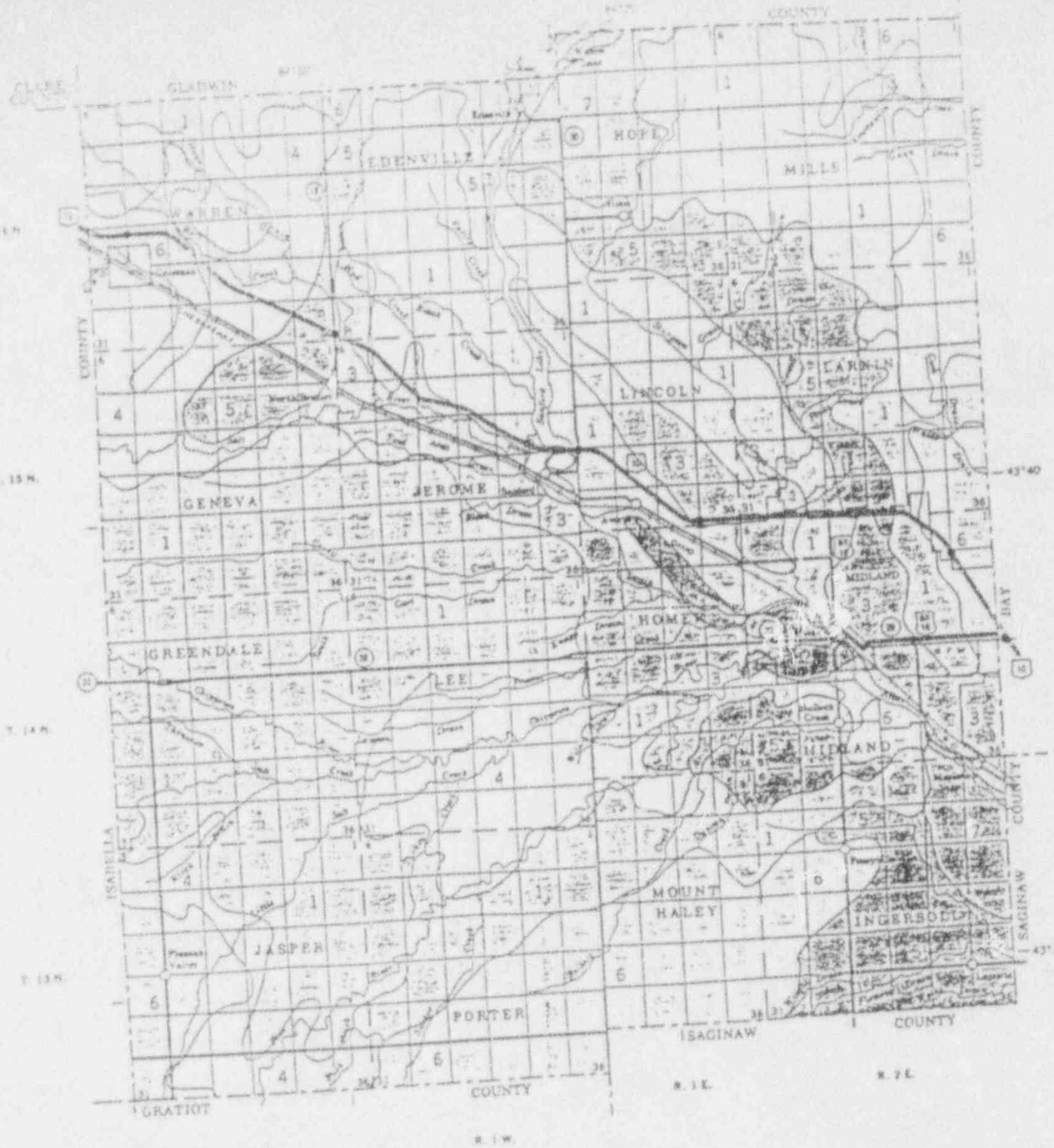


SOURCE: U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
MICHIGAN AGRICULTURAL EXPERIMENT STATION

DOW CHEMICAL U.S.A.
MIDLAND/BAY CITY, MICHIGAN

GENERAL SOIL MAP
BAY COUNTY, MICHIGAN

DATE: 12/1/89	JOB NO. 01097-065	FIGURE
Dames & Moore PEARL RIVER, NEW YORK		3



SOIL LEGEND

1	Kingsville—Pipestone—Covert: Nearly level and gently sloping, poorly drained to moderately well drained soils that have a sandy subsoil or upper substratum; formed in outwash or glacial lake deposits
2	Cohoctah—Sloan: Nearly level, poorly drained and very poorly drained soils that have a loamy subsoil or upper substratum; formed in loamy or sandy and gravelly alluvial deposits
3	Belleville—Wixom: Nearly level and gently sloping, very poorly drained to somewhat poorly drained soils that have a sandy and loamy subsoil or a sandy upper substratum; formed in glaciofluvial material over till or glacial lake deposits
4	Wixom—Belleville—Pipestone: Nearly level and gently sloping, very poorly drained to somewhat poorly drained soils that have a sandy or loamy subsoil or a sandy upper substratum; formed in glaciofluvial material over till and glacial lake deposits
5	Lenawee—Bowers—Wixom: Nearly level and gently sloping, very poorly drained to somewhat poorly drained soils that have a loamy and clayey subsoil or a sandy and loamy subsoil; formed in glaciolacustrine and till deposits
6	Parkhill—Londo: Nearly level and gently sloping, very poorly drained to somewhat poorly drained soils that have a loamy subsoil; formed in glacial till deposits
7	Ingersoll—Pella: Nearly level and gently sloping, poorly drained and somewhat poorly drained soils that have a loamy subsoil; formed in glaciolacustrine and glaciofluvial deposits

Compiled 1978

Each area outlined on this map consists of more than one kind of soil. The map is thus meant for general planning rather than a basis for decisions on the use of specific tracts.

Scale 1:190,080

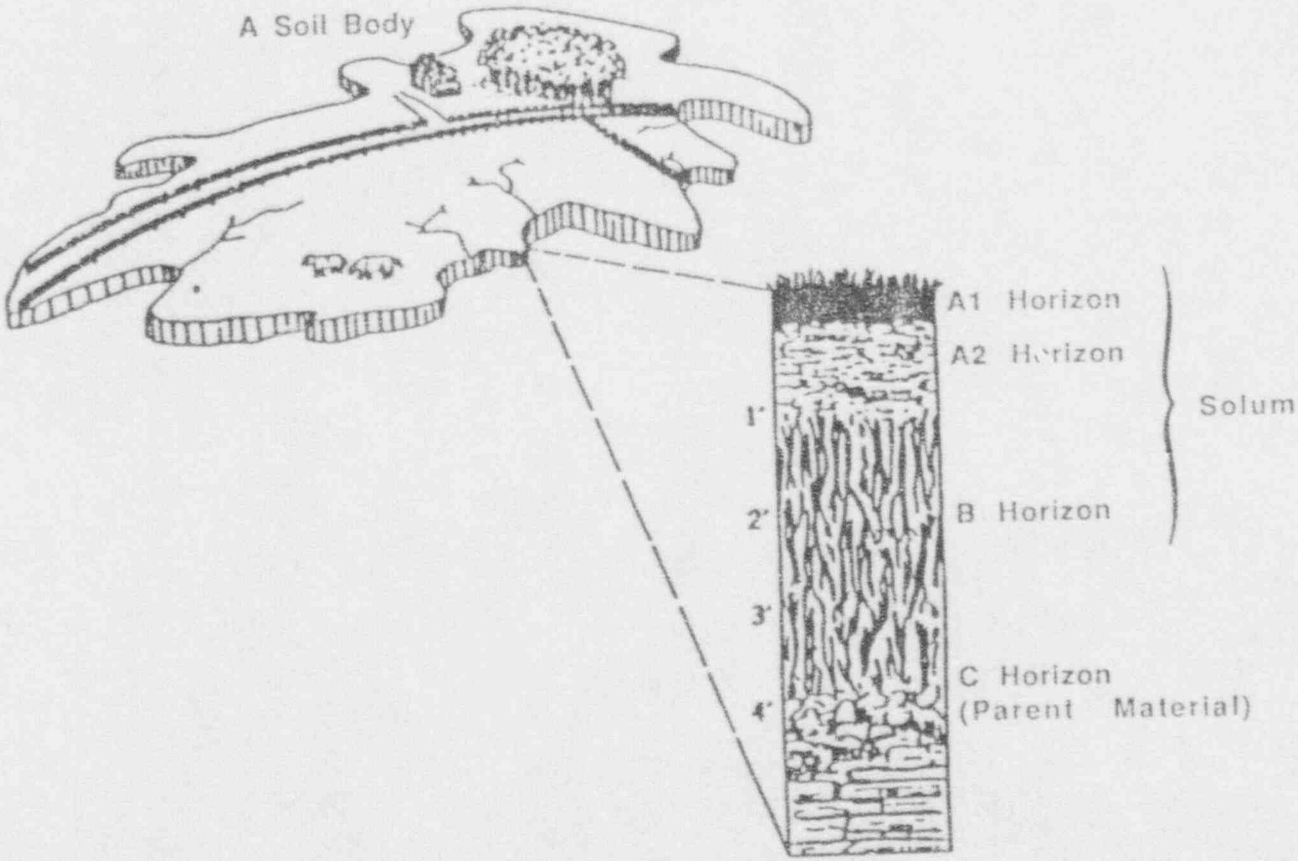
1 0 1 2 3 4 Miles

SOURCE: U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

DOW CHEMICAL U.S.A.
MIDLAND/BAY CITY, MICHIGAN

GENERAL SOIL MAP
MIDLAND COUNTY, MICHIGAN

DATE: 12/1/89	JOB NO. 01097-065	FIGURE
Dames & Moore PEARL RIVER, NEW YORK		4

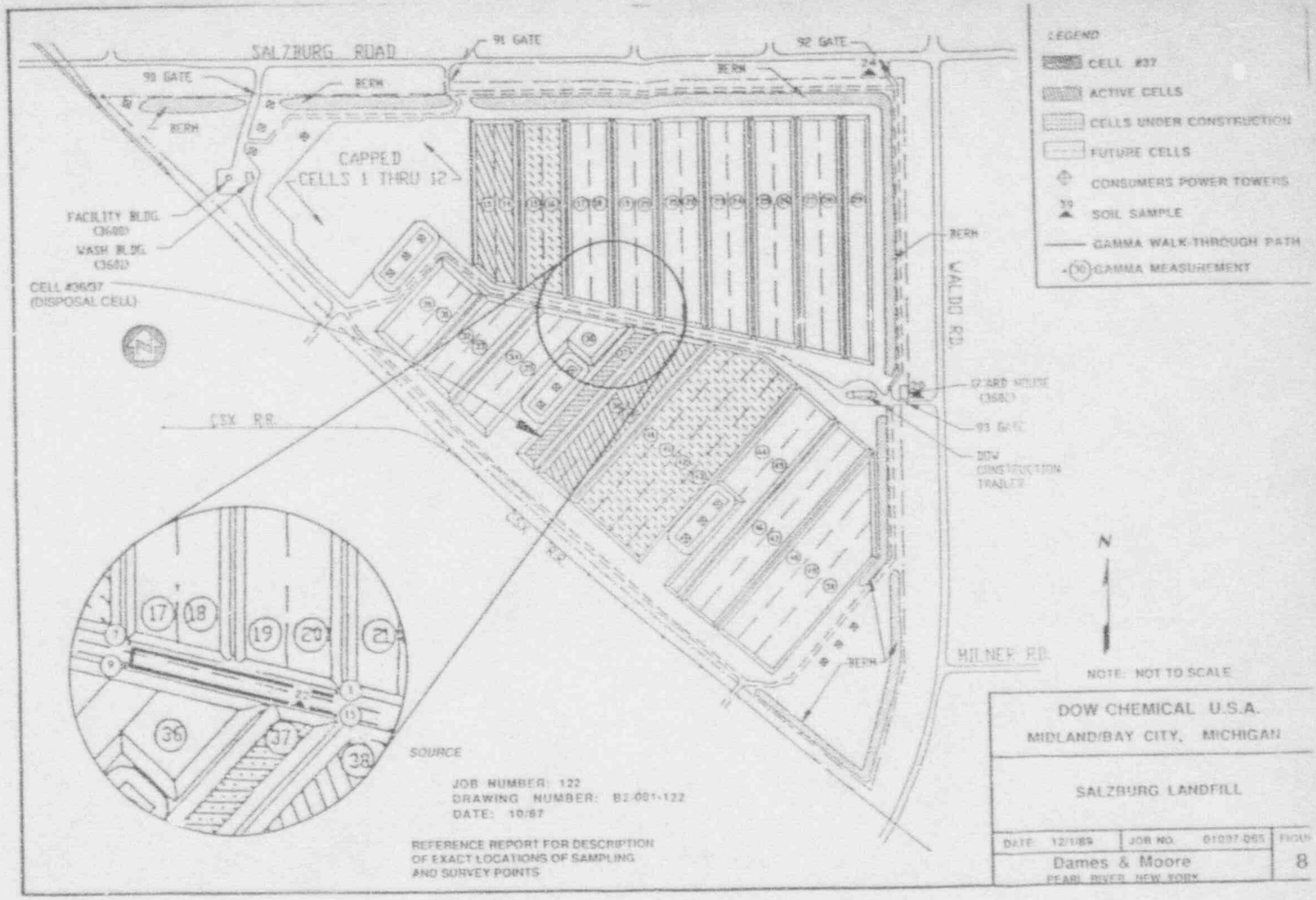


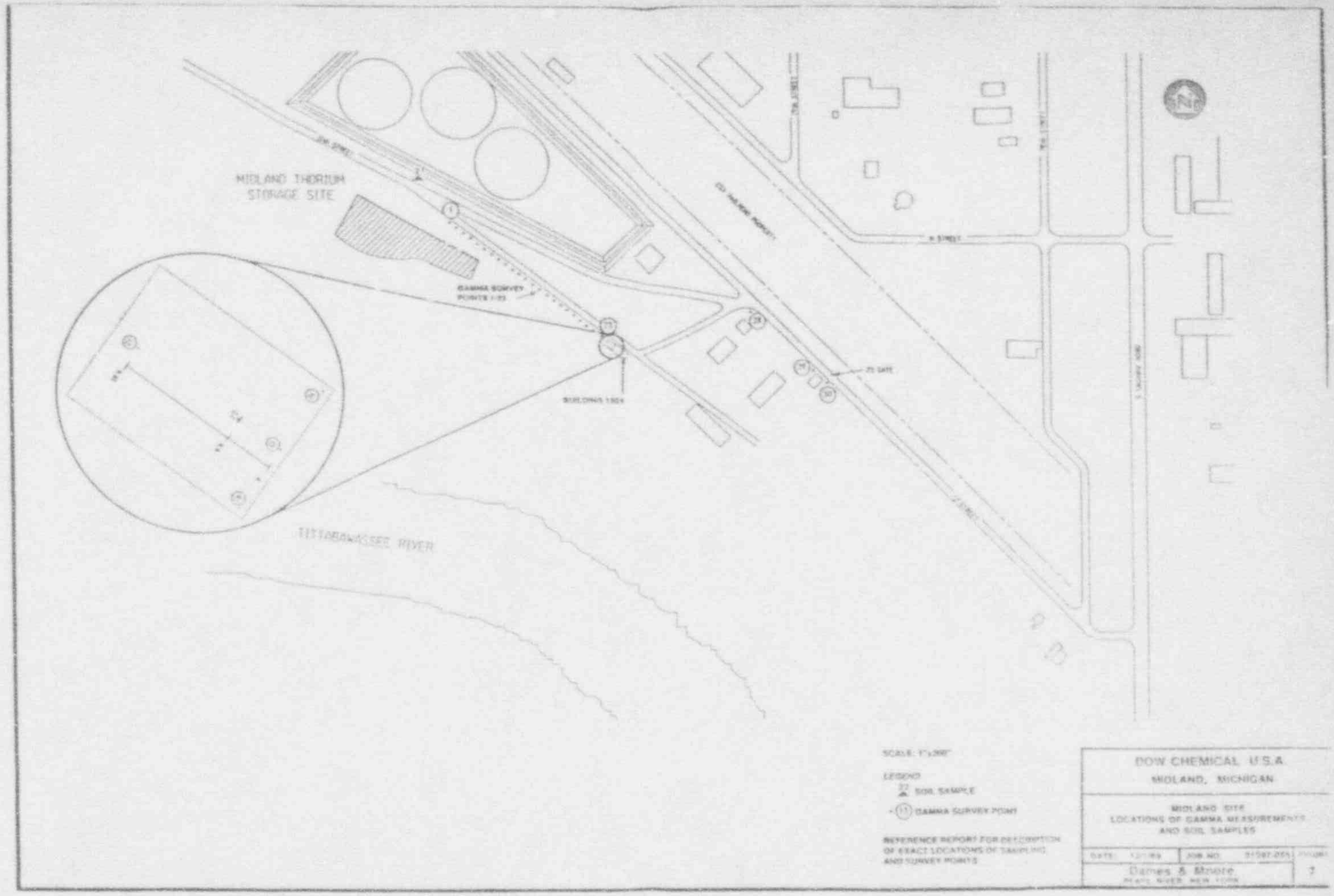
A Soil Profile

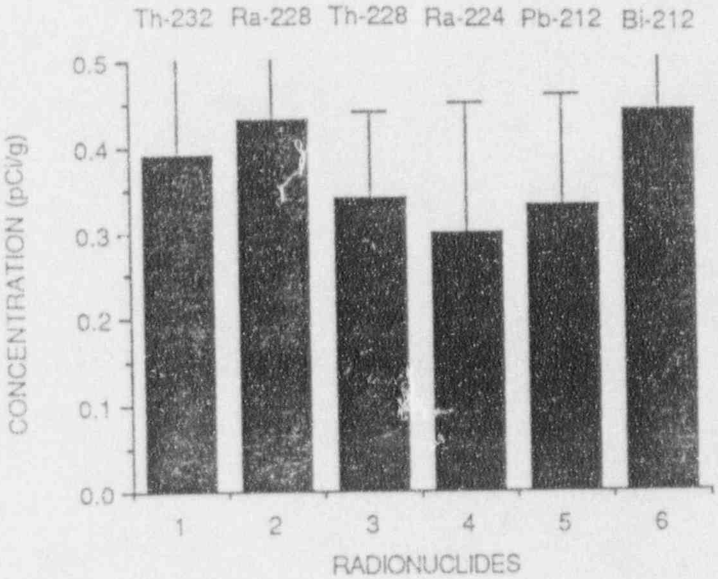
DOW CHEMICAL U.S.A.
MIDLAND/BAY CITY, MICHIGAN

SOIL HORIZONS
WITHIN A SOIL PROFILE

DATE: 12/1/89	JOB NO. 01097-065	FIGURE
Dames & Moore PEARL RIVER, NEW YORK		5

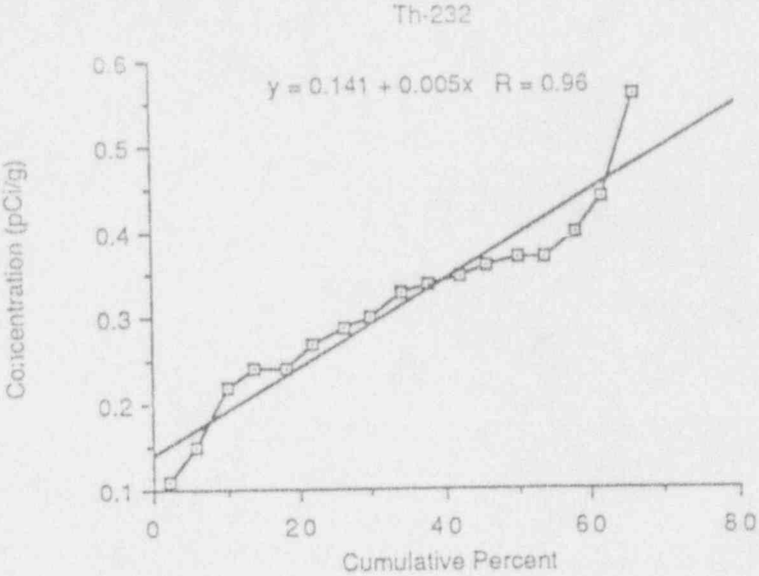

SALZBURG ROAD
90 GATE
91 GATE
92 GATE
93 GATE
BERM
CAPPED CELLS 1 THRU 12
FACILITY BLDG. (3680)
WASH BLDG. (3681)
CELL #36/37 (DISPOSAL CELL)
CSX R.R.
WALDO RD.
GUARD HOUSE (3682)
DOW CONSTRUCTION TRAILER
MILNER RD.
N
NOTE: NOT TO SCALE
LEGEND
CELL #37
ACTIVE CELLS
CELLS UNDER CONSTRUCTION
FUTURE CELLS
CONSUMERS POWER TOWERS
SOIL SAMPLE
GAMMA WALK-THROUGH PATH
GAMMA MEASUREMENT
SOURCE
JOB NUMBER: 122
DRAWING NUMBER: B2-001-122
DATE: 10/87
REFERENCE REPORT FOR DESCRIPTION OF EXACT LOCATIONS OF SAMPLING AND SURVEY POINTS
DOW CHEMICAL U.S.A.
MIDLAND/BAY CITY, MICHIGAN
SALZBURG LANDFILL
DATE 12/1/89
JOB NO. 01027-065
Dames & Moore
PEARL RIVER, NEW YORK
FIGURE
8

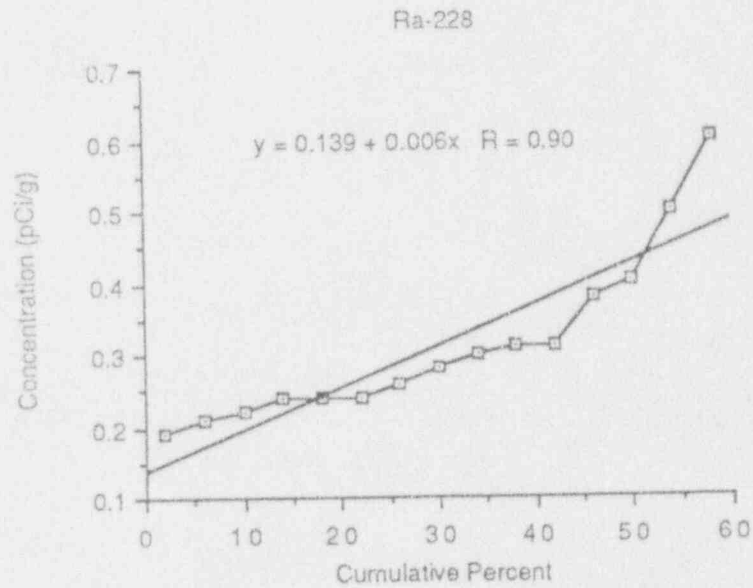

MIDLAND THORIUM STORAGE SITE
GAMMA SURVEY POINTS 1-23
BUILDING 1301
TITTABAWASSEE RIVER
H STREET
SCALE: 1"=200'
LEGEND
SOIL SAMPLE
GAMMA SURVEY POINT
REFERENCE REPORT FOR DESCRIPTION OF EXACT LOCATIONS OF SAMPLING AND SURVEY POINTS
DOW CHEMICAL U.S.A.
MIDLAND, MICHIGAN
MIDLAND SITE
LOCATIONS OF GAMMA MEASUREMENTS AND SOIL SAMPLES
DATE
JOB NO.
FIGURE
Dames & Moore
PEARL RIVER, NEW YORK
7



* BASED ON GEOMETRIC MEANS OF RADIONUCLIDES ALONG TRANSPORTATION ROUTES

DOW CHEMICAL U.S.A. MIDLAND/BAY CITY, MICHIGAN		
NATURAL Th-232 IN EQUILIBRIUM WITH DAUGHTERS		
DATE: 12/1/89	JOB NO. 01097-065	FIGURE
Dames & Moore PEARL RIVER, NEW YORK		10

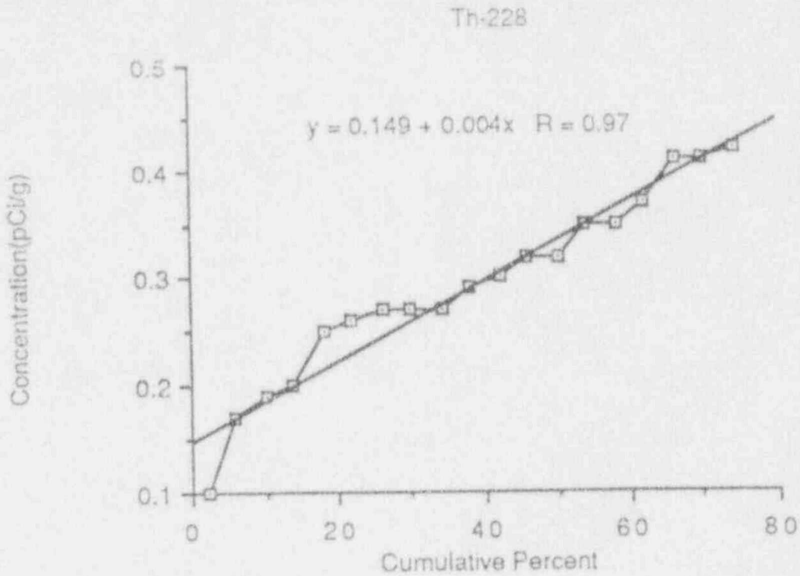


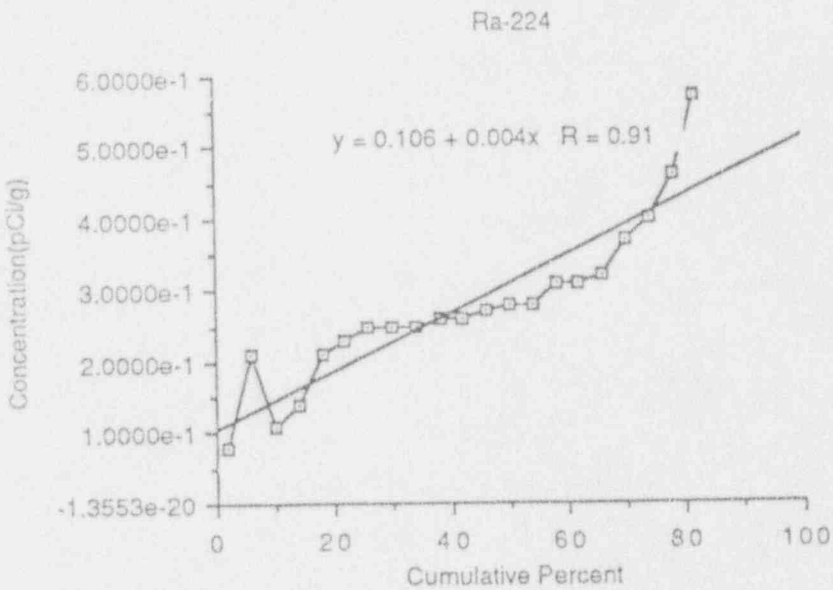


DOW CHEMICAL U.S.A.
MIDLAND/BAY CITY, MICHIGAN

CUMULATIVE FREQUENCY PLOT
THORIUM SERIES

DATE: 12/1/89	JOB NO. 01097-065	FIGURE
Dames & Moore PEARL RIVER, NEW YORK		11

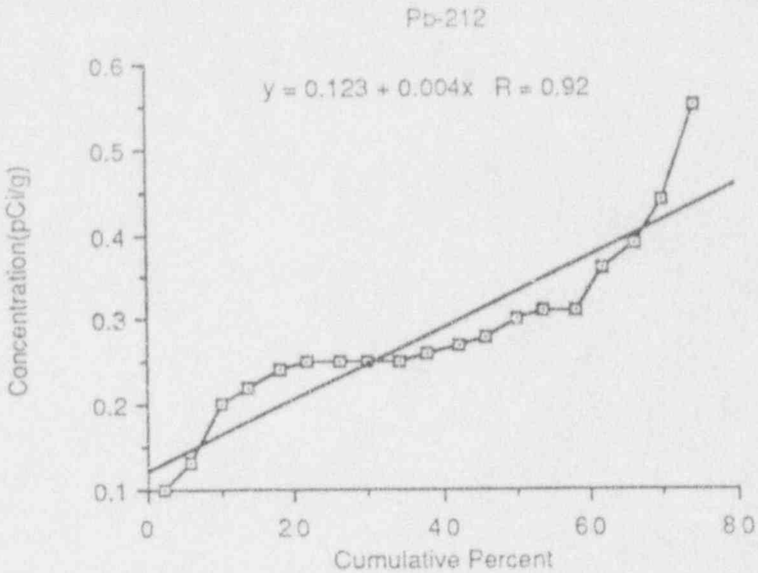


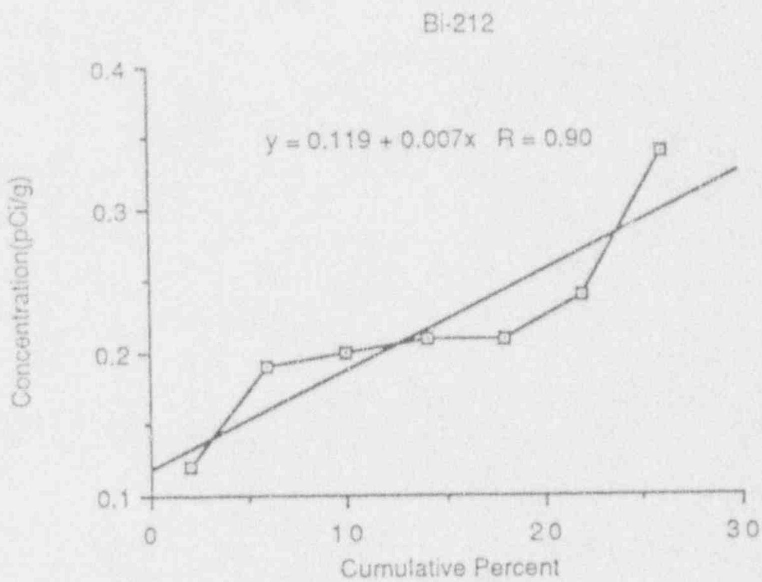


DOW CHEMICAL U.S.A.
MIDLAND/BAY CITY, MICHIGAN

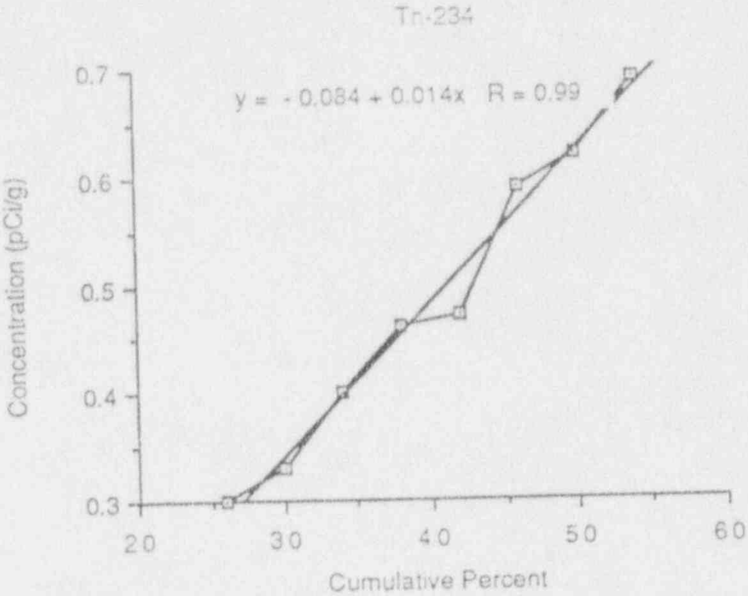
CUMULATIVE FREQUENCY PLOT
THORIUM SERIES

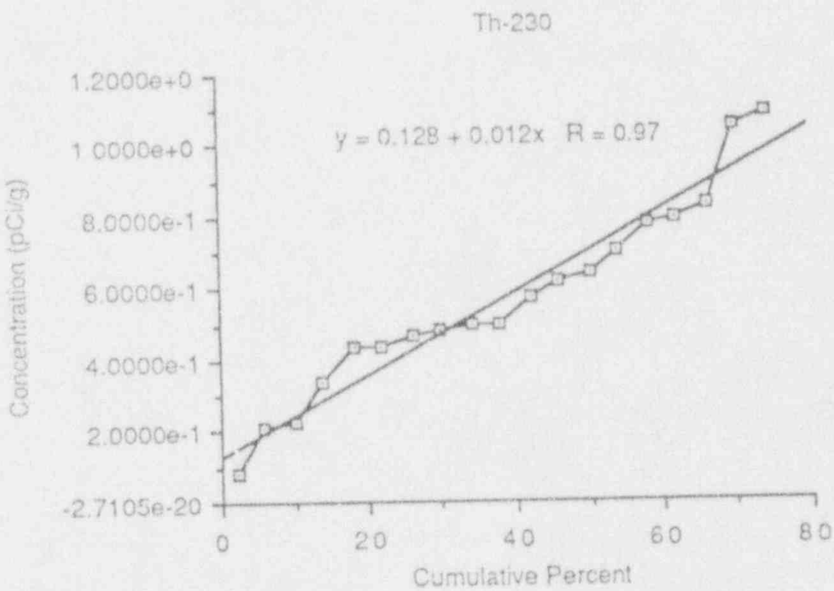
DATE: 12/1/89	JOB NO. 01097-065	FIGURE 11 (cont'd)
Dames & Moore PEARL RIVER, NEW YORK		





DOW CHEMICAL U.S.A. MIDLAND/BAY CITY, MICHIGAN		
CUMULATIVE FREQUENCY PLOT THORIUM SERIES		
DATE: 12/1/89	JOB NO. 01097-065	FIGURE 11 (cont'd
Dames & Moore PEARL RIVER, NEW YORK		



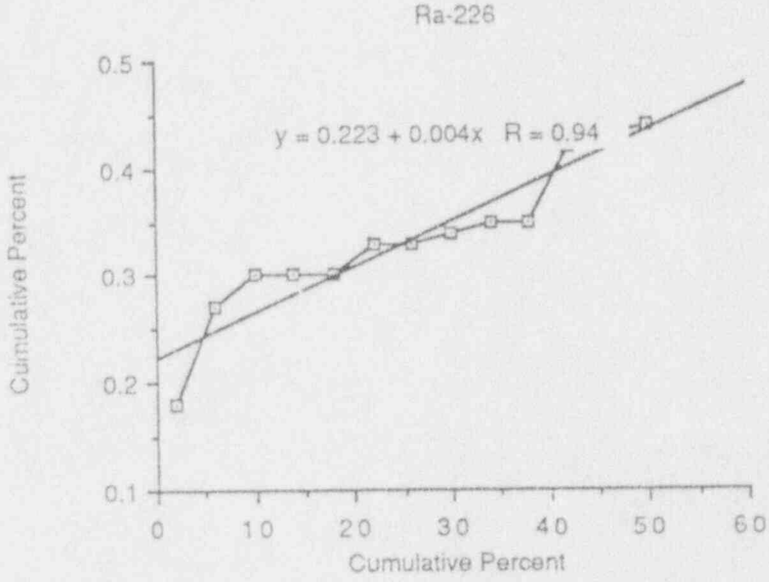


DOW CHEMICAL U.S.A.

MIDLAND/BAY CITY, MICHIGAN

CUMULATIVE FREQUENCY PLOT
URANIUM SERIES

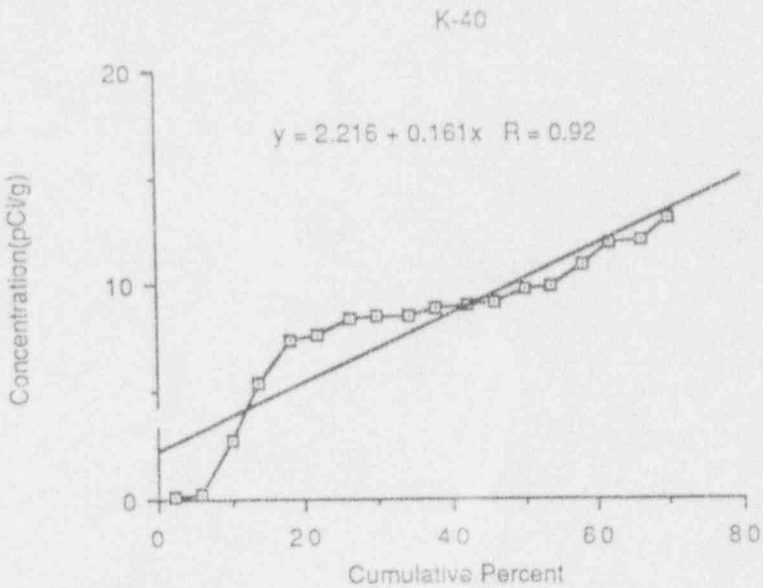
DATE: 12/1/89	JOB NO. 01097-065	FIGURE
Dames & Moore PEARL RIVER, NEW YORK		12

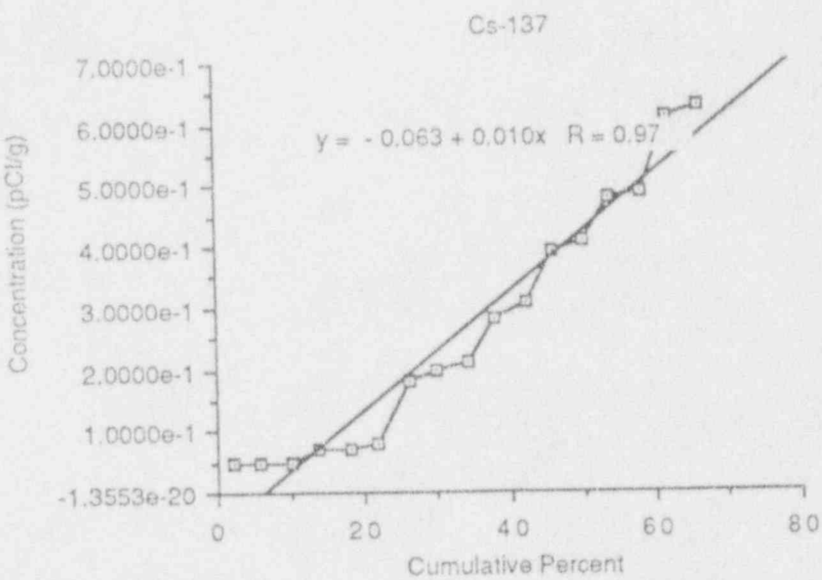


DOW CHEMICAL U.S.A.
MIDLAND/BAY CITY, MICHIGAN

CUMULATIVE FREQUENCY PLOT
URANIUM SERIES

DATE: 12/1/89	JOB NO. 01097-065	FIGURE 12 (cont'd
Dames & Moore PEARL RIVER, NEW YORK		





DOW CHEMICAL U.S.A.
MIDLAND/BAY CITY, MICHIGAN

CUMULATIVE FREQUENCY PLOT
NATURAL (K-40) AND
MAN-MADE SOURCES (Cs-137)

DATE: 12/1/89	JOB NO. 01097-065	FIGURE
Dames & Moore PEARL RIVER, NEW YORK		13

APPENDIX F

Drawings B2-042-884040 and B2-043-884040
Showing Land Use
Surrounding the Salzburg Landfill

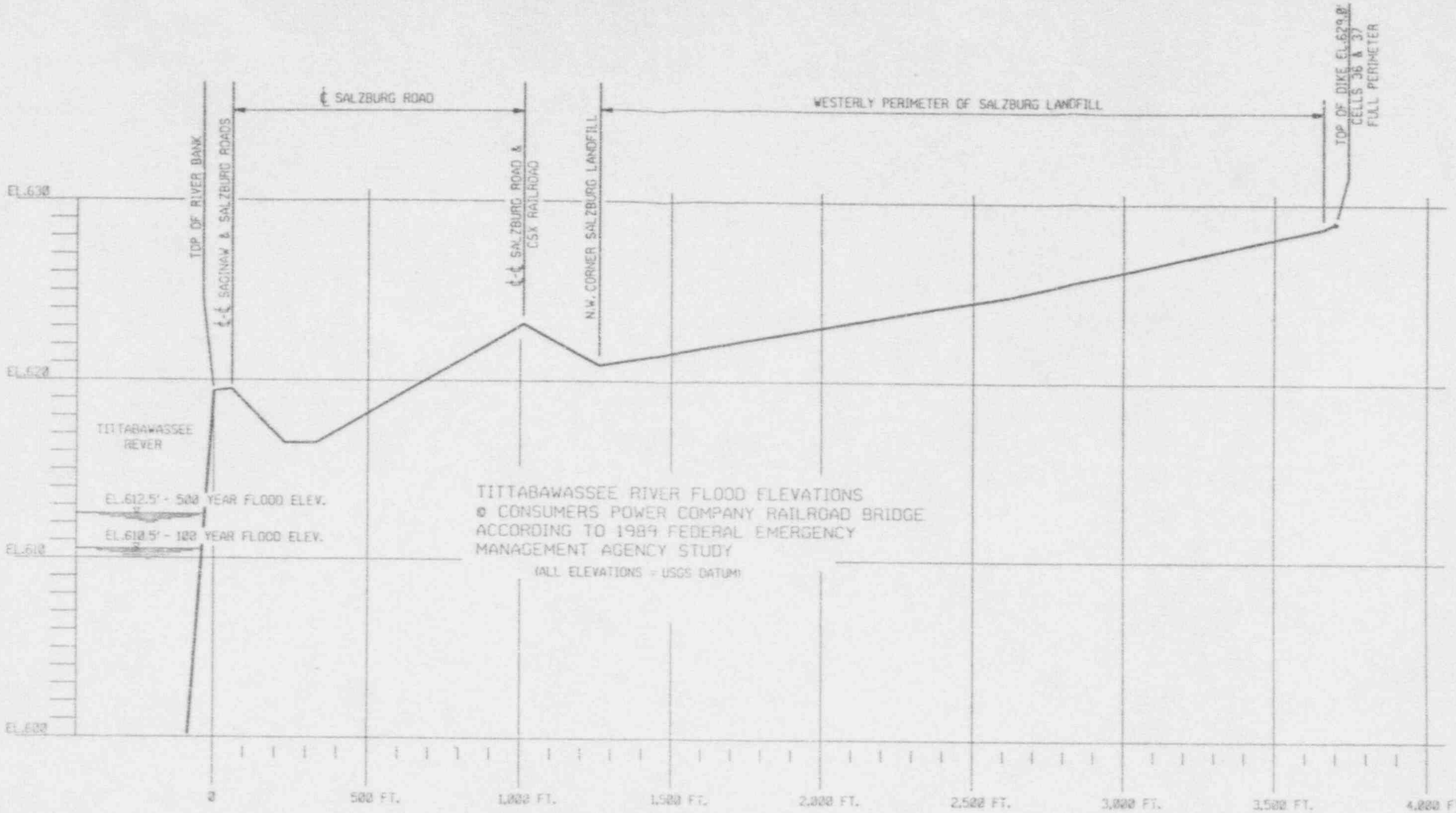
See Figure Binder for

Figure F-1 Cells 36 & 37 Surrounding Land Uses map (Sheet 1 of 2)

Figure F-2 Cells 36 & 37 Surrounding Land Uses map (Sheet 2 of 2)

APPENDIX G

Cells 36 & 37 Elevation Relative to 100 and 500 Year Flood Elevations of the Tittabawassee River



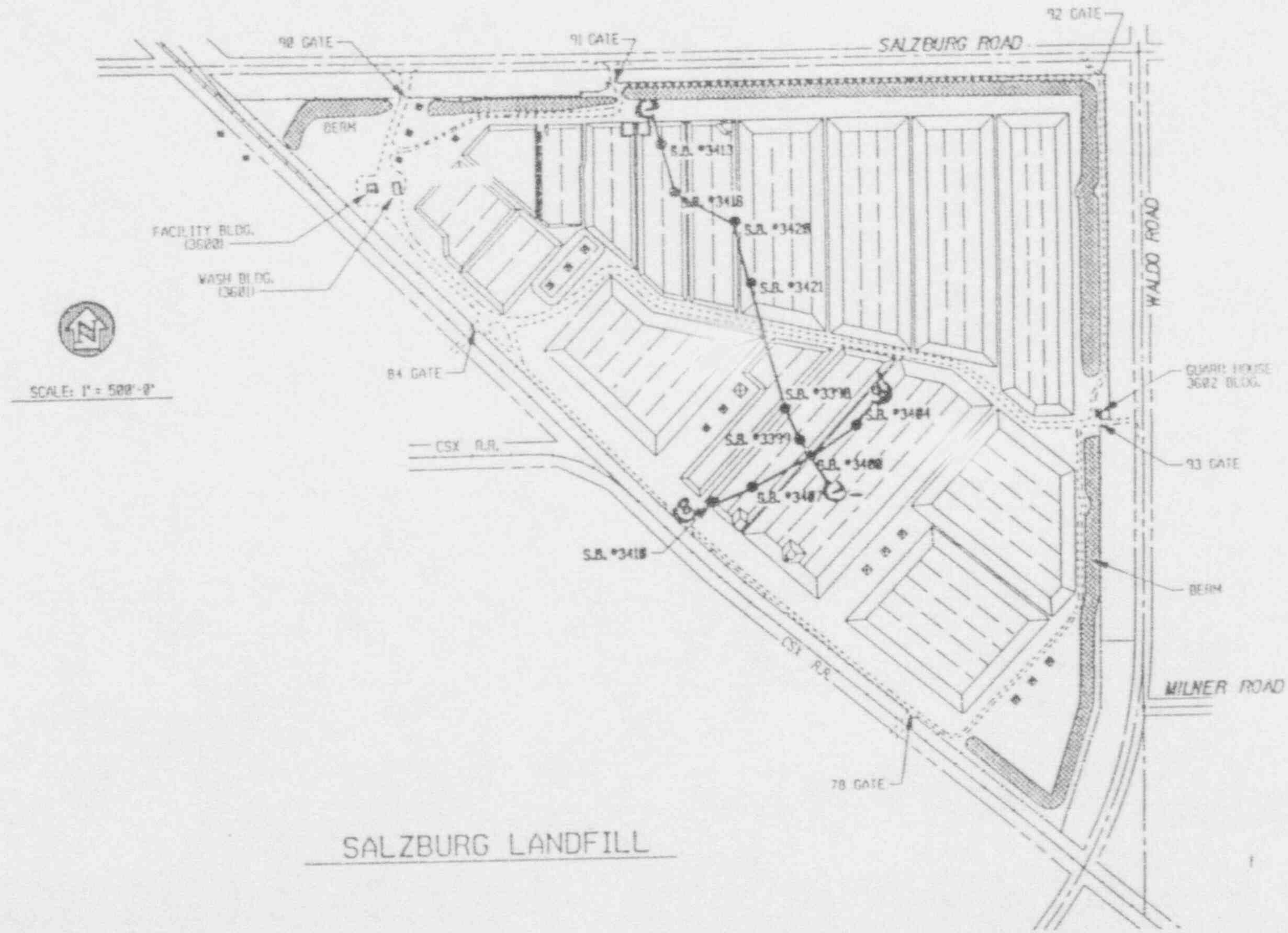
CELLS 36 & 37 DIKE ELEVATION
vs.
TITTABAWASSEE RIVER FLOOD ELEVATIONS

Figure G-1

11/06/91

APPENDIX H

Soil Boring Logs From Borings Near Cells 36 & 37



Michigan Division - Midland Plant
Salzburg Landfill 11/18/91

Map of Cross-Sections of Shallow Borings
Sections 7-7' and 8-8'

Figure H-1

DOW CHEMICAL U.S.A.

Figure H-1a LOG OF SOIL BORING NO. 3398

McDOWELL & ASSOCIATES
Geotechnical Engineers

PROJECT Cells - Salzburg Landfill

JOB NO. 85-52

LOCATION Dow Facilities
Midland, Michigan

SURFACE ELEV. 625.1

DATE 2-27-85

Sample & Type	Depth	Legend	Soil Description	Penetration Blows For 6"	Moisture %	Natural Wt. P.C.F.	Dry Den. Wt. P.C.F.		So %
	1		Moist fine silty brown sand, discoloration						
	2		2'0" Very moist fine silty brown sand						
	3		3'0" Compact wet fine silty brown sand, layers of clay, some slight discoloration						
A	4			4					
UL			4'6"	5					
	5		Compact wet fine clayey gray silt, seams of clay, trace of vegetation	7					
B				5					
UL	6		6'0" Stiff moist silty blue clay	5					
				9					
	7		7'0"						
	8								
	9								
C				7					
UL	10			12					
				13					
	11								
	12								
	13		Very stiff moist silty blue clay, sand and pebbles						
	14								
D				8					
UL	15			9					
				11					
	16								
	17								
	18								
	19								
E				10					
UL	20			10					
				12					
	21								
	22								
	23								
	24		24'0" Extremely stiff moist silty sandy blue clay, pebbles, occasional stones						
F				7	**				
UL	25			10					
				17	(CL)*				

TYPE OF SAMPLE
D. - DISTURBED
U.L. - UNDIST. LINER
S.T. - SHELBY TUBE
S.S. - SPLIT SPOON
R.C. - ROCK CORE
( ) - PENETROMETER

REMARKS: (Cont'd.)

* Unified Soil Classification

Standard Penetration Test - Driving 2" OD Sampler 1' With 140# Hammer Falling 30"; Count Made At 6" Intervals

GROUND WATER OBSERVATIONS

G.W. ENCOUNTERED AT	3 FT	0 INS		
G.W. ENCOUNTERED AT	34 FT	0 INS		
G.W. AFTER COMPLETION	3 FT	0 INS		
G.W. AFTER	HRS.	FT.	INS.	
G.W. VOLUMES	Medium			

Figure H-1b LOG OF SOIL BORING NO. 3398 (Cont'd.)

McDOWELL & ASSOCIATES
Geotechnical Engineers

PROJECT Cells - Salzburg Landfil

JOB NO. 85-52

LOCATION Dow Facilities
Midland, Michigan

SURFACE ELEV. 625.1 DATE 2-27-85

Sample & Type	Depth	Legend	Soil Description	Penetration Blows Per 6"	Moisture %	Natural Wt. P.C.F.	Dry Den Wt. P.C.F.		Sc %
	26		Extremely stiff moist silty sandy blue clay, pebbles, occasional stones						
	28		27'6"						
G	30			43					
UL				46					
	32			--	(SM-SC) *				
	34								
H				17	**				
UL	36			39					
				--	(CL) *				
	38		Extremely stiff moist silty very sandy blue clay, hardpan, pebbles, occasional stones, occasional seams or layers of wet sand						
I	40			35					
UL				49					
	42			--	(SC) *				
	44								
J				26	**				
UL	46			50					
				--	(CL) *				
	48								
K	50			22					
UL				31					
	52			44	(CL) *				
	54								
L				19	**				
UL	56			37					
				--	(CL) *				
	58								
M	60		60'0"	23					
UL				31					
	62			49					
	64		** Big Spoon - Indicates a 3" split-spoon sampler.						
	66								
	68		Coordinates: South - 7591.85 East - 8010.82						
	70								
	72								
	74								
	76								

TYPE OF SAMPLE
- D. - DISTURBED
- U.L. - UNDIST. LINER
- S.T. - SHELBY TUBE
- S.S. - SPLIT SPOON
- R.C. - ROCK CORE
- [ ] - PENETROMETER

REMARKS:

* Unified Soil Classification

Standard Penetration Test - Driving 2" OD Sampler 1' With 140 # Hammer Falling 30"; Count Made At 6" Intervals

GROUND WATER OBSERVATIONS

G.W. ENCOUNTERED AT	3	FT.	0	INS.
G.W. ENCOUNTERED AT	34	FT.	0	INS.
G.W. AFTER COMPLETION	3	FT.	0	INS.
G.W. AFTER	HRS.	FT.		INS.
G.W. VOLUMES	Medium			

Figure H-1c LOG OF SOIL BORING NO. 3399

McDOWELL & ASSOCIATES
Geotechnical Engineers

PROJECT Cells - Salzburg Landfill

JOB NO. 85-52

LOCATION Dow Facilities
Midland, Michigan

SURFACE ELEV. 628.8 DATE 2-28-85

Sample & Type	Depth	Legend	Soil Description	Penetration Blows For 6"	Moisture %	Natural Wt. P.C.F.	Dry Den Wt. P.C.F.	Unc. Comp. Strength PSF	Sr %
	0'0" – 2'0"		Moist fine silty brown sand, vegetation, possible topsoil						
	2'0" – 4'3"		Compact moist fine silty brown sand, some oxidation						
A UL	4'3" – 7'9"		Compact wet fine silty brown sand, trace of vegetation, oxidation	5, 6, 6					
B UL				6, 6, 6					
C UL	7'9" – 13'0"		Stiff moist silty blue clay, layers of wet silt	6, 7, 8					
D UL	13'0" – 17'6"		Very stiff moist silty blue clay, sand and pebbles, occasional stones	7, 10, 12					
E UL	17'6" – 25'0"		Stiff moist silty blue clay, sand and pebbles	4, 5, 6					
F UL	25'0"		Very stiff (Cont'd.)	7, 7, 13					

TYPE OF SAMPLE
D. - DISTURBED
U.L. - UNDIST. LINER
S.T. - SHELBY TUBE
S.S. - SPLIT SPOON
R.C. - ROCK CORE
( ) - PENETROMETER

REMARKS:

Standard Penetration Test - Driving 2" OD Sampler 1' With 140# Hammer Falling 30"; Count Made At 6" Intervals

GROUND WATER OBSERVATIONS

G.W. ENCOUNTERED AT	4 / 8	FT.	3 / 3	INS
G.W. ENCOUNTERED AT	25	FT.	0	INS
G.W. AFTER COMPLETION	4	FT.	3	INS
G.W. AFTER HRS.		FT.		INS
G.W. VOLUMES	Medium			

Figure H-1d LOG OF SOIL BORING NO. 3399 (Cont'

McDOWELL & ASSOCIATES
Geotechnical Engineers

JOB NO. 85-52

PROJECT Cells - Salzburg L

LOCATION Dow Facilities

Midland, Michigan

SURFACE ELEV. 628.8 DATE 2-28-85

Sample & Type	Depth	Legend	Soil Description	Penetration Blows For 6"	Moisture %	Natural Wt. P.C.F.	Dry Den Wt. P.C.F.	Unc. Comp Strength P
	26		moist silty sandy blue clay, pebbles, occasional seams of wet sand, occasional seams or layers of silt					
	28							
G	30			8				
UL				9				
	32			10				
			32'6"					
	34		Extremely stiff moist silty blue clay, seams and lenses of silt					
H				16				
UL	36			31				
				45				
	38							
I	40			10				
UL				15				
			41'0"					
	42		Extremely stiff moist silty sandy blue clay, hardpan, pebbles, occasional stones	19				
	44							
J				16				
UL	46			22				
				35				
	48							
K	50			17				
UL				25				
	52			38				
	54							
L				20				
UL	56			35				
				44				
	58							
M	60		60'0"	25				
UL				37				
	62			48				
	64							
	66		Coordinates: South - 7717.26 East - 8067.44					
	68							
	70							
	72							
	74							
	76							

TYPE OF SAMPLE
- D. - DISTURBED
- U.L. - UNDIST. LINER
- S.T. - SHELBY TUBE
- S.S. - SPLIT SPOON
- R.C. - ROCK CORE
- ( ) - PENETROMETER

REMARKS:

Standard Penetration Test - Driving 2" OD Sampler 1' With 140 # Hammer Falling 30", Count Made At 6" Intervals

GROUND WATER OBSERVATIO

- G.W. ENCOUNTERED AT 4 8 FT
- G.W. ENCOUNTERED AT 25 FT
- G.W. AFTER COMPLETION 4 FT
- G.W. AFTER HRS. FT
- G.W. VOLUMES Medium

Figure H-1e LOG OF SOIL BORING NO. 3421

McDOWELL & ASSOCIATES
Geotechnical Engineers

PROJECT Cells - Salzburg Landfil

JOB NO. 85-52 LOCATION Dow Facilities

SURFACE ELEV. 617.9 DATE 4-22-85 Midland, Michigan

Sample & Type	Depth	Soil Description	Penetration Blows Per 6"	Moisture %	Natural Wt. P.C.F.	Dry Den Wt. P.C.F.	Unc. Comp. Strength PSF	St %
	1							
	2	Stiff moist silty blue clay						
	3							
	4							
A		4'6"	7					
UL	5	Very stiff moist silty blue clay, slight sand and pebble content	9					
			11					
	6							
	7							
	8	S.T. 1 - Pushed 3" Shelby Tube from 8'-10'6"						
ST	9	Recovery - Full						
	10							
	11							
	12							
	13							
	14							
B		14'0"	7					
UL	15	Very stiff moist silty blue clay, sand and pebbles, occasional seams or layers of organic content	9					
			10	(CL-ML) *				
	16							
	17							
	18							
	19							
C			18	**				
UL	20	20'0"	22					
		Extremely stiff moist very sandy blue clay, occasional stones, occasional seams of wet sand, pebbles, layers of silty clayey sand	30	(SM-SC) *				
	21							
	22							
	23							
	24							
D			27					
UL	25		38					
		(Cont'd)	—	(CL-ML) *				

TYPE OF SAMPLE
D. - DISTURBED
U.L. - UNDIST. LINER
S.T. - SHELBY TUBE
S.S. - SPLIT SPOON

REMARKS:
* Unified Soil Classification

GROUND WATER OBSERVATIONS
G.W. ENCOUNTERED AT 20 FT. 0 INS.
G.W. ENCOUNTERED AT FT. INS.
G.W. AFTER COMPLETION Grouted FT. INS.

Figure H-1f LOG OF SOIL BORING NO. B-21 (Cont'd)

McDOWELL & ASSOCIATES
Geotechnical Engineers

PROJECT: Calls - Salzburg Landfill
JOB NO.: 85-52
LOCATION: Dow Facilities, Midland, Michigan
SURFACE ELEV.: 617.9
DATE: 4-22-85

Sample / Type	Depth	Legend	SOIL DESCRIPTION	Penetration Blows For 6"	Moisture %	Natural Wt. P.C.F.	Dry Den Wt. P.C.F.	Unc. Comp. Strength PSF	So. %
	26								
	28								
E UL	30			37 / 54 / —	** (SM-SC) *				
	32								
	34								
F UL	36			27 / 39 / —	(SM-SC) *				
	38								
G UL	40		Extremely stiff moist very sandy blue clay, occasional stones, occasional seams of wet sand, pebbles, layers of silty clayey sand	85 / 40/3" / —	** (SM) *				
	42								
	44								
H UL	46			44 / 53 / —	(SM-SC) *				
	48								
I UL	50			37 / 41	** (SM) *				
	52								
	54								
J UL	56		55'0"						
	58								
	60		** Big Spoon - Indicates a 3" split-spoon sampler.						
	62								
	64								
	66								
	68								
	70								
	72								
	74								
	76								

TYPE OF SAMPLE
D. - DISTURBED
U.L. - UNDIST. LINER
S.T. - SHELBY TUBE
S.S. - SPLIT SPOON
R.C. - ROCK CORE

REMARKS:
* Unified Soil Classification

Standard Penetration Test - Driving 2" OD Sampler 1' With 140 lb Hammer Falling 30"

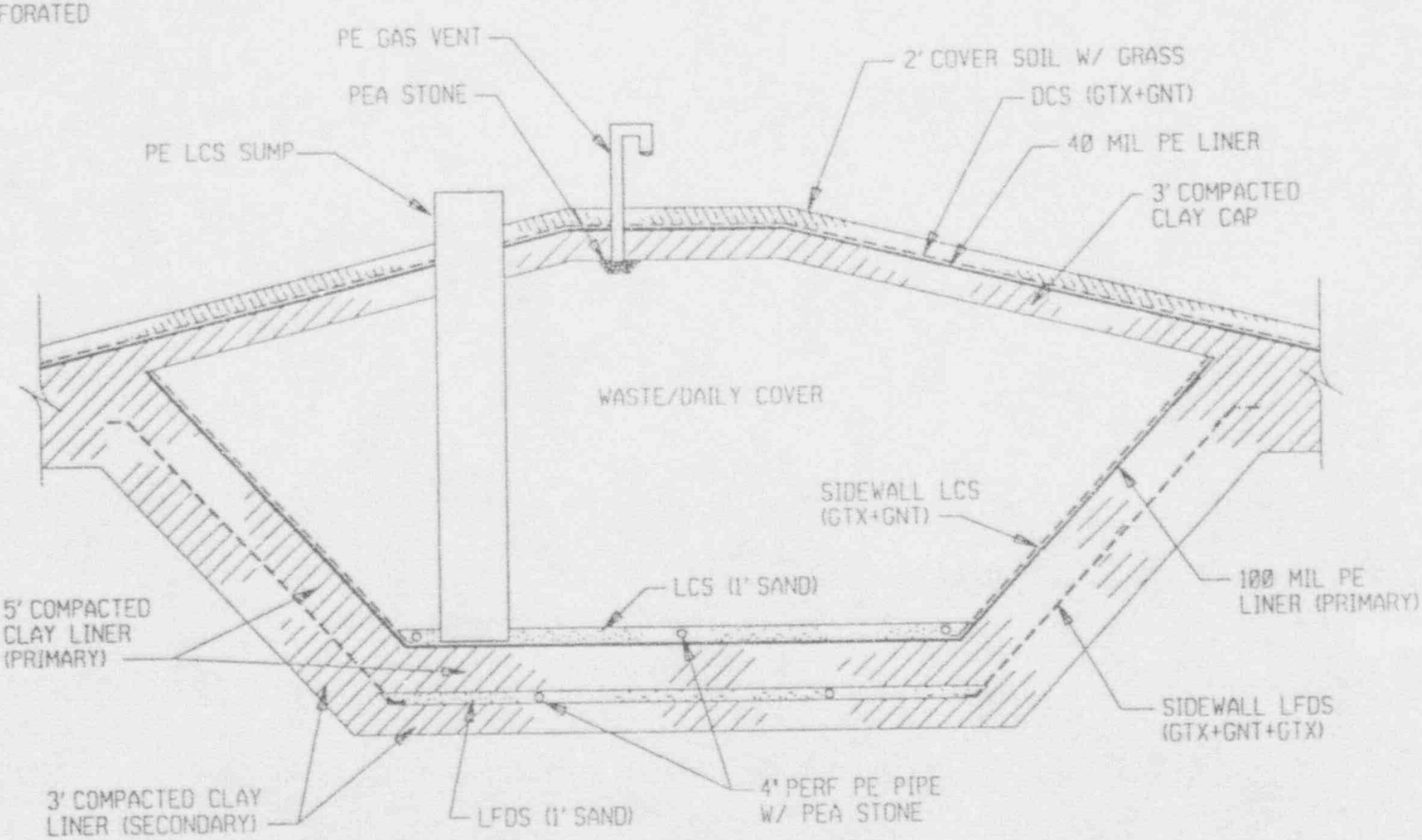
GROUND WATER OBSERVATIONS
G.W. ENCOUNTERED AT 20 FT. 0 INS.
G.W. ENCOUNTERED AT FT. INS.
G.W. AFTER COMPLETION Grouted FT. INS.
G.W. AFTER HRS. FT. INS.

APPENDIX I

Cells 36 & 37 Leachate Collection System
and Analysis of Radiological Concentrations
Permitting Unrestricted Release of Leachate

LEGEND:

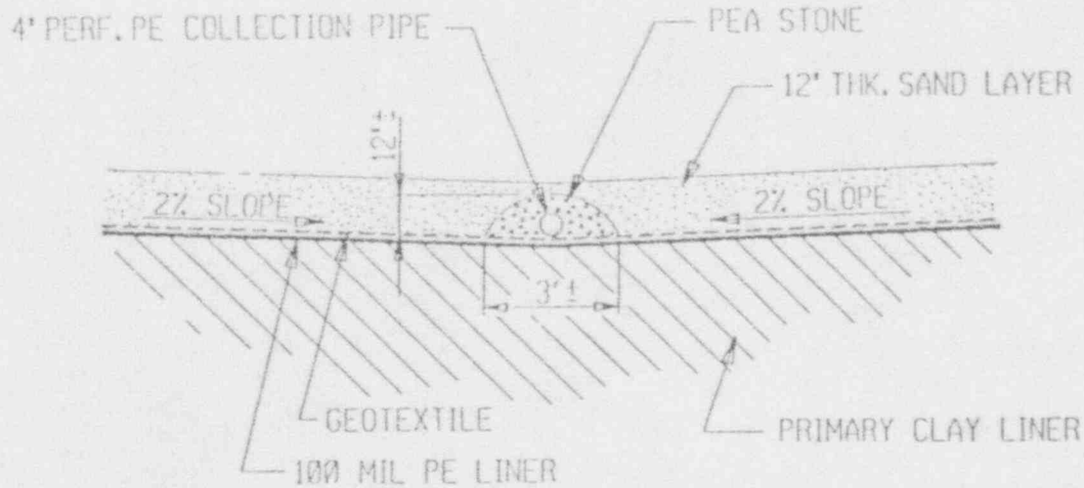
DCS = DRAINAGE COLLECTION SYSTEM
LFDS = LINER FAILURE DETECTION SYSTEM
LCS = LEACHATE COLLECTION SYSTEM
PE = POLYETHYLENE
GTX = GEOTEXTILE
GNT = GEONET
PERF = PERFORATED



SALZBURG LANDFILL
TYPICAL CAP/CELL CROSS SECTION

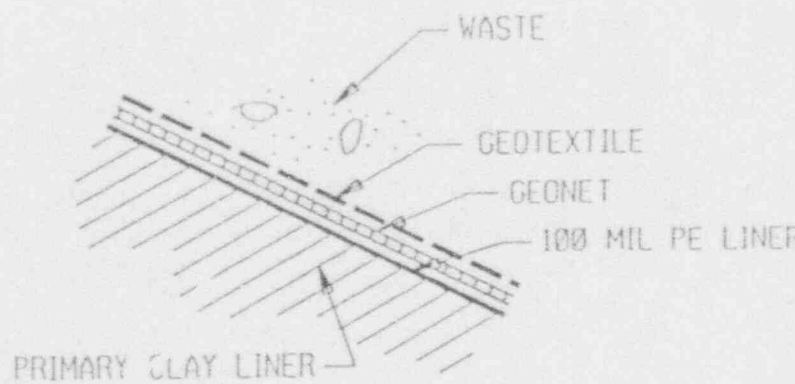
Figure 1-1

REV. 1
2/27/92



LEACHATE COLLECTION PIPE

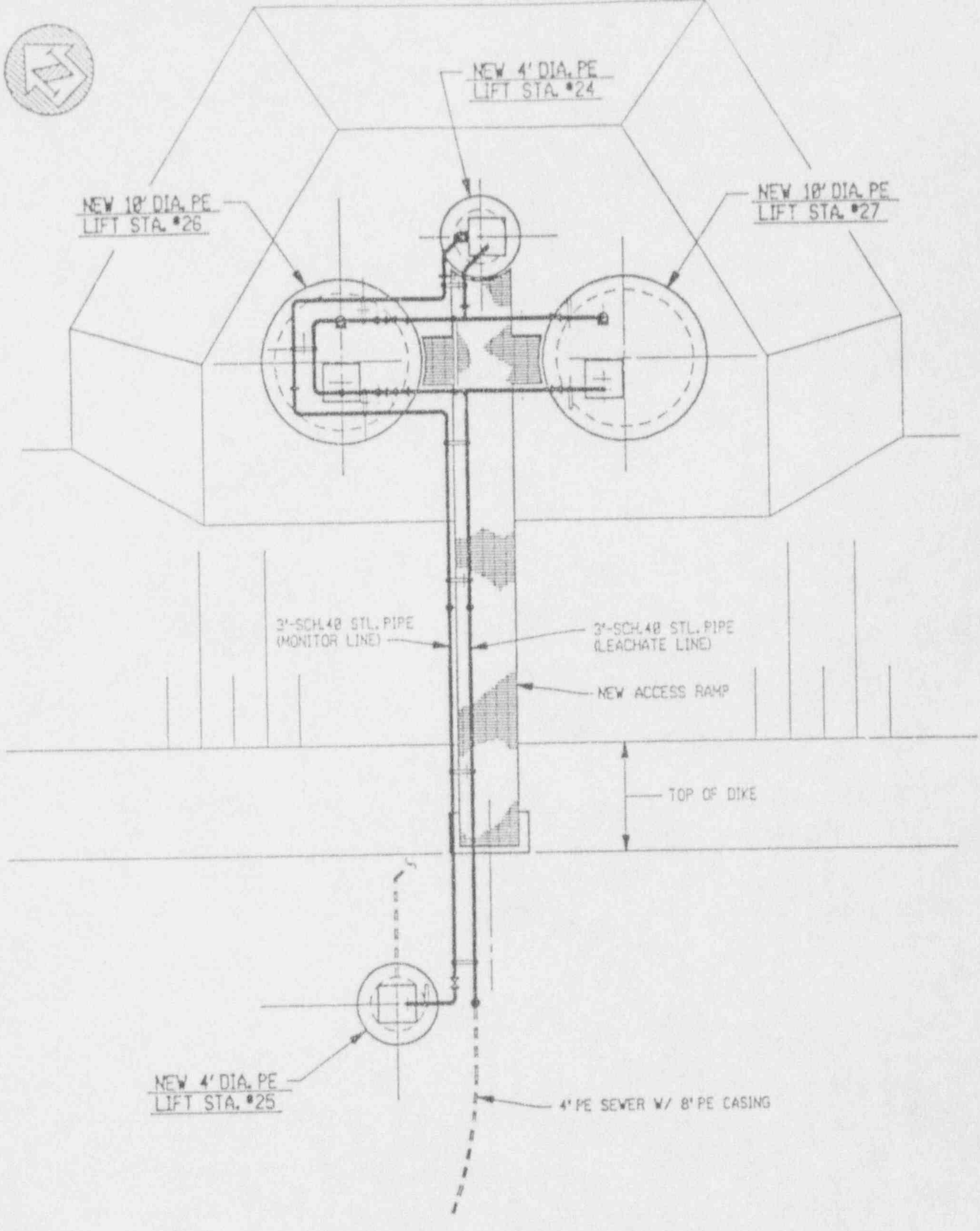
Figure I-2



SIDEWALL LEACHATE
COLLECTION SYSTEM DETAIL

SCALE: NONE

Figure I-3



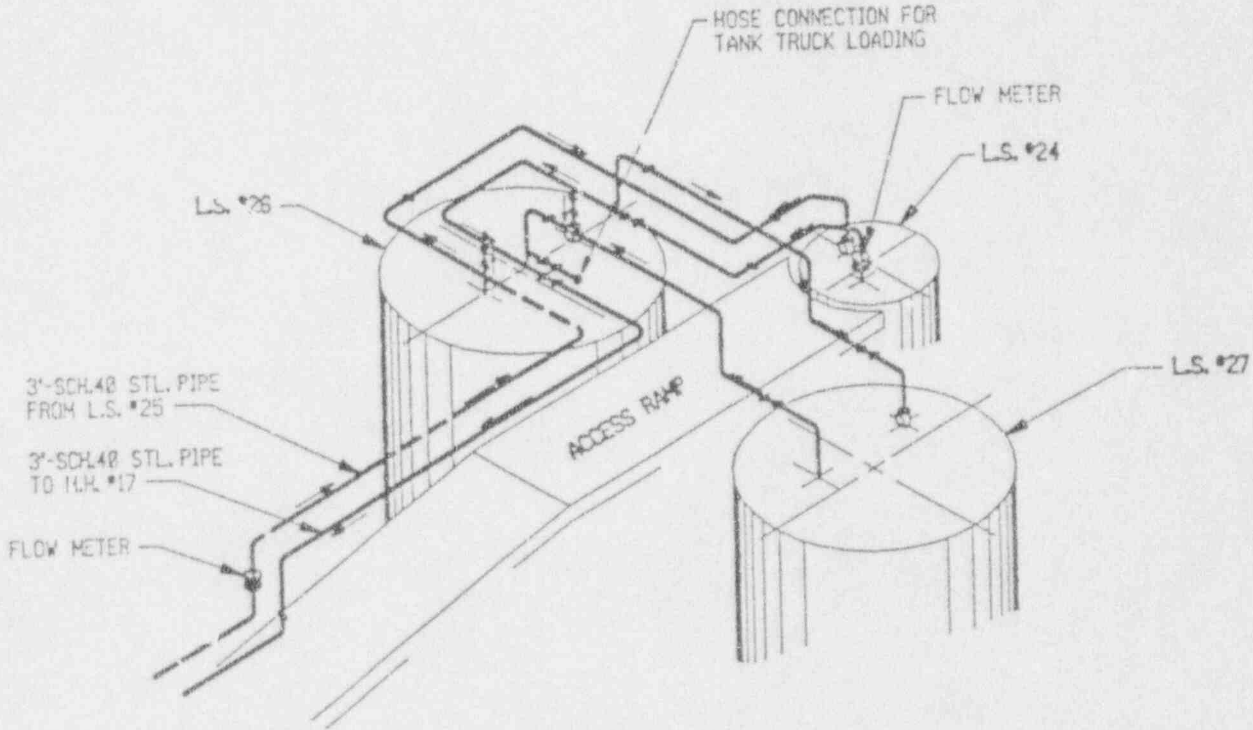
CELLS 36 & 37

PLAN OF LIFT STATION AREA & ABOVE GROUND PIPING

SCALE: 1" = 10'-0"

Figure I-4

11/14/91



ABOVE GROUND PIPING ISOMETRIC

SCALE: NONE

Figure I-5

11/14/91

APPENDIX J

Sample Analysis and Stiff Diagrams
From Salzburg Monitoring Wells

Table J-1

Dow Chemical U.S.A. Michigan Division
Salzburg Landfill Monitoring Results---Second Quarter 1990

Section 3

Table 3, Part 1---Groundwater Wells

All results are in mg/L, except that pH is unitless, conductivity is in micromhos/cm, and U.S.G.S. elevation is in feet.

Sample Date	5/11/90	5/11/90	5/11/90	5/11/90	5/11/90	5/11/90	5/11/90	5/11/90	5/11/90	5/11/90	5/11/90
Parameter	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 8	Well 9	Well 10	Well 11	Well 12
U.S.G.S. Elevation	617.07	620.02	609.21	620.33	620.54	617.62	608.72	609.38	623.99	622.96	621.22

Sample Date	5/14/90	5/14/90	5/14/90	5/14/90	5/14/90	5/14/90	5/14/90	5/14/90	5/14/90	5/14/90	5/14/90
Analyte/Parameter	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 8	Well 9	Well 10	Well 11	Well 12
Conductivity	1279	1086	NS	1407	1491	1855	2350	2160	614	443	478
pH	7.4	7.5	NS	7.8	7.4	7.6	8.2	8.2	8.7	8.3	8.5
Total Org. Carbon	ND	ND	NS	ND	1	ND	ND	2	ND	ND	ND
Calcium	93	120	NS	97	170	80	72	73	19	23	22
Carbonate/Bicarb.	440	360	NS	200	470	800	140	200	140	230	100
Chloride	190	100	NS	190	110	130	480	510	63	17	37
Magnesium	65	60	NS	42	70	140	29	34	12	11	9.5
Sodium	49	34	NS	110	54	150	300	320	67	61	49
Sulfate	30	130	NS	9	300	320	93	58	4	ND	38
Cadmium	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND
Chromium	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND
Copper	0.0062	0.0068	NS	0.0055	0.010	0.0056	0.0053	0.0058	ND	ND	ND
Iron	1.1	0.46	NS	0.43	0.53	0.012	0.39	0.43	0.089	0.038	0.0079
Lead	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND
Manganese	0.079	0.20	NS	0.48	0.32	0.085	0.0081	0.010	0.019	0.083	0.021
Silver	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND
Benzene	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND
Chlorobenzene	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND
Dichloromethane	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND
Styrene	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND

Abbreviations: MDL = Method Detection Limit
ND = Not Detected at the method detection limit
NS = Not Sampled due to insufficient liquid
NA = Not Applicable
NRQ = Not ReQuired in this sampling period

Table J-2

Dow Chemical U.S.A. Michigan Division
Salzburg Landfill Monitoring Results---Second Quarter 1990

Section 3 (cont.)

Table 3, Part 2---Groundwater Wells (cont.)

All results are in mg/L, except that pH is unitless, conductivity is in micromhos/cm, and U.S.G.S. elevation is in feet.

Sample Date	5/11/90	5/10/90	5/10/90	5/10/90	5/10/90	5/10/90	5/10/90	5/11/90	5/11/90	5/11/90	
Parameter	Well 14	Well 15	Well 16	Well 17	Well 18	Well 19	Well 20	Well 3168	Well 2708	Well 3011	MDL
U.S.G.S. Elevation	620.59	618.61	618.93	620.28	612.10	619.60	567.48	623.13	625.00	624.43	NA

Sample Date	5/14/90	5/14/90	5/14/90	5/14/90	5/14/90	5/14/90	5/14/90	5/14/90	5/14/90	5/14/90	
Analyte/Parameter	Well 14	Well 15	Well 16	Well 17	Well 18	Well 19	Well 20	Well 3168	Well 2708	Well 3011	MDL
Conductivity	1652	291	462	431	833	555	7710	1716	1849	1332	NA
pH	7.6	10.0	10.3	9.6	8.2	7.9	9.2	7.7	7.8	7.9	NA
Total Org. Carbon	ND	3	ND	ND	2	ND	ND	ND	ND	ND	1
Calcium	81	5.2	11	8.1	35	25	260	70	58	45	0.03
Carbonate/Bicarb.	180	60	5	50	370	330	ND	140	220	220	5
Chloride	420	20	79	78	63	19	1200	420	410	290	1
Magnesium	40	1.8	0.60	4.9	19	14	49	30	24	18	0.006
Sodium	190	50	73	70	110	73	1500	220	300	210	0.02
Sulfate	36	2	ND	1	1	1	2300	42	65	35	1
Cadmium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.003
Chromium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.005
Copper	0.0046	0.082	ND	ND	0.015	0.0053	0.016	0.0058	0.0044	0.0032	0.003
Iron	0.049	0.093	0.014	0.014	0.0055	0.013	0.029	1.4	1.0	0.65	0.006
Lead	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.02
Manganese	0.11	0.0050	ND	ND	0.12	0.017	ND	0.065	0.066	0.019	0.004
Silver	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.01
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.001
Chlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.001
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0009
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.002
Dichloromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.002
Styrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010

Abbreviations: MDL = Method Detection Limit; ND = Not Detected at the method detection limit; NA = Not Applicable; NRQ = Not ReQuired in this sampling period; NS = Not Sampled due to insufficient liquid

Note 1: Well 2708 results are an average from quadruplicate samples.

Table J-3

Dow Chemical U.S.A. Michigan Division
Salzburg Landfill Monitoring Results---Fourth Quarter 1990

Section 3

Table 3, Part 1---Groundwater Wells

All results are in mg/L, except that pH is unitless, conductivity is in micromhos/cm, and U.S.G.S. elevation is in feet.

Sample Date	10/15/90	10/15/90	10/15/90	10/15/90	10/15/90	10/15/90	10/15/90	10/15/90	10/15/90	10/15/90	10/15/90
Parameter	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 8	Well 9	Well 10	Well 11	Well 12
U.S.G.S. Elevation	615.68	619.96	610.28	620.16	620.72	618.14	608.69	608.64	624.00	623.30	621.37

Sample Date	10/16/90	10/16/90	NS	10/16/90	10/16/90	10/16/90	10/16/90	10/16/90	10/16/90	10/16/90	10/16/90
Analyte/Parameter	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 8	Well 9	Well 10	Well 11	Well 12
Conductivity	1155	1000	NS	1373	1414	1864	2060	2050	542	413	388
pH	6.8	7.2	NS	7.4	7.0	7.0	7.4	7.8	8.1	7.6	8.0
Total Org. Carbon	22	10	NS	3	16	16	8	26	ND	12	6
Calcium	93	93	NS	93	160	92	74	56	22	26	21
Carbonate/Bicarb.	320	360	NS	180	460	800	60	220	120	70	35
Chloride	180	93	NS	200	110	130	380	420	47	15	35
Magnesium	60	57	NS	53	72	150	29	36	11	12	8.7
Sodium	51	37	NS	130	67	150	290	300	60	48	45
Sulfate	28	120	NS	8.6	290	330	85	53	3.9	NQ	36
Cadmium	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND
Chromium	ND	ND	NS	ND	ND	0.0060	ND	ND	ND	ND	ND
Copper	ND	ND	NS	ND	0.0057	ND	ND	ND	ND	ND	ND
Iron	0.95	0.016	NS	0.22	0.53	8.5	0.60	0.041	0.013	0.017	0.0076
Lead	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND
Manganese	0.066	0.090	NS	0.50	0.28	0.086	0.010	0.042	0.025	0.095	0.046
Silver	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND
Benzene	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND
Chlorobenzene	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND
Dichloromethane	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND
Styrene	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND

Abbreviations: NS = Not Sampled due to insufficient liquid
ND = Not Detected at the Method Detection Limit
NQ = Not Quantifiable at the Practical Quantification Limit

Table J-4

Dow Chemical U.S.A. Michigan Division
Salzburg Landfill Monitoring Results---Fourth Quarter 1990

Section 3 (cont.)

Table 3, Part 2---Groundwater Wells (cont.)

All results are in mg/L, except that pH is unitless, conductivity is in micromhos/cm, and U.S.G.S. elevation is in feet.

Sample Date	10/15/90	10/16/90	10/15/90	10/15/90	10/15/90	10/16/90	10/15/90	10/15/90	10/15/90	10/15/90
Parameter	Well 14	Well 15	Well 16	Well 17	Well 18	Well 19	Well 20	Well 3168	Well 2708	Well 3011
U.S.G.S. Elevation	619.85	619.96	621.23	605.91	615.11	618.92	591.62	621.83	623.0 *	622.96

Sample Date	10/16/90	10/16/90	10/16/90	10/16/90	10/16/90	10/16/90	10/16/90	10/16/90	10/16/90	10/16/90		
Analyte/Parameter	Well 14	Well 15	Well 16	Well 17	Well 18	Well 19	Well 20	Well 3168	Well 2708	Well 3011	MDL	PQL
Conductivity	1578	265	430	549	720	540	7300	1694	1792	1261	NA	--
pH	7.5	9.9	9.8	8.6	7.8	7.4	9.6	7.5	7.4	7.4	NA	--
Total Org. Carbon	11	5	3	2	27	11	2	3	4	10	1	--
Calcium	78	2.2	9.3	18	24	24	24	70	60	41	0.03	--
Carbonate/Bicarb.	80	35	20	80	240	240	ND	95	170	120	5	--
Chloride	390	19	75	89	51	21	1100	400	390	290	----	1
Magnesium	47	0.56	0.92	12	16	14	42	38	23	17	0.006	--
Sodium	180	47	75	79	120	69	1500	230	280	200	0.02	--
Sulfate	31	1.1	1.1	NQ	20	1.1	2400	44	64	27	----	1
Cadmium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.003	--
Chromium	ND	ND	ND	0.0058	ND	ND	ND	ND	ND	ND	0.005	--
Copper	ND	ND	ND	ND	0.011	ND	0.0073	ND	ND	ND	0.003	--
Iron	0.21	0.0086	0.0092	0.015	0.017	0.097	0.016	0.68	0.58	1.3	0.006	--
Lead	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.02	--
Manganese	0.063	ND	ND	0.014	0.099	0.050	0.012	0.038	0.064	0.038	0.004	--
Silver	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.01	--
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.001	--
Chlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.001	--
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0009	--
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.002	--
Dichloromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.002	--
Styrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010	--

Abbreviations: MDL - Method Detection Limit PQL - Practical Quantification Limit NA - Not Applicable
ND - Not Detected at the Method Detection Limit NQ - Not Quantifiable at the Practical Quantification Limit

Note 1: Well 2708 results are an average from quadruplicate samples.

* - Computer reading

Table J-5

Dow Chemical U.S.A. Michigan Division
Salzburg Landfill Monitoring Results---Second Quarter 1991

Section 3

Table 3, Part 1---Groundwater Wells

All results are in mg/L, except that pH is unitless, conductivity is in micromhos/cm, and U.S.G.S. elevation is in feet.

Sample Date	4/16/91	4/16/91	NS	4/16/91	4/16/91	4/16/91	4/16/91	4/16/91	4/16/91	4/16/91	4/16/91
Parameter	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 8	Well 9	Well 10	Well 11	Well 12
U.S.G.S. Elevation	616.66	619.61	NS	619.17	620.38	617.60	610.52	610.77	624.88	623.53	622.19

Sample Date	4/18/91	4/18/91	NS	4/18/91	4/18/91	4/18/91	4/18/91	4/18/91	4/18/91	4/18/91	4/18/91
Analyte/Parameter	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 8	Well 9	Well 10	Well 11	Well 12
Conductivity	1160	1050	NS	1300	1100	1545	1960	1680	350	360	360
pH	6.7	7.0	NS	7.5	7.1	7.4	7.1	7.6	8.4	8.0	7.9
Total Org. Carbon	40	22	NS	19	43	69	9	13	12	9	6
Calcium	110	120	NS	110	150	86	77	50	18	22	21
Carbonate/Bicarb.	200	150	NS	94	240	530	100	160	100	150	78
Chloride	200	110	NS	200	110	140	430	440	53	16	32
Magnesium	70	66	NS	54	77	140	29	30	10	11	9.3
Sodium	50	33	NS	130	62	160	290	330	62	48	43
Sulfate	30	150	NS	11	290	330	93	55	2.7	NQ	38
Cadmium	ND	ND	NS	ND	ND	ND	ND	0.064	ND	ND	ND
Chromium	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND
Copper	0.0048	0.0043	NS	0.0045	0.0060	0.0038	ND	0.0073	ND	ND	ND
Iron	1.6	0.42	NS	0.17	0.095	6.0	0.34	0.11	ND	0.026	ND
Lead	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND
Manganese	0.083	0.22	NS	0.59	0.28	0.086	0.017	0.043	0.021	0.076	0.044
Silver	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND
Benzene	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND
Chlorobenzene	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND
Dichloromethane	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND
Styrene	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND

Abbreviations: NS = Not Sampled due to insufficient liquid
ND = Not Detected at the Method Detection Limit
NQ = Not Quantifiable at the Practical Quantification Limit

Table J-6

Dow Chemical U.S.A. Michigan Division
Salzburg Landfill Monitoring Results---Second Quarter 1991

Section 3 (cont.)

Table 3, Part 2---Groundwater Wells (cont.)

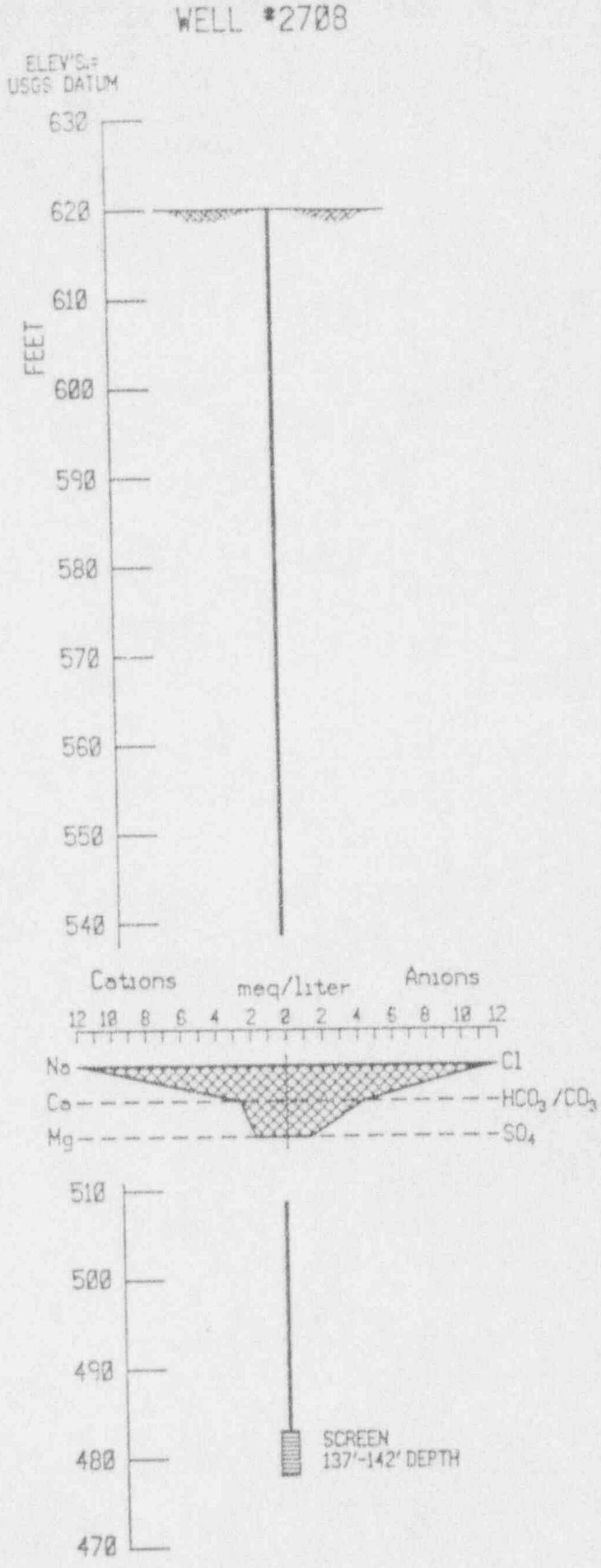
All results are in mg/L, except that pH is unitless, conductivity is in micromhos/cm, and U.S.G.S. elevation is in feet.

Sample Date	4/16/91	4/17/91	4/17/91	4/17/91	4/17/91	4/17/91	4/16/91	4/16/91	4/16/91	4/16/91		
Parameter	Well 14	Well 15	Well 16	Well 17	Well 18	Well 19	Well 20	Well 3168	Well 2708	Well 3011	MDL	PQL
U.S.G.S. Elevation	621.34	620.60	621.49	620.68	619.31	619.37	602.88	623.91	625.72	625.27	NA	NA

Sample Date	4/18/91	4/18/91	4/18/91	4/18/91	4/18/91	4/18/91	4/18/91	4/18/91	4/18/91	4/18/91		
Analyte/Parameter	Well 14	Well 15	Well 16	Well 17	Well 18	Well 19	Well 20	Well 3168	Well 2708	Well 3011	MDL	PQL
Conductivity	1310	320	420	670	620	460	5220	1190	1492	1230	NA	NA
pH	7.4	9.0	10.1	8.4	8.0	7.7	9.7	7.6	7.6	7.2	NA	NA
Total Org. Carbon	9	9	5	4	22	15	2	5	1	10	---	1
Calcium	71	9.0	11	24	24	23	290	72	54	49	0.03	--
Carbonate/Bicarb.	110	25	10	40	220	220	NQ	94	168	140	---	5
Chloride	400	21	79	87	52	24	1200	430	420	290	---	1
Magnesium	35	2.3	1.5	18	15	13	33	30	22	17	0.006	--
Sodium	170	64	69	83	110	72	1300	200	270	190	0.02	--
Sulfate	36	1.4	1.2	2.9	14	1.3	2300	40	62	32	---	1
Cadmium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.003	--
Chromium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.005	--
Copper	ND	ND	ND	ND	ND	ND	0.014	ND	ND	ND	0.003	--
Iron	0.14	0.042	0.0068	0.025	0.030	0.012	0.021	0.70	0.45	1.7	0.006	--
Lead	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.02	--
Manganese	0.087	0.0079	ND	0.069	0.21	0.077	0.0068	0.050	0.056	0.078	0.004	--
Silver	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.01	--
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.001	--
Chlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.001	--
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0009	--
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.002	--
Dichloromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.002	--
Styrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010	--

Abbreviations: MDL = Method Detection Limit; PQL = Practical Quantification Limit; NA = Not Applicable
ND = Not Detected at the Method Detection Limit
NQ = Not Quantifiable at the Practical Quantification Limit

Note 1: Well 2708 results are an average from quadruplicate samples.

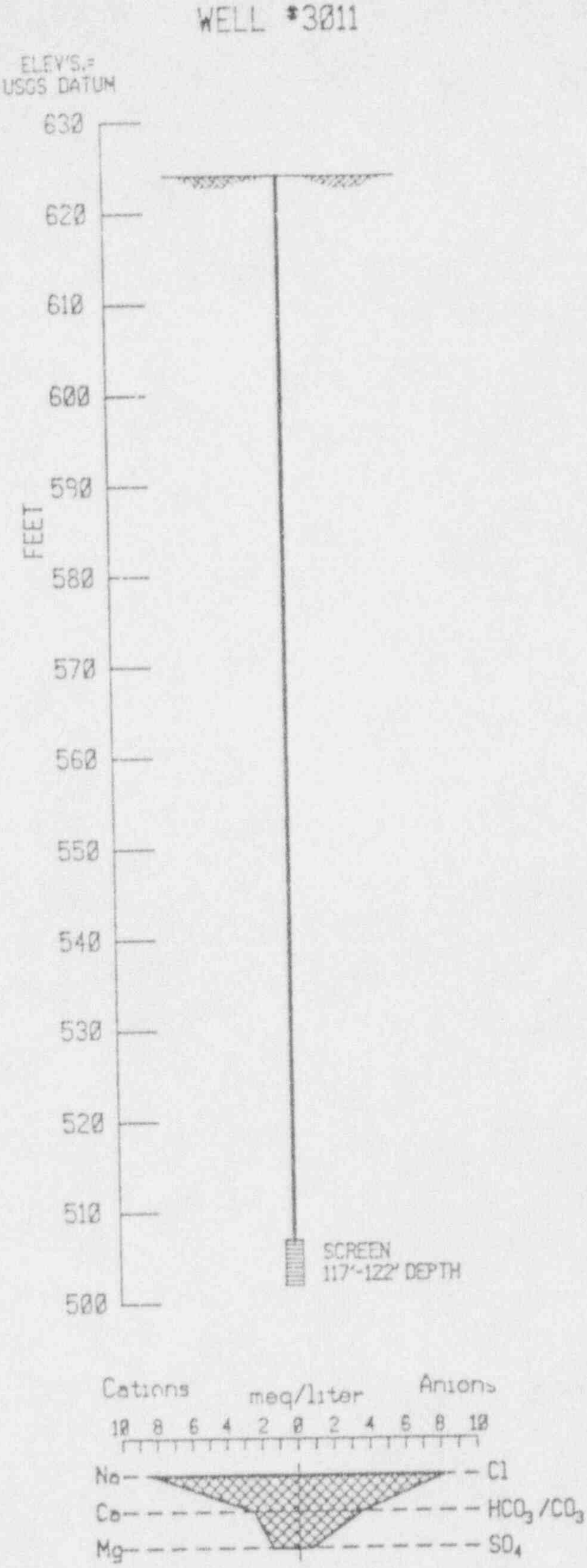


SALZBURG LANDFILL

MONITORING WELL-STIFF DIAGRAM

(BASED ON SAMPLES FROM 4/16/91 & 4/17/91

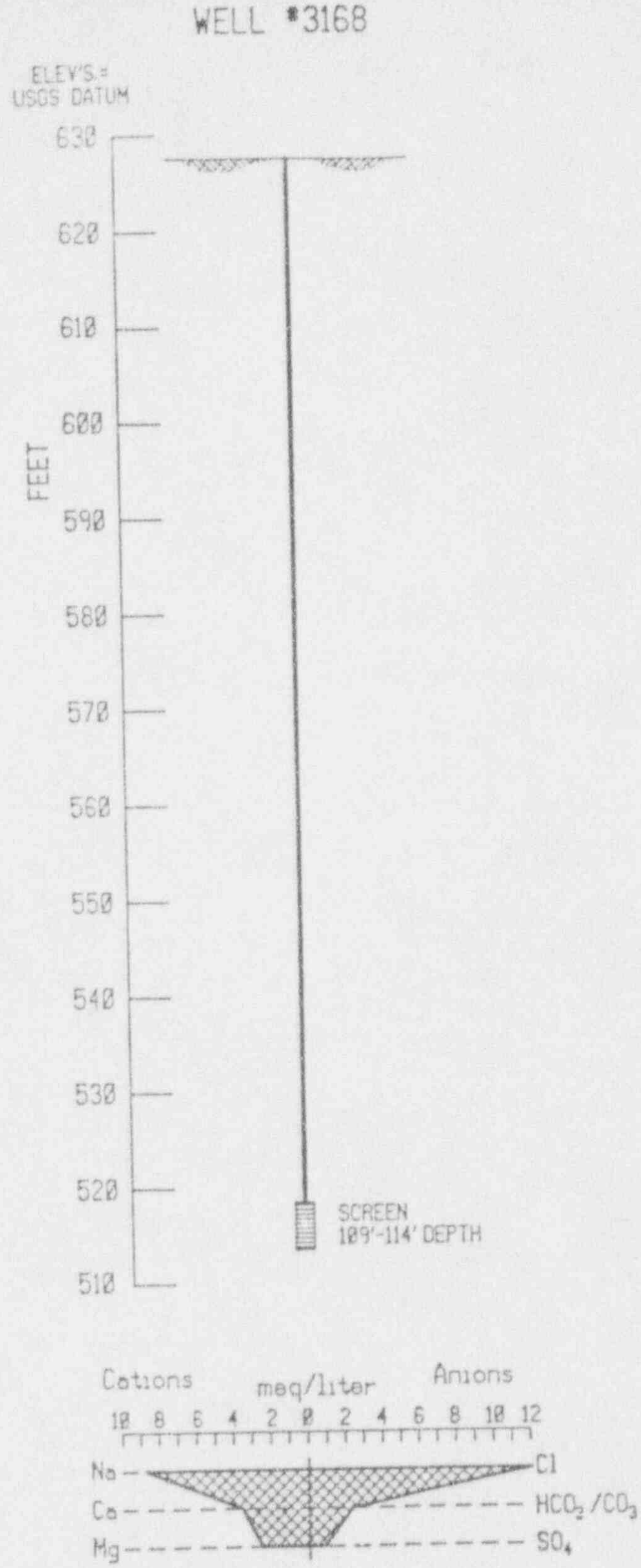
Figure J-1
2/27/92



SALZBURG LANDFILL
MONITORING WELL-STIFF DIAGRAM

(BASED ON SAMPLES FROM 4/16/91 & 4/17/91

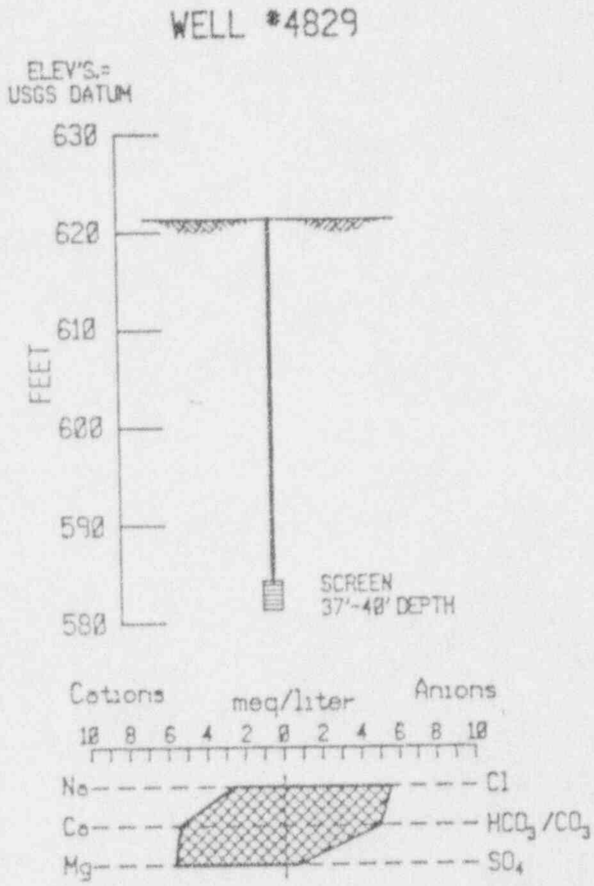
Figure J-2
2/27/92



SALZBURG LANDFILL
MONITORING WELL-STIFF DIAGRAM

(BASED ON SAMPLES FROM 4/16/91 & 4/17/91

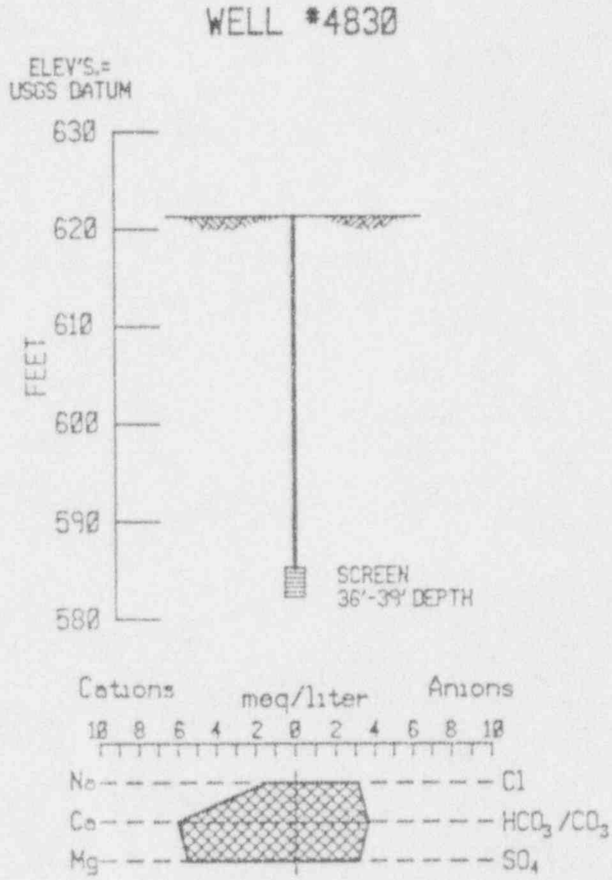
Figure J-3
2/27/92



SALZBURG LANDFILL
MONITORING WELL-STIFF DIAGRAM

(BASED ON SAMPLES FROM 4/16/91 & 4/17/91

Figure J-4
2/27/92

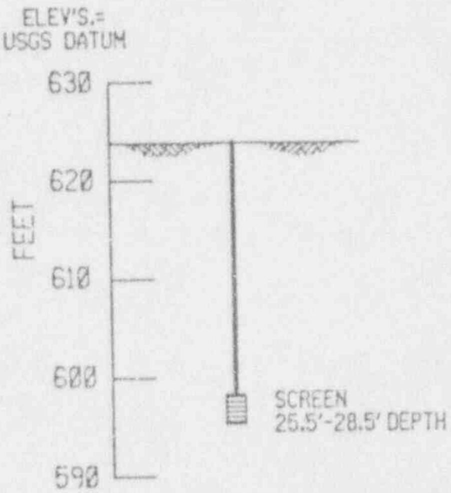


SALZBURG LANDFILL
MONITORING WELL-STIFF DIAGRAM

(BASED ON SAMPLES FROM 4/16/91 & 4/17/91

Figure J-5
2/27/92

WELL #4831



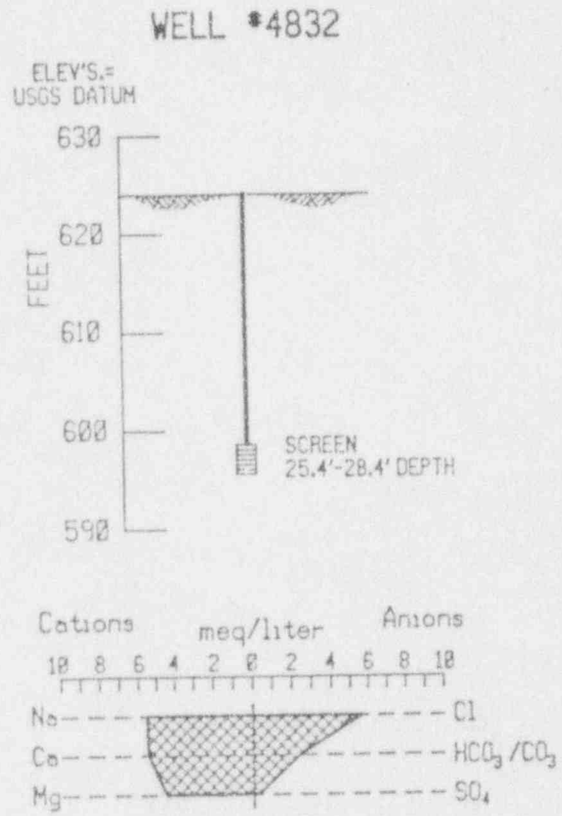
NO SAMPLE
OBTAINED

SALZBURG LANDFILL

MONITORING WELL-STIFF DIAGRAM

(BASED ON SAMPLES FROM 4/16/91 & 4/17/91

Figure J-6
2/27/92



SALZBURG LANDFILL

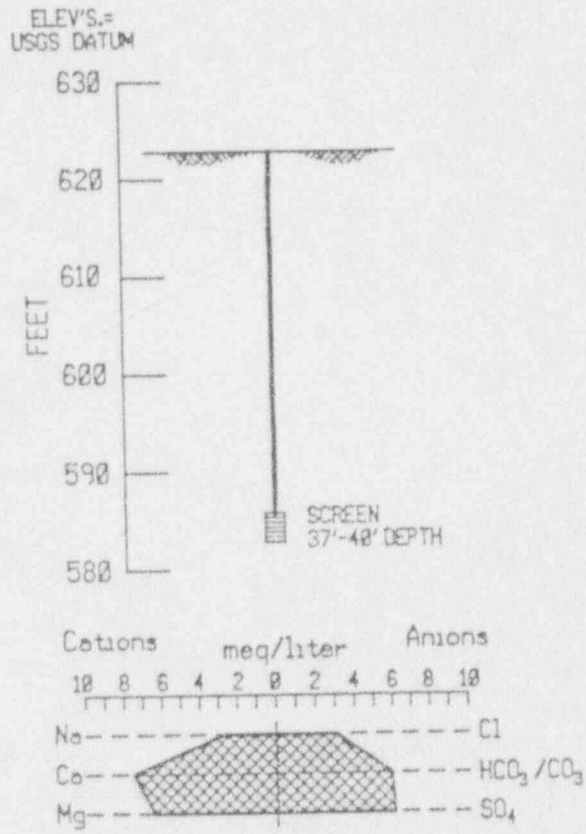
MONITORING WELL-STIFF DIAGRAM

(BASED ON SAMPLES FROM 4/16/91 & 4/17/91

Figure J-7

2/27/92

WELL #4833

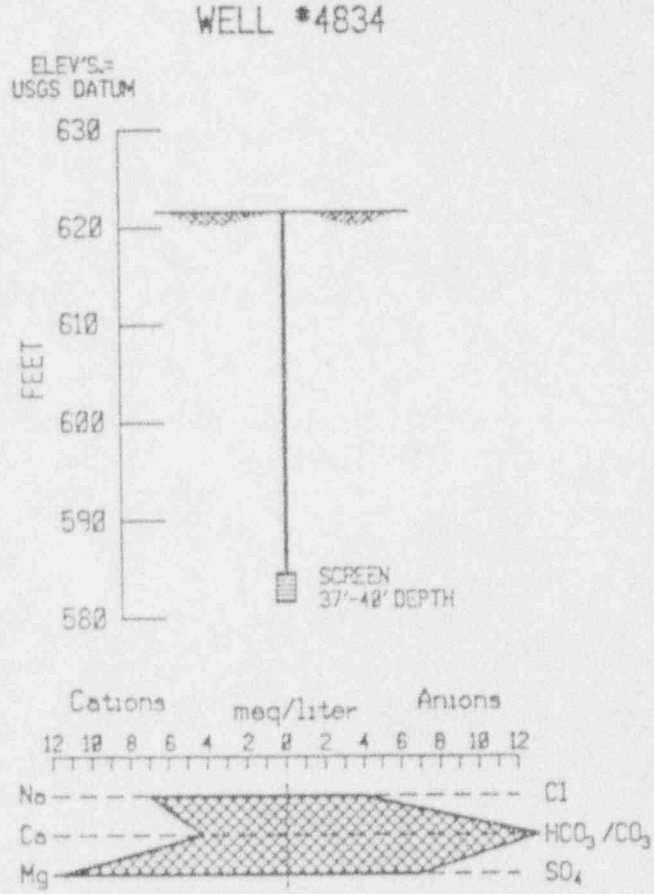


SALZBURG LANDFILL
MONITORING WELL-STIFF DIAGRAM

(BASED ON SAMPLES FROM 4/16/91 & 4/17/91

Figure J-8

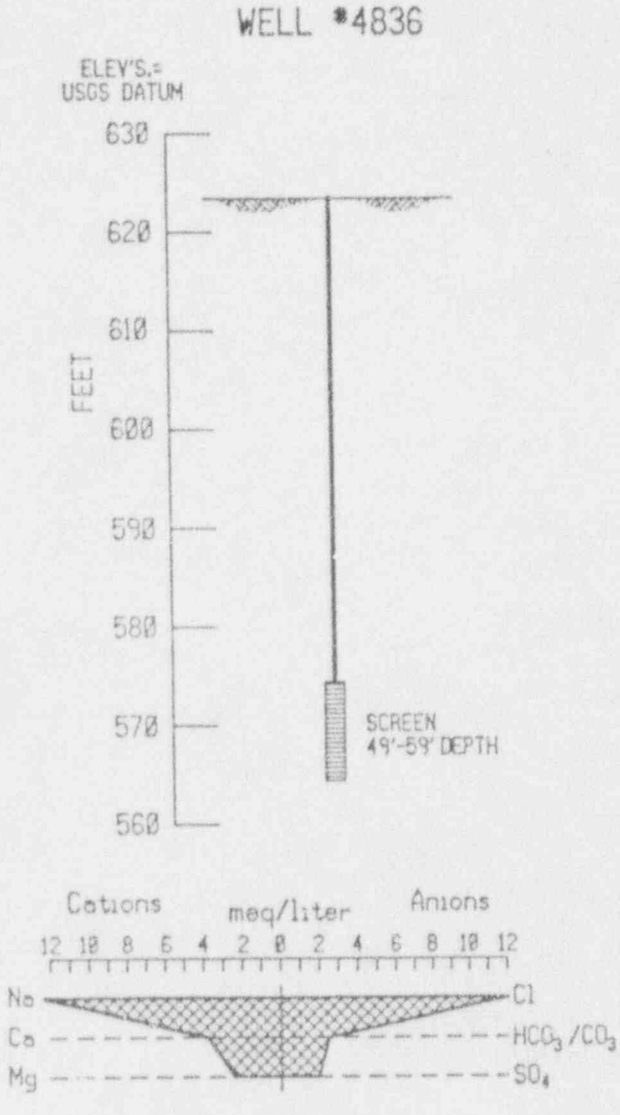
2/27/92



SALZBURG LANDFILL
MONITORING WELL-STIFF DIAGRAM

(BASED ON SAMPLES FROM 4/16/91 & 4/17/91

Figure J-9
2/27/92

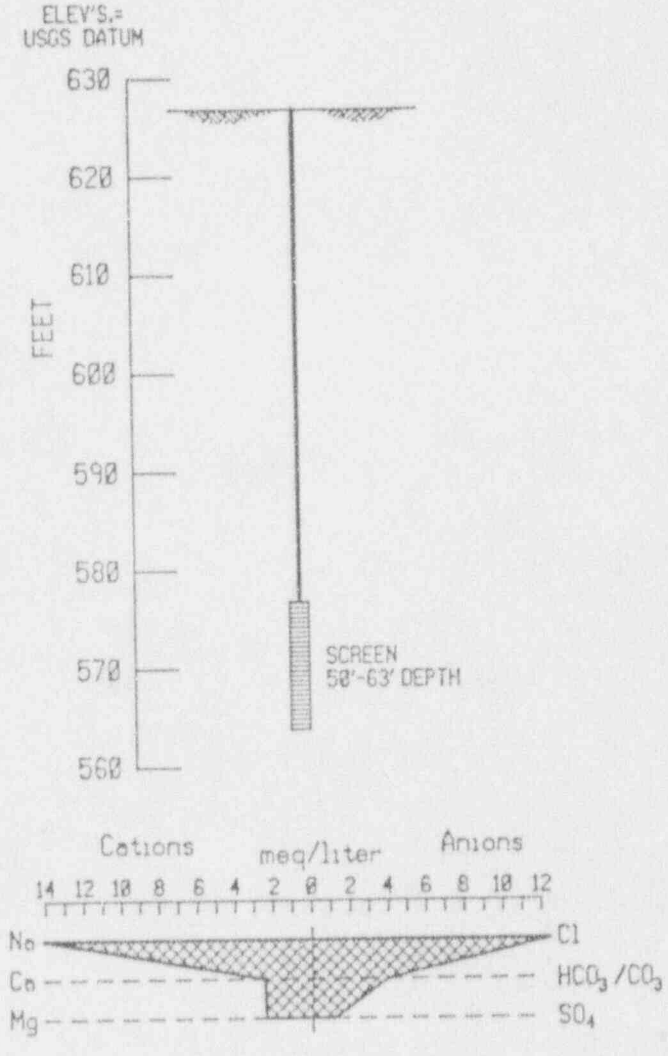


SALZBURG LANDFILL
MONITORING WELL-STIFF DIAGRAM

(BASED ON SAMPLES FROM 4/16/91 & 4/17/91

Figure J-10
2/27/92

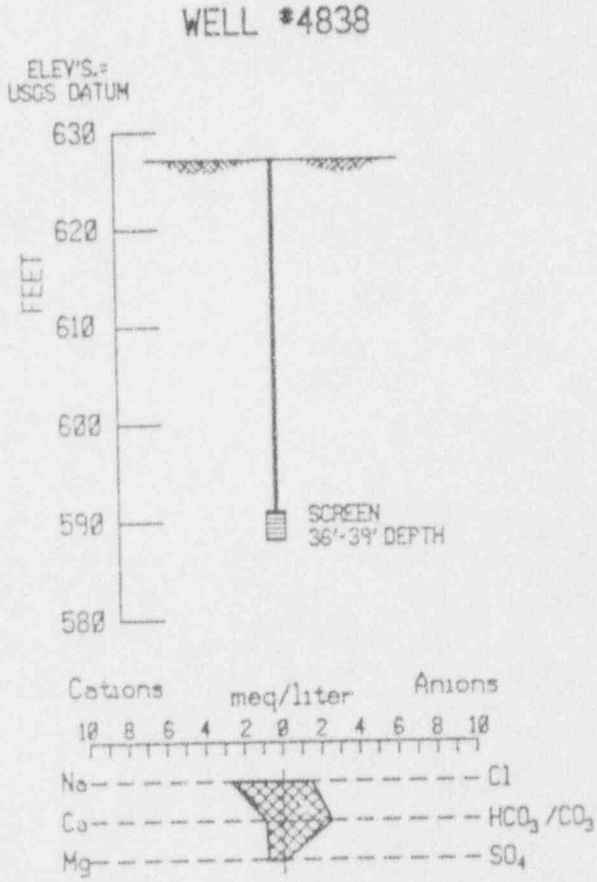
WELL #4837



SALZBURG LANDFILL
MONITORING WELL-STIFF DIAGRAM

(BASED ON SAMPLES FROM 4/16/91 & 4/17/91

Figure J-11
2/27/92

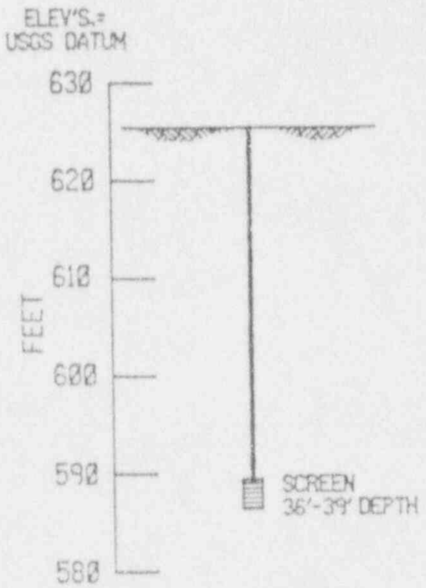


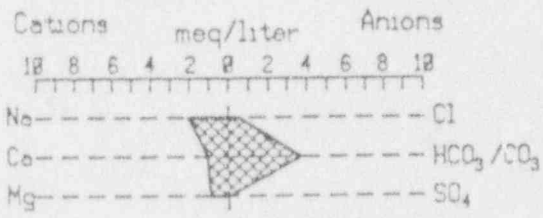
SALZBURG LANDFILL
MONITORING WELL-STIFF DIAGRAM

(BASED ON SAMPLES FROM 4/16/91 & 4/17/91

Figure J-12
2/27/92

WELL #4839

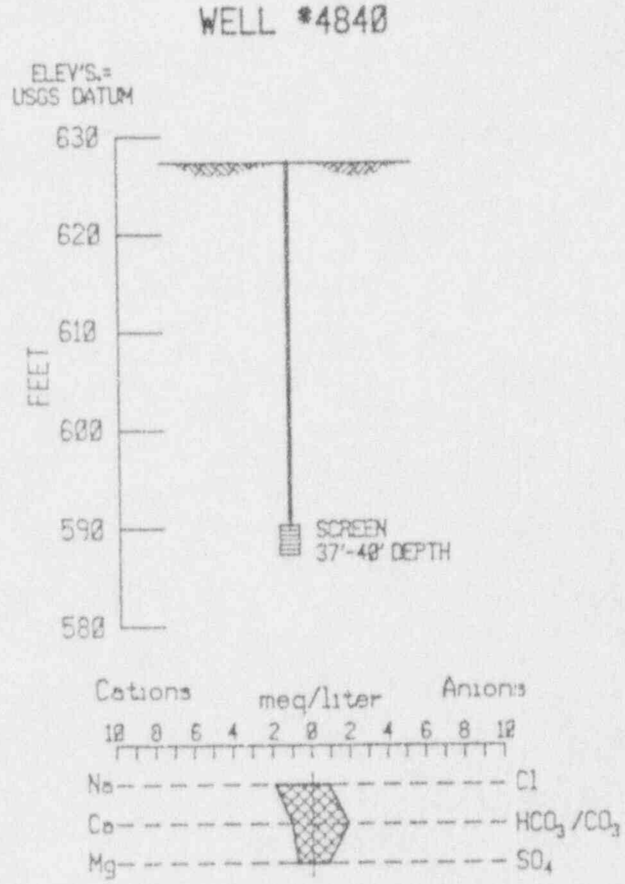




SALZBURG LANDFILL
MONITORING WELL-STIFF DIAGRAM

(BASED ON SAMPLES FROM 4/16/91 & 4/17/91

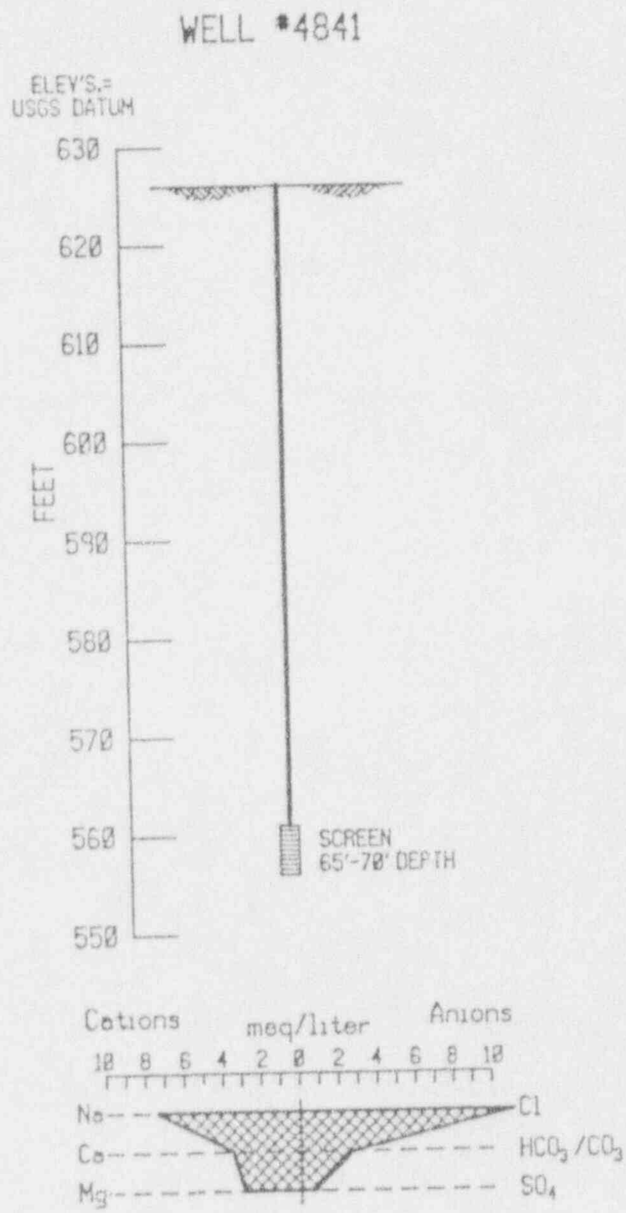
Figure J-13
2/27/92



SALZBURG LANDFILL
MONITORING WELL-STIFF DIAGRAM

(BASED ON SAMPLES FROM 4/16/91 & 4/17/91

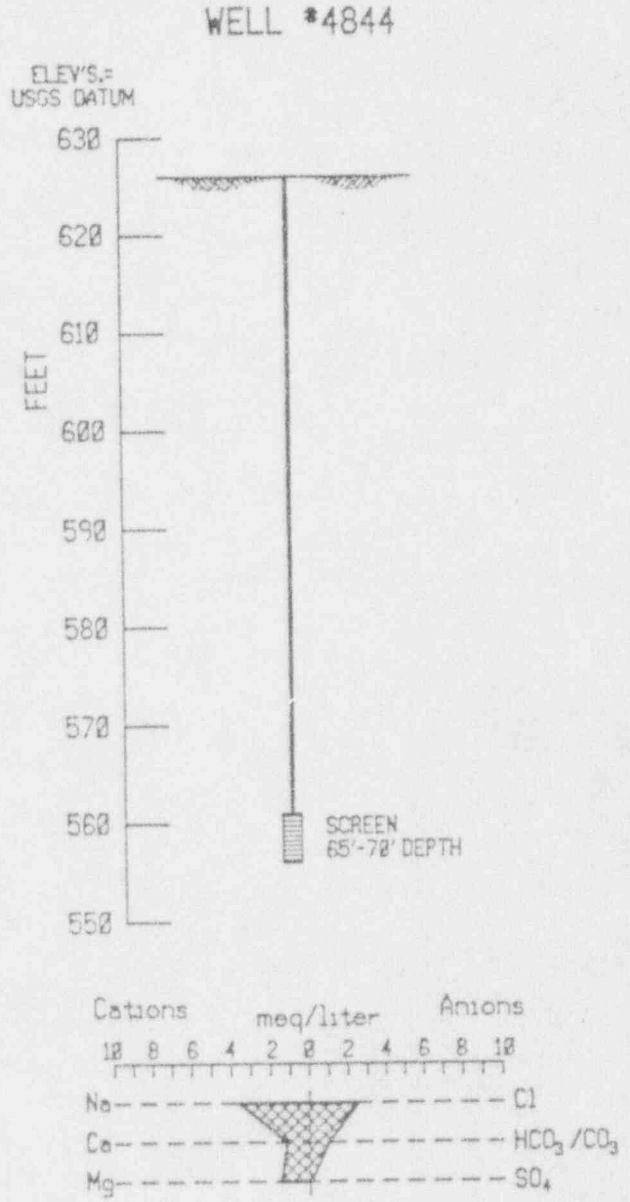
Figure J-14
2/2?/92



SALZBURG LANDFILL
MONITORING WELL-STIFF DIAGRAM

(BASED ON SAMPLES FROM 4/16/91 & 4/17/91

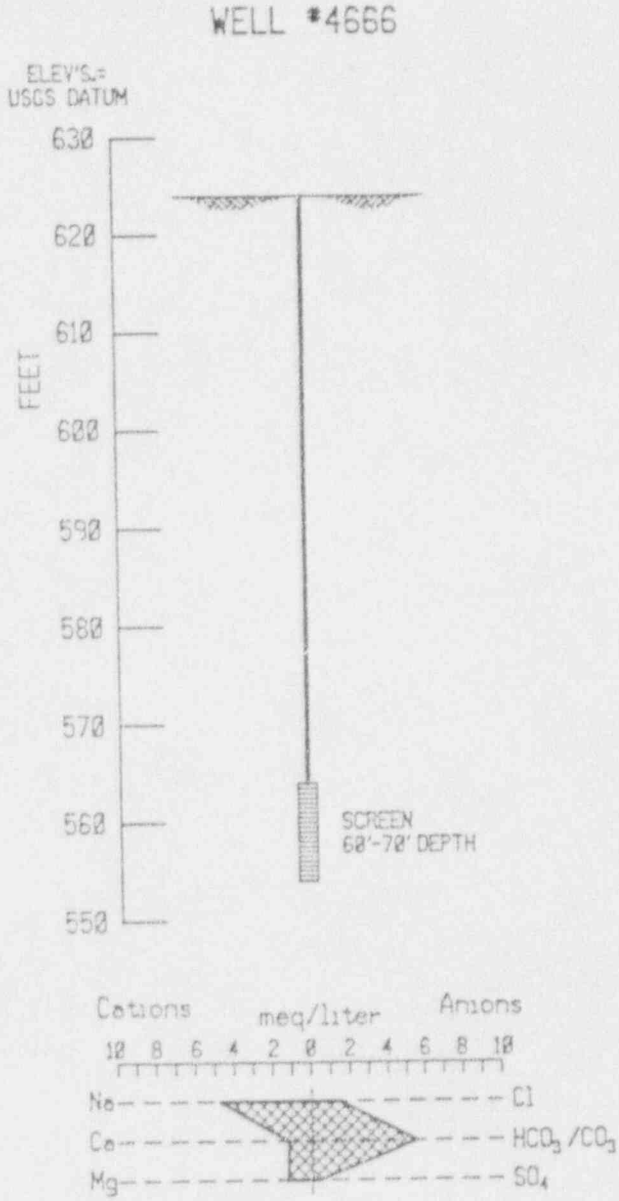
Figure J-15
2/27/92



SALZBURG LANDFILL
MONITORING WELL-STIFF DIAGRAM

(BASED ON SAMPLES FROM 4/16/91 & 4/17/91

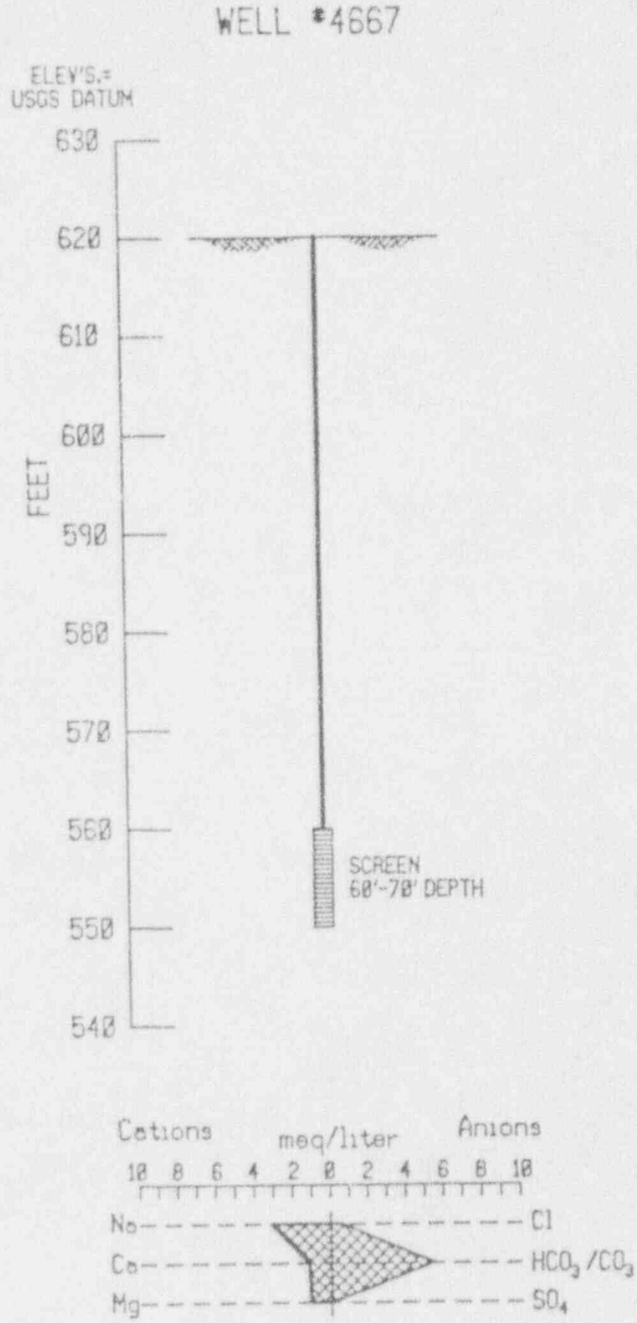
Figure J-16
2/27/92



SALZBURG LANDFILL
MONITORING WELL-STIFF DIAGRAM

(BASED ON SAMPLES FROM 4/16/91 & 4/17/91

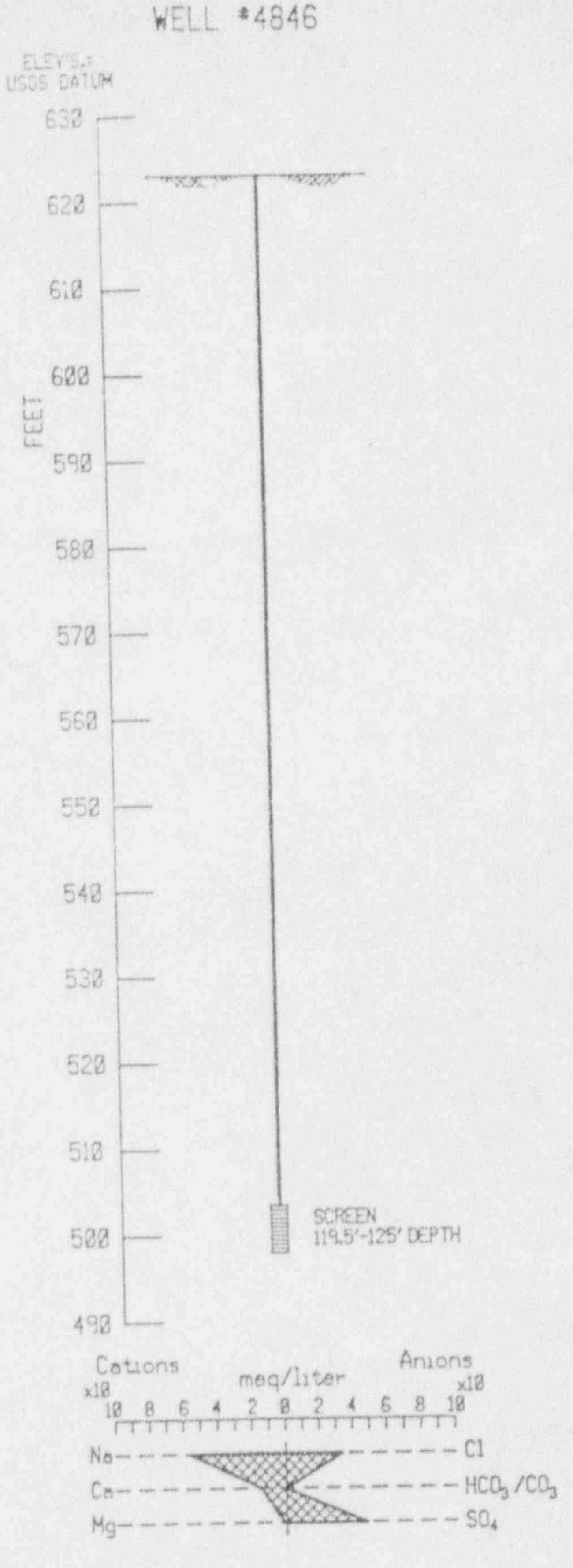
Figure J-17
2/27/92



SALZBURG LANDFILL
MONITORING WELL-STIFF DIAGRAM

(BASED ON SAMPLES FROM 4/16/91 & 4/17/91

Figure J-18
2/27/92



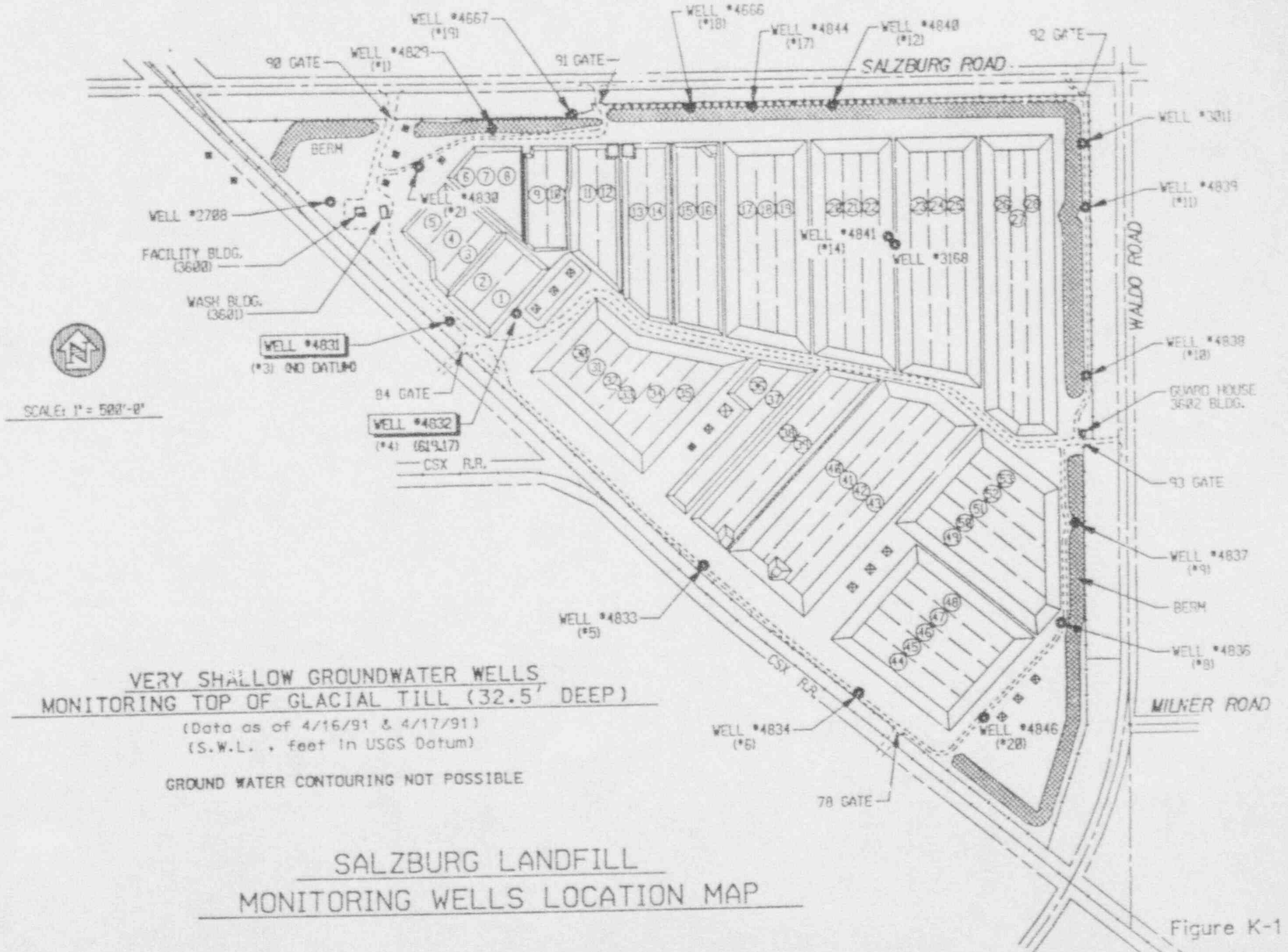
SALZBURG LANDFILL
MONITORING WELL-STIFF DIAGRAM

(BASED ON SAMPLES FROM 4/16/91 & 4/17/91

Figure J-19
2/27/92

APPENDIX K

Groundwater Well Depth
and Flow Monitoring Data
with Groundwater Contours



VERY SHALLOW GROUNDWATER WELLS

MONITORING TOP OF GLACIAL TILL (32.5' DEEP)

(Data as of 4/16/91 & 4/17/91)

(S.W.L. , feet in USGS Datum)

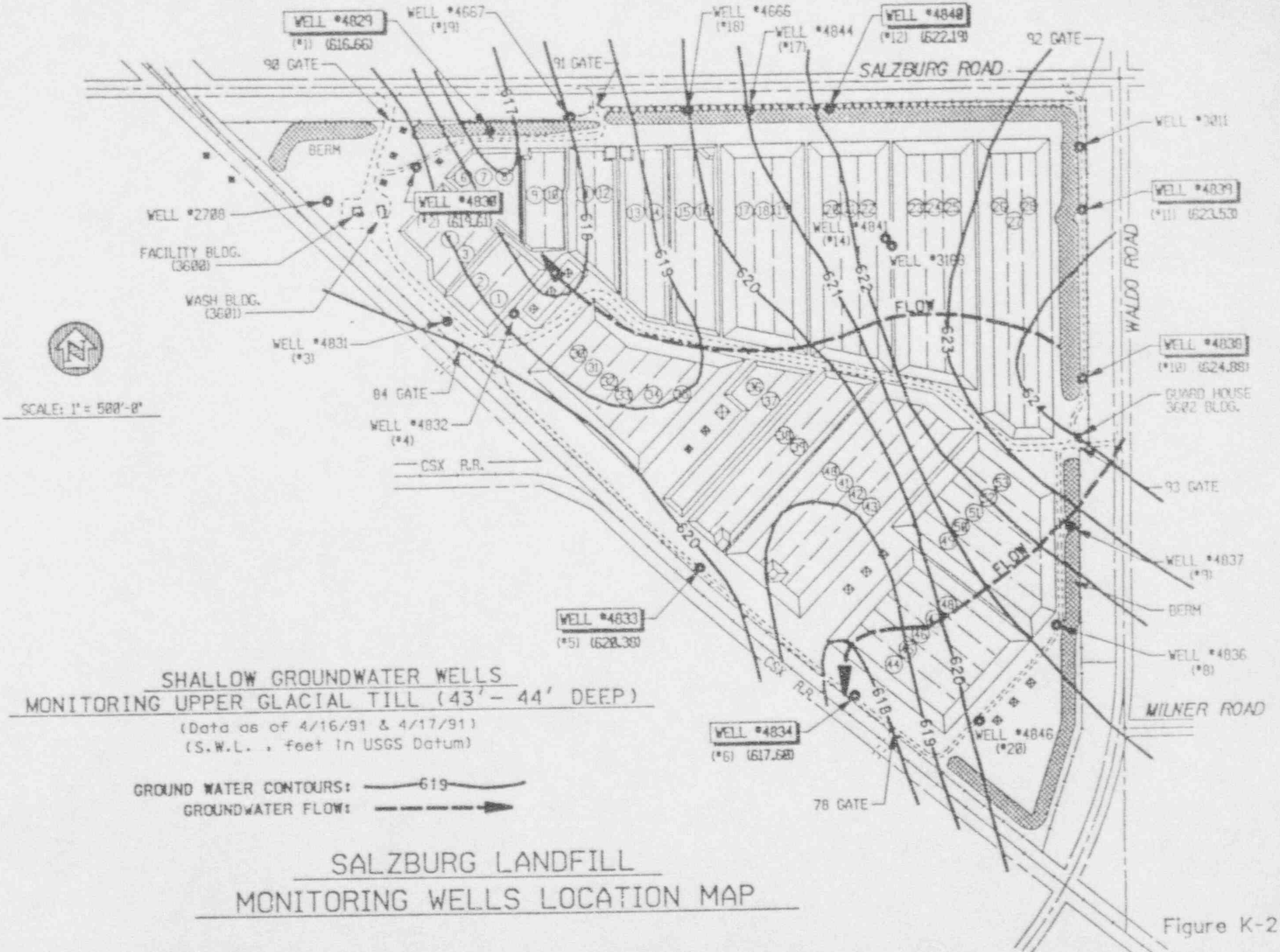
GROUND WATER CONTOURING NOT POSSIBLE

SALZBURG LANDFILL

MONITORING WELLS LOCATION MAP

Figure K-1

2/27/92



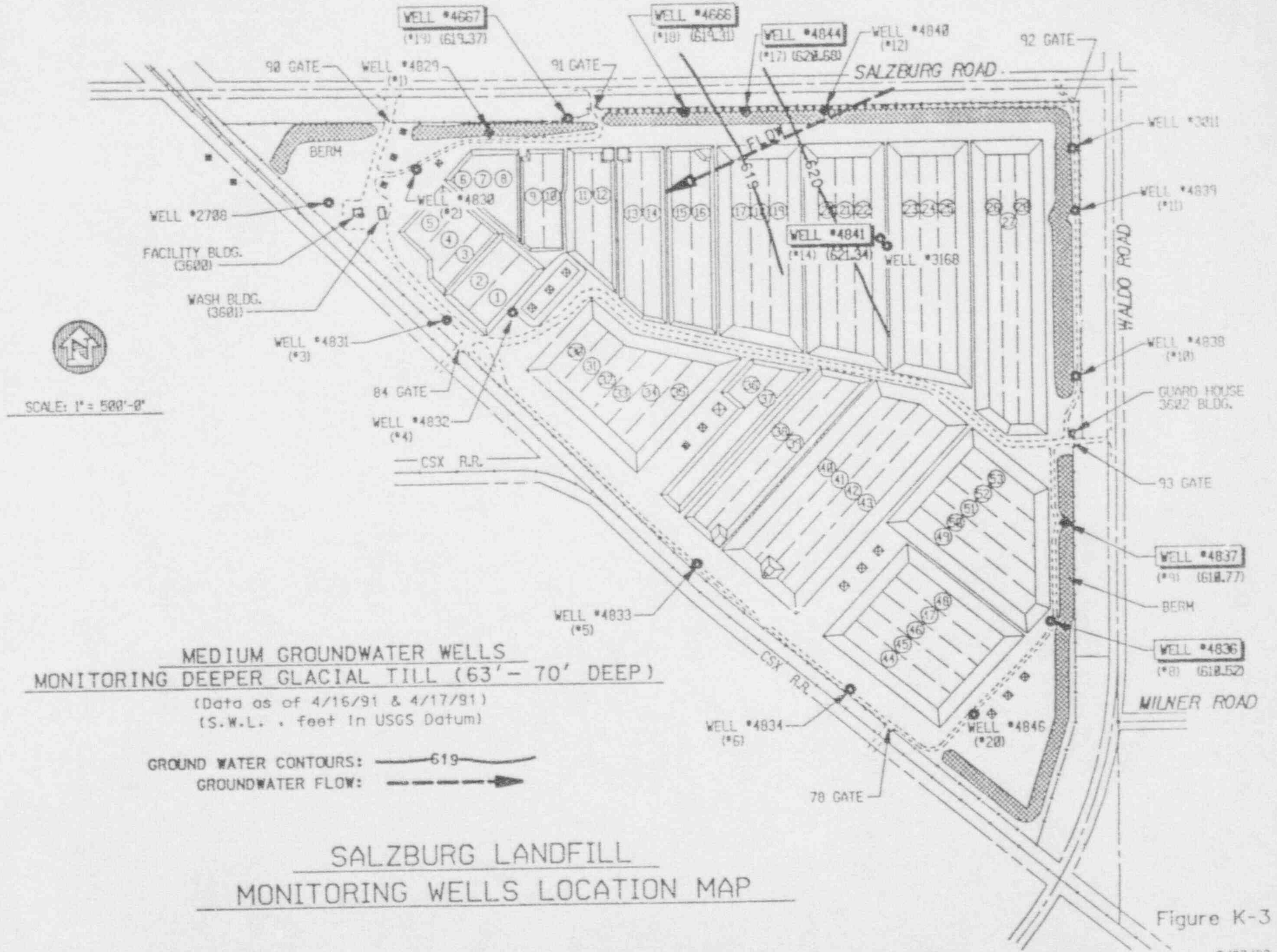
SHALLOW GROUNDWATER WELLS
MONITORING UPPER GLACIAL TILL (43' - 44' DEEP)

(Data as of 4/16/91 & 4/17/91)
(S.W.L. , feet in USGS Datum)

SALZBURG LANDFILL
MONITORING WELLS LOCATION MAP

Figure K-2

2/27/92

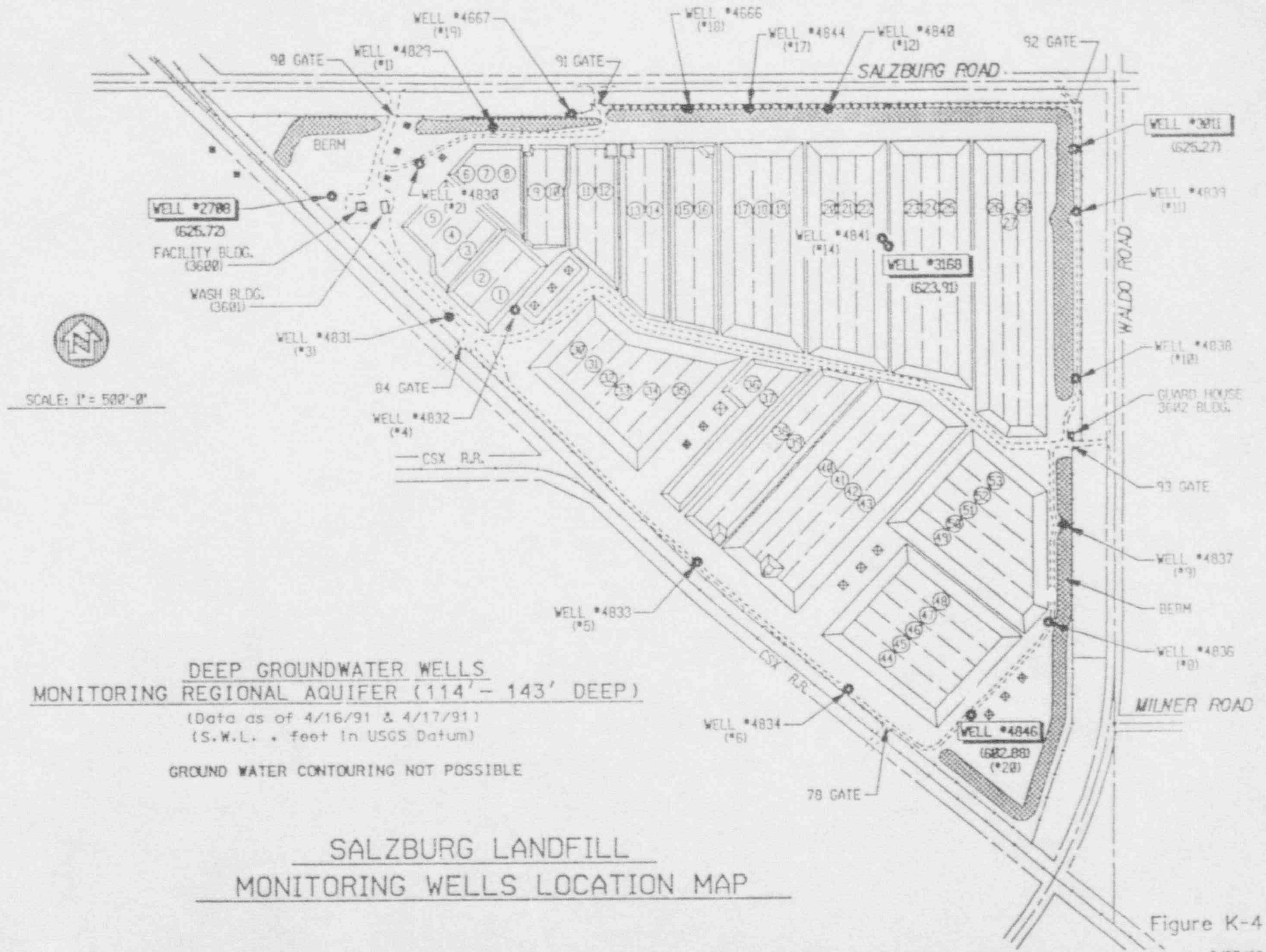


SALZBURG LANDFILL

MONITORING WELLS LOCATION MAP

Figure K-3

2/27/92



SALZBURG LANDFILL

MONITORING WELLS LOCATION MAP

Figure K-4

2/27/92

APPENDIX L

RESRAD Model Analysis
for Various Exposure Scenarios at the Salzburg Landfill

Table of Contents

Part I: Mixture Sums and Single Radionuclide Guidelines

Summary : SALZBURG RESIDUAL ANALYSIS - REDUCED Th Kd, SAME Ra Kd
File : SALZ6.DAT

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	5.700E+03	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	7.000E+00	1.000E+00	---	THICKO
R011	Length parallel to aquifer flow (m)	1.000E+02	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	5.000E+00	1.000E+02	---	BRLD
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	1.000E+03	3.000E+00	---	T(3)
R011	Times for calculations (yr)	5.000E+03	1.000E+01	---	T(4)
R011	Times for calculations (yr)	1.000E+04	3.000E+01	---	T(5)
R011	Times for calculations (yr)	2.000E+04	1.000E+02	---	T(6)
R011	Times for calculations (yr)	4.000E+04	3.000E+02	---	T(7)
R011	Times for calculations (yr)	6.000E+04	1.000E+03	---	T(8)
R011	Times for calculations (yr)	8.000E+04	3.000E+03	---	T(9)
R011	Times for calculations (yr)	1.000E+05	1.000E+04	---	T(10)
R012	Initial principal radionuclide (pCi/g): Th-232	1.510E+02	0.000E+00	---	S(3)
R012	Concentration in groundwater (pCi/L): Th-232	not used	0.000E+00	---	W(3)
R013	Cover depth (m)	1.000E+00	0.000E+00	---	COVERO
R013	Density of cover material (g/cm**3)	1.600E+00	1.600E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	1.000E-05	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.600E+00	1.600E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-05	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	4.000E-01	4.000E-01	---	TPCZ
R013	Contaminated zone effective porosity	2.000E-01	2.000E-01	---	EPCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	1.000E+01	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	5.300E+00	5.300E+00	---	BCZ
R013	Evapotranspiration coefficient	6.000E-01	6.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	1.000E+00	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	2.000E-01	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	1.000E+06	1.000E+06	---	WAREA
R014	Density of saturated zone (g/cm**3)	1.600E+00	1.600E+00	---	DENSAQ
R014	Saturated zone total porosity	4.000E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	2.000E-01	2.000E-01	---	EPSZ
R014	Saturated zone hydraulic conductivity (m/yr)	1.000E+02	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	2.000E-02	2.000E-02	---	HGWT
R014	Saturated zone b parameter	5.300E+00	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	1.000E-03	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	1.000E+01	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	---	MODEL
R014	Individual's use of groundwater (m**3/yr)	not used	1.500E+02	---	UW
R015	Number of unsaturated zone strata	1	1	---	NS

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R015	Unsat. zone 1, thickness (m)	4.000E+00	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	1.600E+00	1.600E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	4.000E-01	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	2.000E-01	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	5.300E+00	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	1.000E+02	1.000E+02	---	HCUZ(1)
R016	Distribution coefficients for Th-232				
R016	Contaminated zone (cm**3/g)	2.500E+02	6.000E+04	---	DCACTC(3)
R016	Unsaturated zone 1 (cm**3/g)	2.500E+02	6.000E+04	---	DCACTU(3,1)
R016	Saturated zone (cm**3/g)	2.500E+02	6.000E+04	---	DCACTS(3)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.427E-04	RLEACH(3)
R016	Distribution coefficients for daughter Ra-228				
R016	Contaminated zone (cm**3/g)	2.500E+02	7.000E+01	---	DCACTC(1)
R016	Unsaturated zone 1 (cm**3/g)	2.500E+02	7.000E+01	---	DCACTU(1,1)
R016	Saturated zone (cm**3/g)	2.500E+02	7.000E+01	---	DCACTS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.427E-04	RLEACH(1)
R016	Distribution coefficients for daughter Th-228				
R016	Contaminated zone (cm**3/g)	2.500E+02	6.000E+04	---	DCACTC(2)
R016	Unsaturated zone 1 (cm**3/g)	2.500E+02	6.000E+04	---	DCACTU(2,1)
R016	Saturated zone (cm**3/g)	2.500E+02	6.000E+04	---	DCACTS(2)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.427E-04	RLEACH(2)
R017	Inhalation rate (m**3/yr)	8.400E+03	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	2.000E-04	2.000E-04	---	MLINH
R017	Dilution length for airborne dust, inhalation (m)	3.000E+00	3.000E+00	---	LM
R017	Occupancy factor, inhalation	4.500E-01	4.500E-01	---	FO3
R017	Occupancy and shielding factor, external gamma	6.000E-01	6.000E-01	---	FO1
R017	Shape factor, external gamma	1.000E+00	1.000E+00	---	FS1
R017	Fractions of annular areas within AREA:				
R017	Outer annular radius (m) = √(1/π)	not used	1.000E+00	---	FRACA(1)
R017	Outer annular radius (m) = √(10/π)	not used	1.000E+00	---	FRACA(2)
R017	Outer annular radius (m) = √(20/π)	not used	1.000E+00	---	FRACA(3)
R017	Outer annular radius (m) = √(50/π)	not used	1.000E+00	---	FRACA(4)
R017	Outer annular radius (m) = √(100/π)	not used	1.000E+00	---	FRACA(5)
R017	Outer annular radius (m) = √(200/π)	not used	1.000E+00	---	FRACA(6)
R017	Outer annular radius (m) = √(500/π)	not used	1.000E+00	---	FRACA(7)
R017	Outer annular radius (m) = √(1000/π)	not used	1.000E+00	---	FRACA(8)
R017	Outer annular radius (m) = √(5000/π)	not used	1.000E+00	---	FRACA(9)
R017	Outer annular radius (m) = √(1.E+04/π)	not used	1.000E+00	---	FRACA(10)
R017	Outer annular radius (m) = √(1.E+05/π)	not used	0.000E+00	---	FRACA(11)
R017	Outer annular radius (m) = √(1.E+06/π)	not used	0.000E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	1.600E+02	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	1.400E+01	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	9.200E+01	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	6.300E+01	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	5.400E+00	5.400E+00	---	DIET(5)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R018	Other seafood consumption (kg/yr)	9.000E-01	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	3.650E+01	0.000E+00	---	SOIL
R018	Drinking water intake (L/yr)	4.100E+02	4.100E+02	---	DWI
R018	Fraction of drinking water from site	1.000E+00	1.000E+00	---	FDW
R019	Livestock fodder intake for meat (kg/day)	6.800E+01	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	5.500E+01	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	5.000E+01	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	1.600E+02	1.600E+02	---	LWI6
R019	Mass loading for foliar deposition (g/m**3)	1.000E-04	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	9.000E-01	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Livestock water fraction from ground water	1.000E+00	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	1.000E+00	1.000E+00	---	FGWIR
R021	Total porosity of the cover material	4.000E-01	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	1.000E-01	1.000E-01	---	TPFL
R021	Volumetric water content of the cover material	5.000E-02	5.000E-02	---	PH2OCV
R021	Volumetric water content of the foundation	1.000E-02	1.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	2.000E-06	2.000E-06	---	DIFCV
R021	in foundation material	2.000E-08	2.000E-08	---	DIFFL
R021	in contaminated zone soil	2.000E-06	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	2.000E+00	2.000E+00	---	HMIX
R021	Average annual wind speed (m/sec)	2.000E+00	2.000E+00	---	WIND
R021	Average building air exchange rate (1/hr)	1.000E+00	1.000E+00	---	REXG
R021	Height of the building (room) (m)	2.500E+00	2.500E+00	---	HRM
R021	Building interior area factor	1.000E+00	1.000E+00	---	FAI
R021	Bulk density of building foundation (g/cm**3)	2.400E+00	2.400E+00	---	DENSFL
R021	Thickness of building foundation (m)	1.500E-01	1.500E-01	---	FLOOR
R021	Building depth below ground surface (m)	1.000E+00	1.000E+00	---	DMFL
R021	Fraction of time spent indoors	5.000E-01	5.000E-01	---	FIND
R021	Fraction of time spent outdoors (on site)	2.500E-01	2.500E-01	---	FOTD
R021	Emanating power of Rn-222 gas	not used	2.000E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	1.000E-01	1.000E-01	---	EMANA(2)

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	active
2 -- inhalation	active
3 -- plant ingestion	active
4 -- meat ingestion	active
5 -- milk ingestion	active
6 -- aquatic foods	active
7 -- drinking water	active
8 -- radon	active
9 -- soil ingestion	active

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Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	5700.00 square meters	Th-232	1.510E+02
Thickness:	7.00 meters		
Cover Depth:	1.00 meters		

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit =   5 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	1.000E+03	5.000E+03	1.000E+04	2.000E+04	4.000E+04	6.000E+04	8.000E+04	1.000E+05
TDOSE(t):	2.200E-14	6.802E-03	2.831E-01	1.317E+02	6.679E+02	6.413E+02	1.539E+02	3.693E+01	8.865E+00	2.129E+00
M(t):	4.399E-15	1.360E-03	5.661E-02	2.633E+01	1.336E+02	1.283E+02	3.078E+01	7.385E+00	1.773E+00	4.259E-01

Maximum TDOSE(t): 9.813E+02 mrem/yr   at t =   14021 ± 4 years

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 14021 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	1.335E-01	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	1.316E+00	0.0013	8.484E-02	0.0001	4.908E-04	0.0000	0.000E+00	0.0000
Total	1.335E-01	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	1.316E+00	0.0013	8.484E-02	0.0001	4.908E-04	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 14021 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	8.398E+02	0.8558	3.400E+00	0.0035	8.870E-03	0.0000	1.098E+02	0.1119	2.600E+01	0.0265	7.344E-01	0.0007	9.813E+02	1.0000
Total	8.398E+02	0.8558	3.400E+00	0.0035	8.870E-03	0.0000	1.098E+02	0.1119	2.600E+01	0.0265	7.344E-01	0.0007	9.813E+02	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	2.200E-14	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	2.200E-14	1.0000	0.000E+00	0.0000	0.000E+?0	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.200E-14	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.200E-14	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	6.802E-03	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	6.802E-03	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.802E-03	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.802E-03	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	2.831E-01	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	2.831E-01	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mre./yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.831E-01	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.831E-01	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+03 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	2.246E-01	0.0017	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	2.246E-01	0.0017	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+03 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	1.127E+02	0.8557	4.562E-01	0.0035	4.313E-03	0.0000	1.473E+01	0.1119	3.488E+00	0.0265	9.852E-02	0.0007	1.317E+02	1.0000
Total	1.127E+02	0.8557	4.562E-01	0.0035	4.313E-03	0.0000	1.473E+01	0.1119	3.488E+00	0.0265	9.852E-02	0.0007	1.317E+02	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+04 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	1.683E-01	0.0003	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	1.683E-01	0.0003	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+04 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	5.724E+02	0.8570	2.317E+00	0.0035	1.073E-02	0.0000	7.481E+01	0.1120	1.772E+01	0.0265	5.005E-01	0.0007	6.679E+02	1.0000
Total	5.724E+02	0.8570	2.317E+00	0.0035	1.073E-02	0.0000	7.481E+01	0.1120	1.772E+01	0.0265	5.005E-01	0.0007	6.679E+02	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 2.000E+04 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	9.477E-02	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	1.394E+00	0.0022	8.987E-02	0.0001	5.199E-04	0.0000	0.000E+00	0.0000
Total	9.477E-02	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	1.394E+00	0.0022	8.987E-02	0.0001	5.199E-04	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 2.000E+04 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	5.483E+02	0.8551	2.220E+00	0.0035	2.467E-03	0.0000	7.168E+01	0.1118	1.698E+01	0.0265	4.795E-01	0.0007	6.413E+02	1.0000
Total	5.483E+02	0.8551	2.220E+00	0.0035	2.467E-03	0.0000	7.168E+01	0.1118	1.698E+01	0.0265	4.795E-01	0.0007	6.413E+02	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 4.000E+04 years

Water Independent Pathways

Radio-Nuclide	Ground mrem/yr	Ground fract.	Dust mrem/yr	Dust fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Th-232	3.049E-02	0.0002	0.000E+00	0.0000	0.000E+00	0.0000	2.407E-01	0.0016	1.552E-02	0.0001	8.977E-05	0.0000	0.000E+00	0.0000
Total	3.049E-02	0.0002	0.000E+00	0.0000	0.000E+00	0.0000	2.407E-01	0.0016	1.552E-02	0.0001	8.977E-05	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 4.000E+04 years

Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Th-232	1.317E+02	0.8556	5.332E-01	0.0035	3.410E-05	0.0000	1.721E+01	0.1118	4.077E+00	0.0265	1.151E-01	0.0007	1.539E+02	1.0000
Total	1.317E+02	0.8556	5.332E-01	0.0035	3.410E-05	0.0000	1.721E+01	0.1118	4.077E+00	0.0265	1.151E-01	0.0007	1.539E+02	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions IDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 6.000E+04 years

Water Independent Pathways

Radio-Nuclide	Ground mrem/yr	Ground fract.	Dust mrem/yr	Dust fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Th-232	1.009E-02	0.0003	0.000E+00	0.0000	0.000E+00	0.0000	2.309E-02	0.0006	1.489E-03	0.0000	8.613E-06	0.0000	0.000E+00	0.0000
Total	1.009E-02	0.0003	0.000E+00	0.0000	0.000E+00	0.0000	2.309E-02	0.0006	1.489E-03	0.0000	8.613E-06	0.0000	0.000E+00	0.0000

Total Dose Contributions IDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 6.000E+04 years

Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Th-232	3.162E+01	0.8564	1.280E-01	0.0035	4.714E-07	0.0000	4.134E+00	0.1119	9.791E-01	0.0265	2.765E-02	0.0007	3.693E+01	1.0000
Total	3.162E+01	0.8564	1.280E-01	0.0035	4.714E-07	0.0000	4.134E+00	0.1119	9.791E-01	0.0265	2.765E-02	0.0007	3.693E+01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 8.000E+04 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	3.473E-03	0.0004	0.000E+00	0.0000	0.000E+00	0.0000	1.861E-03	0.0002	1.200E-04	0.0000	6.941E-07	0.0000	0.000E+00	0.0000
Total	3.473E-03	0.0004	0.000E+00	0.0000	0.000E+00	0.0000	1.861E-03	0.0002	1.200E-04	0.0000	6.941E-07	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 8.000E+04 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	7.595E+00	0.8567	3.075E-02	0.0035	6.516E-09	0.0000	9.927E-01	0.1120	2.351E-01	0.0265	6.641E-03	0.0007	8.865E+00	1.0000
Total	7.595E+00	0.8567	3.075E-02	0.0035	6.516E-09	0.0000	9.927E-01	0.1120	2.351E-01	0.0265	6.641E-03	0.0007	8.865E+00	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+05 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	1.261E-03	0.0006	1.328E-04	0.0001	3.563E-05	0.0000	1.380E-04	0.0001	8.940E-06	0.0000	5.231E-08	0.0000	1.241E-05	0.0000
Total	1.261E-03	0.0006	1.328E-04	0.0001	3.563E-05	0.0000	1.380E-04	0.0001	8.940E-06	0.0000	5.231E-08	0.0000	1.241E-05	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+05 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	1.824E+00	0.8566	7.384E-03	0.0035	9.007E-11	0.0000	2.384E-01	0.1120	5.647E-02	0.0265	1.595E-03	0.0007	2.129E+00	1.0000
Total	1.824E+00	0.8566	7.384E-03	0.0035	9.007E-11	0.0000	2.384E-01	0.1120	5.647E-02	0.0265	1.595E-03	0.0007	2.129E+00	1.0000

*Sum of all water independent and dependent pathways.

Summary : SALZBURG RESIDUAL ANALYSIS - REDUCED Th Kd, SAME Ra Kd
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Dose/Source Ratios Summed Over All Pathways, (mrem/yr)/(pCi/g)

Nuclide (i)	t= 0.000E+00	1.000E+00	1.000E+03	5.000E+03	1.000E+04	2.000E+04	4.000E+04	6.000E+04	8.000E+04	1.000E+05
Th-232	1.457E-16	4.505E-05	1.875E-03	8.720E-01	4.423E+00	4.247E+00	1.019E+00	2.446E-01	5.871E-02	1.410E-02

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 5 mrem/yr

Nuclide (i)	t= 0.000E+00	1.000E+00	1.000E+03	5.000E+03	1.000E+04	2.000E+04	4.000E+04	6.000E+04	8.000E+04	1.000E+05
Th-232	*1.092E+05	*1.092E+05	2.667E+03	5.734E+00	1.130E+00	1.177E+00	4.905E+00	2.045E+01	8.516E+01	3.546E+02

*At specific activity limit

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
at tmin = time of minimum single radionuclide soil guideline
and at tmax = time of maximum total dose = 14021 ± 4 years

Nuclide (i)	Initial pCi/g	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Th-232	1.510E+02	14021 ± 4	6.499E+00	7.694E-01	6.499E+00	7.694E-01

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Part I: Mixture Sums and Single Radionuclide Guidelines

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	5.700E+03	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	7.000E+00	1.000E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	1.000E+02	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	5.000E+00	1.000E+02	---	BRLD
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	3.000E+03	3.000E+03	---	T(9)
R011	Times for calculations (yr)	1.000E+04	1.000E+04	---	T(10)
R012	Initial principal radionuclide (pCi/g): Th-232	1.510E+02	0.000E+00	---	S(3)
R012	Concentration in groundwater (pCi/L): Th-232	not used	0.000E+00	---	W(3)
R013	Cover depth (m)	0.000E+00	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.600E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.600E+00	1.600E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-06	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	4.000E-01	4.000E-01	---	TPCZ
R013	Contaminated zone effective porosity	2.000E-01	2.000E-01	---	EPCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	1.000E+01	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	5.300E+00	5.300E+00	---	BCZ
R013	Evapotranspiration coefficient	6.000E-01	6.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	1.000E+00	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	2.000E-01	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	1.000E+06	1.000E+06	---	WAREA
R014	Density of saturated zone (g/cm**3)	1.600E+00	1.600E+00	---	DENSAQ
R014	Saturated zone total porosity	4.000E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	2.000E-01	2.000E-01	---	EPSZ
R014	Saturated zone hydraulic conductivity (m/yr)	1.000E+02	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	2.000E-02	2.000E-02	---	HGWT
R014	Saturated zone b parameter	5.300E+00	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	1.000E-03	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	1.000E+01	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	---	MODEL
R014	Individual's use of groundwater (m**3/yr)	not used	1.500E+02	---	UW
R015	Number of unsaturated zone strata	1	1	---	NS
R015	Unsat. zone 1, thickness (m)	4.000E+00	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	1.600E+00	1.600E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	4.000E-01	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	2.000E-01	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	5.300E+00	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	1.000E+02	1.000E+02	---	HCUZ(1)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for Th-232				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCACTC(3)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCACTU(3,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCACTS(3)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	5.952E-07	RLEACH(3)
R016	Distribution coefficients for daughter Ra-228				
R016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCACTC(1)
R016	Unsaturated zone 1 (cm**3/g)	7.000E+01	7.000E+01	---	DCACTU(1,1)
R016	Saturated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCACTS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	5.088E-04	RLEACH(1)
R016	Distribution coefficients for daughter Th-228				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCACTC(2)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCACTU(2,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCACTS(2)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	5.952E-07	RLEACH(2)
R017	Inhalation rate (m**3/yr)	8.400E+03	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	2.000E-04	2.000E-04	---	MLINH
R017	Dilution length for airborne dust, inhalation (m)	3.000E+00	3.000E+00	---	LM
R017	Occupancy factor, inhalation	4.500E-01	4.500E-01	---	FO3
R017	Occupancy and shielding factor, external gamma	6.000E-01	6.000E-01	---	FO1
R017	Shape factor, external gamma	1.000E+00	1.000E+00	---	FS1
R017	Fractions of annular areas within AREA:				
R017	Outer annular radius (m) = √(1/π)	not used	1.000E+00	---	FRACA(1)
R017	Outer annular radius (m) = √(10/π)	not used	1.000E+00	---	FRACA(2)
R017	Outer annular radius (m) = √(20/π)	not used	1.000E+00	---	FRACA(3)
R017	Outer annular radius (m) = √(50/π)	not used	1.000E+00	---	FRACA(4)
R017	Outer annular radius (m) = √(100/π)	not used	1.000E+00	---	FRACA(5)
R017	Outer annular radius (m) = √(200/π)	not used	1.000E+00	---	FRACA(6)
R017	Outer annular radius (m) = √(500/π)	not used	1.000E+00	---	FRACA(7)
R017	Outer annular radius (m) = √(1000/π)	not used	1.000E+00	---	FRACA(8)
R017	Outer annular radius (m) = √(5000/π)	not used	1.000E+00	---	FRACA(9)
R017	Outer annular radius (m) = √(1.E+04/π)	not used	1.000E+00	---	FRACA(10)
R017	Outer annular radius (m) = √(1.E+05/π)	not used	0.000E+00	---	FRACA(11)
R017	Outer annular radius (m) = √(1.E+06/π)	not used	0.000E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	1.600E+02	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	1.400E+01	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	9.200E+01	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	6.300E+01	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	5.400E+00	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	9.000E-01	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	3.650E+01	0.000E+00	---	SOIL
R018	Drinking water intake (L/yr)	4.100E+02	4.100E+02	---	DWI
R018	Fraction of drinking water from site	1.000E+00	1.000E+00	---	FDW
R019	Livestock fodder intake for meat (kg/day)	6.800E+01	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	5.500E+01	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	5.000E+01	5.000E+01	---	LWI5

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R019	Livestock water intake for milk (L/day)	1.600E+02	1.600E+02	---	LWI6
R019	Mass loading for foliar deposition (g/m**3)	1.000E-04	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	9.000E-01	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Livestock water fraction from ground water	1.000E+00	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	1.000E+00	1.000E+00	---	FGWIR
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	1.000E-01	1.000E-01	---	TPFL
R021	Volumetric water content of the cover material	not used	5.000E-02	---	PH2OCV
R021	Volumetric water content of the foundation	1.000E-02	1.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.000E-06	---	DIFCV
R021	in foundation material	2.000E-08	2.000E-08	---	DIFFL
R021	in contaminated zone soil	2.000E-06	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	2.000E+00	2.000E+00	---	HMIX
R021	Average annual wind speed (m/sec)	2.000E+00	2.000E+00	---	WIND
R021	Average building air exchange rate (1/hr)	1.000E+00	1.000E+00	---	REXG
R021	Height of the building (room) (m)	2.500E+00	2.500E+00	---	HRM
R021	Building interior area factor	1.000E+00	1.000E+00	---	FAI
R021	Bulk density of building foundation (g/cm**3)	2.400E+00	2.400E+00	---	DENSFL
R021	Thickness of building foundation (m)	1.500E-01	1.500E-01	---	FLOOR
R021	Building depth below ground surface (m)	1.000E+00	1.000E+00	---	DMFL
R021	Fraction of time spent indoors	5.000E-01	5.000E-01	---	FIND
R021	Fraction of time spent outdoors (on site)	2.500E-01	2.500E-01	---	FOTD
R021	Emanating power of Rn-222 gas	not used	2.000E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	1.000E-01	1.000E-01	---	EMANA(2)

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	active
2 -- inhalation	active
3 -- plant ingestion	active
4 -- meat ingestion	active
5 -- milk ingestion	active
6 -- aquatic foods	active
7 -- drinking water	active
8 -- radon	active
9 -- soil ingestion	active

Contaminated Zone Dimensions	
Area:	5700.00 square meters
Thickness:	7.00 meters
Cover Depth:	0.00 meters

Initial Soil Concentrations, pCi/g	
Th-232	1.510E+02

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 5 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03	3.000E+03	1.000E+04
TDOSE(t):	3.530E+02	4.678E+02	7.618E+02	1.676E+03	2.430E+03	2.505E+03	2.505E+03	2.738E+03	3.123E+03	2.520E+03
M(t):	7.060E+01	9.355E+01	1.524E+02	3.353E+02	4.860E+02	5.011E+02	5.010E+02	5.477E+02	6.247E+02	5.040E+02

Maximum TDOSE(t): 3.352E+03 mrem/yr at t = 2287.2 ± 0.7 years

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 2287.2 years

Water Independent Pathways

Radio- Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	1.985E+03	0.5921	2.098E+02	0.0626	5.607E+01	0.0167	2.178E+02	0.0650	1.411E+01	0.0042	8.234E-02	0.0000	1.957E+01	0.0058
Total	1.985E+03	0.5921	2.098E+02	0.0626	5.607E+01	0.0167	2.178E+02	0.0650	1.411E+01	0.0042	8.234E-02	0.0000	1.957E+01	0.0058

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 2287.2 years

Water Dependent Pathways

Radio- Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	7.561E+02	0.2256	2.602E+00	0.0008	0.000E+00	0.0000	8.294E+01	0.0247	5.728E+00	0.0017	2.523E+00	0.0008	3.352E+03	1.0000
Total	7.561E+02	0.2256	2.602E+00	0.0008	0.000E+00	0.0000	8.294E+01	0.0247	5.728E+00	0.0017	2.523E+00	0.0008	3.352E+03	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	1.071E-01	0.0003	1.757E+02	0.4976	0.000E+00	0.0000	1.547E+02	0.4384	1.091E+01	0.0309	6.444E-03	0.0000	1.157E+01	0.0328
Total	1.071E-01	0.0003	1.757E+02	0.4976	0.000E+00	0.0000	1.547E+02	0.4384	1.091E+01	0.0309	6.444E-03	0.0000	1.157E+01	0.0328

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.530E+02	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.530E+02	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	1.091E+02	0.2333	1.764E+02	0.3770	1.049E+00	0.0022	1.580E+02	0.3378	1.100E+01	0.0235	1.493E-02	0.0000	1.219E+01	0.0261
Total	1.091E+02	0.2333	1.764E+02	0.3770	1.049E+00	0.0022	1.580E+02	0.3378	1.100E+01	0.0235	1.493E-02	0.0000	1.219E+01	0.0261

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	[illegible]	0.000E+00	0.0000	4.678E+02	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.678E+02	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	3.833E+02	0.5032	1.800E+02	0.2363	6.995E+00	0.0092	1.666E+02	0.2187	1.137E+01	0.0149	2.925E-02	0.0000	1.346E+01	0.0177
Total	3.833E+02	0.5032	1.800E+02	0.2363	6.995E+00	0.0092	1.666E+02	0.2187	1.137E+01	0.0149	2.925E-02	0.0000	1.346E+01	0.0177

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.618E+02	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.618E+02	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	1.226E+03	0.7315	1.952E+02	0.1164	3.173E+01	0.0189	1.936E+02	0.1155	1.278E+01	0.0076	5.952E-02	0.0000	1.678E+01	0.0100
Total	1.226E+03	0.7315	1.952E+02	0.1164	3.173E+01	0.0189	1.936E+02	0.1155	1.278E+01	0.0076	5.952E-02	0.0000	1.678E+01	0.0100

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.676E+03	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.676E+03	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	1.918E+03	0.7893	2.087E+02	0.0859	5.390E+01	0.0222	2.159E+02	0.0888	1.401E+01	0.0058	8.041E-02	0.0000	1.935E+01	0.0080
Total	1.918E+03	0.7893	2.087E+02	0.0859	5.390E+01	0.0222	2.159E+02	0.0888	1.401E+01	0.0058	8.041E-02	0.0000	1.935E+01	0.0080

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.430E+03	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.430E+03	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	1.987E+03	0.7932	2.100E+02	0.0838	5.614E+01	0.0224	2.181E+02	0.0870	1.413E+01	0.0056	8.245E-02	0.0000	1.960E+01	0.0078
Total	1.987E+03	0.7932	2.100E+02	0.0838	5.614E+01	0.0224	2.181E+02	0.0870	1.413E+01	0.0056	8.245E-02	0.0000	1.960E+01	0.0078

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.505E+03	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.505E+03	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	1.987E+03	0.7932	2.100E+02	0.0838	5.613E+01	0.0224	2.181E+02	0.0870	1.413E+01	0.0056	8.244E-02	0.0000	1.960E+01	0.0078
Total	1.987E+03	0.7932	2.100E+02	0.0838	5.613E+01	0.0224	2.181E+02	0.0870	1.413E+01	0.0056	8.244E-02	0.0000	1.960E+01	0.0078

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.505E+03	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.505E+03	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	1.986E+03	0.7253	2.099E+02	0.0767	5.611E+01	0.0205	2.180E+02	0.0796	1.413E+01	0.0052	8.241E-02	0.0000	1.959E+01	0.0072
Total	1.986E+03	0.7253	2.099E+02	0.0767	5.611E+01	0.0205	2.180E+02	0.0796	1.413E+01	0.0052	8.241E-02	0.0000	1.959E+01	0.0072

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	2.085E+02	0.0761	7.174E-01	0.0003	0.000E+00	0.0000	2.287E+01	0.0084	1.579E+00	0.0006	6.957E-01	0.0003	2.738E+03	1.0000
Total	2.085E+02	0.0761	7.174E-01	0.0003	0.000E+00	0.0000	2.287E+01	0.0084	1.579E+00	0.0006	6.957E-01	0.0003	2.738E+03	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+03 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	1.984E+03	0.6352	2.097E+02	0.0671	5.604E+01	0.0179	2.177E+02	0.0697	1.411E+01	0.0045	8.231E-02	0.0000	1.957E+01	0.0063
Total	1.984E+03	0.6352	2.097E+02	0.0671	5.604E+01	0.0179	2.177E+02	0.0697	1.411E+01	0.0045	8.231E-02	0.0000	1.957E+01	0.0063

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+03 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	5.536E+02	0.1773	1.905E+00	0.0006	0.000E+00	0.0000	6.073E+01	0.0194	4.194E+00	0.0013	1.847E+00	0.0006	3.123E+03	1.0000
Total	5.536E+02	0.1773	1.905E+00	0.0006	0.000E+00	0.0000	6.073E+01	0.0194	4.194E+00	0.0013	1.847E+00	0.0006	3.123E+03	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+04 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	1.976E+03	0.7840	2.088E+02	0.0829	5.581E+01	0.0221	2.168E+02	0.0860	1.405E+01	0.0056	8.197E-02	0.0000	1.948E+01	0.0077
Total	1.976E+03	0.7840	2.088E+02	0.0829	5.581E+01	0.0221	2.168E+02	0.0860	1.405E+01	0.0056	8.197E-02	0.0000	1.948E+01	0.0077

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+04 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	2.592E+01	0.0103	8.918E-02	0.0000	0.000E+00	0.0000	2.843E+00	0.0011	1.963E-01	0.0001	8.648E-02	0.0000	2.520E+03	1.0000
Total	2.592E+01	0.0103	8.918E-02	0.0000	0.000E+00	0.0000	2.843E+00	0.0011	1.963E-01	0.0001	8.648E-02	0.0000	2.520E+03	1.0000

*Sum of all water independent and dependent pathways.

Dose/Source Ratios Summed Over All Pathways, (mrem/yr)/(pCi/g)

Nuclide (i)	t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03	3.000E+03	1.000E+04
Th-232	2.338E+00	3.098E+00	5.045E+00	1.110E+0.	1.609E+01	1.659E+01	1.659E+01	1.814E+01	2.068E+01	1.669E+01

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 5 mrem/yr

Nuclide (i)	t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03	3.000E+03	1.000E+04
Th-232	2.139E+00	1.614E+00	9.910E-01	4.504E-01	3.107E-01	3.014E-01	3.014E-01	2.757E-01	2.417E-01	2.996E-01

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
at tmin = time of minimum single radionuclide soil guideline
and at tmax = time of maximum total dose = 2287.2 ± 0.7 years

Nuclide (i)	Initial pCi/g	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Th-232	1.510E+02	2287.2 ± 0.7	2.220E+01	2.252E-01	2.220E+01	2.252E-01

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Part I: Mixture Sums and Single Radionuclide Guidelines

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	5.700E+03	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	7.000E+00	1.000E+00	---	THICKO
R011	Length parallel to aquifer flow (m)	1.000E+02	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	5.000E+00	1.000E+02	---	BRLD
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	3.000E+03	3.000E+03	---	T(9)
R011	Times for calculations (yr)	1.000E+04	1.000E+04	---	T(10)
R012	Initial principal radionuclide (pCi/g): Th-232	1.510E+02	0.000E+00	---	S(3)
R012	Concentration in groundwater (pCi/L): Th-232	not used	0.000E+00	---	W(3)
R013	Cover depth (m)	1.000E+00	0.000E+00	---	COVERO
R013	Density of cover material (g/cm**3)	1.600E+00	1.600E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	1.000E-06	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.600E+00	1.600E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-06	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	4.000E-01	4.000E-01	---	TPCZ
R013	Contaminated zone effective porosity	2.000E-01	2.000E-01	---	EPCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	1.000E+01	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	5.300E+00	5.300E+00	---	BCZ
R013	Evapotranspiration coefficient	6.000E-01	6.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	1.000E+00	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	2.000E-01	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	1.000E+06	1.000E+06	---	WAREA
R014	Density of saturated zone (g/cm**3)	1.600E+00	1.600E+00	---	DENSAQ
R014	Saturated zone total porosity	4.000E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	2.000E-01	2.000E-01	---	EPSZ
R014	Saturated zone hydraulic conductivity (m/yr)	1.000E+02	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	2.000E-02	2.000E-02	---	HGWT
R014	Saturated zone b parameter	5.300E+00	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	1.000E-03	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	1.000E+01	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	---	MODEL
R014	Individual's use of groundwater (m**3/yr)	not used	1.500E+02	---	UW
R015	Number of unsaturated zone strata	1	1	---	NS
R015	Unsat. zone 1, thickness (m)	4.000E+00	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	1.600E+00	1.600E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	4.000E-01	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	2.000E-01	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	5.300E+00	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	1.000E+02	1.000E+02	---	HCUZ(1)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for Th-232				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCACTC(3)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCACTU(3,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCACTS(3)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	5.952E-07	RLEACH(3)
R016	Distribution coefficients for daughter Ra-228				
R016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCACTC(1)
R016	Unsaturated zone 1 (cm**3/g)	7.000E+01	7.000E+01	---	DCACTU(1,1)
R016	Saturated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCACTS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	5.088E-04	RLEACH(1)
R016	Distribution coefficients for daughter Th-228				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCACTC(2)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCACTU(2,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCACTS(2)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	5.952E-07	RLEACH(2)
R017	Inhalation rate (m**3/yr)	8.400E+03	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	2.000E-04	2.000E-04	---	MLINH
R017	Dilution length for airborne dust, inhalation (m)	3.000E+00	3.000E+00	---	LM
R017	Occupancy factor, inhalation	4.500E-01	4.500E-01	---	FO3
R017	Occupancy and shielding factor, external gamma	6.000E-01	6.000E-01	---	FO1
R017	Shape factor, external gamma	1.000E+00	1.000E+00	---	FS1
R017	Fractions of annular areas within AREA:				
R017	Outer annular radius (m) = √(1/π)	not used	1.000E+00	---	FRACA(1)
R017	Outer annular radius (m) = √(10/π)	not used	1.000E+00	---	FRACA(2)
R017	Outer annular radius (m) = √(20/π)	not used	1.000E+00	---	FRACA(3)
R017	Outer annular radius (m) = √(50/π)	not used	1.000E+00	---	FRACA(4)
R017	Outer annular radius (m) = √(100/π)	not used	1.000E+00	---	FRACA(5)
R017	Outer annular radius (m) = √(200/π)	not used	1.000E+00	---	FRACA(6)
R017	Outer annular radius (m) = √(500/π)	not used	1.000E+00	---	FRACA(7)
R017	Outer annular radius (m) = √(1000/π)	not used	1.000E+00	---	FRACA(8)
R017	Outer annular radius (m) = √(5000/π)	not used	1.000E+00	---	FRACA(9)
R017	Outer annular radius (m) = √(1.E+04/π)	not used	1.000E+00	---	FRACA(10)
R017	Outer annular radius (m) = √(1.E+05/π)	not used	0.000E+00	---	FRACA(11)
R017	Outer annular radius (m) = √(1.E+06/π)	not used	0.000E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	1.600E+02	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	1.400E+01	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	9.200E+01	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	6.300E+01	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	5.400E+00	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	9.000E-01	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	3.650E+01	0.000E+00	---	SOIL
R018	Drinking water intake (L/yr)	4.100E+02	4.100E+02	---	DWI
R018	Fraction of drinking water from site	1.000E+00	1.000E+00	---	FDW
R019	Livestock fodder intake for meat (kg/day)	6.800E+01	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	5.500E+01	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	5.000E+01	5.000E+01	---	LWI5

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R019	Livestock water intake for milk (L/day)	1.600E+02	1.600E+02	---	LWI6
R019	Mass loading for foliar deposition (g/m**3)	1.000E-04	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	9.000E-01	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Livestock water fraction from ground water	1.000E+00	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	1.000E+00	1.000E+00	---	FGWIR
R021	Total porosity of the cover material	4.000E-01	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	1.000E-01	1.000E-01	---	TPFL
R021	Volumetric water content of the cover material	5.000E-02	5.000E-02	---	PH2OCV
RC21	Volumetric water content of the foundation	1.000E-02	1.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	2.000E-06	2.000E-06	---	DIFCV
R021	in foundation material	2.000E-08	2.000E-08	---	DIFFL
R021	in contaminated zone soil	2.000E-06	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	2.000E+00	2.000E+00	---	HMIX
R021	Average annual wind speed (m/sec)	2.000E+00	2.000E+00	---	WIND
R021	Average building air exchange rate (1/hr)	1.000E+00	1.000E+00	---	REXG
R021	Height of the building (room) (m)	2.500E+00	2.500E+00	---	HRM
R021	Building interior area factor	1.000E+00	1.000E+00	---	FAI
R021	Bulk density of building foundation (g/cm**3)	2.400E+00	2.400E+00	---	DENSFL
R021	Thickness of building foundation (m)	1.500E-01	1.500E-01	---	FLOOR
R021	Building depth below ground surface (m)	1.000E+00	1.000E+00	---	DMFL
R021	Fraction of time spent indoors	5.000E-01	5.000E-01	---	FIND
R021	Fraction of time spent outdoors (on site)	2.500E-01	2.500E-01	---	FOTD
R021	Emanating power of Rn-222 gas	not used	2.000E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	1.000E-01	1.000E-01	---	EMANA(2)

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	active
2 -- inhalation	active
3 -- plant ingestion	active
4 -- meat ingestion	active
5 -- milk ingestion	active
6 -- aquatic foods	active
7 -- drinking water	active
8 -- radon	active
9 -- soil ingestion	active

Contaminated Zone Dimensions	
Area:	5700.00 square meters
Thickness:	7.00 meters
Cover Depth:	1.00 meters

Initial Soil Concentrations, pCi/g	
Th-232	1.510E+02

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 5 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0 000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03	3.000E+03	1.000E+04
TDOSE(t):	2.200E-14	6.801E-03	3.952E-02	1.706E-01	2.870E-01	2.989E-01	2.994E-01	2.347E+02	6.226E+02	2.946E+01
M(t):	4.399E-15	1.360E-03	7.903E-03	3.412E-02	5.740E-02	5.978E-02	5.988E-02	4.693E+01	1.245E+02	5.891E+00

Maximum TDOSE(t): 8.502E+02 mrem/yr at t = 2287.2 ± 0.7 years

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 2287.2 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract	mrem/yr	fract.	mrem/yr	fract.
Th-232	3.041E-01	0.0004	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	3.041E-01	0.0004	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 2287.2 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	7.561E+02	0.8893	2.602E+00	0.0031	0.000E+00	0.0000	8.294E+01	0.0975	5.728E+00	0.0067	2.523E+00	0.0030	8.502E+02	1.0000
Total	7.561E+02	0.8893	2.602E+00	0.0031	0.000E+00	0.0000	8.294E+01	0.0975	5.728E+00	0.0067	2.523E+00	0.0030	8.502E+02	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	2.200E-14	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	2.200E-14	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.200E-14	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.200E-14	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	6.801E-03	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	6.801E-03	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.801E-03	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.801E-03	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	3.952E-02	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	3.952E-02	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.952E-02	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.952E-02	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	1.706E-01	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	1.706E-01	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.706E-01	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.706E-01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	2.870E-01	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	2.870E-01	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.870E-01	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.870E-01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	2.989E-01	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	2.989E-01	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.989E-01	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.989E-01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	2.994E-01	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	2.994E-01	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.994E-01	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.994E-01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	3.011E-01	0.0013	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	3.011E-01	0.0013	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	2.085E+02	0.8885	7.174E-01	0.0031	0.000E+00	0.0000	2.287E+01	0.0975	1.579E+00	0.0067	6.957E-01	0.0030	2.347E+02	1.0000
Total	2.085E+02	0.8885	7.174E-01	0.0031	0.000E+00	0.0000	2.287E+01	0.0975	1.579E+00	0.0067	6.957E-01	0.0030	2.347E+02	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+03 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	3.058E-01	0.0005	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	3.058E-01	0.0005	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+03 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	5.536E+02	0.8892	1.905E+00	0.0031	0.000E+00	0.0000	6.073E+01	0.0975	4.194E+00	0.0067	1.847E+00	0.0030	6.226E+02	1.0000
Total	5.536E+02	0.8892	1.905E+00	0.0031	0.000E+00	0.0000	6.073E+01	0.0975	4.194E+00	0.0067	1.847E+00	0.0030	6.226E+02	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+04 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	3.232E-01	0.0110	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	3.232E-01	0.0110	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+04 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	2.592E+01	0.8799	8.918E-02	0.0030	0.000E+00	0.0000	2.843E+00	0.0965	1.963E-01	0.0067	8.648E-02	0.0029	2.946E+01	1.0000
Total	2.592E+01	0.8799	8.918E-02	0.0030	0.000E+00	0.0000	2.843E+00	0.0965	1.963E-01	0.0067	8.648E-02	0.0029	2.946E+01	1.0000

*Sum of all water independent and dependent pathways.

Dose/Source Ratios Summed Over All Pathways, (mrem/yr)/(pCi/g)

Nuclide (i)	t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03	3.000E+03	1.000E+04
Th-232	1.457E-16	4.504E-05	2.617E-04	1.130E-03	1.901E-03	1.980E-03	1.983E-03	1.554E+00	4.123E+00	1.951E-01

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 5 mrem/yr

Nuclide (i)	t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03	3.000E+03	1.000E+04
Th-232	*1.092E+05	*1.092E+05	1.911E+04	4.426E+03	2.631E+03	2.526E+03	2.522E+03	3.217E+00	1.213E+00	2.563E+01

*At specific activity limit

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
at tmin = time of minimum single radionuclide soil guideline
and at tmax = time of maximum total dose = 2287.2 ± 0.7 years

Nuclide (i)	Initial pCi/g	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Th-232	1.510E+02	2287.2 ± 0.7	5.630E+00	8.880E-01	5.630E+00	8.880E-01

Table of Contents

Part I: Mixture Sums and Single Radionuclide Guidelines

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	5.700E+03	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	7.000E+00	1.000E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	1.000E+02	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	5.000E+00	1.000E+02	---	BRLD
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	3.000E+03	3.000E+03	---	T(9)
R011	Times for calculations (yr)	1.000E+04	1.000E+04	---	T(10)
R012	Initial principal radionuclide (pCi/g): Th-228	1.510E+02	0.000E+00	---	S(2)
R012	Initial principal radionuclide (pCi/g): Th-232	1.510E+02	0.000E+00	---	S(3)
R012	Concentration in groundwater (pCi/L): Th-228	not used	0.000E+00	---	W(2)
R012	Concentration in groundwater (pCi/L): Th-232	not used	0.000E+00	---	W(3)
R013	Cover depth (m)	1.000E+00	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	1.600E+00	1.600E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.600E+00	1.600E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-06	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	4.000E-01	4.000E-01	---	TPCZ
R013	Contaminated zone effective porosity	2.000E-01	2.000E-01	---	EPCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	1.000E+01	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	5.300E+00	5.300E+00	---	BCZ
R013	Evapotranspiration coefficient	6.000E-01	6.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	1.000E+00	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	2.000E-01	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	1.000E+06	1.000E+06	---	WAREA
R014	Density of saturated zone (g/cm**3)	1.600E+00	1.600E+00	---	DENSAQ
R014	Saturated zone total porosity	4.000E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	2.000E-01	2.000E-01	---	EPSZ
R014	Saturated zone hydraulic conductivity (m/yr)	1.000E+02	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	2.000E-02	2.000E-02	---	HGWT
R014	Saturated zone b parameter	5.300E+00	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	1.000E-03	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	1.000E+01	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	---	MODEL
R014	Individual's use of groundwater (m**3/yr)	not used	1.500E+02	---	UW
R015	Number of unsaturated zone strata	1	1	---	NS

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R015	Unsat. zone 1, thickness (m)	4.000E+00	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	1.600E+00	1.600E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	4.000E-01	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	2.000E-01	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	5.300E+00	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	1.000E+02	1.000E+02	---	HCUZ(1)
R016	Distribution coefficients for Th-228				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCACTC(2)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCACTU(2,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCACTS(2)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	5.952E-07	RLEACH(2)
R016	Distribution coefficients for Th-232				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCACTC(3)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCACTU(3,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCACTS(3)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	5.952E-07	RLEACH(3)
R016	Distribution coefficients for daughter Ra-228				
R016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCACTC(1)
R016	Unsaturated zone 1 (cm**3/g)	7.000E+01	7.000E+01	---	DCACTU(1,1)
R016	Saturated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCACTS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	5.088E-04	RLEACH(1)
R017	Inhalation rate (m**3/yr)	8.400E+03	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	2.000E-04	2.000E-04	---	MLINH
R017	Dilution length for airborne dust, inhalation (m)	3.000E+00	3.000E+00	---	LM
R017	Occupancy factor, inhalation	4.500E-01	4.500E-01	---	FOI
R017	Occupancy and shielding factor, external gamma	6.000E-01	6.000E-01	---	FO1
R017	Shape factor, external gamma	1.000E+00	1.000E+00	---	FS1
R017	Fractions of annular areas within AREA:				
R017	Outer annular radius (m) = √(1/π)	not used	1.000E+00	---	FRACA(1)
R017	Outer annular radius (m) = √(10/π)	not used	1.000E+00	---	FRACA(2)
R017	Outer annular radius (m) = √(20/π)	not used	1.000E+00	---	FRACA(3)
R017	Outer annular radius (m) = √(50/π)	not used	1.000E+00	---	FRACA(4)
R017	Outer annular radius (m) = √(100/π)	not used	1.000E+00	---	FRACA(5)
R017	Outer annular radius (m) = √(200/π)	not used	1.000E+00	---	FRACA(6)
R017	Outer annular radius (m) = √(500/π)	not used	1.000E+00	---	FRACA(7)
R017	Outer annular radius (m) = √(1000/π)	not used	1.000E+00	---	FRACA(8)
R017	Outer annular radius (m) = √(5000/π)	not used	1.000E+00	---	FRACA(9)
R017	Outer annular radius (m) = √(1.E+04/π)	not used	1.000E+00	---	FRACA(10)
R017	Outer annular radius (m) = √(1.E+05/π)	not used	0.000E+00	---	FRACA(11)
R017	Outer annular radius (m) = √(1.E+06/π)	not used	0.000E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	1.600E+02	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	1.400E+01	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	9.200E+01	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	6.300E+01	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	5.400E+00	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	9.000E-01	9.000E-01	---	DIET(6)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R018	Soil ingestion rate (g/yr)	3.650E+01	0.000E+00	---	SOIL
R018	Drinking water intake (L/yr)	4.100E+02	4.100E+02	---	DWI
R018	Fraction of drinking water from site	1.000E+00	1.000E+00	---	FDW
R019	Livestock fodder intake for meat (kg/day)	6.800E+01	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	5.500E+01	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	5.000E+01	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	1.600E+02	1.600E+02	---	LWI6
R019	Mass loading for foliar deposition (g/m**3)	1.000E-04	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	9.000E-01	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Livestock water fraction from ground water	1.000E+00	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	1.000E+00	1.000E+00	---	FGWIR
R021	Total porosity of the cover material	4.000E-01	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	1.000E-01	1.000E-01	---	TPFL
R021	Volumetric water content of the cover material	5.000E-02	5.000E-02	---	PH2OCV
R021	Volumetric water content of the foundation	1.000E-02	1.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	2.000E-06	2.000E-06	---	DIFCV
R021	in foundation material	2.000E-08	2.000E-08	---	DIFFL
R021	in contaminated zone soil	2.000E-06	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	2.000E+00	2.000E+00	---	HMIX
R021	Average annual wind speed (m/sec)	2.000E+00	2.000E+00	---	WIND
R021	Average building air exchange rate (1/hr)	1.000E+00	1.000E+00	---	REXG
R021	Height of the building (room) (m)	2.500E+00	2.500E+00	---	HRM
R021	Building interior area factor	1.000E+00	1.000E+00	---	FAI
R021	Bulk density of building foundation (g/cm**3)	2.400E+00	2.400E+00	---	DENSFL
R021	Thickness of building foundation (m)	1.500E-01	1.500E-01	---	FLOOR
R021	Building depth below ground surface (m)	1.000E+00	1.000E+00	---	DMFL
R021	Fraction of time spent indoors	5.000E-01	5.000E-01	---	FIND
R021	Fraction of time spent outdoors (on site)	2.500E-01	2.500E-01	---	FOTD
R021	Emanating power of Rn-222 gas	not used	2.000E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	1.000E-01	1.000E-01	---	EMANA(2)

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	active
2 -- inhalation	active
3 -- plant ingestion	active
4 -- meat ingestion	active
5 -- milk ingestion	active
6 -- aquatic foods	active
7 -- drinking water	active
8 -- radon	active
9 -- soil ingestion	active

Contaminated Zone Dimensions	
Area:	5700.00 square meters
Thickness:	7.00 meters
Cover Depth:	1.00 meters

Initial Soil Concentrations, pCi/g	
Th-228	1.510E+02
Th-232	1.510E+02

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 5 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03	3.000E+03	1.000E+04
TDOSE(t):	2.871E-01	2.084E-01	1.398E-01	1.941E-01	3.701E-01	6.985E-01	5.537E+01	[illegible].738E+03	3.123E+03	2.520E+03
M(t):	5.742E-02	4.167E-02	2.797E-02	3.881E-02	7.402E-02	1.397E-01	1.107E+01	5.477E+02	6.247E+02	5.040E+02

M-ximum TDOSE(t): 3.352E+03 mrem/yr at t = 2287.2 ± 0.7 years

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 2287.[illegible] years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	1.985E+03	0.5921	2.098E+02	0.0626	5.607E+01	0.0167	2.178E+02	0.0650	1.411E+01	0.0042	8.234E-02	0.0000	1.957E+01	0.0058
Total	1.985E+03	0.5921	2.098E+02	0.0626	5.607E+01	0.0167	2.178E+02	0.0650	1.411E+01	0.0042	8.234E-02	0.0000	1.957E+01	0.0058

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 2287.2 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	7.561E+02	0.2256	2.602E+00	0.0008	0.000E+00	0.0000	8.294E+01	0.0247	5.728E+00	0.0017	2.523E+00	0.0008	3.352E+03	1.0000
Total	7.561E+02	0.2256	2.602E+00	0.0008	0.000E+00	0.0000	8.294E+01	0.0247	5.728E+00	0.0017	2.523E+00	0.0008	3.352E+03	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-228	2.871E-01	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	2.200E-14	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	2.871E-01	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.871E-01	1.0000
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.200E-14	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.871E-01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-228	2.015E-01	0.9671	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	6.862E-03	0.0329	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	2.084E-01	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.015E-01	0.9671
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.862E-03	0.0329
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.084E-01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-228	2.015E-01	0.9671	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	6.862E-03	0.0329	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	2.084E-01	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) fo: Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.015E-01	0.9671
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.862E-03	0.0329
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.084E-01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-228	9.928E-02	0.7100	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	4.055E-02	0.2900	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	1.398E-01	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.928E-02	0.7100
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.055E-02	0.2900
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.398E-01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-228	8.333E-03	0.0429	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	1.857E-01	0.9571	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	1.941E-01	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.333E-03	0.0429
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.857E-01	0.9571
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.941E-01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-228	7.022E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	3.701E-01	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	3.701E-01	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.022E-06	0.0000
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.701E-01	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.701E-01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-228	1.220E-16	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	6.985E-01	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	6.985E-01	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.220E-16	0.0000
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.985E-01	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.985E-01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	3.865E+00	0.0698	0.000E+00	0.0000	0.000E+00	0.0000	4.836E+01	0.8735	3.119E+00	0.0563	1.799E-02	0.0003	0.000E+00	0.0000
Total	3.865E+00	0.0698	0.000E+00	0.0000	0.000E+00	0.0000	4.836E+01	0.8735	3.119E+00	0.0563	1.799E-02	0.0003	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.537E+01	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.537E+01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	1.986E+03	0.7253	2.099E+02	0.0767	5.611E+01	0.0205	2.180E+02	0.0796	1.413E+01	0.0052	8.241E-02	0.0000	1.959E+01	0.0072
Total	1.986E+03	0.7253	2.099E+02	0.0767	5.611E+01	0.0205	2.180E+02	0.0796	1.413E+01	0.0052	8.241E-02	0.0000	1.959E+01	0.0072

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	2.085E+02	0.0761	7.174E-01	0.0003	0.000E+00	0.0000	2.287E+01	0.0084	1.579E+00	0.0006	6.957E-01	0.0003	2.738E+03	1.0000
Total	2.085E+02	0.0761	7.174E-01	0.0003	0.000E+00	0.0000	2.287E+01	0.0084	1.579E+00	0.0006	6.957E-01	0.0003	2.738E+03	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+03 years

Water Independent Pathways

Radio-Nuclide	Ground mrem/yr	Ground fract.	Dust mrem/yr	Dust fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	1.984E+03	0.6352	2.097E+02	0.0671	5.604E+01	0.0179	2.177E+02	0.0697	1.411E+01	0.0045	8.231E-02	0.0000	1.957E+01	0.0063
Total	1.984E+03	0.6352	2.097E+02	0.0671	5.604E+01	0.0179	2.177E+02	0.0697	1.411E+01	0.0045	8.231E-02	0.0000	1.957E+01	0.0063

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+03 years

Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	5.536E+02	0.1773	1.905E+00	0.0006	0.000E+00	0.0000	6.073E+01	0.0194	4.194E+00	0.0013	1.847E+00	0.0006	3.123E+03	1.0000
Total	5.536E+02	0.1773	1.905E+00	0.0006	0.000E+00	0.0000	6.073E+01	0.0194	4.194E+00	0.0013	1.847E+00	0.0006	3.123E+03	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+04 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	1.976E+03	0.7840	2.088E+02	0.0829	5.581E+01	0.0221	2.168E+02	0.0860	1.405E+01	0.0056	8.197E-02	0.0000	1.948E+01	0.0077
Total	1.976E+03	0.7840	2.088E+02	0.0829	5.581E+01	0.0221	2.168E+02	0.0860	1.405E+01	0.0056	8.197E-02	0.0000	1.948E+01	0.0077

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+04 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	2.592E+01	0.0103	8.918E-02	0.0000	0.000E+00	0.0000	2.843E+00	0.0011	1.963E-01	0.0001	8.648E-02	0.0000	2.520E+03	1.0000
Total	2.592E+01	0.0103	8.918E-02	0.0000	0.000E+00	0.0000	2.843E+00	0.0011	1.963E-01	0.0001	8.648E-02	0.0000	2.520E+03	1.0000

*Sum of all water independent and dependent pathways.

Dose/Source Ratios Summed Over All Pathways, (mrem/yr)/(pCi/g)

Nuclide (i)	t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03	3.000E+03	1.000E+04
Th-228	1.901E-03	1.334E-03	6.575E-04	5.519E-05	4.650E-08	8.077E-19	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Th-232	1.457E-16	4.545E-05	2.686E-04	1.230E-03	2.451E-03	4.626E-03	3.667E-01	1.814E+01	2.068E+01	1.669E+01

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 5 mrem/yr

Nuclide (i)	t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03	3.000E+03	1.000E+04
Th-228	2.630E+03	3.747E+03	7.605E+03	9.060E+04	1.075E+08	*8.192E+14	*8.192E+14	*8.192E+14	*8.192E+14	*8.192E+14
Th-232	*1.092E+05	*1.092E+05	1.862E+04	4.065E+03	2.040E+03	1.081E+03	1.364E+01	2.757E-01	2.417E-01	2.996E-01

*At specific activity limit

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
at tmin = time of minimum single radionuclide soil guideline
and at tmax = time of maximum total dose = 2287.2 ± 0.7 years

Nuclide (i)	Initial pCi/g	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Th-228	1.510E+02	0.000E+00	1.901E-03	2.630E+03	0.000E+00	*8.192E+14
Th-232	1.510E+02	2287.2 ± 0.7	2.220E+01	2.252E-01	2.220E+01	2.252E-01

*At specific activity limit

APPENDIX M

RESRAD Model Calculations
for Groundwater Transport

Summary : SALZBURG RESIDUAL ANALYSIS - VARY DISTRIBUTION COEFF
File : SALZ3.DAT

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Part I: Mixture Sums and Single Radionuclide Guidelines

Summary : SALZBURG RESIDUAL ANALYSIS - VARY DISTRIBUTION COEFF
File   : SALZ3.DAT

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	5.700E+03	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	7.000E+00	1.000E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	1.000E+02	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	5.000E+00	1.000E+02	---	BRLD
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	3.000E+03	3.000E+03	---	T(9)
R011	Times for calculations (yr)	1.000E+04	1.000E+04	---	T(10)
R012	Initial principal radionuclide (pCi/g): Th-232	1.510E+02	0.000E+00	---	S(3)
R012	Concentration in groundwater (pCi/L): Th-232	not used	0.000E+00	---	W(3)
R013	Cover depth (m)	1.000E+00	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	1.600E+00	1.600E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	1.000E-06	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.600E+00	1.600E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-06	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	4.000E-01	4.000E-01	---	TPCZ
R013	Contaminated zone effective porosity	2.000E-01	2.000E-01	---	EPCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	1.000E+01	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	5.300E+00	5.300E+00	---	BCZ
R013	Evapotranspiration coefficient	6.000E-01	6.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	1.000E+00	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	2.000E-01	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	1.000E+06	1.000E+06	---	WAREA
R014	Density of saturated zone (g/cm**3)	1.600E+00	1.600E+00	---	DENSAQ
R014	Saturated zone total porosity	4.000E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	2.000E-01	2.000E-01	---	EPSZ
R014	Saturated zone hydraulic conductivity (m/yr)	1.000E+02	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	2.000E-02	2.000E-02	---	HGWT
R014	Saturated zone b parameter	5.300E+00	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	1.000E-03	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	1.000E+01	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	---	MODEL
R014	Individual's use of groundwater (m**3/yr)	not used	1.500E+02	---	UW
R015	Number of unsaturated zone strata	1	1	---	NS

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R015	Unsat. zone 1, thickness (m)	4.000E+00	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	1.600E+00	1.600E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	4.000E-01	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	2.000E-01	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	5.300E+00	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	1.000E+02	1.000E+02	---	HCUZ(1)
R016	Distribution coefficients for Th-232				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCACTC(3)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCACTU(3,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCACTS(3)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	5.952E-07	RLEACH(3)
R016	Distribution coefficients for daughter Ra-228				
R016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCACTC(1)
R016	Unsaturated zone 1 (cm**3/g)	7.000E+01	7.000E+01	---	DCACTU(1,1)
R016	Saturated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCACTS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	5.088E-04	RLEACH(1)
R016	Distribution coefficients for daughter Th-228				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCACTC(2)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCACTU(2,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCACTS(2)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	5.952E-07	RLEACH(2)
R017	Inhalation rate (m**3/yr)	8.400E+03	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	2.000E-04	2.000E-04	---	MLINH
R017	Dilution length for airborne dust, inhalation (m)	3.000E+00	3.000E+00	---	LM
R017	Occupancy factor, inhalation	4.500E-01	4.500E-01	---	FO3
R017	Occupancy and shielding factor, external gamma	6.000E-01	6.000E-01	---	FO1
R017	Shape factor, external gamma	1.000E+00	1.000E+00	---	FS1
R017	Fractions of annular areas within AREA:				
R017	Outer annular radius (m) = $\sqrt{(1/\pi)}$	not used	1.000E+00	---	FRACA(1)
R017	Outer annular radius (m) = $\sqrt{(10/\pi)}$	not used	1.000E+00	---	FRACA(2)
R017	Outer annular radius (m) = $\sqrt{(20/\pi)}$	not used	1.000E+00	---	FRACA(3)
R017	Outer annular radius (m) = $\sqrt{(50/\pi)}$	not used	1.000E+00	---	FRACA(4)
R017	Outer annular radius (m) = $\sqrt{(100/\pi)}$	not used	1.000E+00	---	FRACA(5)
R017	Outer annular radius (m) = $\sqrt{(200/\pi)}$	not used	1.000E+00	---	FRACA(6)
R017	Outer annular radius (m) = $\sqrt{(500/\pi)}$	not used	1.000E+00	---	FRACA(7)
R017	Outer annular radius (m) = $\sqrt{(1000/\pi)}$	not used	1.000E+00	---	FRACA(8)
R017	Outer annular radius (m) = $\sqrt{(5000/\pi)}$	not used	1.000E+00	---	FRACA(9)
R017	Outer annular radius (m) = $\sqrt{(1.E+04/\pi)}$	not used	1.000E+00	---	FRACA(10)
R017	Outer annular radius (m) = $\sqrt{(1.E+05/\pi)}$	not used	0.000E+00	---	FRACA(11)
R017	Outer annular radius (m) = $\sqrt{(1.E+06/\pi)}$	not used	0.000E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	1.600E+02	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	1.400E+01	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	9.200E+01	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	6.300E+01	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	5.400E+00	5.400E+00	---	DIET(5)

Summary : SALZBURG RESIDUAL ANALYSIS - VARY DISTRIBUTION COEFF
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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R018	Other seafood consumption (kg/yr)	9.000E-01	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	3.650E+01	0.000E+00	---	SOIL
R018	Drinking water intake (L/yr)	4.100E+02	4.100E+02	---	DWI
R018	Fraction of drinking water from site	1.000E+00	1.000E+00	---	FDW
R019	Livestock fodder intake for meat (kg/day)	6.800E+01	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	5.500E+01	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	5.000E+01	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	1.600E+02	1.600E+02	---	LWI6
R019	Mass loading for foliar deposition (g/m**3)	1.000E-04	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	9.000E-01	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Livestock water fraction from ground water	1.000E+00	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	1.000E+00	1.000E+00	---	FGWIR
R021	Total porosity of the cover material	4.000E-01	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	1.000E-01	1.000E-01	---	TPFL
R021	Volumetric water content of the cover material	5.000E-02	5.000E-02	---	PH2OCV
R021	Volumetric water content of the foundation	1.000E-02	1.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	2.000E-06	2.000E-06	---	DIFCV
R021	in foundation material	2.000E-08	2.000E-08	---	DIFFL
R021	in contaminated zone soil	2.000E-06	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	2.000E+00	2.000E+00	---	HMIX
R021	Average annual wind speed (m/sec)	2.000E+00	2.000E+00	---	WIND
R021	Average building air exchange rate (1/hr)	1.000E+00	1.000E+00	---	REXG
R021	Height of the building (room) (m)	2.500E+00	2.500E+00	---	HRM
R021	Building interior area factor	1.000E+00	1.000E+00	---	FAI
R021	Bulk density of building foundation (g/cm**3)	2.400E+00	2.400E+00	---	DENSFL
R021	Thickness of building foundation (m)	1.500E-01	1.500E-01	---	FLOOR
R021	Building depth below ground surface (m)	1.000E+00	1.000E+00	---	DMFL
R021	Fraction of time spent indoors	5.000E-01	5.000E-01	---	FIND
R021	Fraction of time spent outdoors (on site)	2.500E-01	2.500E-01	---	FOTD
R021	Emanating power of Rn-222 gas	not used	2.000E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	1.000E-01	1.000E-01	---	EMANA(2)

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	active
2 -- inhalation	active
3 -- plant ingestion	active
4 -- meat ingestion	active
5 -- milk ingestion	active
6 -- aquatic foods	active
7 -- drinking water	active
8 -- radon	active
9 -- soil ingestion	active

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Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	5700.00 square meters	Th-232	1.510E+02
Thickness:	7.00 meters		
Cover Depth:	1.00 meters		

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 5 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03	3.000E+03	1.000E+04
TDOSE(t):	2.200E-14	6.801E-03	3.952E-02	1.706E-01	2.870E-01	2.989E-01	2.994E-01	2.347E+02	6.226E+02	2.946E+01
M(t):	4.399E-15	1.360E-03	7.903E-03	3.412E-02	5.740E-02	5.978E-02	5.988E-02	4.693E+01	1.245E+02	5.891E+00

Maximum TDOSE(t): 8.502E+02 mrem/yr at t = 2287.2 ± 0.7 years

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 2287.2 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	3.041E-01	0.0004	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	3.041E-01	0.0004	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 2287.2 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	7.561E+02	0.8893	2.602E+00	0.0031	0.000E+00	0.0000	8.294E+01	0.0975	5.728E+00	0.0067	2.523E+00	0.0030	8.502E+02	1.0000
Total	7.561E+02	0.8893	2.602E+00	0.0031	0.000E+00	0.0000	8.294E+01	0.0975	5.728E+00	0.0067	2.523E+00	0.0030	8.502E+02	1.0000

*Sum of all water independent and dependent pathways.

Summary : SALZBURG RESIDUAL ANALYSIS - VARY DISTRIBUTION COEFF
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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	2.200E-14	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	2.200E-14	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.200E-14	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.200E-14	1.0000

*Sum of all water independent and dependent pathways.

Summary : SALZBURG RESIDUAL ANALYSIS - VARY DISTRIBUTION COEFF
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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	6.801E-03	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	6.801E-03	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.801E-03	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.801E-03	1.0000

*Sum of all water independent and dependent pathways.

Summary : SALZBURG RESIDUAL ANALYSIS - VARY DISTRIBUTION COEFF
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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	3.952E-02	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	3.952E-02	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.952E-02	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.952E-02	1.0000

*Sum of all water independent and dependent pathways.

Summary : SALZBURG RESIDUAL ANALYSIS - VARY DISTRIBUTION COEFF
File : SALZ3.DAT

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	1.706E-01	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	1.706E-01	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.706E-01	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.706E-01	1.0000

*Sum of all water independent and dependent pathways.

Summary : SALZBURG RESIDUAL ANALYSIS - VARY DISTRIBUTION COEFF
File : SALZ3.DAT

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	2.870E-01	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	2.870E-01	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.870E-01	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.870E-01	1.0000

*Sum of all water independent and dependent pathways.

Summary : SALZBURG RESIDUAL ANALYSIS - VARY DISTRIBUTION COEFF
File : SALZ3.DAT

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	2.989E-01	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	2.989E-01	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.989E-01	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.989E-01	1.0000

*Sum of all water independent and dependent pathways.

Summary : SALZBURG RESIDUAL ANALYSIS - VARY DISTRIBUTION COEFF
File : SAL23.DAT

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	2.994E-01	1.0000	0.000E+00	0.0000	0.0[illegible]E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	2.994E-01	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.994E-01	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.994E-01	1.0000

*Sum . all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	3.011E-01	0.0013	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	3.011E-01	0.0013	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	2.085E+02	0.8885	7.174E-01	0.0031	0.000E+00	0.0000	2.287E+01	0.0975	1.579E+00	0.0067	6.957E-01	0.0030	2.347E+02	1.0000
Total	2.085E+02	0.8885	7.174E-01	0.0031	0.000E+00	0.0000	2.287E+01	0.0975	1.579E+00	0.0067	6.957E-01	0.0030	2.347E+02	1.0000

*Sum of all water independent and dependent pathways.

Summary : SALZBURG RESIDUAL ANALYSIS - VARY DISTRIBUTION COEFF
File : SALZ3.DAT

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+03 years

Water Independent Pathways

Radio-Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	3.058E-01	0.0005	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	3.058E-01	0.0005	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+03 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	5.536E+02	0.8892	1.905E+00	0.0031	0.000E+00	0.0000	6.073E+01	0.0975	4.194E+00	0.0067	1.847E+00	0.0030	6.226E+02	1.0000
Total	5.536E+02	0.8892	1.905E+00	0.0031	0.000E+00	0.0000	6.073E+01	0.0975	4.194E+00	0.0067	1.847E+00	0.0030	6.226E+02	1.0000

*Sum of all water independent and dependent pathways.

Summary : SALZBURG RESIDUAL ANALYSIS - VARY DISTRIBUTION COEFF
File : SALZ3.DAT

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+04 years

Water Independent Pathways

Radio-	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	3.232E-01	0.0110	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	3.232E-01	0.0110	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+04 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	2.592E+01	0.8799	8.918E-02	0.0030	0.000E+00	0.0000	2.843E+00	0.0965	1.963E-01	0.0067	8.648E-02	0.0029	2.946E+01	1.0000
Total	2.592E+01	0.8799	8.918E-02	0.0030	0.000E+00	0.0000	2.843E+00	0.0965	1.963E-01	0.0067	8.648E-02	0.0029	2.946E+01	1.0000

*Sum of all water independent and dependent pathways.

Dose/Source Ratios Summed Over All Pathways, (mrem/yr)/(pCi/g)

Nuclide (i)	t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03	3.000E+03	1.000E+04
Th-232	1.457E-16	4.504E-05	2.617E-04	1.130E-03	1.901E-03	1.980E-03	1.983E-03	1.554E+00	4.123E+00	1.951E-01

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 5 mrem/yr

Nuclide (i)	t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03	3.000E+03	1.000E+04
Th-232	*1.092E+05	*1.092E+05	1.911E+04	4.426E+03	2.631E+03	2.526E+03	2.522E+03	3.217E+00	1.213E+00	2.563E+01

*At specific activity limit

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
at tmin = time of minimum single radionuclide soil guideline
and at tmax = time of maximum total dose = 2287.2 ± 0.7 years

Nuclide (i)	Initial pCi/g	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Th-232	1.510E+02	2287.2 ± 0.7	5.630E+00	8.880E-01	5.630E+00	8.880E-01

APPENDIX N

Impacts - BRC Model Analysis
of "Bathtubbing" at the Salzburg Landfill

ONSITE INC. I. JAC

SALISBURG

TRANSPORTATION ICRP IMPACTS BY NUCLIDE (MREM/YR)

NUC	MAX INDIVIDUAL
RA-228	7.497E+01
TH-228	1.217E+02
TH-232	2.978E-03

TOTAL TRANSPORTATION IMPACTS = 1.967E+02

INTRUDER ICRP IMPACTS BY NUCLIDE (MREM/YR)

**** IMPACTS ARE NOT NORMALIZED BY NUMBER OF DISPOSAL FACILITIES ****

NUC	CONSTRUCTION	AGRICULTURE
RA-228	1.223E+02	5.796E+02
TH-228	1.011E+02	4.767E+02
TH-232	1.328E+01	5.341E+01
RADON		0.000E+00
TOTAL NON-NORMALIZED INTRUDER IMPACTS	2.367E+02	1.110E+03

EXPOSED WASTE ICRP IMPACTS BY NUCLIDE (MREM/YR)

**** IMPACTS ARE NOT NORMALIZED BY NUMBER OF DISPOSAL FACILITIES ****

NUC	INTRUDER-AIR	EROSION-AIR	INTRUDER-WATER	EROSION-WATER
RA-228	3.433E+01	4.737E-02	3.746E-02	5.611E-06
TH-228	7.145E+01	1.673E-13	7.297E-03	5.694E-18
TH-232	3.511E+02	4.330E+03	7.608E-02	3.817E-01
TOTAL NON-NORMALIZED EXPOSED WASTE IMPACTS	4.569E+02	4.330E+03	1.208E-01	3.817E-01

OVERFLOW ICRP IMPACTS BY NUCLIDE (MREM/YR)

**** IMPACTS ARE NOT NORMALIZED BY NUMBER OF DISPOSAL FACILITIES ****

NUC	TREATMENT	OVERFLOW	EVAPORATOR
RA-228	6.284E-01	5.759E-01	8.182E-01
TH-228	1.755E-01	1.220E-01	1.241E+01
TH-232	1.207E+00	1.207E+00	6.063E+01
TOTAL NON-NORMALIZED OVERFLOW IMPACTS	2.021E+00	1.905E+00	7.386E+01

GROUNDWATER ICRP IMPACTS BY NUCLIDE (MREM/YR) AT EACH TIME

**** IMPACTS ARE NOT NORMALIZED BY NUMBER OF DISPOSAL FACILITIES ****

FIRST ROW IS INTRUDER WELL

```
SECOND ROW IS POPULATION WELL
THIRD ROW IS SURFACE WATER

   20YR     40YR     60YR     80YR    100YR    120YR    140YR    200YR    400YR    600Y
R  800YR    1K YR    2K YR    5K YR   10K YR   20K YR

  RA-228
 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+0
0 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00
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  TH-228
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0 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00
  TH-232
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0 0.0E+00 0.0E+00 5.5E+01 4.8E+01 1.2E+02 1.5E+02
 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+0
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 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+0
0 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00

  TOTAL NON-NORMALIZED GROUNDWATER IMPACTS
 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+0
0 0.0E+00 0.0E+00 5.5E+01 4.8E+01 1.2E+02 1.5E+02
 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+0
0 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00
 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+0
0 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00 0.0E+00
-------------------------------------------------------
 Total Run Time =   0.8233E-01 Minute(s)
```

APPENDIX O

Dow Drawings B2-040-884040 and B2-041-884040
Showing Topographic Features
and Surface Contours at Salzburg Landfill

See Figure Binder for

Figure O-1 Cells 36 & 37 Site Topographic Map (Sheet 1 of 2)

Figure O-2 Cells 36 & 37 Site Topographic Map (Sheet 2 of 2)

APPENDIX P

Calculation of Impacts
from Dust Released by Transport Trucks

CALCULATION OF IMPACTS FROM DUST RELEASED BY TRANSPORT TRUCKS

PROBLEM

Trucks transporting waste from Bay City or Midland are postulated to allow some dust to escape, resulting in a radiological impact to persons along the transport route.

METHOD

Dose (D) from inhalation is given by the expression:

$$D = \Sigma C_i \times BR \times \tau \times DCF_i$$

where

C_i	=	Concentration of nuclide i (pCi/m^3)
BR	=	Breathing Rate (m^3/y)
τ	=	Fraction of year exposed
DCF_i	=	Dose Conversion Factor for nuclide i (mrem/pCi)

ANALYSIS

Concentration - All isotopes are assumed to be in equilibrium in the waste. The concentration for each isotope is therefore the amount of material released divided into the available volume.

The release of dust is estimated to be equivalent to a truck bottom dump, a rate given in Regulatory Guide 3.59 as 0.002 lb/ton, or 10^{-6} g/g.

With each truck containing 20 tonnes of the higher activity waste from Bay City (188 pCi/g), the release per truckload is:

$$R = (10^{-6}\ g/g)\ (20\ Tonne/Truck)\ (10^{6}\ g/Tonne)\ (188\ pCi/g) = 3760\ pCi$$

The volume is assumed to be a box along the route 10 meters on each side and 3 meters high. The route from Bay City to the Salzburg Landfill is 32 km, giving a volume of $1.94 \times 10^6\ m^3$.

The concentration of each isotope is therefore $2 \times 10^{-4}\ pCi/m^3$. This is assumed to be constant over the period of transport.

Breathing Rate - A standard person breathes $8000/m^3/y$.

Time - It is assumed that the trucks will transport material continuously during working hours for 2 months, or 320 hours.

DCF - Inhalation Dose Conversion Factors were obtained from NUREG/CR-5517, the USER's MANUAL for IMPACTS-BRC, Version 2, published in April, 1990.

	HE (mrem/pCi)
Th-232	1.64
Ra-228	.342
Th-228	.00477
TOTAL	1.99 mrem/pCi

CALCULATION

Since all isotopes are in equal concentrations, we can sum the DCFs and base the calculation on the amount of Th-232.

$$D = C \times BR \times \tau \times DCF$$

$$= (2 \times 10^{-4}\ pCi/m^3)\ (8000\ m^3/y)\ (320h)\ (1y/8760h)\ (1.99\ mRem/pCi)$$

$$D = 0.12\ mRem$$

APPENDIX Q

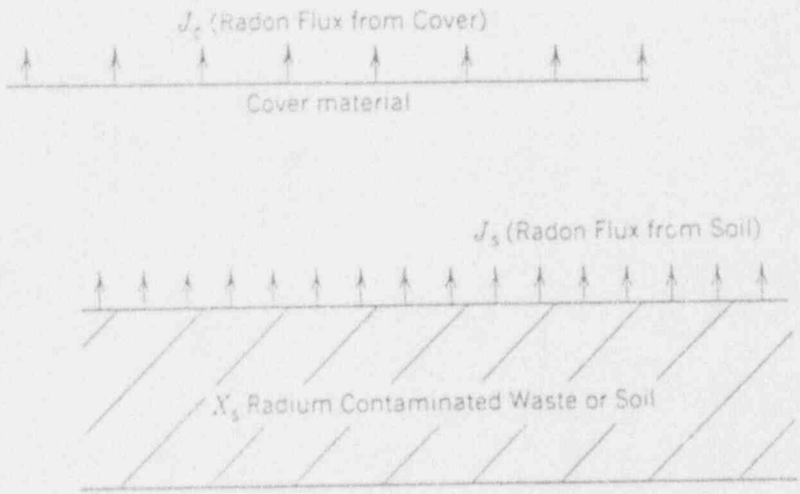
Diffusion Model for Thoron Emanation from the Slag

From: Berlin, R.E. and Stanton, C.C. Radioactive Waste Management, John Wiley & Sons, Inc., New York, 1989, 376-378.

The steady state diffusion equation governing radon diffusion from radium-contaminated soil or waste is:

$$D\frac{d^2C}{dx^2} - \lambda C + \frac{\rho \lambda E}{P} = 0 \tag{1}$$

where C = radon concentration in pore space (pCi/cm^3)
D = diffusion coefficient for radon (cm^2/sec)
λ = decay constant of radon (2.1 x 10^{-6} sec^{-1})
R = specific activity of radium in soil (pCi/g)
ρ = dry bulk density of soil (g/cm^3)
E = radon emanation coefficient
P = total porosity



The radon emission (flux) from the surface of a bulk material is related to the radon concentration in the pore space of the material through Fick's law.

$$J = 10^4 DP \frac{dC}{dx} \tag{2}$$

where J = surface radon flux (pCi/m^2-sec)
X = thickness of bulk material (cm)

Equations (1) and (2) can be solved for the cases where (1) there is no cover over the radium-contaminated waste or soil and (2) there is a cover applied to the waste or soil to reduce the radon flux at the surface.

1. Bulk Waste or Soil: Boundary conditions:

dC/dx (at $X=X_s$) = 0, $C(X=0) = 0$

The solution to (1) and (2) is:

$$J_s = 10^4 R \rho E \sqrt{\frac{D_s}{\lambda}} \tanh \sqrt{\frac{\lambda}{D_s X_s}} \qquad (3)$$

where J_s = radon flux from waste or soil surface (pCi/m²-sec)
s = waste or soil region

2. Covered Waste or Soil: Boundary conditions: Flux is continuous from soil to cover, or

$$\frac{C_s}{1-(1-k)\,m_s} = \frac{C_c}{1-(1-k)\,m_c}$$

and

$$P_s D_s \frac{dC_s}{dx} = P_c D_c \frac{dC_c}{dx}$$

It is also assumed that the radium source term in the cover is negligible. The solution to (1) and (2) is

$$J_c = \frac{2 J_s e^{-b_c X_c}}{[1 + \sqrt{\frac{a_s}{a_c}} \tanh(b_s X_s)] + [1 - \sqrt{\frac{a_s}{a_c}} \tanh(b_s X_s)]\, e^{-2b_c X_c}} \qquad (4)$$

where

$$b_i = \sqrt{\frac{\lambda}{d_i}}$$
$$a_i = P_i^2 [1-(1-k)\, m_i]^2$$
$$m = 10^{-2} \frac{\rho M}{p} = \text{fractional moisture saturation}$$
$$M = \text{moisture content (dry weight percent)}$$
$$K = 0.26 \frac{pCi/cm^3\text{-water}}{pCi/cm^3\text{-air}}$$
$$c = \text{cover material}$$

Table Q-1
Surface flux as a function of cover thickness

Thickness (inches)	Flux-Clay Cover (pCi/m²-sec)	Flux-Soil Cover (pCi/m²-sec)
1.0	347	---
1.5	70	---
2.0	14	---
3.0	0.56	45
4.0	0.022	6.6
5.0	9.1E-04	0.98
6.0	3.7E-07	0.14
12.0	1.6E-13	1.5E-06
24.0	2.9E-30	---

The following parameters were used to solve for equations (1) and (2):

Material	ρ (g/cm^3)	D (cm^2/sec)	P (fraction)	M (%)	m (fraction)
Tailings Pile	1.5	0.013	0.44	11.7	0.4
Clay	1.9	0.0078	0.30	6.3	0.4
Natural Overburden	1.7	0.022	0.37	5.4	0.25

The flux rates through varying cover thickness for both clay and soil are presented in Table Q-1.

APPENDIX R

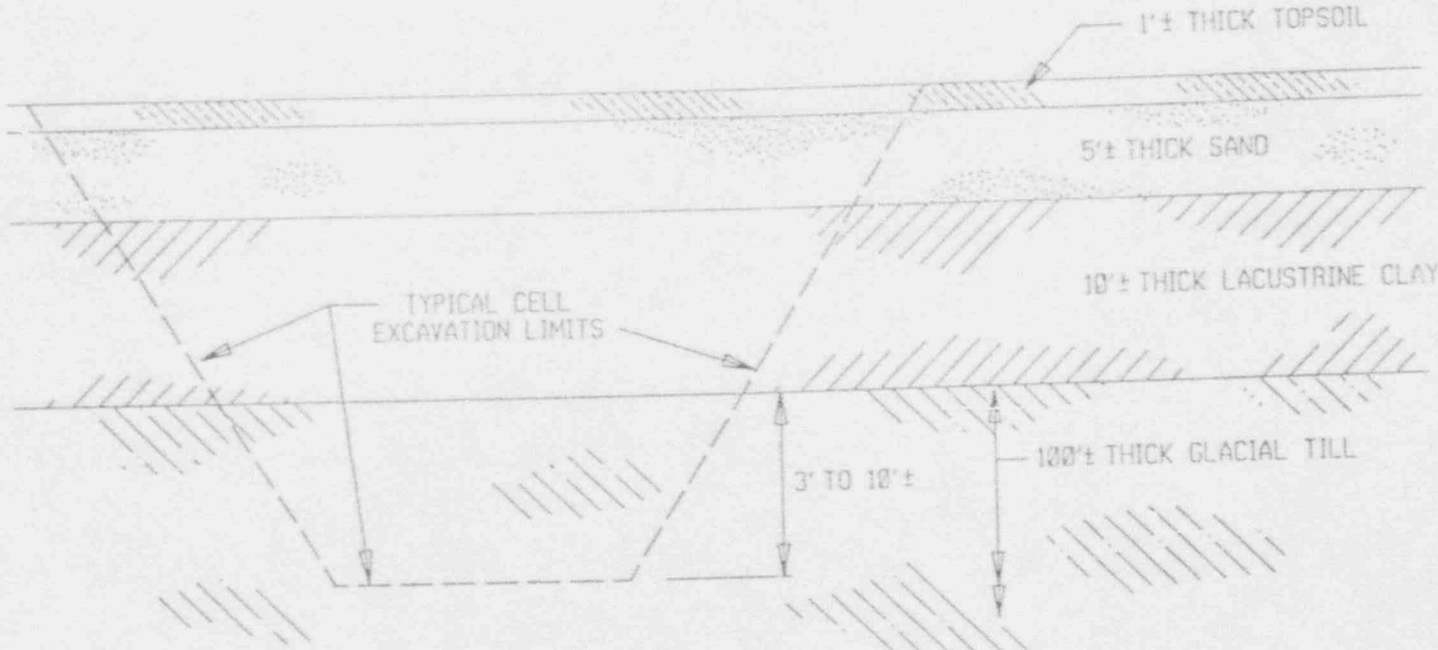
Table of Contents of Salzburg Landfill
RCRA Part B Application

SALZBURG LANDFILL
PART B APPLICATION

TABLE OF CONTENTS

APPENDIX S

Diagram Showing Typical Cell Excavation
and Geologic Profile



TYPICAL CELL EXCAVATION
AND GEOLOGIC PROFILE

Figure S-1

APPENDIX T

Cells 36 & 37 Design Drawings

1

IMAGE EVALUATION
TEST TARGET (MT-3)

150mm

6"

1

IMAGE EVALUATION TEST TARGET (MT-3)

1.0 2.8 2.5 3.2 2.2 3.6 2.0 4.0 1.1 1.8 1.25 1.4 1.6

150mm

6"

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

1

IMAGE EVALUATION
TEST TARGET (MT-3)

150mm

6"

See Figure Binder for

APPENDIX U

NESHAPS Compliance Assessment
for Bay City and Midland Thorium Piles

NESHAPS COMPLIANCE ASSESSMENT
BAY CITY AND MIDLAND, MI
THORIUM PILES

PREPARED FOR:

DOW CHEMICAL COMPANY USA

December, 1990

DAMES & MOORE

TABLE OF CONTENTS

1.0 INTRODUCTION

This document has been prepared as a record of the assessment performed by Dames & Moore to demonstrate compliance with the emission/dose standard from airborne particulate releases specified in 40 CFR 61, National Emission Standards for Hazardous Air Pollutants (NESHAPS), as defined for radionuclide releases from NRC and agreement-State licensed facilities. The assessment was performed for releases from piles on the properties owned by Dow Chemical USA (DOW) at Bay City and Midland, MI. The properties contain piles of thorium-bearing foundry slag material. Since, as will be shown in the following text, compliance has been demonstrated this document is a record that validates the exemption for reporting to the EPA. This record will be kept at the Midland site and will be available for inspection as per section 61.105, Recordkeeping Requirements, of 40 CFR Part 61.

In order to assure completeness of the documentation, and to assist in any subsequent inspection, the content and order of the following sections will follow the outline provided in section 61.104, Reporting Requirements.

2.0 NAME OF FACILITIES

Dow Bay City and Midland Facilities

3.0 RESPONSIBLE PERSONNEL

Decommissioning of material - Donald Berry, Dow Chemical USA.
Preparation of Assessment - Dr. Robert Berlin and Dr. William Duggan of Dames & Moore, Pearl River, NY.

4.0 LOCATION OF FACILITY

The thorium-bearing material piles are located at the Dow facilities in Bay City and Midland, MI.

5.0 MAILING ADDRESS

Mail should be addressed to Dow Chemical USA, attention Donald Berry, Environmental Services, 1261 Building, Midland, MI 48667.

6.0 RADIOACTIVE MATERIALS AT SITE

The slag material at the Bay City and Midland sites contains the radionuclide Th-232. The daughter products of Th-232 in the decay chain will also be present. At Bay City, it is estimated that there is a total of up to 40,000 cubic yards of material (thorium concentration above 5 pCi/g) with an average activity of about 188 pCi/g of Th-232 and a total activity of 9.2 Ci. At the Midland site, there is approximately 12,000 cubic yards of material with an average Th-232 activity of about 29 pCi/g and a total activity of 0.46 Ci.

7.0 STATUS OF THE RADIOACTIVE MATERIALS

The thorium-bearing material is currently being stored at the sites. A remediation program is planned involving the excavation and removal of the thoriated material for disposal in a cell at the Dow-owned Salzburg landfill in Midland. This assessment evaluates the Effective Dose Equivalent (EDE) for the current storage, phase and the removal operations.

8.0 RELEASE OF RADIOACTIVE MATERIALS TO THE ATMOSPHERE

The thorium may potentially be released to the atmosphere adhering to fugitive dust particles that are eroded from the surface of the material and picked up by the wind. Thoron gas is also potentially released by diffusion through the material and emanation from the surface of the piles

9.0 EFFLUENT CONTROLS

Controls on dust and gaseous releases at Bay City include an asphaltic sealant over the area of highest thorium concentration. The sealant is cracked and weathered in places and is no longer completely impervious. In addition the site is vegetated and is generally wet because of the proximity to marshes and the Saginaw River. The Midland site is covered with a clay cap averaging 1-2 feet in thickness with a light vegetative cover. Additionally, during material removal operations, only localized work areas will have the surface cover disturbed and water (or chemical) sprays will be used as required to minimize dusting.

10.0 DISTANCE FROM POINT OF RELEASE

Using an equivalent centralized point source for the release point gives a distance of 0.5 mile (2640 feet) to the nearest residence, at Bay City, and 0.3 mile (1584 feet) at Midland, which are the bases for the EDE analyses. There are no producing farms in the region of either site that would be affected by releases from the sites.

11.0 ASSESSMENT OF EFFECTIVE DOSE EQUIVALENT (EDE) FOR CURRENT SITE STATUS

The EDE has been assessed for the current site status (no action case) and for the planned remediation phase involving the excavation and removal of the material for burial at the Salzburg Landfill.

As confirmed in conversations with Mr. James Hardin of the EPA, (1) the EDE for NRC licensed facilities is to be applied to areal sources such as the Bay City and Midland sites. (2) The EDE is restricted to doses from airborne particulate releases of radionuclides which are to be treated as "fugitive emissions" from the surface in the same manner as prescribed for uranium mill tailings (areal site) under "Uranium Fuel Cycle Facilities" in 40 CFR Part 61. (3) thoron and its daughter products are excluded from the EDE for NRC licensed facilities.

The attachment I diagrammatically depicts the various options available for applying the NESHAPs methodology to an areal site like the Bay City and Midland sites. It shows the approach for assessing the EDE from particulate emissions.

The calculation of the source terms is provided in section 11.1 and the procedure used to demonstrate compliance with the emission standards is described in section 11.2 for the current status of the site. Thoron emissions are discussed in section 11.3.

11.1 SOURCE TERMS

40 CFR 61 states that the "the source terms for emissions from uranium mill tailings piles is estimated---using NRC's methodology". NRC methodology is defined in Regulatory Guide 3.59, "Methods for Estimating Radioactive and Toxic Airborne Source Terms for Uranium Milling Operations," and is used to calculate particulate emission source terms, where the source is defined by:

$$S = Ew\ A\ C\ f\ N\ (1-R) \qquad \text{---(1)}$$

where S = Radionuclide source (Ci/yr) of individual isotope

Ew = Emission factor ($g/m^2 \cdot yr$)

A = Exposed surface area of pile (m^2)

C = Radionuclide concentration in material (pCi/g)

N = Activity enrichment ratio of concentration in dust/bulk material (unitless)

R = Control factor on releases (unitless) - Appendix C of Reg. Guide 3.59

f = fracti : of each radionuclide present

and the emission factor, Ew, is defined by:

$$Ew = 0.1\ [(3.156\ e + 7)/0.5]\ \Sigma_s\ Rs\ Fs \qquad \text{---(2)}$$

where

Fs = annual average frequency of occurrence of wind speed groups obtained from joint relative frequency wind distribution for site

Rs = Dusting rate at average wind speed for wind speed groups for particles ≤ 20μm in diameter ($g/m^2 \cdot sec$) - Table 1 of Reg. Guide 3.59.

3.156×10^7 = number of seconds per year

0.5 = fraction of total dust loss by particles ≤ 20μm in diameter

0.1 = emission reduction factor due to particle size

(There are significantly less particulates on the surface of the material pile at the Bay City and Midland sites subject to wind erosion than those from tailings piles because of their larger size and greater cohesiveness. Thus, the source calculation approach used by the NRC staff (SECTION 1.2.2 of Reg. Guide 3.59) relative to ore pads is used to establish an emission factor at the Bay City and Midland sites of 10 percent of that calculated for a tailings pile).

The site specific parameters used to calculate the source terms are:

A - Surface area of pile = 90,000 ft^2 (8400 m^2) at Bay City
20,000 ft^2 (1900 m^2) at Midland

C - Average radionuclide concentration in material of piles

There are three main isotopes present: Ra-228, Th-232, and Th-228. The average concentration of Th-232 is 188 pCi/g at Bay City and 29 pCi/g at Midland. The other isotopic concentrations are determined based on conservatively assumed equilibrium ratios as below:

Th-228 = 100% Th-232
Ra 228 = 100% Th-232

The average radionuclide concentrations thus are:

Bay City	Midland
Th-232-188 pCi/g	Th-232 - 29 pCi/g
Th-228-188 pCi/g	Th-228 - 29 pCi/g
Ra-228-188 pCi/g	Ra-228 - 29 pCi/g

f - the fraction of each radionuclide currently present is taken as 1.0

N - the enrichment ratio = 2.5

R - the only emission control factor used to reduce the release of particulates is conservatively taken as the wind break at the height of the pile from the surrounding buildings, trees, and hills, thus providing a 50% reduction in releases. No credit is taken for the asphalt sealant, vegetative cover, or high moisture content of the surface at Bay City. In addition, the clay covered pile at Midland can be considered a complete enclosure with R= 0.99, but such control has not been assumed in the calculation.

Fs- The summary windrose for the 1983-1987 period measured at the Tri-City, Michigan Airport is used for both the Bay City and Midland sites.

Rs - As provided in Table 1 of Reg. Guide 3.59

While there are no producing farms in the vicinity of the sites, the COMPLY Code requires, as input, a distance to an assumed farm. This was taken as 800 meters at Bay city and 500 meters at Midland which will not impact the results significantly.

Ew-

SPEED Knots	Frequency (Fs)	Dusting Factor (Rs)	Rs Fs
0-3	0.0727	0	0
4-6	0.27169	0	0
7-10	0.36299	3.92×10^{-7}	1.42×10^{-7}
11-16	0.23663	9.68×10^{-6}	2.29×10^{-6}
17-21	0.04395	5.71×10^{-5}	2.51×10^{-6}
21 +	0.00669	2.08×10^{-4}	1.39×10^{-4}

$\Sigma RsFs = 6.33 \times 10^{-6}$

Based on use of the above input parameters we obtain Ew = 40 g/m^2 - yr for Bay City and for Midland

	Bay City	Midland
and S =	0.79e-4 Ci/yr of Th-232	0.28e-5 Ci/yr of Th-232
	0.79e-4 Ci/yr of Th-228	0.28e-5 Ci/yr of Th-228
	0.79e-4 Ci/yr of Ra-228	0.28e-5 Ci/yr of Ra-228

11.2 COMPLIANCE WITH EDE EMISSION STANDARD FOR PARTICULATES

Using the calculated source term (see section 11.1), and the appropriate meteorological and population data, the COMPLY Code at Level 4 compliance model (most accurate) was used to calculate the dose to the nearest individual outside the site boundary at Bay City and Midland (See attachment I for output from the COMPLY model runs). An annual maximum dose of 0.1 mrem/yr was calculated for Bay City and 0.008 mrem/yr for Midland, which is less than the 1 mrem/yr limit requiring an annual report. Thus this report will serve to internally document the results of the assessment.

While not required by the NESHAPs procedure, an alternative approach generally used to assess environmental doses from onsite sources was also applied to validate the COMPLY assessment.

- The Alternative uses the source concentrations of Th-232 as in the source calculations of section 11.1, and the same source enrichment ratio. However, the airborne concentration of dust above the thoriated material, Ed is taken as 22 $\mu g/m^3$ based on modeling of dust releases from comparable site conditions, and the airborne dust burden at the property boundary is assumed to be less than 5 percent of the dust burden onsite (based on data from UMTRA Vicinity Properties program in Grand Junction). Thus the airborne radionuclide concentrations at the site boundary are:

Ca = CNEd

where

Ca = airborne concentrations of Th-232 at site boundary (pCi/m^3)

C, N are as defined in section 11.1

Ed = Airborne dust emissions ($\mu g/m^3$)

Ca = 5.17×10^{-4} pCi/m^3 at Bay City and 0.8×10^{-4} pCi/m^3 at Midland.

and the dose to an individual spending 100 percent of their time for the entire year at the site boundary is calculated as:

$$Dose = [Ca \times DCF]\ Th\text{-}232 \times \frac{8760}{2000}$$

where

DCF Th-232, = Respective inhalation total 50 year committed dose conversion factors for non-occupational exposure

$\left(\frac{mrem}{yr} \text{ per } \frac{pCi}{m^3}\right)$ based on a 2000 hr/year exposure = 117 $\frac{mrem}{yr}$ per $\frac{pCi}{m^3}$

8760 = number of hours/year

The calculated dose at Bay City is 0.26 mrem/yr to the individual at the site boundary which compares quite well with the dose of 0.1 mrem/yr to the nearest resident determined from the COMPLY code. At Midland the calculated dose is 0.04 mrem/yr which also is quite comparable to the 0.008 mrem/yr calculated using the COMPLY code.

11.3 THORON EMISSIONS FROM PILE SURFACE

Thoron (Radon-220) fluxes were not assessed for the Bay City or Midland piles. The NESHAPs imposes no constraint on Thoron fluxes even for areal sources such as tailings piles or phosphogypsum stacks. Thoron has a short half-life (56 sec compared to 3.8 days for radon), and its diffusion is significantly retarded by moisture in the material. Thus the combination of these factors with the significant distances to the site boundary and the effect of local climatological conditions will result in inconsequentially small Thoron and Thoron daughter concentrations at the site boundary.

12.0 ASSESSMENT OF EFFECTIVE DOSE EQUIVALENT (EDE) FOR EXCAVATION AND REMOVAL OF BAY CITY AND MIDLAND PILES

The thorium-based material in the Bay City and Midland sites will be excavated and trucked to the Dow owned Salzburg Landfill upon receipt of NRC approval of the License Application of October, 1989. All the material in each pile will be excavated until remaining Th-232 concentrations of 10 pCi/g are achieved. To accomplish this localized work areas will be marked off, and the excavation performed with water or chemical stabilizers used to minimize dusting. The slag will be maintained in a moist condition during the transport to Salzburg, and tarpaulins, will be used to prevent airborne release of material. The slag material will be emplaced in cell 36/37 at Salzburg which has been set aside solely for the Bay City and Midland material, with void space being filled with clean borrow material. Emplacement of the material will be conducted in a manner that minimizes airborne dust generation, and the material will be immediately covered with a multi-barrier cap of combined artificial and natural materials. Personnel and area monitoring programs will be conducted at all these locations during the course of the material moving operations.

The EDE is evaluated for the slag removal at Bay City and Midland and for the emplacement process at Salzburg in the following sections.

12.1 SOURCE TERM

The process of excavating the slag material can be treated in the same manner as in Reg. Guide 3.59 for "Process Emissions" resulting from such operations as material handling (Section 1.1). Thus, the source is defined by:

$$S_p = MCEN\ (1-R) \qquad \text{--- (5)}$$

where S_p = Radionuclide source (Ci/yr) of individual isotope from removal process

M = process rate (tons/yr) of overlying soil to be excavated.

C = Radionuclide concentration (pCi/g)

E = Emission factor for the process ($\frac{\text{lb. dust released}}{\text{ton material handled}}$)

N = Enrichment Ratio (unitless)

R = Emissions control factor on releases (unitless)

The site specific parameters used to calculate the source term are:

M - The process rate is 60,000 tons/yr for the Bay City material and 18,000 tons/yr for the Midland material based on a bulk density of 1.5 tons/yd^3.

C - The radionuclide concentrations are the same as used in the analysis of the existing status in Section 11.1.

E - It is conservatively assumed that a mechanical shovel (or equivalent) is used to remove the slag material, with each soil removal causing emissions comparable to that from a truck end dump, and that an average of 2 soil removals is required per cubic yard of material removed. An uncontrolled emission factor of 0.04 lb/yd^3 (from Appendix B of Reg. Guide 3.59) is therefore used.

N - The enrichment ratio is 2.5

R - The emission control factors used are: (Appendix C of Reg. Guide 3.59)

- Wind break at height of the pile = 50%
- Water sprays will be used as needed to keep the material surface most = 50%

Substituting these parameters into equation (5) gives a source term, S_p for the slag removal of 1.71e-4 Ci/yr for Th-232, Th-228, and Ra-228 at Bay City and 0.79e-5 Ci/yr for these radionuclides at Midland.

12.2 COMPLIANCE WITH EDE EMISSION STANDARD FOR PARTICULATES FOR EXCAVATION REMOVAL OPERATION

Using the COMPLY Code at Level 4 compliance model permits us to calculate the total doses to the nearest individual outside the site boundary at Bay City and Midland. Full time exposure to the dust in the air from the soil and/or component removal operation is conservatively assumed.

For the source terms calculated in Section 12.1 for the slag excavation and removal process, and the same meteorological conditions and population distribution as in the COMPLY code analysis for the current site status, the COMPLY code level 4 analysis for the excavation and removal gives a total annual EDE of 0.32 mrem/yr at Bay City and 0.031 mrem/yr at Midland. Since these doses are less than the 1 mrem/yr limit requiring an annual report submittal, no submittal is required for the excavation and removal process, and this report will serve to internally document the results of the assessment.

12.3 COMPLIANCE WITH EDE EMISSION STANDARD FOR PARTICULATES FOR EMPLACEMENT OF MATERIAL AT SALZBURG

The assessment of emissions at the Salzburg Landfill for the emplacement of material is being included for completeness even though it is not an NRC licensed facility and NESHAPS is not applicable.

The EDE at Salzburg prior to emplacement is essentially zero since there is no radioactive material currently being handled or stored at this facility.

The source term for the emplacement of the slag in the cell at Salzburg is determined in the same manner as for the removal process (section 12.1). The parameters are the same with the exception of the Emission Factor. Since the slag will be dumped from the end of a truck in one operation, only 1 deposition per cubic yard of material will occur. The same uncontrolled emission factor of 0.04 lb/yd^3 is used for this one deposition. Applying equation (5) gives a source term of 0.86e-4 Ci/yr for Th-232, Th-228, and Ra-228 for the material shipped from Bay City and 0.04e-4 Ci/yr for these radionuclides for the material shipped from Midland.

Using the COMPLY Code at Level 4 compliance model with these source terms and the same meteorological data, and at a distance from the cell to the nearest resident of 1400 ft, gives a total annual EDE of 0.44 mrem/yr. Since these doses are less than the 1 mrem/yr limit requiring an annual report submittal, no submittal is required for the slag deposition at Salzburg, and this report will serve to internally document the results of the assessment.

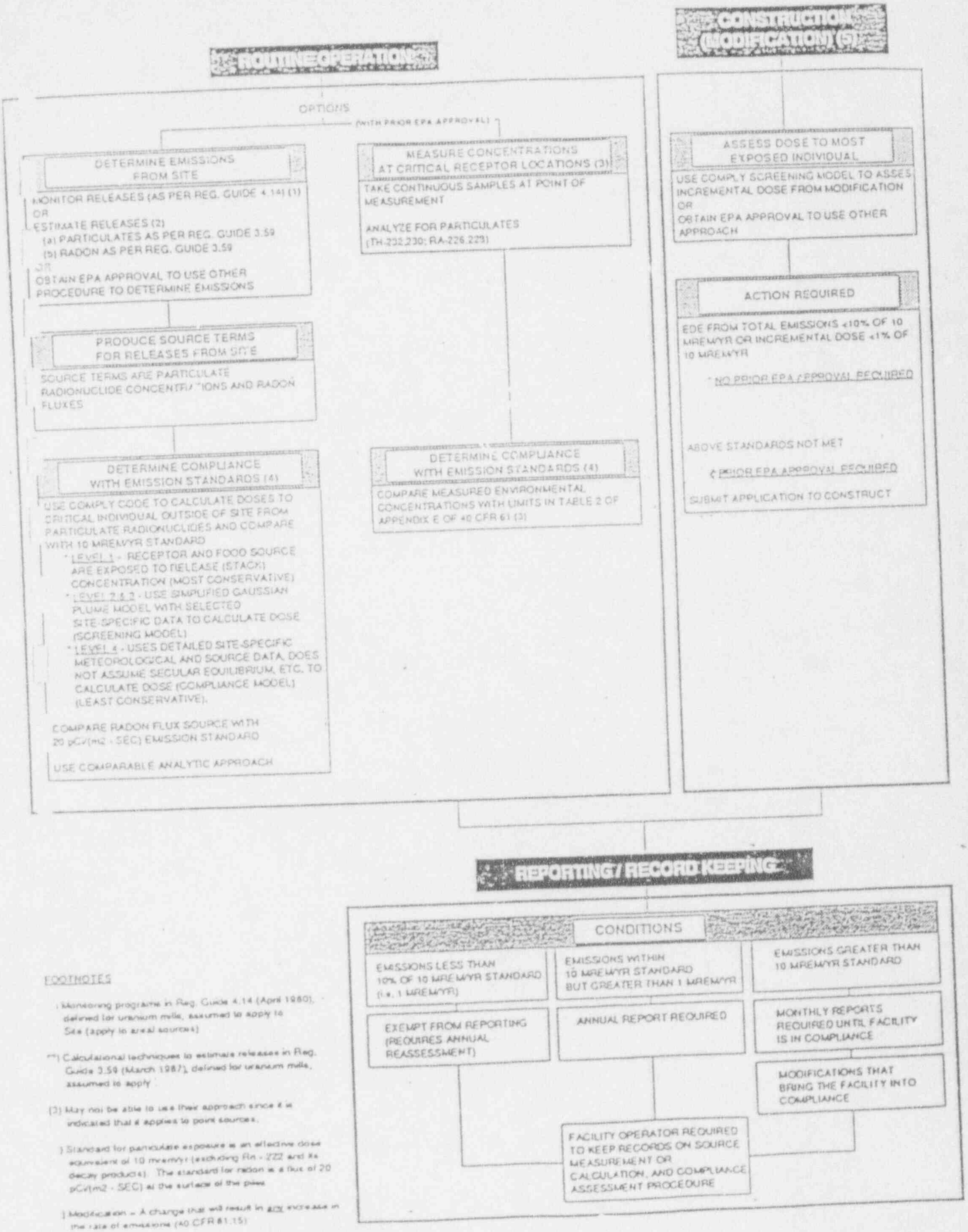
It is emphasized that, regardless of the low airborne concentrations of particulates and doses projected for the slag excavation and emplacement, DOW will perform a continual emissions reduction program (i.e. use of sprays, restriction of work area, washing of vehicles) and conduct appropriate health physics monitoring of onsite-workers to assure that ALARA conditions are being maintained. Area airborne monitoring will also be conducted to validate that concentrations are being maintained at levels to assure that offsite doses remain within the NESHAPS standard.

13.0 SUMMARY OF NESHAPS COMPLIANCE ASSESSMENT

As demonstrated by the NESHAPS compliance analyses and supporting calculations described in sections 11.0 and 12.0, the airborne particulate emissions from the site, for both the current site status and the excavation and removal of the slag and emplacement at Salzburg, do not result in EDE's greater that 1 mrem/yr. Thus DOW is exempt from the annual reporting requirement. As required, this documentation will be kept on file at the site and an annual reassessment will be made of the EDE if the site status remains the same. If different site construction (modification) is contemplated, a separate compliance assessment will be performed prior to initiation of the activity.

FIGURE 1

APPLICATION OF NESHAPS METHODOLOGY TO AREAL SITE



FOOTNOTES

(1) Monitoring programs in Reg. Guide 4.14 (April 1980), defined for uranium mills, assumed to apply to Site (apply to areal sources)

(2) Calculational techniques to estimate releases in Reg. Guide 3.59 (March 1987), defined for uranium mills, assumed to apply

(3) May not be able to use their approach since it is indicated that it applies to point sources.

(4) Standard for particulate exposure is an effective dose equivalent of 10 mrem/yr (excluding Rn - 222 and its decay products). The standard for radon is a flux of 20 pCi/(m2 - SEC) at the surface of the piles

(5) Modification = A change that will result in any increase in the rate of emissions (40 CFR 61.15)

ATTACHMENT 1

07/24/90 10:06

40 CFR Part 61
National Emission Standards
for Hazardous Air Pollutants

REPORT ON COMPLIANCE WITH

THE CLEAN AIR ACT LIMITS FOR RADIONUCLIDE EMISSIONS

FROM THE COMPLY CODE, VERSION 1.2, SEPT. 1989

Prepared by:

DOW CHEMICAL
BAY CITY THORIUM STORAGE SITE
BAY CITY, MICHIGAN

Dr. Robert Berlin
914-735-1200

Prepared for:

U.S. Environmental Protection Agency
Office of Radiation Programs
Washington, D.C. 20460

BAY CITY NESHAPS COMPLIANCE ASSESSMENT

SCREENING LEVEL 4

DATA ENTERED:

Nuclide		Release Rate (curies/YEAR)
TH-232	W	7.900E-05
TH-228	Y	7.900E-05
RA-228	W	7.900E-05

Release height 3 meters.

Building height 3 meters.

The source and receptor are not on the same building.

Building width 10 meters.

Building length 10 meters.

STACK DISTANCES, FILE: b:\dow\baydist.dat

DIR FROM	Distance (meters)
N	800.000
NNE	800.000
NE	800.000
ENE	800.000
E	800.000
ESE	800.000
SE	800.000
SSE	800.000
S	800.000
SSW	800.000
SW	800.000
WSW	800.000
W	800.000
WNW	800.000
NW	800.000
NNW	800.000

WINDROSE DATA, FILE: b:\dow\midwind.dat

Source of wind rose data: Commercial Weather Services, Inc.
Dates of coverage: 1983-1987
Wind rose location: Tri-City Airport
Distance to facility: 10 miles

Percent calm: 0.04

Wind FROM	Frequency	Speed (knots)
N	0.026	7.76
NNE	0.054	8.48
NE	0.068	9.25
ENE	0.060	8.39
E	0.026	7.39
ESE	0.026	7.35
SE	0.021	7.61
SSE	0.080	8.71
S	0.067	8.86
SSW	0.073	9.42
SW	0.078	9.89
WSW	0.148	9.78
W	0.055	9.34
WNW	0.050	9.12
NW	0.041	8.86
NNW	0.086	8.00

Distance from the SOURCE to the FARM producing VEGETABLES is 800 meters.

Distance from the SOURCE to the FARM producing MILK is 800 meters.

Distance from the SOURCE to the FARM producing MEAT is 800 meters.

NOTES:

The receptor exposed to the highest concentration is located 800. meters to the ENE.

He gets his VEGETABLES from a farm located 800. meters to the ENE.

He gets his MEAT from a farm located 800. meters to the ENE.

He gets his MILK from a farm located 800. meters to the ENE.

Input parameters outside the "normal" range:

Distance from stack to receptor is unusually FAR.

RESULTS:

WHOLE BODY dose: 0.1 (mrem/year).

*** COMPLY at level 4.

This facility is in COMPLIANCE.

It may or may not be EXEMPT from reporting to the EPA.

You may contact your regional EPA office for more information.

********** END OF COMPLIANCE REPORT **********

07/24/90 09:53

40 CFR Part 61
National Emission Standards
for Hazardous Air Pollutants

REPORT ON COMPLIANCE WITH
THE CLEAN AIR ACT LIMITS FOR RADIONUCLIDE EMISSIONS
FROM THE COMPLY CODE, VERSION 1.2, SEPT. 1989

Prepared by:

DOW CHEMICAL
MIDLAND THORIUM STORAGE SITE
MIDLAND, MICHIGAN

Dr. Robert Berlin
914-735-1200

Prepared for:

U.S. Environmental Protection Agency
Office of Radiation Programs
Washington, D.C. 20460

MIDLAND NESHAPS COMPLIANCE ASSESSMENT

SCREENING LEVEL 4

DATA ENTERED:

Nuclide		Release Rate (curies/YEAR)
TH-232	W	2.800E-06
TH-228	Y	2.800E-06
RA-228	W	2.800E-06

Release height 3 meters.

Building height 3 meters.

The source and receptor are not on the same building.

Building width 10 meters.

Building length 10 meters.

STACK DISTANCES, FILE: b:\dow\middist.dat

DIR FROM	Distance (meters)
N	500.000
NNE	500.000
NE	500.000
ENE	500.000
E	500.000
ESE	500.000
SE	500.000
SSE	500.000
S	500.000
SSW	500.000
SW	500.000
WSW	500.000
W	500.000
WNW	500.000
NW	500.000
NNW	500.000

WINDROSE DATA, FILE: b:\dow\midwind.dat

Source of wind rose data: Commercial Weather Services, Inc.
Dates of coverage: 1983-1987
Wind rose location: Tri-City Airport
Distance to facility: 10 miles

Percent calm: 0.04

Wind FROM	Frequency	Speed (knots)
N	0.026	7.76
NNE	0.054	8.48
NE	0.068	9.25
ENE	0.060	8.39
E	0.026	7.39
ESE	0.026	7.35
SE	0.021	7.61
SSE	0.080	8.71
S	0.067	8.86
SSW	0.073	9.42
SW	0.078	9.89
WSW	0.148	9.78
W	0.055	9.34
WNW	0.050	9.12
NW	0.041	8.86
NNW	0.086	8.00

Distance from the SOURCE to the FARM producing VEGETABLES is 500 meters.

Distance from the SOURCE to the FARM producing MILK is 500 meters.

Distance from the SOURCE to the FARM producing MEAT is 500 meters.

NOTES:

The receptor exposed to the highest concentration is located
500. meters to the ENE.

He gets his VEGETABLES from a farm located
500. meters to the ENE.

He gets his MEAT from a farm located
500. meters to the ENE.

He gets his MILK from a farm located
500. meters to the ENE.

Input parameters outside the "normal" range:

None.

RESULTS:

WHOLE BODY dose: 8.2E-03 (mrem/year).

*** COMPLY at level 4.

This facility is in COMPLIANCE.

It may or may not be EXEMPT from reporting to the EPA.

You may contact your regional EPA office for more information.

********** END OF COMPLIANCE REPORT **********

APPENDIX V

Chelation Effects on Thorium Disposal by Carbonate-Rich Sediments
(A Literature Study)

APPENDIX V

Comment No. 44 raises the question of whether conditions of the Salzburg Landfill (i.e. pH, clay type, etc.), will cause the thorium to chelate in the presence of water and carbonate-rich sediments? The comment implies that in the Landfill environment, thorium chelation may, in fact, take place and the radioactive material could be transported to the water table.

The support for this argument was drawn from a study in which the conclusions seemed to suggest this relationship between thorium compounds and carbonates acting as chelating agents. In the concluding statements on Thorium Carbonate Complexes, the article states, "To us, it seems most likely that the carbonate complexes are formed by the addition of CO_2 to a coordinate oxide, forming a bridge linking several such units together. For example, we may imagine that $Th_8 (OH)_{24}(CO_2)^{8+}$ is formed from $Th_4 (OH)_{12}^{4+}$ by using a minimum of one bridging carbonate group. However, at this stage all discussions of the stoichiometry of these complexes will be speculative." The last words state "It seems quite obvious from the results obtained in this study that carbonate may also affect the speciation, and hence, the solubility of actinide(IV) compounds, at pH<7." [2].

In light of the language used in this conclusion, such as 'It seems most likely ... we may imagine ... all discussions .. will be speculative', the certainty of stating that 'It seems quite obvious...' that thorium will chelate when exposed to water is arguable. Aside from the verbiage sued in the study, the environment used to do the experiments differs considerably from that of the Salzburg Landfill. The concentration range of $2.5 \leq$ test pH ≤ 5 was used, as opposed to the pH of the landfill of $7.3 \leq$ landfill pH ≤ 9.0. The questions now pending is: Will chelation take place in the 7.3-9.0 range of pH?

"Humic compounds and other organic chelates can significantly increase the solubilities of Th (IV) ... and other elements in water..." under various pH and concentrations [4] Thus, the chelation of a substance is greatly affected by pH, when exposed to weak solutions of alkali carbonates, thorium salt solutions would precipitate [7]. High concentrations of carbonate would dissolve the precipitates into carbonate complexes [3,8].

The type of clay may also play a role in the chelating process. The ion exchange capacity of clays is low, but increases slightly with pH, due to its kaolinitic nature [6]. This characteristic may inhibit the chelation process. Fischer reports in USGS Circular #973, that "Attenuation can occur through a variety of physical and chemical processes, but the two most prominent processes appear to be sorption and ion exchange. Sorption involves the adhesion of molecules to the surface of aquifer material; The ion exchange process displaces ions on the surface of minerals by ions in solution. Both processes can result in the removal of contaminants from groundwater moving from LLW (Low-Level Waste) disposal areas (Brown, 1967). The sorption and ion exchange processes are caused primarily by the electrical surface charge in mineral particles, generally clay-rich materials that carry an excess of negative charges. Studies by Olsen and others (1983) at disposal sites at the Oak Ridge National Laboratory reaffirmed that illite clay retards the migration of cesium-137. In his investigation of the hydrogeology at the West Valley, N.Y., commercial LLW site, Prudic (in Press) found that the transport of cesium and strontium was retarded because of ion exchange between the contaminants in solution in groundwater and the clay component of the glacial till. In contrast, investigators at a cold-scrap recovery plant in Rhode Island found that the clay-free sands did not retard significantly the transport of strontium-90 (B.J. Ryan, U.S. Geological Survey, oral commun., 1984). Thus, the clay fraction and clay type play important roles in sorption and ion exchange processes; the determination of clay fraction and type should be part of the site-selection process." [1].

Table 1 shows results of various leachants with chelating agents and water [4]. The formation and extractability of a chelate are highly dependent upon the acidity of the reaction medium with the stability of a thorium oxide chelated with Dibromopyrogallol Red in an aqueous solution not achievable above a pH of 5.5 [5].

TABLE 1

Leaching Results of Composite Soil and Ore Samples with Chelating Agents and Water (leaching time: 21 days, temperature: 25° C)

Leachate	Concentration (mg/l)	Soil Sample a	Soil Sample b	Ore Sample a	Ore Sample b
Water	- -	8	0.001	12	0.0009
Humic Acids (HA)	10	79	0.014	30	0.0021
Humic Acids (HA)	100	162	0.028	168	0.0120
Oxalic Acid (HOx)	100	1203	0.207	7.6	0.0005
NTA[c]	100	1300	0.223	396	0.0280
DTPA[c]	100	1642	0.282	902	0.0630

[a] Solution concentration of Th-232 after 21 days (µg/l).

[b] Percentage Th-232 released based on an initial Th-232 concentration in soil (0.5%) and ore (1.42%).

[c] NTA = nitrilotriacetic acid; DTPA = diethylenetriaminepenta-acetic acid.

REFERENCES

1. J.N. Fischer, U.G. Geological Survey, Circ. 973, 1986, 18.

2. I. Grenthe, B. Lagerman, *Acta Chem. Scandinavica*, 45, 1991, 231-228.

3. Kirk Othermer Encyclopedia of Chemical Technology, *Thorium and Thorium Compounds*, 1978, 977-988.

4. N. Miekeley, R.M. Dotto, I.L. Kuchler, P. Linsalata, *Mater. Res. Soc. Symp. Proc.*, 44 (Sci. Basis Nuclear Waste Management), 1985, 591-597.

5. S.C. Pande, S.P. Sangal, *Microchem. J.*, 13(4), 1968, 674-684.

6. S.O. Richert, J. *Geophys.* Res., 67, 1962, 4365.

7. S. Shibata, M. Furukawa, R. Kamata, D. Goto, *Anal. Chem. Acta*, 50, 1970, 439-446.

8. Treatise on Analytical Chemistry, *Thorium Carbonate*, 5, 1961, 156.

APPENDIX W

Declaration of Restrictive Covenants

DECLARATION OF RESTRICTIVE COVENANTS

The Dow Chemical Company ("Dow"), a Delaware corporation with executive offices at 2030 Dow Center, Midland, Michigan 48674 is the record owner of the following described premises located in Midland Township, Midland County, Michigan, to wit:

SEE ATTACHED EXHIBIT A FOR A LEGAL DESCRIPTION AND EXHIBIT B FOR A DIAGRAM OF THE PROPERTY.

Dow is in the process of constructing a landfill cell on the property described in Exhibit A for the permanent disposal of radioactive thorium-bearing material pursuant to a license granted by the United States Nuclear Regulatory Commission ("NRC") under 10 CFR 20.302.

Now, therefore, these restrictive covenants are executed by Dow to insure the long-term integrity of the disposal facility for the safety of the people of the state of Michigan, to wit:

(1) These covenants shall be in addition to those restrictive covenants currently on record affecting the above-described premises, and recorded at Liber 496, Pages 540 through 542, and Liber 537, Pages 406 through 409, Midland County Records.

(2) No excavation or construction, except as necessary to maintain the integrity of the facility shall be allowed after the thorium-bearing material is disposed of and the cell closed.

(3) No uses of the property shall be made which may impair the integrity of the facility. Any change in use following closure of the cell shall require the prior written consent of the NRC, which shall not be unreasonably withheld.

(4) Dow shall erect, and it and its successors in interest, shall thereafter continuously maintain a metal monument placed on the above-described property, said monument to be approved by the NRC to warn of the presence of radioactive thorium-bearing material at the site.

(5) Dow shall notify the NRC of its intent to convey any interest in the property described herein. Such conveyance shall not be made without the prior written approval of the NRC, provided however that such approval by the NRC is not to be unreasonably withheld. No conveyance of title, easement or other interest in the property shall be consummated by Dow without adequate and complete provision for continued maintenance of the facility.

(6) Any governmental agency adversely affected by any violations of these restrictive covenants may enforce them by legal action in the Circuit Court for Midland County.

(7) The property described in Exhibit A is subject to an existing easement of record granted to Consumers Power Company for electric transmission lines.

These restrictive covenants shall run with the land in perpetuity and shall be binding upon Dow, its successors and assigns.

Dated this ______ day of ______________, 1992.

Witness ____________________ THE DOW CHEMICAL COMPANY

Witness ____________________ By: ______________________

STATE OF MICHIGAN)
) ss.
COUNTY OF MIDLAND)

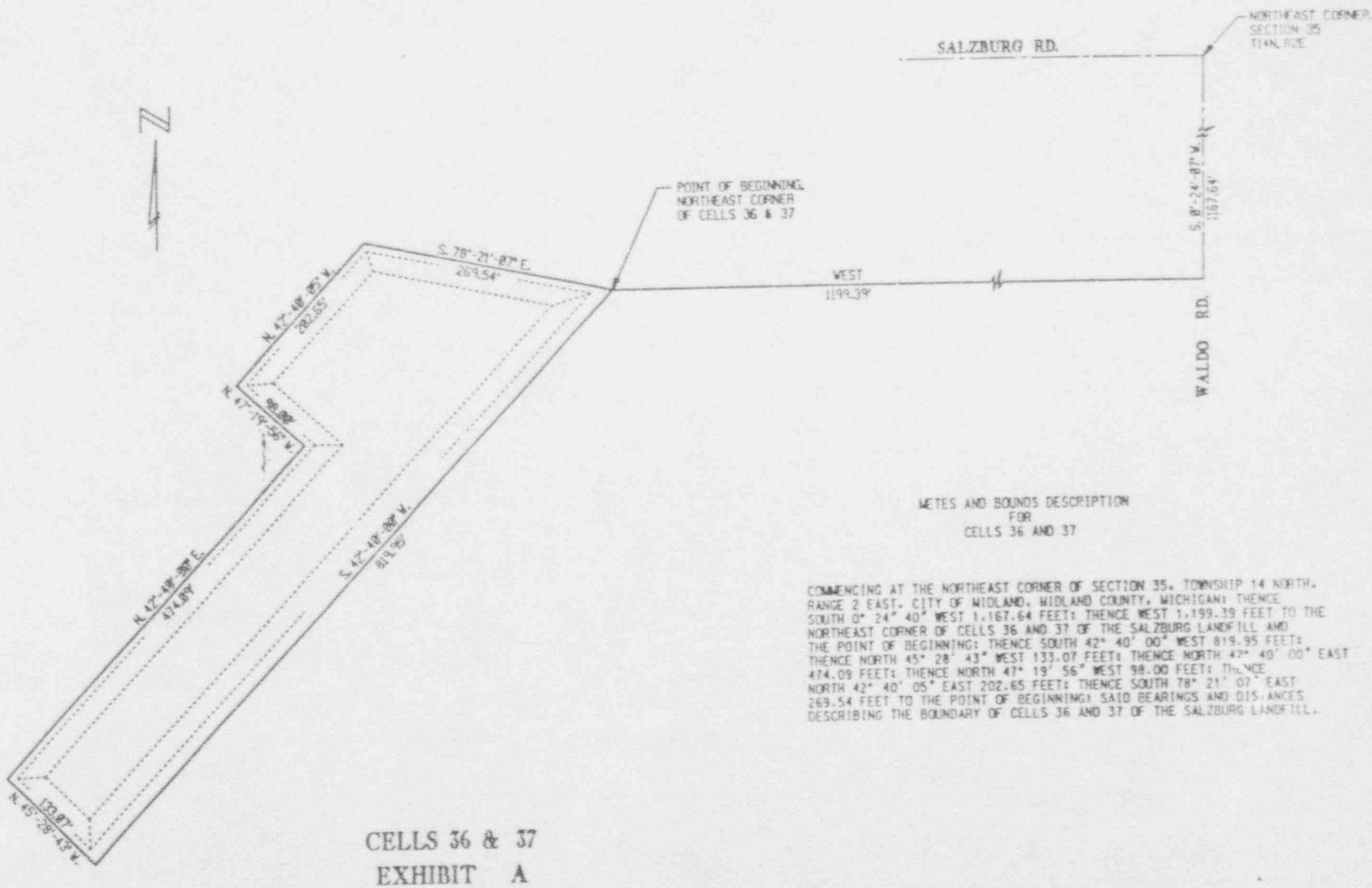
The foregoing instrument was acknowledged before me this ______ day of ______________, 1992, by ________________ of The Dow Chemical Company on behalf of the Corporation.

____
NOTARY PUBLIC

UNITED STATES NUCLEAR
REGULATORY COMMISSION

By: ______________________

This document was drafted by:
Tom McCormick, Division Counsel
The Dow Chemical Company
Michigan Division, Legal Department
47 Bldg., Midland, MI 48667

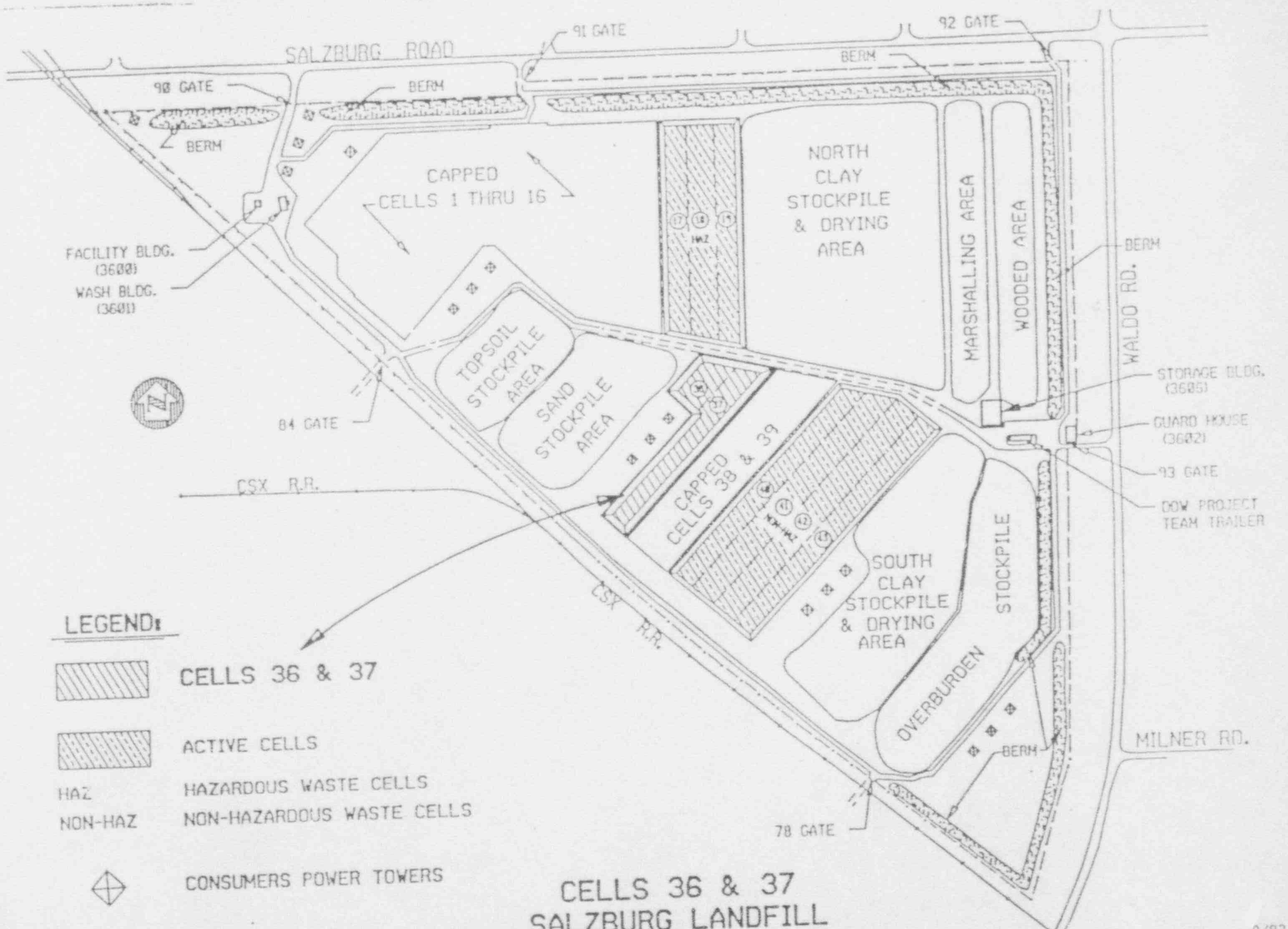


METES AND BOUNDS DESCRIPTION
FOR
CELLS 36 AND 37

COMMENCING AT THE NORTHEAST CORNER OF SECTION 35, TOWNSHIP 14 NORTH, RANGE 2 EAST, CITY OF MIDLAND, MIDLAND COUNTY, MICHIGAN; THENCE SOUTH 0° 24' 40" WEST 1,167.64 FEET; THENCE WEST 1,199.39 FEET TO THE NORTHEAST CORNER OF CELLS 36 AND 37 OF THE SALZBURG LANDFILL AND THE POINT OF BEGINNING; THENCE SOUTH 42° 40' 00" WEST 819.95 FEET; THENCE NORTH 45° 28' 43" WEST 133.07 FEET; THENCE NORTH 42° 40' 00" EAST 474.09 FEET; THENCE NORTH 47° 19' 56" WEST 98.00 FEET; THENCE NORTH 42° 40' 05" EAST 202.65 FEET; THENCE SOUTH 78° 21' 07" EAST 269.54 FEET TO THE POINT OF BEGINNING; SAID BEARINGS AND DISTANCES DESCRIBING THE BOUNDARY OF CELLS 36 AND 37 OF THE SALZBURG LANDFILL.

CELLS 36 & 37
EXHIBIT A

JJA/LEA



CELLS 36 & 37
SALZBURG LANDFILL
EXHIBIT B

FEB 11 11 31 AM 1981

DECLARATION OF RESTRICTIVE COVEN[ANT]

RECEIVED
DEC 1 7 1980
RES. RECOVERY REG. II

RECORDED IN DEEDS
MIDLAND ... MICH.

THIS INDENTURE made the 24th day of November, 19 80, by and between, THE DOW CHEMICAL COMPANY whose address is: 2030 Dow Center, Midland, Michigan 48640 part(y) (ies) of the first part; and Howard A. Tanner, Director of the Michigan Department of Natural Resources for and on behalf of the State of Michigan, whose address is: Steven T. Mason Building, Lansing, Michigan 48913, party of the second part;

WITNESSETH THAT:

WHEREAS, application for licensure under provisions of 1978, PA 641, 1970 CL 299.401 *et seq*, for the purpose of conducting, managing, maintaining or operating a disposal area upon lands situated in the City of Midland, County of Midland, more particularly described as: Commencing at the North Quarter (1/4) corner of Section 35, Township 14 North, Range 2 East; thence South 89°-47'-50" East 433.38 feet along the North line of said Section 35; thence South 0°-12'-10" West 252.08 feet to the point of beginning; thence continu[ing] South 0°-12'-10" West 413.65 feet; thence South 42°-55'27" West 476.54 feet; thence North 45°-39'42" West 560.70 feet; thence North 42°-41'-11" East 506.25 feet; thence South 89°-47'-[50"] East 383.80 feet to the point of beginning; containing 8.15 ± acres. has been properly made; and

WHEREAS, the Director of the Department of Natural Resources, will contemporaneously issue such license; and

WHEREAS, 1978 PA 641, *supra*, Section 16 requires that at the time of licensing of a sanitary landfill, an instrument which imposes a restrictive covenant upon the land involved shall be executed by all the owners of the tract of land upon the landfill is located and the director.

NOW THEREFORE, THE DOW CHEMICAL COMPANY, the part(y) (ies) of the first part, do for themselves, their heirs, successors, lessees, or assigns declare, covenant and agree:

R-5527
Rev 2/80

1. That the lands hereinbefore described have been or will hereafter be used as a sanitary landfill, and that neither they, nor their servants, agents, employees, nor any of the heirs, successors, lessees or assigns shall (or shall by their leave or sufferance permit others to) engage in filling, grading, excavating, drilling or mining of the lands and premises above described until 15 years after completion of all landfill activity upon the same, unless written authorization therefor is obtained from the Director of the Department of Natural Resources; and that the State of Michigan or any municipality may in addition to any other remedy available at law bring an action for an injunction or other process against any person, county, or municipality to restrain or prevent any violation of the restrictive covenant hereby imposed upon the subject premises.

2. That at the time of the ensealing and delivery of these presents the above described premises are free from all encumbrances whatever, (except) a right of way granted to Consumers Power Company for above ground electrical transmission lines.

The director of the department of natural resources does for and on behalf of the State of Michigan covenant and agree to execute, acknowledge, and deliver to the party of the first part, a release of the within restrictive covenant, in suitable form, upon the expiration of the 15 year period provided for herein.

R-5527
Rev 2/80

LIBER 496 PAGE 542

RECEIVED

DEC 17 1980

RES. RECOVERY DIV.

-A-
(CORPORATION)

ONE OF THE FOLLOWING THREE PAGES MUST BE COMPLETED BY THE APPLICANT. PLEASE SELECT THE PAGE CORRESPONDING TO APPLICANT'S MANAGEMENT: A-Corporation B-Partnership C-Individual

Signed in presence of:

Barbara Schwartz
* Barbara Schwartz

Cheryl A. Johnson
Cheryl A. Johnson

Signed

THE DOW CHEMICAL COMPANY
GRANTOR

By I F Harlow
Its I. F. HARLOW, VICE PRESIDENT
Attest: R.W. Barker, Assistant Secretary
R. W. Barker

Signed in presence of:

Nancy Kay McDowell
* Nancy Kay McDowell

Leonard Lipinski
* Leonard Lipinski

STATE OF MICHIGAN

By Fred B. Kellow
*Fred B. Kellow, Chief
Resource Recovery Division (on behalf of)
Director of the Department of Natural Resources for the State of Michigan

STATE OF MICHIGAN)
) ss
COUNTY OF Midland)

The foregoing instrument was acknowledged before me this 24th day of November, 1980 by I. F. Harlow and R. W. Barker, the Vice President and Assistant Secretary of The Dow Chemical Company ~~corporation on behalf of the corporation~~.

Cheryl A. Johnson
Notary Public
Midland County, Michigan
My Commission Expires ______
My Commission Expires June 1, 1983

STATE OF MICHIGAN)
) ss
COUNTY OF INGHAM)

The foregoing instrument was acknowledged before me on this 16th day of [illegible] 19[illegible], by [illegible] Kellow (on behalf), Director of the Department of Natural Resources, on behalf of the State of Michigan.

[signature]
Notary Public
Ingham County, Michigan
My Commission Expires 4.1.84

When recorded, return to:

State of Michigan
DNR-Resource Recovery Division
Box 30028
Lansing, Michigan 48909

*TYPE OR PRINT NAME UNDER SIGNATURE

Form Drafted By:
State of Michigan

Form Completed By:
W. G. Meagher
The Dow Chemical Company
Real Estate Department
47 Building
Midland, Mi. 48640

R-5527
Rev 2/80

RESTRICTIVE CONVENANTS

THE DOW CHEMICAL COMPANY, a Delaware corporation with executive offices at
(Name) (Company, Partnership, etc.) (Address)
2030 Dow Center in Midland County, Michigan,
is the record owner of the following described premises in the Township of
Midland, Midland County, Michigan, to wit:

SEE ATTACHED EXHIBIT-A

The Dow Chemical Company (Name) is in the process of constructing a hazardous waste landfill on a portion of its property above described, pursuant to 1979 PA 64 and the rules promulgated thereunder, the location of the facility being described in Exhibit A, attached hereto, and hereby

NOW, THEREFORE, these Restrictive Covenants are executed by The Dow Chemical (Name) to insure the integrity of said disposal facility for the safety of the people of the State of Michigan, to-wit:

(1) No vehicles, except vehicles needed and actually used for maintenance and inspection, shall be allowed within the areas which are enclosed by a sound and secure fence, pursuant to Paragraph (4), below, except as indicated in Paragraph (8) below.

(2) No excavation or construction, except as necessary to maintain the integrity of the facility, shall be allowed after closure of the facility in the areas which are enclosed by a sound and secure fence, pursuant to Paragraph (4), below, except as indicated in Paragraph (8) below.

(3) No uses of the property shall be made which may or will impair the integrity of the facility.

RECORDED

JUL 3 4 13 PM '84

RICHARD C. DIMENT
REGISTER OF DEEDS
MIDLAND COUNTY, MICH

3/81 R 4906

(4) The Dow Chemical Company Name shall erect, and it and its successors in interest, shall thereafter continuously maintain until further order of the Department of Natural Resources: (i) a secure and sound fence enclosing the area containing the disposal facility at least FIFTY (50) feet measured from all edges of the disposal facility; and (ii) a sign stating: "Warning, Hazardous Waste Disposal Area, KEEP OUT," inside the fence, visible from each side.

(5) The Dow Chemical Company Name shall notify the Director of the Michigan Department of Natural Resources of its intent to convey any interest in land located in City of Midland, Section 35 in Midland Township, Midland County, Michigan. No conveyance of title, easement, or other interest in the property shall be consummated by The Dow Chemical Company Name without adequate and complete provision for continued maintenance of the facility and monitoring systems described in the Closure and Post Closure Maintenance and Monitoring Plans described in Exhibit B, attached hereto and hereby made a part hereof. For the purpose of assuring adequate maintenance of the facility's monitoring system(s), no property owned by The Dow Chemical Co. Name, described in Exhibit A shall be conveyed without prior written approval of the Director of the Michigan Department of Natural Resources. Such approval by the Director is not to be unreasonably withheld.

(6) Until further notice from the Director of the Michigan Department of Natural Resources, set forth above, The Dow Chemical Co. Name, and its successors in title will maintain and monitor the facility as described in Section 41(1) of 1979 PA 64.

(7) Any governmental agency adversely affected by any violations of these restrictions may enforce them by legal actions in the Circuit Court.

(8) The property described in Exhibit A is subject to an existing easement of record granted to Consumers Power Company for electric transmission lines.

These Restrictive Covenants shall run with the land and be binding upon first party, its successors, and assigns.

DATED: This 4th day of July, 1981.

THE DOW CHEMICAL COMPANY

By ____________________

Its L. F. HARLOW, VICE PRESIDENT

____

Director, Michigan Department of Natural Resources

WITNESSES:

____
Cheryl A. Johnson

____
Lu Ellen Joslyn

STATE OF MICHIGAN)
) ss.
COUNTY OF MIDLAND

The foregoing insturment was acknowledged before me this 4th day of July, 1981, by L. F. Harlow, of The Dow Chemical Company ~~corporation~~, on behalf of the Corporation.

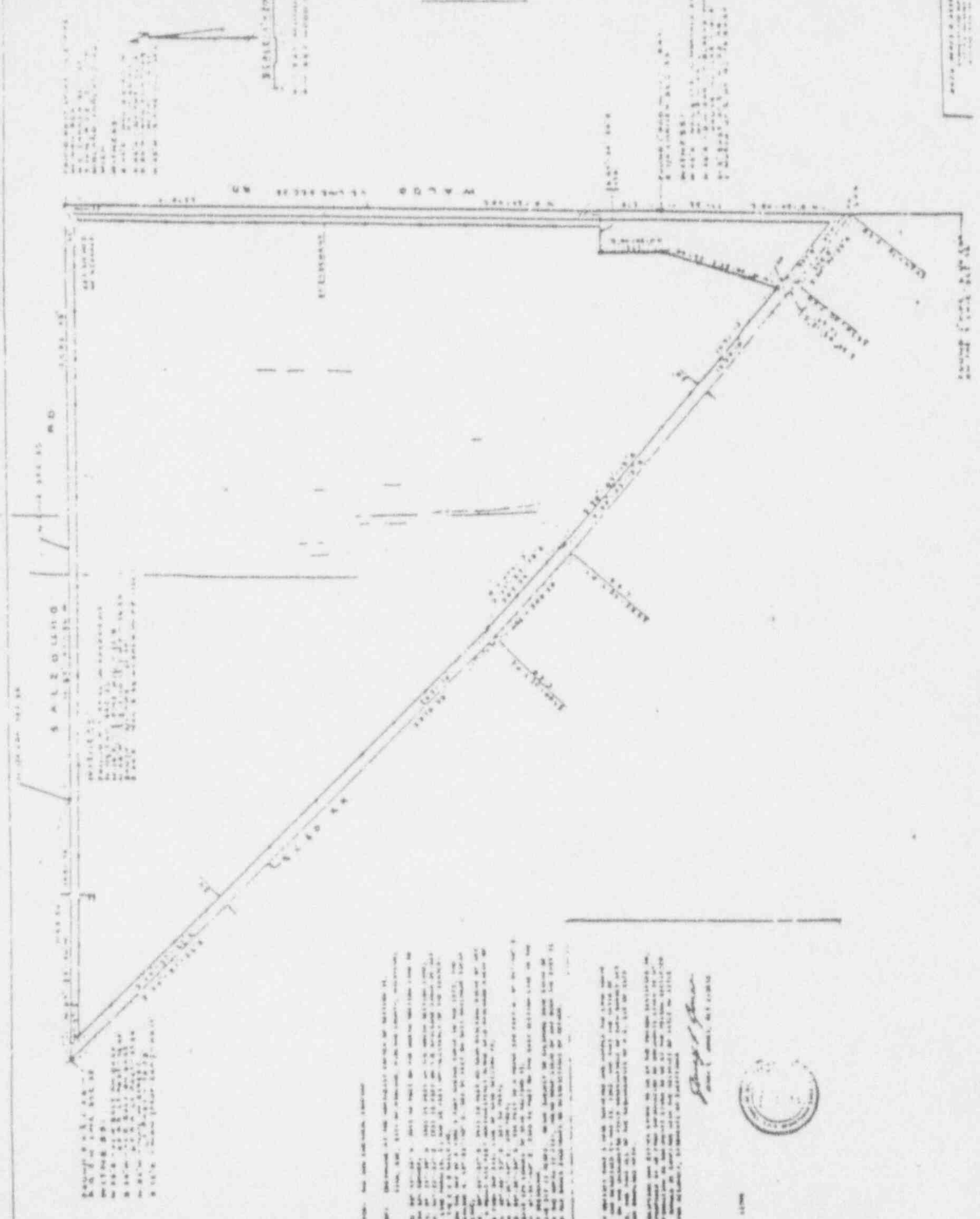
The information necessary to complete this instrument was supplied by The Dow Chemical Company, however, the instrument was prepared by the Michigan Department of Natural Resources.

____
NOTARY PUBLIC

CHERYL A. JOHNSON
Notary Public, Midland County, Michigan
My Commission Expires June 1, 1983

537 409

EXHIBIT A



DOW CHEMICAL U.S.A.

October 30, 1989

MICHIGAN DIVISION
MIDLAND MICHIGAN 48667

Germain LaRoche
MS6H3
U.S. Nuclear Regulatory Commission
Washington, DC 20555

SUBJECT: DOW THORIUM STORAGE SITE 20.302 APPLICATION AND DECOMMISSIONING PLANS

Attached is the 20.302 application for Dow NRC license STB-527 with plans for the decommissioning of the Bay City Thorium Storage Facility and a Health and Safety Plan.

Our intentions are to remove the thorium material from the storage site located on our Bay City Plant site and place it in a special cell at the Salzburg Landfill. There are State legislative deadlines in place which requires an expeditious regulatory review and approval, so your prompt attention is appreciated.

Please contact Don Berry (517-636-3595), if you have any questions or need additional information.

Randy Croyle

R. M. Croyle, Manager
Environmental Services
1261 Building
517-636-2646

cc: George Bruchman, MI Department of Public Health
Richard Traub, U.S. EPA, Region V
Mohammad Yusaf, MI Department of Natural Resources

9008280282

A/4

Quality Performance

Dow U.S.A.

The Dow Chemical Company
Midland, Michigan 48667

November 18, 1992

John Austin, Chief
Decommissioning & Regulatory Issues Branch
Mail Stop 5-E4
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Austin:

The Dow Chemical Company (Dow) has previously filed an application seeking authorization under 10 CFR 20.302 to dispose of certain thoriated wastes in its Salzburg Landfill. Dow now requests an exemption pursuant to 10 CFR 40.14(a) from any requirements arising from 10 CFR 40.42(f)(3) relating to the termination of Dow's license for these thoriated materials.

Section 40.42(f)(3) requires that a licensee demonstrate that the premises are suitable for release as an unrestricted site. The staff has stated that this provision requires a showing that an intruder will not incur a dose in excess of a few mrem/year even if the covers and cap of the disposal cell were removed. As shown by the enclosed materials, it is inappropriate to require such a showing in the case of disposal of the thoriated wastes at the Salzburg Landfill.

The disposal of the wastes in the Salzburg Landfill will assure protection of the environment and the public health, because the Salzburg Landfill includes inherent characteristics, design, and controls that will serve to assure the long-term isolation of the wastes. Moreover, the site possesses, and will maintain rigorous institutional controls that will assure the security and integrity of the site in perpetuity. It is our view that there is no other disposal site that is better designed and managed than our Salzburg Landfill and that will provide the long-term protections that this site offers.

The following materials provide information to be considered in connection with this request. If you have any questions or concerns, please contact me at your convenience.

Hayden Schoen

Hayden Schoen
The Dow Chemical Company
1261 Building
Midland, MI 48667
(517) 636-3874

9211200276

A15

UNRESTRICTED RELEASE EXEMPTION CRITERIA TO BE CONSIDERED FOR THE DISPOSAL OF THORIATED MATERIAL AT THE SALZBURG LANDFILL

I. Application Format

This application for an exemption for specific disposal licensing requirements has been organized to demonstrate the effectiveness of institutional controls over the site considered for disposal of this thoriated material. The following table of contents summarizes the issues for this exemption:

In order to limit the size of this application, information germane to the discussion that is contained in previous submittals will be referenced only, and will generally be found in:

1) the *License Application On-Site Thorium Disposal At The Salzburg Landfill* (Application) submitted to the NRC in October, 1989, and

2) *Response to Comments Dated September 18, 1991 on 10 CFR 20.302 Application for Disposal of Magnesium-Thorium Slag Material at the Salzburg Landfill Disposal Facility* (Response).

II. Facility Background

The Salzburg Landfill, located in Midland, Michigan, is owned and operated by Dow. The facility is used to manage hazardous wastes, regulated under Michigan Public Act 64, the Resource Conservation and Recovery Act (RCRA), and the Hazardous Solid Waste Amendments, along with non-hazardous solid wastes, regulated under Michigan Public Act 641, with all associated rules and regulations. The facility maintains active permits with respect to all four statutes, and is in full compliance with governing agencies.

The original design of the Salzburg Landfill spelled out a series of 52 cell units to be built, as needed, for management of the solid and hazardous wastes. The landfill is currently expected to have capacity at least through the year 2051, at which time the final cell would be capped and the entire 152 acre facility would enter its closure period, followed by post-closure care.

The cells proposed for the thorium disposal are referred to as cells 36 & 37, and a diagram of the landfill detailing the relative size and placement of the cells in relation to the landfill facility can be seen in Figure 5.1-1 of the Application. The design and construction of this unit would follow the stringent standards imposed on hazardous waste landfill cells, and would be overseen by the Michigan Department of Natural Resources (MDNR).

Thoriated material deposited in cells 36 & 37 of the Salzburg Landfill will be isolated from the environment, as detailed in the Application and Response. The superior long-term capability, inherent in disposal of thoriated material at the Salzburg Landfill, is displayed by:

1. Insolubility and lack of mobility of thoriated material in a soil/water environment,

2. Design of cells 36 & 37 to meet RCRA and NRC standards (e.g. multi-barrier liner and cap construction, full encapsulation of the waste, leachate monitoring and collection to eliminate potential migration pathway, etc.),

3. Characteristics of the Salzburg Landfill location to provide inherent isolation (e.g. geology, distance to aquifers, remoteness of surface water, clay content of soil, etc.),

4. Design of the repository (e.g. buffer zone to the perimeter, very low population density near the site, distance from hazardous waste cells, water management program to minimize run-on and percolation through cover, extensive groundwater monitoring, etc), and

5. National recognition of the Salzburg Landfill's superior design and performance.

III. Unrestricted Release

The Dow Chemical Company (Dow) recently submitted its Response to the Nuclear Regulatory Commission (NRC) for review. Comments from the NRC had proposed that dose calculations for the landfill facility should assume that the site is released for unrestricted use. The assumption was to be made that an intruder would unsuspectingly remove the covers and cap from the disposed-of thoriated waste, and unknowingly receive this dosage. A calculated dosage of less than a few mrem/yr would be acceptable, according to the NRC.

In Dow's Response, the position was taken that cells 36 & 37 were not to be intended for unrestricted release, and that sufficient institutional controls would be established in order to isolate the material from intrusion and the environment. Since the entire Salzburg Landfill is permitted as a RCRA disposal facility, the entire facility is subject to restrictive covenants, approved closure and post-closure plans, financial assurance, and long-term institutional control. Dow proposes the imposition of further restrictive covenants on cells 36 & 37. Dow does not intend for the disposal site to be released for unrestricted use, but rather intends to provide operational and institutional controls designed to propoerly manage the site in perpetuity.

The dosage, as calculated by using the scenario of the intrusion of an unsuspecting intruder would be greater than a few mrem/yr, but with the proper controls in place to preclude an intruder, as such, the appropriate scenario would have the covers left in place. The calculated dosage is very small if the cap and covers are left in place, as detailed in the Response.

IV. Superiority of Salzburg Landfill

Of the various alternatives available for disposal of Dow's thoriated material, the Salzburg Landfill is the most appropriate site for the proper management of the waste. There are no other available sites, better designed and operated, that will provide more superior barriers against intrusion. The comparative superiority of the Salzburg Landfill, relative to an offsite commercial facility, for disposal is demonstrated by:

1. Dow's ownership and operation of the Salzburg Landfill will assure the continuing responsibility of the generator for the emplaced waste. Offsite disposal at a commercial facility means transfer of the responsibility for the waste to the disposal site operator, with the attendant performance characteristics of that site's operation and potential for contamination,

2. There is currently only one offsite facility that can realistically be considered for the thoriated waste. While Dow has no reason to question the design, operation, or performance characteristics of the site, the Salzburg Landfill offers at least comparable characteristics, in terms of design and operation, along with the further guarantee of Dow's long-term responsibility and liability for material contamination,

3. The short transport distance (less than twenty miles) from Midland and Bay City to the Salzburg Landfill (vs over one thousand miles to commercial facilities) results in lower population and driver exposure, reduced accident potential, minimal community concerns, etc.,

4. Comparative total disposal costs are considerably less for Salzburg Landfill disposal with no sacrifice of protection of human health and the environment,

5. Disposal at Salzburg Landfill, which is essentially onsite disposal, adheres to the national policy encouraging onsite disposal over offsite disposal,

6. The potential for intrusion doses is as likely to be minimized by this approach as by the approaches in commercial facilities,

6. Consideration of intrusion into the waste as a potential pathway, with the attendant high doses applies equally to any location where near-surface disposal is used, as at available commercial facilities, and

7. More reliable long-term isolation can be achieved by depending on cell construction and landfill repository design (as at Salzburg Landfill) than on a buffer zone created by currently low population density (as at any available commercial facilities).

V. RCRA Controls

All of the 152 acre Salzburg Landfill site is subject to regulation under RCRA. The whole facility is considered to be a solid waste management unit, and is permitted as such. As new, individual cells are proposed for construction, the design is reviewed by MDNR, which maintains control over compliance with RCRA for the site, including waste management, groundwater contamination, leachate collection and analysis, landfill operation and administration, air monitoring, cell closure and maintenance, and security.

Under RCRA, the facility is subject to extensive monitoring and regulation, as detailed at 40 CFR Part 264, both during its active life and in post-closure. An extensive surveillance and inspection program is required, ensuring protection of human health and the environment. There are a multitude of operational and administrative controls that prevent unauthorized access to the facility. These controls can be found, spelled out in great detail, in the facility Operating License.

The Salzburg Landfill is operated in compliance with its Operating License, granted by MDNR in accordance with RCRA. This subjects the entire facility to the jurisdiction of RCRA and its regulations. Furthermore, the facility is then also subject to the submittal and approval process of Closure Plans and Post-Closure Plans. When the facility capacity has been consumed, RCRA requires that the operator notify the agency, and close the facility as per the Closure Plan.

Regulations concerning the Closure and Post-Closure requirements regarding hazardous waste management facilities are found at 40 CFR 264 Subpart G. As stated in the regulations, owners or operators of sites, such as Salzburg Landfill, *must close the facility in a manner that minimizes the need for further maintenance* and *protects human health and the environment.*

Once closure is complete, the facility enters the Post-Closure period, for which the initial period lasts thirty years. At any time during this phase, the Regional Administrator may extend the period if necessary to protect human health and the environment. As stated at 40 CFR 264.117, *The Regional Administrator may also require, at partial and final closure, continuation of any of the security requirements* when *access by the public or domestic livestock may pose a hazard to human health.*

This same regulation further states that Post-Closure use of a facility such as Salzburg Landfill *never be allowed to disturb the integrity of the final cover, liner(s),* unless the Regional Administrator approves of the action. There will be a very strict control over the entire Salzburg Landfill facility, even after it has been closed. This period can be as long as needed, in order to protect human health and the environment.

VI. Institutional Controls

The Salzburg Landfill facility has demonstrated the capacity to assure site integrity for the short and long-terms. These include:

1. Site access control (security fence, administrative criteria for entry, controlled gate access),

2. History of trouble-free operation at Salzburg Landfill, along with no evidence of offsite contaminant migration,

3. Extensive experience of the site operating personnel and Dow in the management of disposal facilities,

4. Imposition of strict restrictive covenants assuring Dow's long-term responsibility in generating cells 36 & 37 integrity, and

5. Support of the State of Michigan for the use of Salzburg Landfill to deposit the thoriated material, along with use of restrictive covenants to assure perpetual control of the site.

Another of the administrative constraints on the facility is found in section 3004 of RCRA, as regulated under 40 CFR 264 Subpart H. This details the requirement to maintain adequate financial resources that will establish financial assurance for closure and post-closure care of the facility. This is subject to a continued review process, and ensures that there will be sufficient funds for the long-term care of the site.

Following an administrative determination pursuant to section 3008 of RCRA that the owner of operator has failed to perform post-closure care in accordance with the approved post-closure plan and other permit requirements, the Regional Administrator may draw on the letter of credit, or other financial instrument, used to provide the financial assurance.

VII. CERCLA Liability

One of the basic tenets of Dows' waste management philosophy is to ensure that the waste it produces is managed in a manner that is protective of human health and the environment. To this end, Dow is devoted to managing its wastes in its own facilities, in the knowledge that these facilities have been located, designed, constructed, operated, and closed in the environmentally best fashion possible. One result of this is that Dow's liability under CERCLA is limited.

The Salzburg Landfill site generally should never have to remediated under CERCLA due to its superior characteristics. If Dow's thoriated material is transferred to an offsite commercial facility, Dow loses control over the destiny of the material. Dow has the ability to manage its wastes in its own facilities, but gives up that control when wastes are sent offsite. This loss of control is unsatisfactory to Dow.

Even though the ownership and responsibility to manage Dow's thoriated material would change hands if it was managed at a commercial facility, Dow would retain potential responsibility under CERCLA. If the commercial facility were to fail, and/or have any environmental contamination concerns, Dow could become a potentially responsible party for an entire remedial action by virtue of having arranged for disposal of regulated material at the site. This liablity is unacceptable to Dow, when there is an equally, if not superior, alternative available. This superior alternative is the use of Salzburg Landfill for disposal of Dow's thoriated material.

VIII. Restrictive Covenants

The Salzburg Landfill facility is required under RCRA to record a notice at the office of the County Register of Deeds as to the nature of materials disposed of on the site along with their location. This Declaration of Restrictive Covenants was attached to the deed to the property when the original RCRA license was obtained for the landfill in 1981.

More extensive, perpetual language has been developed for inclusion in the Declaration of Restrictive Covenants to reflect the potential disposal of the thoriated material at the Salzburg Landfill. Item 1 of the Attachments contains this updated Declaration of Restrictive Covenants, which meets the legal requirements of an equitable servitude under Michigan law. Dow and the NRC would bind the successors and assigns of the property to the terms of the Declaration by recording the document at the office of the County Register of Deeds.

Precedent in Michigan courts and the common law upon which the Michigan courts have relied, as well as doctrines of equity, support the enforceability of the Declaration. This ensures the long-term isolation of the thoriated material, in perpetuity. Item 2 of the Attachments contains an Opinion of Counsel which supports the enforceability of the provisions by Michigan Courts. As stated in the Declaration of Restrictive Covenants, the property use restrictions could be easily enforced by any local, state, or federal governmental agency, or any adjoining landowner to the property.

IX. Public Support

Meetings have been held with the public to communicate the plans for disposal of the thoriated material at the Salzburg Landfill. Personal visits to local homeowners and Salzburg Landfill neighbors were made to discuss Dow's plan. Communication with local groups of decision and policy makers, along with the news media, both in Bay City and Midland, has taken place. Public support has been very positive, as represented by the attached letter from Mary Sinclair, a local citizen activist.

Recent communication with the Midland Community Advisory Panel shows its support for the disposal of the material at the Salzburg Landfill. The general position taken is that the proposal is a constructive way to address the issue.

X. Agency Support

The MDNR is responsible for design, operation, and maintenance of hazardous waste facilities. Dow's proposal is to dispose of the thoriated waste in a landfill cell designed according to the stringent requirements for hazardous waste landfills. This agency has reviewed the Application and Response from a technical point of view, and is supportive of the disposal concept for the thoriated material in a cell at the Salzburg Landfill, constructed and operated according to hazardous waste landfill criteria. Written support from the MDNR can be found in Item 3 of the Attachments.

The Michigan Low Level Radioactive Waste Authority has reviewed both the Application and Response from a technical point of view. The Office of the Governor of the State of Michigan has also reviewed the Application and Response. Both of these groups are supportive of disposal of Dow's thoriated material at the Salzburg Landfill.

The Michigan Department of Public Health manages the radiological health program of the state, and has reviewed both the Application and Response from a technical point of view. The Environmental Protection Agency Region V has confirmed that, with the adequate degree of acceptable regulatory control by the state agencies, it has no concern with the proposal.

XI. Request Summary

The Salzburg Landfill will be properly managed and secure, today, as well as in the future. There need be no concern about leaking or leaching of material from the Salzburg Landfill, causing harm to human health and the environment. There should also be no concern about intrusion onto this site. Facility operational and administrative constraints such as site access control, site history, operating experience, and imposition of restrictive covenants will assure site integrity for the short and long terms.

The long-term control of the proposed disposal site is assured due to the stringent requirements imposed by the RCRA licensing of the facility. At the same time, institutional control of the site will be ensured by the extensive restrictions proposed to be added to the property deed. These provisions will enable this site to be properly managed in perpetuity.

Dow's Salzburg Landfill is the most appropriate site for the proper management of its low-level thorium waste. There is no other site that is better designed and managed, that will provide the isolation of this material from the environment.

For these reasons, proper isolation of Dow's thoriated waste would be assured if disposed of at the Salzburg Landfill, and this application for an exemption from the specific use of unrestricted release criteria should be granted, allowing full credit for the engineered barriers that will isolate this material from the environment.

ATTACHMENTS

ITEM 1

DECLARATION OF RESTRICTIVE COVENANTS

ITEM 2

OPINION OF COUNSEL

ITEM 3

LETTERS OF SUPPORT

DECLARATION OF RESTRICTIVE COVENANTS

DECLARATION OF RESTRICTIVE COVENANTS

The Dow Chemical Company ("Dow"), a Delaware corporation with executive offices at 2030 Dow Center, Midland, Michigan 48674 is the record owner of the following described premises located in Midland Township, Midland County, Michigan, to wit:

SEE ATTACHED EXHIBIT A FOR A LEGAL DESCRIPTION AND EXHIBIT B FOR A DIAGRAM OF THE PROPERTY.

Dow is in the process of constructing a landfill cell on the property described in Exhibit A for the permanent disposal of radioactive thorium-bearing material pursuant to a license granted by the United States Nuclear Regulatory Commission ("NRC") under 10 CFR 20.302.

Now, therefore, these restrictive covenants are executed by Dow to insure the long-term integrity of the disposal facility for the safety of the people of the state of Michigan, to wit:

(1) These covenants shall be in addition to those restrictive covenants currently on record affecting the above-described premises, and recorded at Liber 496, Pages 540 through 542, and Liber 537, Pages 406 through 409, Midland County Records.

(2) No excavation or construction, except as necessary to maintain the integrity of the above-described premises shall be allowed after the thorium-bearing material is disposed of and the cell closed.

(3) No uses of the property shall be made which may impair its integrity. Any change in use following closure of the cell shall require the prior written consent of the NRC, which shall not be unreasonably withheld.

(4) Dow shall erect, and it and its successors in interest, shall thereafter continuously maintain a metal monument placed on the above-described property, said monument to be approved by the NRC to warn of the presence of radioactive thorium-bearing material at the site.

(5) Dow shall notify the NRC of its intent to convey any interest in the property described herein. Such conveyance shall not be made without the prior written approval of the NRC, provided however that such approval by the NRC is not to be unreasonably withheld. No conveyance of title, easement or other interest in the property shall be consummated by Dow without adequate and complete provision for continued maintenance of the property.

(6) Any local, state or federal governmental agency, or any adjoining landowner to the property described herein affected by any violations of these restrictive covenants, may enforce them by legal action in the Circuit Court for Midland County.

(7) Dow agrees that any of the parties mentioned in the previous paragraph may obtain an immediate temporary restraining order from the Circuit Court upon an allegation that these restrictive covenants have been violated without any further showing being required. Dow shall then bear the burden of proof as to why such temporary restraining order should not be made a permanent injunction by the Court; Dow agrees not to contest the issuance of a permanent injunction unless it has the written concurrence of the NRC.

(8) Dow, its successors and assigns shall not at any time institute legal proceedings. by way of quiet title or otherwise, to remove or amend these restrictive covenants unless the NRC has given Dow advance written approval.

(9) The property described in Exhibit A is subject to an existing easement of record granted to Consumers Power Company for electric transmission lines.

These restrictive covenants shall run with the land in perpetuity and shall be binding upon Dow, its successors and assigns.

Dated this ______ day of ______________, 1992.

Witness ____________________ THE DOW CHEMICAL COMPANY

Witness ____________________ By: ______________________

STATE OF MICHIGAN)
) ss.
COUNTY OF MIDLAND)

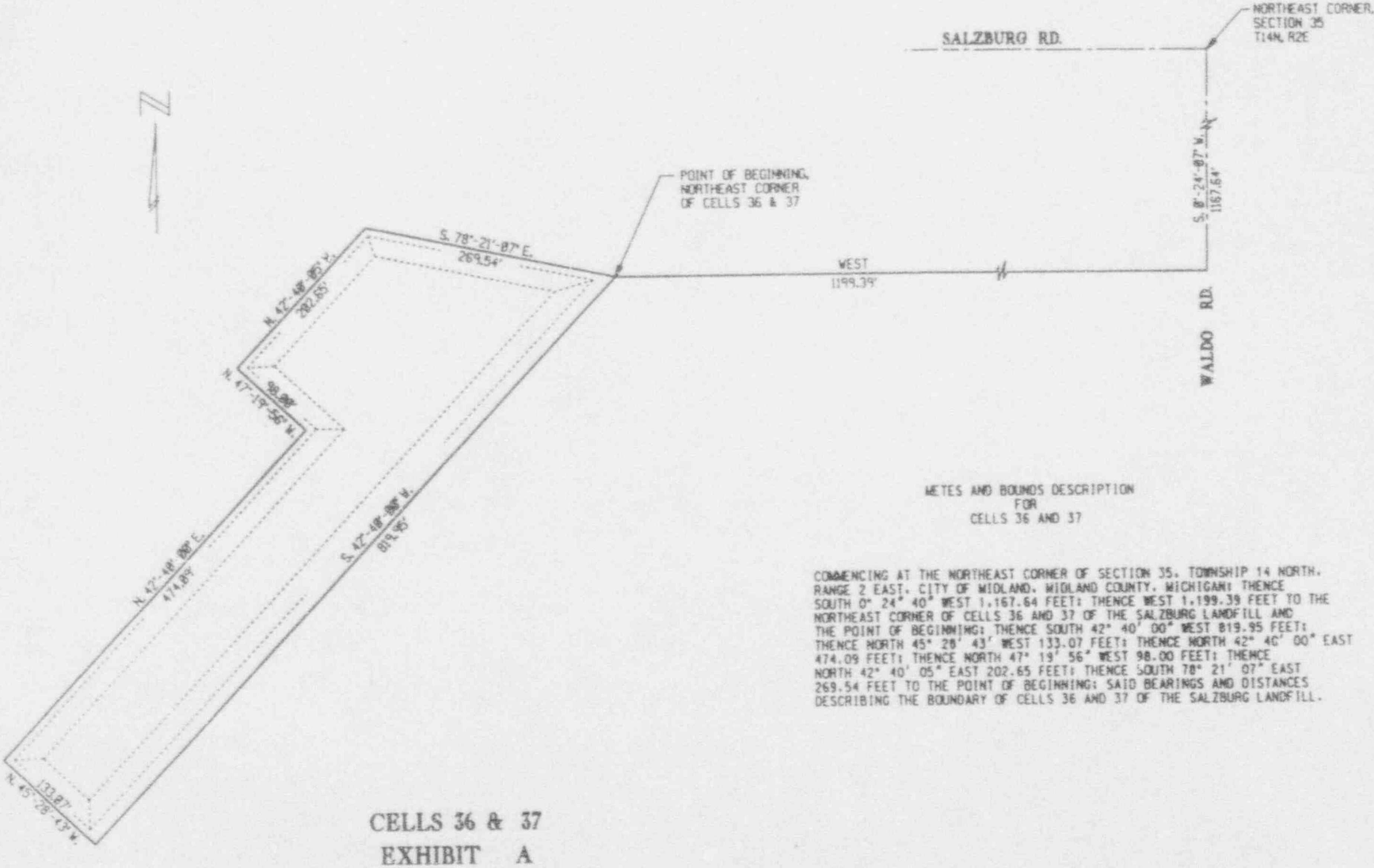
The foregoing instrument was acknowledged before me this ______ day of ______________, 1992, by ______________ of The Dow Chemical Company on behalf of the Corporation.

____
NOTARY PUBLIC

UNITED STATES NUCLEAR
REGULATORY COMMISSION

By: ______________________

This document was drafted by:
Tom McCormick, Division Counsel
The Dow Chemical Company, Michigan Division,
Legal Department, 47 Bldg., Midland, MI 48667

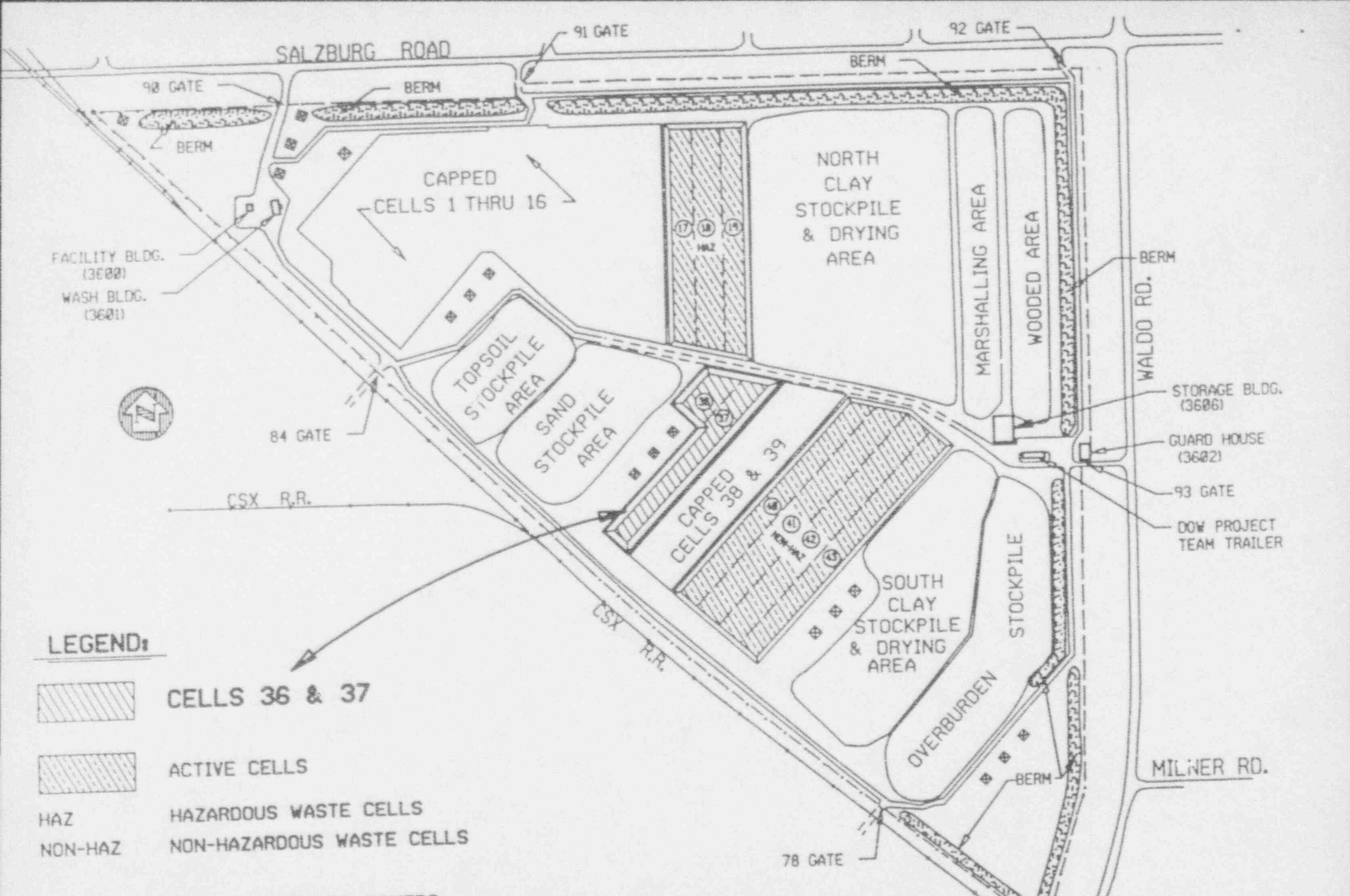


METES AND BOUNDS DESCRIPTION
FOR
CELLS 36 AND 37

COMMENCING AT THE NORTHEAST CORNER OF SECTION 35, TOWNSHIP 14 NORTH, RANGE 2 EAST, CITY OF MIDLAND, MIDLAND COUNTY, MICHIGAN; THENCE SOUTH 0° 24' 40" WEST 1,167.64 FEET; THENCE WEST 1,199.39 FEET TO THE NORTHEAST CORNER OF CELLS 36 AND 37 OF THE SALZBURG LANDFILL AND THE POINT OF BEGINNING; THENCE SOUTH 42° 40' 00" WEST 819.95 FEET; THENCE NORTH 45° 28' 43' WEST 133.07 FEET; THENCE NORTH 42° 40' 00" EAST 474.09 FEET; THENCE NORTH 47° 19' 56" WEST 98.00 FEET; THENCE NORTH 42° 40' 05" EAST 202.65 FEET; THENCE SOUTH 78° 21' 07" EAST 269.54 FEET TO THE POINT OF BEGINNING; SAID BEARINGS AND DISTANCES DESCRIBING THE BOUNDARY OF CELLS 36 AND 37 OF THE SALZBURG LANDFILL.

CELLS 36 & 37
EXHIBIT A

J.J.A. / L.E.G.
8/12/92



CELLS 36 & 37
SALZBURG LANDFILL
EXHIBIT B

8/92

OPINION OF COUNSEL

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CAROLYN P. CARY
IRENNA GARAPETIAN WEEKS
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WILLIAM G. TISHKOFF
BRIAN S. MAKARIC

Novemer 2, 1992

REPLY TO:
Saginaw

Mr. Thomas McCormick
Legal Department
The Dow Chemical Company
47 Building
Midland, Michigan 48667

RE: Enforceability of Restrictive Covenants and Equitable Servitudes in Michigan

Dear Mr. McCormick:

You have requested our opinion concerning whether the attached Declaration of Restrictive Covenants (the "Declaration") will be enforced by a Michigan Circuit Court.

It is our opinion that the Declaration will be enforced by a Michigan Circuit Court and a permanent injunction against The Dow Chemical Company ("Dow") will be issued if the Court determines that Dow has violated, or is about to violate, the Declaration.

The term "Restrictive Covenant" is somewhat of a misnomer as used in the Declaration. The covenants and restrictions contained in the Declaration are more accurately referred to as "Equitable Servitudes." The main distinction between the two terms is that the former requires privity of estate while the latter does not. The following is a brief review of the evolution of the common law governing Restrictive Covenants and Equitable Servitudes.

Restrictions imposed on real property are common today. The party imposing the restrictions generally desires them to be binding and enforceable against successors in title. The restrictions may be established in several ways, including by covenants at law which run with the land and by equitable servitudes.

Several requirements must be met before a restrictive covenant will run with the land. To have a covenant running with the land in Michigan, a three-part test is applied. The Court of Appeals set forth this test in Greenspan v Rehberg, 56 Mich App 310; 224 NW2d 67 (1974), stating that to have a covenant running with the land, "... the grantor and grantee must have intended that the covenant run with the land; the covenant must affect or concern the land with which it runs; and there must be privity of estate between the party claiming the benefit and the party who rests under the burden." Greenspan at 320-321, citing 21 CJS, Covenants, §54, p 923.

The privity requirement is the most difficult to prove. In Kotesky v Davis, 355 Mich 536; 94 NW2d 796 (1959), the Court discussed the issue of privity in a case involving building and use restrictions. The Court noted that where the plaintiff did not own any other property which the restriction might have benefited and, at the time the suit was brought, retained no interest in the parcel in question, the requirement of privity was not met.

The Declaration of Dow Chemical will not meet the requirements of a covenant at law. As in Kotesky v Davis, no privity of estate exists between Dow Chemical and the United States Nuclear Regulatory Commission ("NRC") or the other parties which may enforce the Declaration. However, the Declaration will be upheld as an equitable servitude.

The Michigan courts make a distinction between covenants running with the land and equitable servitudes. The various requirements of privity, so important to the enforcement of a covenant at law against successors to the original parties, are not applicable to an equitable servitude. Thus, the requirements for an equitable servitude are more liberal than the requirements for the running of a covenant at law.

An equitable servitude is particularly powerful against successors and assigns. Whereas a covenant at law will run only if the original parties had some sort of property relationship, anyone who takes possession of the burdened property will be bound by an equitable servitude, as long as there is sufficient notice, even though there is no privity of estate between the possessing party and the original promisor. An equitable servitude will also bind the holder of a lesser estate, such as a lessee or a licensee. Additional protection is therefore created by an equitable servitude for the NRC and other parties who may enforce the Declaration of Dow Chemical.

Equitable servitudes were first recognized in England. The inadequacy of legal remedies for breach of a use restriction led to the famous English case of Tulk v Moxhay, 41 Eng Rep 1143 (1848). The Court in Tulk granted the plaintiff an injunction in the Court of Equity even though the covenant was not enforceable at law. The

Court relied principally on a theory of unjust enrichment. The Court assumed that because a use restriction was placed on the property, the promisor in the second transaction had paid a lower price. The Court concluded that the promisor should not be allowed to convey to another without having the other bound to the restriction. The Court determined it would be inequitable to allow the original purchaser to sell the property without the restriction because the purchaser could then sell the property for a greater price without the restriction the day after the purchase.

Since Tulk v Moxhay, equity courts in both England and America have been willing to enforce an agreement as an equitable servitude against the burdened land when the subsequent purchaser has actual or constructive notice. The courts have done so whether or not the agreement constituted a valid covenant running with the land at law.

The enforcement of a restrictive covenant by someone other than the original parties has historically rested upon two different theories:

(1) That the covenant creates an equitable servitude or easement in favor of the covenantee's land, the benefit of which passes with the land upon its subsequent conveyance; or

(2) That the covenant is specifically enforceable in equity as a contract affecting real property, by the persons intended to be benefited thereby, as third party beneficiaries of the contract, regardless of the absence of privity of estate. 20 Am Jur 2d p 857-858.

Michigan courts have treated equitable servitudes as a special class of covenants that are enforceable simply because of the equities presented by the facts of a particular case. The courts do not require that use restrictions run with the land. The case of Sun Oil Company v Trent Auto Wash, Inc., 379 Mich 182; 150 NW2d 818 (1967), sets forth the doctrine of equitable servitudes which the Michigan courts embrace. In Sun Oil, the Court enforced a use restriction against a subsequent grantee, even though the restriction did not, on its face, purport to run with the land. In this case, a vendor, Clara Williams, conveyed property to Sun Oil. The deed contained a clause which provided that the adjacent land held by Clara Williams would not be used as a gasoline service station. Later, Clara Williams deeded the adjacent parcel to Trent Auto Wash. Trent Auto Wash had knowledge of the covenant entered into between Clara Williams and Sun Oil. Trent Auto Wash did not wish to abide by the prior agreement. The Michigan Supreme Court held that a court in equity could enjoin the vendor and those in privity with the vendor as long as the party had notice of the agreement. Enforcement did not depend on the doctrine of the running of a covenant with the land; rather, the Court stressed that since defendant had actual knowledge of the promise made in the deed to promisor, the defendant was bound to it.

The Court found that an equitable servitude existed, stating the following:

> The principal is stated by Lord Chancellor in the case of Tulk v Moxhay (1848), 2 Ph 774 (41 Eng Rep 1143), affirming 11 Beav 571 (50 Eng Rep 937):
>
> "The question does not depend upon whether the covenant runs with the land.... [I]f there was a mere agreement and no covenant, this court would enforce it against the party purchasing with notice of it; for if an equity is attached to the property by the owner, no one purchasing with notice of that equity can stand in a different situation from the party from whom he purchased."
>
> The principal of Tulk has been widely recognized and followed in numerous cases. Sun Oil at 186, 150 NW2d at 820.

The Michigan Supreme Court, in its opinion in Sun Oil, followed the decisions of several other courts. The Court cited the case of Thodos v Shirk, 248 Iowa 172; 79 NW2d 733 (1956), where the court, in discussing the doctrine of equitable servitudes, stated:

> Since the doctrine of equitable servitude rests upon the theory of a servitude imposed upon the land, enforceable against all subsequent purchasers of the land who are charged with notice actual or constructive, the requirement of the special words such as 'and assigns' is unnecessary in the deed. The sole test for the running of the burden in equity is the intention of the parties to impose a servitude upon the land as distinguished from a personal promise of the present owner. (Emphasis added) Thodos at 179.

According to its decision, use restrictions will run with the land as long as the original parties to the agreement to restrict the use of the property intend that the restriction so run. Thus, since it is the intention of Dow Chemical and the NRC that the Declaration run with the land, the successors and assigns of the property of Dow Chemical will be bound.

In Sun Oil, the Court also relied on Coomes v Aero Theatre and Shopping Center, Inc., 207 MD 432; 114 A2d 631 (1955):

> We reaffirm the doctrine [of Tulk] that if the owner of land enters into a covenant concerning its use, subjecting it to an easement or personal servitude, and the land is afterwards conveyed to one who has notice of the covenant, the grantee will take the land bound by the covenant and will be compelled in equity to specifically execute it or will be restrained from violating it; and it makes no difference, with respect to this liability in equity, whether or not the covenant is one which runs with the land. (Citations omitted) Coomes at 437.

The Court in Sun Oil, and the decisions upon which the Court relied, recognized the necessity of notice for an equitable servitude. Thus, an agreement against a subsequent purchaser will not be enforced in equity unless there was notice of the restriction. The notice requirement is satisfied not only if the subsequent purchaser has actual knowledge but also if he has constructive knowledge. If the restriction appears in the purchaser's direct chain of title, it will be sufficient to place him on constructive notice of the restriction. However, it is not necessary that the restriction be put in any deed of conveyance or that it be shown by any writing as long as notice is provided.[1] Furthermore, a conveyance is not required in order for restrictions to be upheld. Use restrictions of property are matters of private contract and may be upheld if consideration and the other essentials of a contract are present. The mutual agreement of the parties to an instrument to conform to use restrictions is deemed to be sufficient consideration to support a contract. 20 Am Jur 2d 729 - 730.

Even though the Declaration is not part of a deed or conveyance, Dow Chemical and the NRC have entered into a contract which will be validly recognized by Michigan courts. Since the Declaration of Dow Chemical will be recorded, constructive notice will be provided for all successors and assigns. Thus, the successors and assigns of Dow Chemical will be bound to the use restrictions set forth in the Declaration.

---

[1] This situation may be likened to the case of negative reciprocal easements, where a landowner is put on notice by the appearance of a common plan or scheme in the development.

CONCLUSION

Restrictions on the use of property in the State of Michigan will be upheld if there is a covenant at law which runs with the land or if there is an enforceable equitable servitude. An equitable servitude will be enforceable against any party in control or possession of the property as long as the original parties intended to bind the successors and assigns of the original promisee to the restrictions and the subsequent parties have notice of the restrictions.

The Declaration entered into between Dow Chemical and the NRC meets the requirements of an equitable servitude: Dow Chemical and the NRC intend to bind the successors and assigns of the property to the terms of the Declaration, as specified in the Declaration itself; furthermore, sufficient constructive notice of the terms of the Declaration will be provided to successors and assigns.

In conclusion, precedent in the Michigan courts and the common law upon which the Michigan courts have relied, as well as the doctrines of equity, support the enforceability of the Declaration.

Very Truly Yours,

Tom Luplow

THOMAS R. LUPLOW

TRL/cah

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LETTERS OF SUPPORT

5711 Summerset Drive
Midland, MI 48640
May 1, 1989

Pat Brink
Michigan Division
Dow Chemical Co.
Midland, MI 48667

Dear Pat:

In my letter to you on environmental problems in the Great Lakes region, I mentioned the fact that heavy metals pollution from the plating industry is generally agreed to be one of the worst. I also mentioned that Harry DeSoi of the Pioneer Metal Finishing Co. had been able to control this problem and that he addressed the Backyard Eco Conference on this issue.

A few days ago, I spoke with Ann Hunt, who is director of the organization named Citizens for Alternatives to Chemical Contamination in order to get his complete address and phone number. I also told her about meeting with Dow representatives on better environmental control in connection with the magnesium-thorium slag problem and the lunch session presentation you sponsored on waste reduction. Her response was so positive and encouraging that I thought I should share it with you.

I am going to be representing this organization at the annual meeting of Great Lakes United to be held in Canada this weekend. I have been asked to make a presentation at this meeting on the low level radioactive waste issue and I will be glad to relate the manner in which you initiated a better resolution of the magnesium-thorium slag problem as a good example of a constructive way to handle these kinds of problems.

Yours sincerely,

Mary Sinclair

STATE OF MICHIGAN

JOHN ENGLER, Governor

DEPARTMENT OF NATURAL RESOURCES

Stevens T. Mason Building, P.O. Box 30028, Lansing, MI 48909

ROLAND HARMES, Director

November 13, 1992

Mr. Jack Parrott, Program Manager
Nuclear Material Safety & Safeguards
U.S. Nuclear Regulatory Commission
One White Flint North Building
11555 Rockville Pike
Rockville, Maryland 20852

Dear Mr. Parrott:

SUBJECT: The Dow Chemical Company, Midland, Michigan
Disposal of Thorium Waste in the Salzburg Landfill
MID 980 617 435

Staff of the Michigan Department of Natural Resources (Department), Waste Management Division (WMD), have met with Mr. Hayden Schoen of The Dow Chemical Company (Dow) and has reviewed Dow's preliminary application to dispose of thorium waste at the Salzburg Landfill. This waste is currently being stored at the Bay City and Midland Plants. The Department is authorized by the U.S. Environmental Protection Agency for the administration and enforcement of the state's hazardous and solid waste programs. The Salzburg Landfill is regulated under licenses issued by the Department pursuant to the Hazardous Waste Management Act, 1979 P.A. 64, as amended (Act 64), and the Solid Waste Management Act, 1978 P.A. 641, as amended (Act 641). Michigan's Radioactive Waste Compact Act, 1987 P.A. 203, prohibits the disposal of radioactive waste in Michigan, unless the Nuclear Regulatory Commission approves of a disposal plan by January 1, 1993.

Based on discussions with Mr. Schoen, our understanding is that the thorium waste is to be placed in a separate cell at the Salzburg Landfill that meets the Act 64 hazardous waste landfill design standards. Provided Dow meets the applicable Act 64 and Act 641 landfill design requirements for the thorium waste disposal cell and constructs a separate leachate collection system for this cell, the Department has no objections to the concept of disposal of the thorium waste in the Salzburg Landfill. We have advised Mr. Schoen that it will be necessary for Dow to amend its license application(s) as necessary to include this proposal so that WMD staff can carry out the appropriate technical reviews needed for final Department approval.

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If you need additional information or have questions regarding the Department's position on this matter, please contact Mr. Ken Burda, Chief, Hazardous Waste Permits Section, Waste Management Division, Department of Natural Resources, P.O. Box 30241, Lansing, Michigan 48909, or at telephone number 517-373-0530.

Sincerely,

Russell J. Harding
Deputy Director
517-373-7917

cc: ✓Mr. Hayden Schoen, The Dow Chemical Co.
Mr. Rich Traub, U.S. EPA
Ms. Lorraine Kosik, U.S. EPA
Mr. Chad McIntosh, Governor's Office
Mr. Jim Sygo, DNR
Mr. Ken Burda, DNR/O.L. File
Mr. Steve Buda, DNR
Mr. Ed Haapala, DNR/Saginaw-Bay