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Risk-Based Prioritization for the Interim Remediation of Inactive Low-Level Liquid Radioactive Waste Underground Storage Tanks at Oak Ridge National Laboratory, Oak Ridge, Tennessee

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EXECUTIVE SUMMARY

This paper presents a risk-based approach for rapid prioritization of low-level liquid radioactive waste underground storage tanks (LLLW USTs), for possible interim corrective measures and/or ultimate closure. The ranking of LLLW USTs is needed to ensure that tanks with the greatest potential for adverse impact on the environment and human health receive top priority for further evaluation and remediation.

Wastes from the LLLW USTs at Oak Ridge National Laboratory were pumped out when the tanks were removed from service. The residual liquids and sludge contain a mixture of radionuclides and chemicals. Contaminants of concern that were identified in the liquid phase of the inactive LLLW USTs include the radionuclides ^{90}Sr, ^{137}Cs, and ^{233}U and the chemicals carbon tetrachloride, trichloroethene, tetrachloroethene, methyl ethyl ketone, mercury, lead, and chromium.

The risk-based approach for prioritization of the LLLW USTs is based upon three major criteria: (1) leaking characteristics of the tank, (2) location of the tanks, and (3) toxic potential of the tank contents.

Leaking characteristics of LLLW USTs will aid in establishing the potential for the release of contaminants to environmental media. In this study, only the liquid phase was assumed to be released to the environment. Scoring criteria for release potential of LLLW USTs was determined after consideration of the magnitude of any known leaks and the tank type for those that are not known to leak.

The location of the tanks will further aid in establishing the potential for contaminant migration into the environment. Location criteria can be based on the proximity of the tanks to ground and surface water and to human habitats. For this study, only the proximity to surface water bodies (White Oak Creek and its tributaries) was considered after analysis of the site conditions.

The toxic potential of the tank contents helps establish the potential for adverse impact of contaminant migration on environmental media, the food chain, and human health. Three factors are considered in establishing the toxic potential of the LLLW USTs: (1) the toxicity of the tank contents as determined by the toxicity factors—reference doses (RfDs) for noncarcinogens, cancer potency factors (CPFs) for chemical carcinogens, and cancer slope factors (CSFs) for radionuclides; (2) the concentrations of the contaminants of concern in the liquid phase; and (3) the liquid volume in each tank. These factors are combined into a single dimensionless number called the toxicity index (TI), which represents the total toxic potential of the tank.

For each tank, three weighted criteria were scored on a scale of 1 to 5. The sum of the three weighted scores represented the individual tank score (the maximum or worst possible score for a tank would be 30). All the inactive LLLW USTs were ranked on the basis of their individual scores.

The numeric scoring method proved adequate as a risk-based approach (using limited available information) for rapid prioritization of LLLW USTs for further evaluation and remediation.

INTRODUCTION

Closure of inactive low-level liquid radioactive waste underground storage tanks (LLLW USTs) located at Oak Ridge National Laboratory (ORNL) (Figs. 1 and 2) is required by U. S. Environmental Protection Agency (EPA) regulations (40 *CFR* Part 265). Currently, 40 LLLW USTs have been declared inactive. This report presents a risk-based approach to prioritize inactive USTs for further evaluation to determine if interim corrective measures (ICMs) are necessary. The ranking of inactive LLLW USTs is needed to ensure that tanks with greatest potential for adverse impact on the environment and human health receive first priority for further evaluation. A written plan for prioritization of inactive LLLW USTs for further evaluation is a stated requirement of the Federal Facilities Agreement (FFA) between the Department of Energy Oak Ridge Field Office (DOE-OR), EPA, and the Tennessee Department of Environment and Conservation (TDEC). A subsequent tank prioritization will be performed to determine which LLLW USTs require ICMs and in what priority.

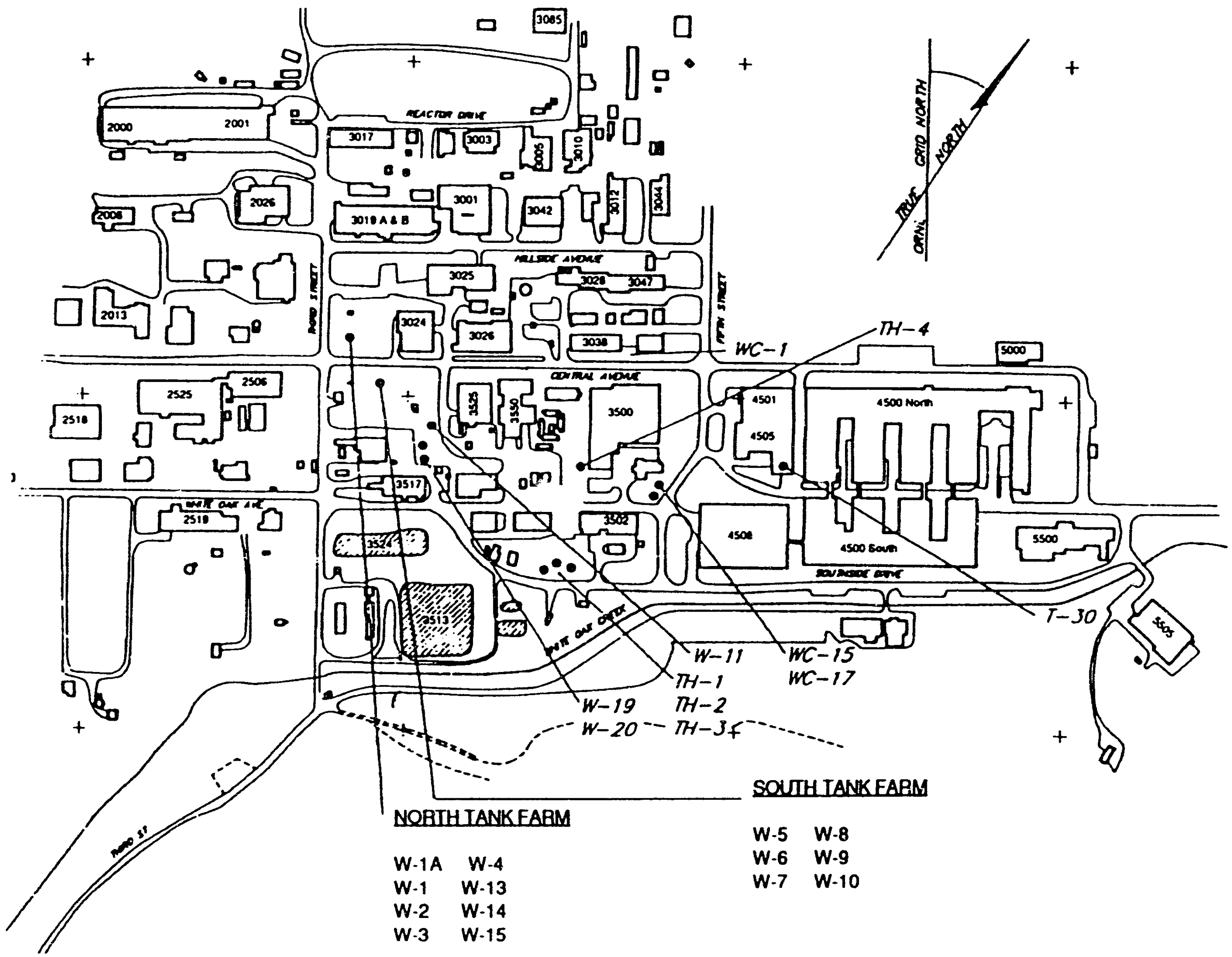

Fig. 1. Inactive waste storage tanks within the main plant area.

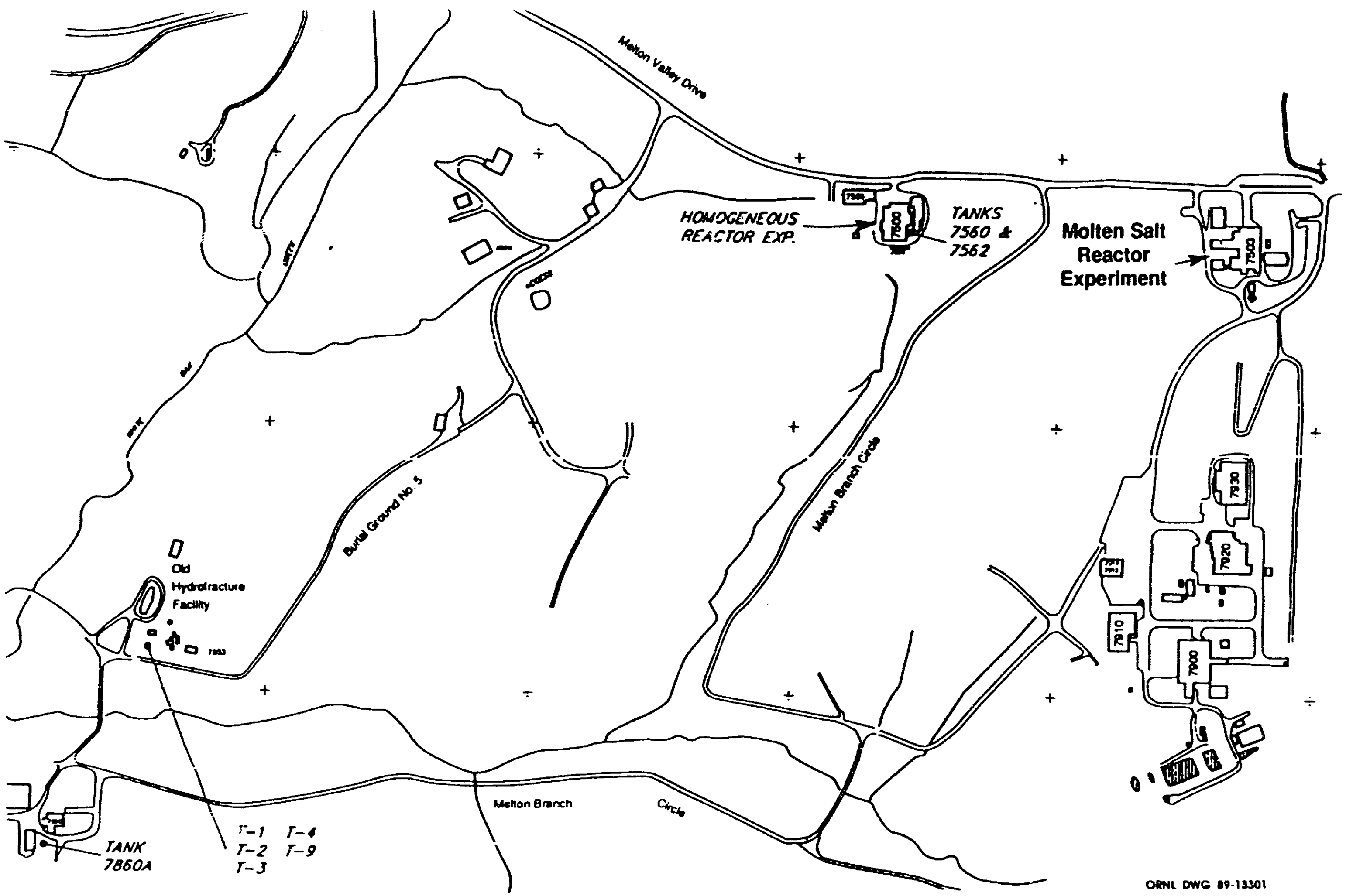

Fig. 2. Inactive waste storage tanks outside the main plant area.

BACKGROUND INFORMATION

Radioactive and hazardous chemical wastes have been produced from normal facility operations at Oak Ridge National Laboratory (ORNL) since its inception in 1943. Traditionally, USTs have been used for storage and treatment of LLLWs. Forty LLLW USTs have been declared inactive for various reasons including leaking tanks and/or leaking ancillary equipment, groundwater infiltration, development of better waste-handling systems, and the termination of operations that produced the wastes. Twenty-five inactive LLLW USTs are concentrated in the main plant area, six are located near the Old Hydrofracture Facility (OHF), and two are near the Homogeneous Reactor Experiment (HRE). Seven more USTs have been recently scheduled for sampling.

Although wastes from inactive LLLW USTs were pumped out when the tanks were removed from service, residual liquid and sludge remain in the tanks. Of the 40 inactive LLLW USTs, 30 have been sampled for preliminary characterization.[1] Of these 30 LLLW USTs, 3 were found empty and 1 (Tank 7860A) has been scheduled for closure under a separate plan. Sampling of the remaining ten inactive LLLW USTs is now underway. The more ubiquitous contaminants identified in the liquid phase of the inactive LLLW USTs include: the radionuclides ^{3}H, ^{90}Sr, ^{137}Cs, ^{60}Co, ^{233}U, ^{154}Eu, and ^{232}Th; the metals mercury, lead, and chromium; and the organics carbon tetrachloride, trichloroethene, tetrachloroethene, and methyl ethyl ketone.

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1. At the time of the study (June 1990), 40 tanks were designated as inactive. As of June 1991, 39 tanks in the Environmental Restoration Program and an additional 18 Waste Management tanks were designated as inactive.

METHODOLOGY

The risk-based approach for prioritization of the inactive LLLW USTs for further evaluation is based on three major criteria: (1) leaking characteristics of the tanks, (2) location of the tanks, and (3) toxicological characteristics of contaminants in the tanks. These three criteria are discussed in the following sections.

LEAKING CHARACTERISTICS

Leaking characteristics of the inactive LLLW USTs help establish the likelihood and extent of contaminant migration to environmental media. For currently known leakers, the scoring criteria are based on the quantity or degree of leakage (as determined from the leak data); when the leaking criteria of a tank are currently unknown, the scoring criteria are based on the structural material of the tank. For example, tanks constructed of porous concrete or mild steel susceptible to corrosion are more likely to leak than tanks constructed of stainless steel.

LOCATION

The location of inactive USTs further establishes the likelihood and extent of contaminant migration to environmental media. The location criterion is site-specific and is based on the proximity of the tank to groundwater and surface water and on the type and characteristics of the soil surrounding the tank. For the ORNL site, this criterion is based primarily on the proximity of the LLLW USTs to surface water.

TOXICOLOGICAL CHARACTERISTICS

Toxicological characteristics of contaminants detected in the tanks' residual liquids help establish the potential for adverse impact of contaminant migration on environmental media, the food chain, and human health (Autrey et al. 1990). Although USTs contain both liquid wastes and sludge, only the toxicological characteristics of liquid wastes will be considered because of their greater tendency to migrate to environmental media in the event of a leak.

Three factors are considered in establishing the toxicological characteristics of the LLLW USTs: (1) the toxicity of contaminants as determined by the reference dose (RfD) for noncarcinogenic chemicals, the cancer potency factor (CPF) for nonradioactive carcinogens, and the cancer slope factor (CSF) for radionuclides; (2) the concentration of the contaminants of concern in the liquid; and (3) the liquid volume in each tank. These factors are combined into a single dimensionless number called the Toxic Index (TI). Steps necessary to calculate the TI for an inactive LLLW UST are shown in the following sections.

Lifetime Reference Dose

RfDs for noncarcinogenic chemicals, CPFs for nonradioactive carcinogenic chemicals, and CSFs for radionuclides are converted into lifetime RfDs (EPA 1991).

Noncarcinogenic chemicals. For noncarcinogenic chemicals, a lifetime RfD (mg) is the total amount a person takes in over a lifetime if that person takes in the RfD for 70 years. Lifetime RfD is a product of the oral RfD (mg/kg/d), the reference body weight (70 kg), and the average lifetime exposure (70 years).

$$\text{Lifetime RfD (mg)} = \text{RfD (mg/kg/d)} \times 70\ \text{(kg)} \times 70\ \text{(years)} \times 365\ \text{(d/year)}$$

Nonradioactive carcinogenic chemicals. For nonradioactive carcinogenic chemicals, a lifetime RfD (mg) is the total dose a person receives over a lifetime of 70 years if that person takes in a daily dose equivalent to the 10^{-6} lifetime risk level. Lifetime RfD is a product of the acceptable lifetime cancer risk (10^{-6}), reference body weight (70 kg), and lifetime exposure (70 years × 365 d/year), divided by the oral CPF.

$$\text{Lifetime RfD (mg)} = \frac{10^{-6} \times 70\ \text{(kg)} \times 70\ \text{(years)} \times 365\ \text{(d/year)}}{\text{CPF (mg/kg/d)}^{-1}}$$

Radionuclides. For radionuclides, a lifetime RfD (pCi) is the total amount of radioactivity a person takes in if total exposure over a lifetime produces a 10^{-6} lifetime risk level. Lifetime RfDs (in pCi) are derived by dividing the 10^{-6} acceptable risk level by the ingestion CSFs (in pCi^{-1}).

$$\text{Lifetime RfD} = \frac{10^{-6}}{\text{CSF (pCi}^{-1}\text{)}}$$

Reference Volume

Reference volume is the volume of a contaminant-containing liquid that a person must ingest to receive a lifetime RfD. To define the reference volume in an inactive LLLW UST, a contaminant's lifetime RfD is divided by its highest concentration detected in the liquid.

$$\text{Reference Volume} = \frac{\text{Lifetime RfD for Contaminant}}{\text{Contaminant Concentration}}$$

Concentrations for noncarcinogenic and carcinogenic chemicals are expressed in mg/L. Concentrations for radionuclides are expressed in pCi/L. Reference volumes are computed for each contaminant of concern in an inactive LLLW UST. The resultant reference volumes for carcinogens and noncarcinogens are calculated separately (Chidambariah et al. 1991) and presented as follows:

$$\mathbf{CRV} = [\,\Sigma\, 1/V_i\,]^{-1}$$

$$\mathbf{NRV} = [\,\Sigma\, 1/V_i\,]^{-1}$$

where CRV is the cancer reference volume, NRV is the noncancer reference volume, and *i* is the identity of a particular contaminant. The lower of the two reference volumes is chosen as the representative reference volume for the particular tank.

Toxic Index

The TI is the number of reference volumes in the volume of residual liquid found in a tank. The TI considers both the toxicity of the contaminant and the volume of the contaminant in the liquid. To calculate the TI for an inactive LLLW UST, liquid volume (the volume of residual liquid in a tank, assumed to be constant over the period of sampling) is divided by the representative reference volume of the tank.

$$\text{Toxic Index} = \frac{\text{Liquid Volume}}{\text{Reference Volume}}$$

A range of TIs will be developed and suitably divided to separate the tanks into distinct groups, based on their individual TIs. To identify the range, the TIs for the individual tanks are calculated and inspected. These indexes are arranged so that the high and low ends of the range can be identified. The range of TIs is then subdivided and assigned score values ranging from 1 to 5.

SCORING PROCESS

The three criteria (leaking, location, and toxic potential) are used to rank the inactive LLLW USTs with respect to potential for adverse impact on the environment and human health. Using a scale of 0 to 5, a numeric score is assigned to each of the three criteria, with a score of 5 indicating highest priority. The scores from the three categories will be weighted according to their perceived importance. The sum of the scores for the three criteria is the score for a particular tank, and the highest possible score for a tank is 30. The following site-specific criteria are used to score the inactive LLLW USTs located at ORNL.

LEAKING CHARACTERISTICS

LLLW USTs that are known to be leaking are scored higher than those with unknown leaking characteristics.

Leaking characteristics	Score
Major outleaker	5
Small outleaker	4
Inleaker	3
Indeterminate leaker:	
Concrete	2
Mild steel	1
Stainless steel	0

The leaking characteristics category carries a weight of 3.

LOCATION

Inactive LLLW USTs located at the OHF and south of Central Avenue in the main plant area are scored higher because of their closer proximity to water bodies such as Melton Branch and White Oak Creek. Other inactive LLLW USTs are considered to be relatively distant from water bodies (tanks to the north of Central Avenue and those near the HRE) or have their contents pumped directly into the active LLLW waste system (tanks W1A and T30). These tanks are therefore scored lower in the location category.

Location	Score
Old Hydrofracture Tanks	5
South of Central Avenue	3
North of Central Avenue	2
HRE tanks	1
Pumped to Active Waste Systems	0

The location category carries a weight of 1.

TOXIC POTENTIAL

Toxic potentials of the contents of the LLLW USTs are scored on the basis of their respective TIs. A screening of toxic indexes indicated the following range is suitable to separate the tanks with respect to toxic potential.

Toxic Index	Score
$>10^{10}$	5
10^{10} to 10^{8}	4
10^{8} to 10^{6}	3
10^{6} to 10^{4}	2
$<10^{4}$	1

The toxic potential category carries a weight of 2.

APPLICATION

The inactive LLLW USTs are ranked in descending order, based on their scores. Tanks having the same or similar scores are grouped together. LLLW USTs with the highest scores are given first priority for further evaluation. A summary of scores for 29 of the ORNL inactive LLLW USTs is presented in Table 1 (The remaining tanks are currently undergoing sampling). Individual score sheets for each tank are provided in Appendix A. The priority list for the 29 inactive LLLW USTs is provided in the following table.

Priority	Inactive LLLW USTs
1	South tank farm (W-5,6,7,8,9,10); W-11
2	North tank farm (W-1,2,3,4,13,14,15); W-1A
3	Old Hydrofracture Facility tank farm (T-1,2,3,4,9)
4	Thorium tank TH-4
5	Thorium tanks (TH-1,2,3)
6	T30, 7562, 7560, W-19, W-20, WC-17, WC-1, WC-15

Tanks W-11, and W-13, W-14, and W-15 were included in their respective groups on the basis of proximity rather than the score. Tanks W-19, W-20, and 7560 were found to be empty during sampling and will not require further evaluation.

Table 1. Summary of Scores for Prioritization of 29 ORNL Inactive Tanks

Tank	Leak	Location	Toxic Index	Total Score
W1	6	2	4	12
W1A	9	2	6	17
W2	6	2	4	12
W3	9	2	8	19
W4	9	2	8	19
W5	9	3	8	20
W6	9	3	8	20
W7	9	3	10	22
W8	9	3	10	22
W9	9	3	8	20
W10	9	3	10	22
W11	9	3	4	16
W13	0	2	8	10
W14	0	2	8	10
W15	0	2	8	10
T1-T4, T9	3	5	8	16
TH1	0	3	6	9
TH2	0	3	6	9
TH3	0	3	6	9
TH4	6	3	6	15
WC1	0	2	6	8
WC15	0	3	4	7
WC17	0	3	2	5
T30	0	3	4	7
7562	0	1	6	7

CONCLUSIONS

The numeric scoring method proves adequate as a quick risk-based approach to prioritize inactive LLLW USTs for further evaluation. The resulting priority list is in agreement with qualitative assessments made by plant personnel familiar with tank operations.

REFERENCES

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APPENDIX

TOXIC INDEX CALCULATIONS

SAMPLE TOXIC INDEX CALCULATION

$$\mathbf{CRV = [\Sigma\ 1/v_i]^{-1}}$$

$$\mathbf{TI = \frac{Liquid\ Volume\ (L)}{CRV\ (L)}},$$

where

CRV	= cancer reference volume (L) for the tank,
v_i	= reference volume for the individual contaminant (L),
TI	= toxic index for the tank.

Tank # WC-1

Primary Contaminants	**Concentration(pCi/L)**	**Lifetime RfD (pCi)**	**Ref. Vol. (L)**
Cesium-137	1.7E+09	3.6E+04	2.1E-05
Strontium-90	8.9E+07	3.0E+04	3.4E-04
Plutonium-238	3.0E+07	3.6E+03	1.2E-04
Americium-241	3.5E+06	3.2E+03	9.1E-04

$$\mathbf{CRV = [\Sigma\ 1/v]^{-1} = 1.7E\text{-}05\ L}$$

$$TI = \frac{375\ \text{gal} \times 3.8\ (\text{L/gal})}{1.7E-05\ \text{L}} = 8.4E+07$$

Tank # WC-15

Primary Contaminants	**Concentration(pCi/L)**	**Lifetime RfD (pCi)**	**Ref. Vol. (L)**
Cesium-137	1.0E+05	3.6E+04	3.6E-01
Strontium-90	9.2E+04	3.0E+04	3.3E-01

$$\mathbf{CRV = [\Sigma\ 1/v]^{-1} = 0.17\ L}$$

$$TI = \frac{1000\ \text{gal} \times 3.8\ (\text{L/gal})}{0.17\ \text{L}} = 2.2E+04$$

Tank # T-4

Primary Contaminants	**Concentration(pCi/L)**	**Lifetime RfD (pCi)**	**Ref. Vol. (L)**
Cesium-137	8.1E+09	3.6E+04	4.4E-06

$$TI = \frac{9341\ \text{gal} \times 3.8\ (\text{L/gal})}{4.4E-06\ (\text{L})} = 8.1E+09$$

Tank # T-3

Primary Contaminants	**Concentration (pCi/L)**	**Lifetime RfD (pCi)**	**Ref. Vol. (L)**
Cesium-137	7.3E+09	3.6E+04	4.9E-06

$$\mathbf{TI} = \frac{\mathbf{2063\ gal \times 3.8\ (L/gal)}}{\mathbf{4.9E{-}06\ (L)}} = \mathbf{1.6E{+}09}$$

Tank # TH-2

Primary Contaminant	**Concentration (pCi/L)**	**Lifetime RfD (pCi)**	**Ref. Vol. (L)**
Cesium-137	7.4E+07	3.6E+04	4.9E-04
Strontium-90	7.9E+07	3.0E+04	3.8E-04

$$\mathbf{CRV = [\Sigma\ 1/v]^{-1} = 2.1E{-}04\ L}$$

$$\mathbf{TI} = \frac{\mathbf{72\ gal \times 3.8\ (L/gal)}}{\mathbf{2.1E{-}04\ L}} = \mathbf{1.3E{+}06}$$

Tank # T-9

Primary Contaminant	**Concentration (pCi/L)**	**Lifetime RfD (pCi)**	**Ref. Vol. (L)**
Cesium-137	7.8E+09	3.6E+04	4.6E-06
Strontium-90	9.7E+09	3.0E+04	3.1E-06

$$\mathbf{CRV = [\Sigma\ 1/v]^{-1} = 1.9E{-}06\ L}$$

$$\mathbf{TI} = \frac{\mathbf{1290\ gal \times 3.8\ (L/gal)}}{\mathbf{1.9E{-}06\ L}} = \mathbf{2.6E{+}09}$$

Tank # T-2

Primary Contaminant	Concentration (pCi/L)	Lifetime RfD (pCi)	Ref. Vol. (L)
Cesium-137	3.8E+09	3.6E+04	9.5E-06

$$TI = \frac{11{,}048 \text{ gal} \times 3.8 \text{ (L/gal)}}{9.5E\text{-}06 \text{ L}} = 4.4E{+}09$$

Tank # T-1

Primary Contaminant	Concentration (pCi/L)	Lifetime RfD (pCi)	Ref. Vol. (L)
Cesium-137	2.0E+09	3.6E+04	1.8E-05
Strontium-90	9.2E+07	3.0E+04	3.3E-04

$$CRV = [\Sigma\ 1/v]^{-1} = 1.7E\text{-}05$$

$$TI = \frac{11{,}047 \text{ gal} \times 3.8 \text{ (L/gal)}}{1.7E\text{-}05 \text{ L}} = 2.5E{+}09$$

Tank # TH-1

Primary Contaminant	Concentration (pCi/L)	Lifetime RfD (pCi)	Ref. Vol. (L)
Cesium-137	2.5E+08	3.6E+04	1.5E-04
Strontium-90	2.7E+08	3.0E+04	1.1E-04

$$CRV = [\Sigma\ 1/v]^{-1} = 6.3E\text{-}05$$

$$TI = \frac{278 \text{ gal} \times 3.8 \text{ (L/gal)}}{6.3E\text{-}05 \text{ L}} = 1.7E{+}07$$

Tank # TH-3

Primary Contaminant	Concentration (pCi/L)	Lifetime RfD (pCi)	Ref. Vol. (L)
Cesium-137	2.3E+08	3.6E+04	1.6E-04
Strontium-90	2.3E+08	3.0E+04	1.3E-04

$$\text{CRV} = [\Sigma\ 1/v]^{-1} = 7.1\text{E-05 L}$$

$$\text{TI} = \frac{145\ \text{gal} \times 3.8\ (\text{L/gal})}{7.1\text{E}-05\ \text{L}} = 7.8\text{E}+06$$

Tank # W-11

Primary Contaminant	Concentration (pCi/L)	Lifetime RfD (pCi)	Ref. Vol. (L)
Strontium-90	1.1E+06	3.0E+04	2.6E-02

$$\text{TI} = \frac{897\ \text{gal} \times 3.8\ (\text{L/gal})}{2.6\text{E}-02\ \text{L}} = 1.3\text{E}+05$$

Tank TH-4

Primary Contaminant	Concentration (pCi/L)	Lifetime RfD (pCi)	Ref. Vol. (L)
Cesium-137	6.5E+06	3.6E+04	5.5E-05
Strontium-90	5.4E+05	3.0E+04	5.6E-02

$$\text{CRV} = [\Sigma\ 1/v]^{-1} = 5.0\text{E-03 L}$$

$$\text{TI} = \frac{16{,}982\ \text{gal} \times 3.8\ (\text{L/gal})}{5.0\text{E}-03\ \text{L}} = 1.3\text{E}+07$$

Tank # W-5

Primary Contaminant	**Concentration (pCi/L)**	**Lifetime RfD (pCi)**	**Ref. Vol. (L)**
Cesium-137	1.5E+08	3.6E+04	2.4E+04
Strontium-90	4.3E+06	3.0E+04	7.0E-03

$$CRV = [\Sigma\ 1/v]^{-1} = 2.3E\text{-}04\ L$$

$$TI = \frac{10{,}278\ gal \times 3.8\ (L/gal)}{2.3E-04\ L} = 1.7E+08$$

Tank # W-6

Primary Contaminant	**Concentration (pCi/L)**	**Lifetime RfD (pCi)**	**Ref. Vol. (L)**
Cesium-137	5.4E+08	3.6E+04	6.7E-05

$$TI = \frac{77{,}044\ gal \times 3.8\ (L/gal)}{6.7E-05\ L} = 4.4E+09$$

Tank # W-7

Primary Contaminant	**Concentration (pCi/L)**	**Lifetime RfD (pCi)**	**Ref. Vol. (L)**
Cesium-137	1.7E+10	3.6E+04	2.1E-06

$$TI = \frac{7{,}044\ gal \times 3.8\ (L/gal)}{2.1E-06\ L} = 1.3E+10$$

Tank # W-8

Primary Contaminant	Concentration (pCi/L)	Lifetime RfD (pCi)	Ref. Vol. (L)
Cesium-137	1.1E+10	3.6E+04	3.3E-06

$$TI = \frac{28{,}244 \text{ gal} \times 3.8 \text{ (L/gal)}}{3.3\text{E}-06 \text{ L}} = 3.3\text{E}+10$$

Tank # W-9

Primary Contaminant	Concentration (pCi/L)	Lifetime RfD (pCi)	Ref. Vol. (L)
Cesium-137	1.7E+09	3.6E+04	2.1E-05

$$TI = \frac{12{,}990 \text{ gal} \times 3.8 \text{ (L/gal)}}{2.1\text{E}-05 \text{ L}} = 2.4\text{E}+09$$

Tank # W-1

Primary Contaminant	Concentration (pCi/L)	Lifetime RfD (pCi)	Ref. Vol. (L)
Cesium-137	4.9E+05	3.6E+04	7.3E-02

$$TI = \frac{1{,}213 \text{ gal} \times 3.8 \text{ (L/gal)}}{7.3\text{E}-02 \text{ L}} = 6.3\text{E}+04$$

Tank # W-2

Primary Contaminant	Concentration (pCi/L)	Lifetime RfD (pCi)	Ref. Vol. (L)
Cesium-137	5.9E+05	3.6E+04	6.1E-02

$$TI = \frac{647 \text{ gal} \times 3.8 \text{ (L/gal)}}{6.1\text{E}-02 \text{ L}} = 4.0\text{E}+04$$

Tank # W-4

Primary Contaminant	Concentration (pCi/L)	Lifetime RfD (pCi)	Ref. Vol. (L)
Cesium-137	5.7E+07	3.6E+04	6.3E-04
Strontium-90	7.8E+06	3.0E+04	3.8E-03

$$\mathrm{CRV} = [\Sigma\ 1/v]^{-1} = 5.4\mathrm{E}{-04}\ \mathrm{L}$$

$$\mathrm{TI} = \frac{17{,}062\ \mathrm{gal} \times 3.8\ (\mathrm{L/gal})}{5.4\mathrm{E}{-04}\ \mathrm{L}} = 1.2\mathrm{E}{+08}$$

Tank # W-10

Primary Contaminant	Concentration (pCi/L)	Lifetime RfD (pCi)	Ref. Vol. (L)
Cesium-137	6.5E+09	3.6E+04	5.5E-06

$$\mathrm{TI} = \frac{70{,}618\ \mathrm{gal} \times 3.8\ (\mathrm{L/gal})}{5.5\mathrm{E}{-06}\ \mathrm{L}} = 4.9\mathrm{E}{+10}$$

Tank # W-3

Primary Contaminant	Concentration (pCi/L)	Lifetime RfD (pCi)	Ref. Vol. (L)
Cesium-137	3.5E+07	3.6E+04	9.7E-04

$$\mathrm{TI} = \frac{31{,}847\ \mathrm{gal} \times 3.8\ (\mathrm{L/gal})}{9.7\mathrm{E}{-04}\ \mathrm{L}} = 1.2\mathrm{E}{+08}$$

Tank # WC-17

Primary Contaminant	**Concentration (pCi/L)**	**Lifetime RfD (pCi)**	**Ref. Vol. (L)**
Cesium-137	3.5E+04	3.6E+04	1.0E+00

$$TI = \frac{370 \text{ gal} \times 3.8 \text{ (L/gal)}}{1.0 \text{ L}} = 1.4E{+}03$$

Tank # W-13

Primary Contaminant	**Concentration (pCi/L)**	**Lifetime RfD (pCi)**	**Ref. Vol. (L)**
Cesium-137	1.7E+10	3.6E+04	2.1E-06
Strontium-90	1.6E+10	3.0E+04	1.9E-06

$CRV = [\Sigma\, 1/v]^{-1} = 1.0E{-}06$

$$TI = \frac{457 \text{ gal} \times 3.8 \text{ (L/gal)}}{1.0E{-}06 \text{ L}} = 1.7E{+}09$$

Tank # W-14

Primary Contaminant	**Concentration (pCi/L)**	**Lifetime RfD (pCi)**	**Ref. Vol. (L)**
Cesium-137	1.1E+10	3.6E+04	3.3E-06
Strontium-90	1.2E+10	3.0E+04	2.5E-06

$CRV = [\Sigma\, 1/v]^{-1} = 1.4E{-}06$ L

$$TI = \frac{259 \text{ gal} \times 3.8 \text{ (L/gal)}}{1.4E{-}06 \text{ L}} = 7.0E{+}08$$

Tank # W-15

Primary Contaminant	Concentration (pCi/L)	Lifetime RfD (pCi)	Ref. Vol. (L)
Cesium-137	4.3E+10	3.6E+04	8.4E-07
Strontium-90	4.6E+10	3.0E+04	6.5E-07

$$\text{CRV} = [\Sigma\ 1/v]^{-1} = 3.7\text{E-07 L}$$

$$\text{TI} = \frac{664 \text{ gal} \times 3.8 \text{ (L/gal)}}{3.7\text{E}-07 \text{ L}} = 6.8\text{E}+09$$

Tank # W-1A

Primary Contaminant	Concentration (pCi/L)	Lifetime RfD (pCi)	Ref. Vol. (L)
Cesium-137	3.8E+06	3.6E+04	9.5E-03
Strontium-90	8.6E+06	3.0E+04	3.5E-03
Plutonium-238	5.1E+07	3.6E+03	7.1E-05
Plutonium-239	1.8E+06	3.2E+03	1.8E-03

$$\text{CRV} = [\Sigma\ 1/v]^{-1} = 6.6\text{E-05 L}$$

$$\text{TI} = \frac{25 \text{ gal} \times 3.8 \text{ (L/gal)}}{6.6\text{E}-05 \text{ L}} = 1.4\text{E}+06$$

Tank # T-30

Primary Contaminant	Concentration (pCi/L)	Lifetime RfD (pCi)	Ref. Vol. (L)
Cesium-137	1.1E+05	3.6E+04	3.3E-01
Strontium-90	4.1E+05	3.0E+04	7.3E-02
Uranium-238	1.1E+05	7.7E+03	7.0E-02
Plutonium-239	9.5E+04	3.2E+05	3.3E+00
Curium-244	8.4E+05	5.0E+03	5.9E-03

$$\mathbf{CRV = [\Sigma\ 1/v]^{-1} = 5.0E\text{-}03\ L}$$

$$TI = \frac{40\ \text{gal} \times 3.8\ (\text{L/gal})}{5.0\text{E}-03\ \text{L}} = 3.0\text{E}+04$$

Tank # 7562

Primary Contaminant	Concentration (pCi/L)	Lifetime RfD (pCi)	Ref. Vol. (L)
Strontium-90	4.6E+07	3.0E+04	6.5E-04

$$TI = \frac{378\ \text{gal} \times 3.8\ (\text{L/gal})}{6.5\text{E}-04\ \text{L}} = 2.2\text{E}+06$$

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