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SEP 28 2000

ENGINEERING DATA TRANSMITTAL

Page 1 of 1

1. EDT 630431

2. To: (Receiving Organization) Distribution	3. From: (Originating Organization) CPO Requirements Planning and Support	4. Related EDT No.: N/A
5. Proj./Prog./Dept./Div.: At-Tank Low-Activity Waste Feed Homogeneity Analysis Verification/River Protection Project/CPO RP&S/Characterization Project & Matrix Support	6. Design Authority/ Design Agent/Cog. Engr.: James G. Douglas	7. Purchase Order No.: N/A
8. Originator Remarks: This document is being released into the supporting document system for retrievability purposes.		9. Equip./Component No.: N/A 10. System/Bldg./Facility: N/A
11. Receiver Remarks: 11A. Design Baseline Document? [] Yes [X] No For release.		12. Major Assm. Dwg. No.: N/A 13. Permit/Permit Application No.: N/A 14. Required Response Date: 09/27/00

15. DATA TRANSMITTED

(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Approval Desig-nator	(G) Reason for Trans-mittal	(H) Origi-nator Dispo-sition	(I) Receiv-er Dispo-sition
1	RPP-7029	N/A	0	At-Tank Low-Activity Waste Feed Homogeneity Analysis Verification	N/A	2	1	1

16. KEY

Approval Designator (F)	Reason for Transmittal (G)		Disposition (H) & (I)	
E, S, Q, D or N/A (see WHC-CM-3-5, Sec.12.7)	1. Approval 2. Release 3. Information	4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment	4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION
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BD-7400-172-2 (05/96) GEF097

BD-7400-172-1

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At-Tank Low-Activity Waste Feed Homogeneity Analysis Verification

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Office of River Protection Contract DE-AC06-99RL14047

EDT/ECN: EDT-630431 UC: 2070
Org Code: 7NK00 CACN/COA: 108931/B000
B&R Code: EW 3120074 Total Pages: 39

Key Words: At-Tank, Low-Activity Waste, Waste Feed, Analysis Verification, ICD-19, ICD-20, Grab Sampling, Homogeneity

Abstract:
This report evaluates the merit of selecting sodium, aluminum, and cesium-137 as analytes to indicate homogeneity of soluble species in low-activity waste (LAW) feed and recommends possible analytes and physical properties that could serve as rapid screening indicators for LAW feed homogeneity. The three analytes are adequate as screening indicators of soluble species homogeneity for tank waste when a mixing pump is used to thoroughly mix the waste in the waste feed staging tank and when all dissolved species are present at concentrations well below their solubility limits. If either of these conditions is violated, then the three indicators may not be sufficiently chemically representative of other waste constituents to reliably indicate homogeneity in the feed supernatant. Additional homogeneity indicators that should be considered are anions such as fluoride, sulfate, and phosphate, total organic carbon/total inorganic carbon, and total alpha to estimate the transuranic species. Physical property measurements such as gamma profiling, conductivity, specific gravity, and total suspended solids are recommended as possible at-tank methods for indicating homogeneity. Indicators of LAW feed homogeneity are needed to reduce the U.S. Department of Energy, Office of River Protection (ORP) Program's contractual risk by assuring that the waste feed is within the contractual composition and can be supplied to the waste treatment plant within the schedule requirements.

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9/28/00
Release Approval Date

DATE: SEP 28 2000 STA: 4 HANFORD RELEASE ID: 2
Release Stamp

Approved for Public Release

RPP-7029
Revision 0

AT-TANK LOW-ACTIVITY WASTE FEED HOMOGENEITY ANALYSIS VERIFICATION

J. G. Douglas
CH2M HILL Hanford Group, Inc.

Date Published
September 2000

CH2MHILL
Hanford Group, Inc.

Prepared for the U.S. Department of Energy
Office of River Protection

ABSTRACT

This report evaluates the merit of selecting sodium, aluminum, and cesium-137 as analytes to indicate homogeneity of soluble species in low-activity waste (LAW) feed and recommends possible analytes and physical properties that could serve as rapid screening indicators for LAW feed homogeneity. The three analytes are adequate as screening indicators of soluble species homogeneity for tank waste when a mixing pump is used to thoroughly mix the waste in the waste feed staging tank and when all dissolved species are present at concentrations well below their solubility limits. If either of these conditions is violated, then the three indicators may not be sufficiently chemically representative of other waste constituents to reliably indicate homogeneity in the feed supernatant. Additional homogeneity indicators that should be considered are anions such as fluoride, sulfate, and phosphate, total organic carbon/total inorganic carbon, and total alpha to estimate the transuranic species. Physical property measurements such as gamma profiling, conductivity, specific gravity, and total suspended solids are recommended as possible at-tank methods for indicating homogeneity. Indicators of LAW feed homogeneity are needed to reduce the U.S. Department of Energy, Office of River Protection (ORP) Program's contractual risk by assuring that the waste feed is within the contractual composition and can be supplied to the waste treatment plant within the schedule requirements.

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ABBREVIATIONS AND ACRONYMS

BNFL	British Nuclear Fuels Limited, Inc.
bq	Becquerel
CFR	Code of Federal Regulations
cm	centimeter
DOE	U.S. Department of Energy
DST	double-shell tank
ft/s	feet per second
FY	fiscal year
g	gram
g/cc	grams per cubic centimeter
g/L	gram per liter
HLW	high-level waste
HTWOS	Hanford Tank Waste Operation Simulator
ICD	interface control document
in.	inch
kgal	kilogallons
kL	kiloliters
LAW	low-activity waste
m/s	meters per second
moles/L	moles per liter (molarity)
ORP	Office of River Protection
$S\ cm^2\ mol^{-1}$	siemens-square centimeter per mole
sp gr	specific gravity
SST	single-shell tank
TFCO&UP	Tank Farm Contractor Operation and Utilization Plan
TIC	total inorganic carbon
TOC	total organic carbon
TRU	transuranic actinides
TWRS	Tank Waste Remediation System (now River Protection Project)
TWRSO&UP	Tank Waste Remediation System and Utilization Plan (now TFCO&UP)
vol%	volume percent
WTP	waste treatment plant
°C	degrees Celsius
%	percent

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1.0 SUMMARY AND CONCLUSIONS

1.1 SUMMARY

This report has two objectives:

(1) to evaluate the merit of selecting sodium (Na), aluminum (Al), and cesium-137 (^{137}Cs) as analytes to indicate homogeneity of soluble species in low-activity waste (LAW) feed to the waste treatment plant (WTP) and

(2) to evaluate and recommend analytes or physical properties that could serve as rapid "screening" indicators for assessing the mixing or settling status (homogeneity) of LAW feed tank batches.

Sodium, aluminum, and cesium-137 are specified as homogeneity indicators in Interface Control Document 19 (ICD-19) "...because their [concentrations are] at least ten times higher than [their respective detection limits], cesium is not affected by the solids concentrations, and sodium and aluminum may be affected by the 'solids' in the tank waste" (BNFL 2000a). Welsh (1994) demonstrates the feasibility of using waste analytes to indicate the homogeneity of waste in tank 241-AP-102.

This report does not attempt to generate a statistical basis for determining feed homogeneity. The intent is to examine the suitability of chemical and radiochemical constituents and physical properties of LAW feed to act as indicators for determining the homogeneity of the feed. This report also does not assess the sampling and analytical methods or the statistical means, accuracy, and precision that would be required to make the at-tank measurements of these analytes or waste properties.

To evaluate candidate homogeneity indicators, Case 3 was selected from the *Tank Waste Remediation System Operation and Utilization Plan* as a "typical" model for processing Phase 1 LAW feed (Kirkbride et al. 1999). Kirkbride et al. (1999) has since been superceded by the release of the *Tank Farm Contractor Operation and Utilization Plan* (Kirkbride et al. 2000), but for the purpose of this document, Case 3 is still adequate as a processing model.

1.2 CONCLUSIONS

The conclusions and recommendations presented in this report are summarized as follows:

(1) The three ICD-19-specified analytes are adequate as screening indicators of soluble species homogeneity for tank waste in two situations:

- when a mixing pump is used to thoroughly mix the staged waste as indicated by a suitable at-tank homogeneity screening method and

- when all dissolved species are present at concentrations well below their solubility limits.

If either of these conditions is violated, then the three indicators may not reliably indicate homogeneity in the feed supernatant. Additional homogeneity indicators that should be considered are anions such as fluoride, sulfate, and phosphate, total organic carbon/total inorganic carbon, and total alpha to estimate the transuranic species. The primary criterion for proposing these additional indicators is that the three ICD-19-specified indicators may not sufficiently represent the chemical behavior of all the major species in the supernatant. For example, temperature or pH gradients in the supernatant may cause metal carbonates or phosphates to precipitate from the supernatant and, therefore, form non-homogenous concentration gradients in the supernatant.

(2) If it can be demonstrated that in-tank mixing sufficiently homogenizes the LAW feed, then measuring a single waste feed analyte or property may be sufficient to verify homogeneity of a waste feed batch.

(3) Because the order for processing feeds for delivery is not well established at this time, evaluating candidate homogeneity indicators based on a comparison of indicator concentrations in adjacent feed batches was not deemed a highly useful approach.

(4) Physical property measurements such as gamma profiling, conductivity, specific gravity, and total suspended solids are recommended as possible at-tank methods for indicating homogeneity. These physical property measurements correlate with major species in the waste feed such as ^{137}Cs, sodium, hydroxide, nitrate, and weight percent suspended solids. Gamma profiling responds predominantly to the ^{137}Cs content in the waste. The concentrations of sodium, hydroxide, and nitrate in the waste supernatant dominate the conductivity of the supernatant. Because supernatant specific gravity is correlated with the sodium and nitrate concentrations in the waste supernatant, measuring specific gravity of the supernatant may indicate the distribution of sodium and nitrate throughout the waste feed. Finally, if measurement of suspended solids shows these to be uniformly distributed throughout the tank, then it seems safe to assume that the supernatant is homogeneously mixed as well.

2.0 INTRODUCTION

2.1 BACKGROUND

The U.S. Department of Energy (DOE) Office of River Protection (ORP) directs the operation of 177 large underground tanks for the storage of corrosive, radioactive, aqueous wastes at the Hanford Site in southeast Washington State. Of these tanks, 149 are single-shell tanks (SSTs) and 28 are double-shell tanks (DSTs). The DSTs have nominal capacities of 4,391 kL (1,160 kgal). The waste materials were generated as by-products from the production and separation of special nuclear materials. Tank storage and operations are conducted under the management of CH2M HILL Hanford Group, Inc., for the DOE ORP.

The ORP is preparing to initiate the treatment and immobilization of Hanford tank wastes. The tank wastes will be treated to yield separate vitrified high-level waste (HLW) and low-activity waste (LAW) products. The LAW feed staged for treatment will be composed of dissolved tank waste constituents with a limited quantity of suspended solids.

Prior to delivery to the WTP, the waste feed must meet the specifications in DOE (1998), Interface Control Document 19 (ICD-19) (BNFL 2000a) for LAW feed, and Interface Control Document 20 (ICD-20) (BNFL 2000b) for HLW feed. The specifications include chemical and physical properties of the waste. For LAW feed, ICD-19 requires that the soluble species in the supernatant must also be homogeneous (BNFL 2000a).

In addition to meeting specification requirements, other conditions may require a homogeneity test prior to feed delivery. These conditions may include a partial delivery of waste feed from a source tank known to be stratified or from a waste source known to contain a large fraction of suspended solids. The need for homogeneity indicators is dependent, in part, on the feed delivery approach, the to-be-determined definition of a feed "batch" used for feed certification, and waste properties that impact the ability to obtain a representative sample of a waste batch. Homogeneity testing may not be required for every feed delivery, such as staged LAW feed for which very little driving force exists to stratify the waste or for those feeds for which "whole-tank" composite samples are adequate to characterize the feed as allowed under ICD-19.

Indicators of LAW feed homogeneity are needed to reduce the ORP Program's contractual risk by assuring that the waste feed is within the contractual composition and can be supplied to the WTP within the schedule requirements. The ICD-19 states that Na, Al, and ^{137}Cs were chosen as homogeneity indicators "...because their [concentrations are] at least ten times higher than [their respective detection limits], cesium is not affected by the solids concentrations, and sodium and aluminum may be affected by the 'solids' in the tank waste."

The ICD-19 defines the verification method for homogeneity determination as: (1) mixing the tank waste contents with a mixer pump to create a homogeneous waste material; (2) turning off the mixer pump; (3) immediately grab sampling the waste from eight different depths below a single riser; (4) analyzing each sample in the laboratory for Na, Al, and ^{137}Cs; and (5) performing a statistical analysis of analytical data to determine if the waste is homogeneous (BNFL 2000a). The statistical analysis is used to determine if the soluble tank contents are homogeneous (location variability is not distinguishable from zero), "practically" homogeneous (spatial variability is less than or equal to 20 percent), in need of additional mixing and sampling (consider if spatial variability is greater the 20 percent), or if further negotiations with WTP operations are needed (evaluation of additional data after additional mixing and sampling still are not within the spatial variability of 20 percent). This report does not assess the ability of sampling methods, analytical methods, or sensors to generate data adequate to allow a statistical determination of waste feed homogeneity. Welsh (1994) demonstrated the feasibility of using analytes in tank waste to assess the homogeneity of supernatant waste in tank 241-AP-102.

2.2 LOW-ACTIVITY WASTE FEED SPECIFICATIONS

The composition of the LAW feed must meet the specifications outlined in Specification 7 of DOE (1998). Sampling and laboratory analysis will be used to evaluate compliance to these specifications:

- the sodium concentration must be between 3 moles/L and 10 moles/L,

- the suspended solids content may contain up to 2 weight percent (dry weight) suspended solids,

- the soluble components in the LAW feed must meet the mole ratio to sodium for non-radionuclides and Becquerel-to-mole ratio to sodium for radionuclides as listed in Tables 2-1 and 2-2,

- trace quantities of chemical constituents and radionuclides other than those listed in Tables 2-1 and 2-2 may be present in the feed,

- the feed provided to the WTP shall not contain a visible separate organic phase, and

- the feed must meet all operating and safety requirements for the tank farms (except free hydroxide).

Table 2-1. Low-Activity Waste Chemical Composition, Soluble Fraction Only[1]

Chemical Analyte	Maximum Ratio, analyte (mole) to sodium (mole)		
	Envelope A	Envelope B	Envelope C
Al	2.50E-01	2.50E-01	2.50E-01
Ba	1.00E-04	1.00E-04	1.00E-04
Ca	4.00E-02	4.00E-02	4.00E-02
Cd	4.00E-03	4.00E-03	4.00E-03
Cl	3.70E-02	8.90E-02	3.70E-02
Cr	6.90E-03	2.00E-02	6.90E-03
F	9.10E-02	2.00E-01	9.10E-02
Fe	1.00E-02	1.00E-02	1.00E-02
Hg	1.40E-05	1.40E-05	1.40E-05
K	1.80E-01	1.80E-01	1.80E-01
La	8.30E-05	8.30E-05	8.30E-05
Ni	3.00E-03	3.00E-03	3.00E-03
NO_2	3.80E-01	3.80E-01	3.80E-01
NO_3	8.00E-01	8.00E-01	8.00E-01
Pb	6.80E-04	6.80E-04	6.80E-04
PO_4	3.80E-02	1.30E-01	3.80E-02
SO_4	1.00E-02	7.00E-02	2.00E-02
TIC[2]	3.00E-01	3.00E-01	3.00E-01
TOC[3]	5.00E-01	5.00E-01	5.00E-01
U	1.20E-03	1.20E-03	1.20E-03

Notes:

TIC = total inorganic carbon
TOC = total organic carbon

[1]DOE (1998)
[2]Mole of inorganic carbon atoms/mole sodium
[3]Mole of organic carbon atoms/mole sodium

Table 2-2. Low-Activity Waste Radionuclide Content[1], Soluble Fraction Only[2]

Radionuclide	Maximum Ratio, radionuclide (Bq) to sodium (mole)		
	Envelope A	Envelope B	Envelope C
TRU[3]	4.80E+05	4.80E+05	3.00E+06
^{137}Cs	4.30E+09	2.00E+10	4.30E+09
^{90}Sr	4.40E+07	4.40E+07	8.00E+08
^{99}Tc	7.10E+06	7.10E+06	7.10E+06
^{60}Co	6.10E+04	6.10E+04	3.70E+05
^{154}Eu and ^{155}Eu	1.20E+06	1.20E+06	4.30E+06

Notes:

TRU = transuranic actinides

[1]The activity limit as of the feed certification date.
[2]DOE (1998)
[3]TRU is defined in 10 CFR Part 61.55.

Some radionuclides, such as ^{90}Sr and ^{137}Cs, have daughters with relatively short half-lives. These daughters are not listed in this table. However, they are present in concentrations associated with the normal decay chains of the radionuclides.

2.3 PROBLEM STATEMENT

The first objective of this work was to evaluate the merit of using Na, Al, and ^{137}Cs as indicators to determine the homogeneity of Phase 1 LAW. A second objective was to evaluate and recommend alternative analyte indicators or physical properties that could also serve as rapid "screening" indicators for indicating feed homogeneity.

This report does not generate a statistical basis for determining feed homogeneity, nor does it address the precision and accuracy needed to indicate a homogeneous or non-homogeneous condition. The intent is to examine the suitability of specific chemical and radiochemical constituents and physical properties of LAW feed to act as indicators that can be used to indicate a homogeneous or non-homogeneous waste batch condition. Sampling methods, analytical methods, and sensors needed to make the requisite measurements will be identified in future documents. All the analytes listed in Tables 2-1 and 2-2 were considered as possible candidate homogeneity indicators. Additional properties of the feed, such as gamma activity, conductivity, specific gravity, and total suspended solids, are also potential "screening" indicators for feed homogeneity. For grab sampling of tank 241-AP-102 supernatant and laboratory analysis of the grab samples, Welsh (1994) demonstrated that the homogeneity of the supernatant waste could be demonstrated by measuring specific waste analytes and properties.

In order to evaluate what waste feed constituents or properties may be useful homogeneity indicators, some of the major causes for waste inhomogeneity or stratification must be considered. Stratification of waste may occur when:

- waste streams of varying densities are added to a tank with no subsequent intentional mixing,

- suspended solids in the waste feed settle according to size and density,

- temperature gradients exist in the waste (caused, for example, by a thermally hot sludge heel in the tank) that might cause the non-uniform precipitation or dissolution of sparingly soluble species, and

- pH gradients exist in the waste (caused, for example, by intentional additions of transfer line flushes or additions of caustic to the feed for corrosion control) that might cause the non-uniform precipitation or dissolution of sparingly soluble species.

Useful homogeneity indicators or sets of indicators should be able detect these conditions and allow a determination of whether or not a waste batch is homogeneous prior to delivery to the WTP.

2.4 TANK MIXING AND HOMOGENEITY INDICATORS

If mixing sufficient to homogenize the LAW feed can be demonstrated, then measuring one waste feed analyte or property may be sufficient to verify homogeneity in a tank. The results of two studies are presented that support this conclusion, one based on the sampling and analysis of tank 241-AP-102 samples, and the other based on computer simulations.

Welsh (1994) presents data that show that 4,200 kL (1,110 kgal) of waste in tank 241-AP-102 were homogeneous after approximately 53 days of mixing with an in-tank mixer pump. Homogeneity was determined by analyzing eighteen grab samples pulled at random depths from three risers. These eighteen samples were analyzed for metals, anions, hydroxide, total inorganic carbon, total organic carbon, radionuclides, specific gravity, and percent water. The data from these analyses were subjected to an analysis of variance to determine any significant differences among the samples. The analysis of variance revealed that all the analytes were distributed homogeneously throughout the supernatant with the exceptions of beryllium and carbonate. This particular study demonstrated that a single analyte such as sodium may be sufficient to demonstrate homogeneity throughout the supernatant portion of tank contents after thorough mixing, provided the species is below its saturation level.

Computer-simulated mixing tests provide evidence that one hour of mixing waste slurry is sufficient to homogenize 2,930 kL (775 kgal) of waste in a tank (Onishi and Recknagle 1998). Mixing evaluations based upon the TEMPEST computer code for waste in tank 241-AN-105 indicate that when the supernatant in the tank is mixed with 7.23 vol% of the tank solids, a suspended solids distribution of 94.4% uniformity is obtained in one hour (Onishi and Recknagle 1998). The computer code modeled a single 300-horsepower mixing jet pump located at the bottom center of the tank. The pump was modeled with two diametrically opposed, 15-cm (6-in.) diameter discharge jets located 18 cm (7 in.) off the tank bottom. The two jets discharged outward horizontally at 18 m/s (60 ft/s) just above the tank bottom and rotate to cover the total tank bottom area. A reasonable assumption is that if the insoluble suspended solids in the tank are nearly homogeneously distributed throughout the liquid waste, then the soluble components in the liquid waste should also be homogeneously distributed. This assumption would need to be verified prior to using suspended insoluble solids as a homogeneity indicator for the soluble species in LAW feed.

3.0 EVALUATION OF ICD-19-DEFINED HOMOGENEITY INDICATORS

This section provides an evaluation of the three ICD-19-defined homogeneity indicators: Na, Al, and ^{137}Cs. The evaluation does not include an assessment of sampling, analytical methods, or sensors required for measuring these indicators, and does not examine the accuracy and precision to which homogeneity may be determined. Section 5.0 contains some candidate at-tank sensing methods for determining homogeneity. Because of the differing chemical natures of the constituents in the waste feed, measurement of several analytes may be required to assure waste feed batch homogeneity.

All of the LAW feed constituents listed in Tables 2-1 and 2-2 were considered as possible additional or alternative candidate homogeneity indicators. To evaluate candidate homogeneity indicators, the Phase 1 Case 3 LAW processing scenario was selected from the *Tank Waste Remediation System and Utilization Plan* (TWRSO&UP) (now *Tank Farm Contractor Operation and Utilization Plan* [TFCO&UP]) as a "typical" model for processing Phase 1 LAW feed (Kirkbride et al. 1999, 2000). The final model chosen to process LAW feed will likely be different from Case 3. However, many of the general assumptions regarding waste volumes processed, volumes of flush solution used to flush the lines after waste transfers, and volumes of tank heels left after processing a batch should be comparable irrespective of the process model used. For example, Case 3 LAW feed will be staged in batches that range from 1,554 kL (411 kgal) (batch 9) to 4,016 kL (1,061 kgal) (batch 11) with supernatant tank heels of about 104 kL (27.5 kgal) (Kirkbride et al. 1999).

Two approaches were considered for evaluating homogeneity indicators:

(1) comparing the relative differences of LAW feed constituent concentrations from one feed batch to the next, and

(2) grouping the LAW feed constituents by chemical characteristics.

3.1 COMPARISON OF LOW-ACTIVITY WASTE FEED CONSTITUENT CONCENTRATIONS BY BATCH

In this approach, a useful homogeneity indicator would be a waste constituent that exhibits widely varying concentrations from one feed batch to the next. As the feeds are mixed, the indicator would show a large change from its initial concentrations in the feed batches to its final concentration in the mixed batch. To have high confidence in the homogeneity indication, this approach would require that approximately equivalent quantities of waste feeds from the different batches would be mixed in the staging tanks, and assumes a particular order in which the waste feeds will be staged.

In Case 3, batches of LAW feed will be mixed with any tank heel in the staging tank prior to sending the feed to the WTP. If the tank heel in the staging tank is 104 kL (27.5 kgal) (Kirkbride et al. 1999, Appendix A), the largest contribution of the tank heel to the total waste volume will be six percent when mixed with the 1,554 kL (411 kgal) of batch 9. This LAW feed batch will be staged in tank 241-AN-101.

Because Case 3 requires no significant blending of LAW feeds in the staging tanks, and because the order for processing feeds for delivery is not settled, evaluating candidate homogeneity indicators based on comparison of indicator concentrations in adjacent feed batches was not deemed a highly useful approach. However, when the waste feed delivery schedule is established, this approach may become more feasible.

3.2 GROUPING LOW-ACTIVITY WASTE FEED CONSTITUENTS BY CHEMICAL CHARACTERISTICS

The second approach to evaluating candidate homogeneity indicators is to consider how well a candidate indicator acts as a surrogate for the chemical nature of other constituents in the feed. For this evaluation, the analytes and radionuclides in Tables 2-1 and 2-2 were combined and sorted by their fundamental chemical characteristics. Table 3-1 presents the results of this sort by chemical characteristics.

Table 3-1. Low-Activity Waste Feed Analytes Sorted by Chemical Characteristics, Soluble Fraction Only (2 sheets)

Analyte	Likely Species Charge or Oxidation State	Chemical Grouping[1]	Possible Supernatant Species
PO_4	3-	anion	PO_4^{3-}
SO_4	2-	anion	SO_4^{2-}
TIC	2-	anion	CO_3^{2-}
TOC	1-, 2-	organic anion	formate, acetate, oxalate
F	1-	VIIA	F^-
Cl	1-	VIIA	Cl^-
NO_2	1-	anion	NO_2^-
NO_3	1-	anion	NO_3^-
Na	1+	IA	Na^+
K	1+	IA	K^+
^{137}Cs	1+	IA	$^{137}Cs^+$
Ca	2+	IIA	Ca^{2+}
^{90}Sr	2+	IIA	$^{90}Sr^{2+}$
Ba	2+	IIA	Ba^{2+}
^{60}Co	2+	VIII	$^{60}Co^{2+}$
Ni	2+	VIII	Ni^{2+}
Cd	2+	IIB	Cd^{2+}
Hg	2+	IIB	Hg^{2+}

Table 3-1. Low-Activity Waste Feed Analytes Sorted by Chemical Characteristics, Soluble Fraction Only (2 sheets)

Analyte	Likely Species Charge or Oxidation State	Chemical Grouping[1]	Possible Supernatant Species
Pb	2+	IVA	Pb^{2+}
Al	3+	IIIA	$Al(OH)_4^-$
Fe	3+	VIII	$Fe(OH)_4^-$
La	3+	lanthanide	La^{3+}
^{154}Eu and ^{155}Eu	3+	lanthanide	Eu^{3+}
U	6+	actinide	UO_2^{2+}
TRU[2]	≥3+	actinide	see note 2
Cr	6+	VIB	CrO_4^{2-}
^{99}Tc	7+	VIIB	TcO_4^-

Notes:

TIC = total inorganic carbon
TOC = total organic carbon
TRU = transuranic actinides

[1]Roman numerals refer to periodic table grouping
[2]The transuranic species include ^{137}Np, and isotopes of plutonium, americium, and curium. The exact oxidation state is dependent upon the chemical species.

Table 3-1 may be used to compare the chemical nature of the three analytes identified in ICD-19 with other constituents of interest in LAW feed. The greater the similarity between the indicators and the other constituents, the greater the confidence that the indicators will be valid for predicting homogeneity of other analytes of interest in the LAW feed. For example, should a temperature gradient exist in the tank, a non-uniform precipitation of solids from the supernatant could result and cause concentration gradients to occur in the supernatant (see Section 2.3). In such circumstances, the selected homogeneity indicators should reflect the resulting concentration gradients in the supernatant.

Examination of Table 3-1 reveals that:

- of these indicators, sodium and ^{137}Cs are both singly charged alkali metal cations and should adequately represent the singly charged alkali metal cations in the waste feed,
- aluminum may represent the alkaline earth and transition metal cations that easily form metal hydroxide precipitates,
- none of these indicators represent phosphate, sulfate, or carbonate anions that easily form metal precipitates,
- none of these indicators represent organic species,

- none of these indicators represent uranium or the transuranic species.

As an example of how the three existing indicators may not represent all species in the supernatant, calcium carbonate could precipitate non-uniformly from the supernatant because of a temperature gradient in the tank waste and not be adequately registered by any of the existing indicators.

Because the three original indicators may not adequately represent all the LAW feed analytes, additional indicators are recommended to cover all the analytes. These indicators are the anions, especially fluoride, sulfate, and phosphate, total inorganic carbon/total organic carbon, and total alpha for the transuranic species. Not all of the at-tank homogeneity screening methods discussed in Section 5.0 respond to these additional indicator analytes. Sampling of the LAW feed coupled with laboratory analyses will be required to determine these additional indicator analytes.

4.0 WASTE FEED STAGING

This section provides waste feed characterization data and a description of the process delivery and sampling procedure defined in ICD-19 that will be used in assessing the homogeneity status. This information is supportive in understanding the range of chemical analyte concentrations, volumes of liquids and solids in the feed, batch sizes, types of waste, and sequence of processing.

4.1 LOW-ACTIVITY WASTE FEED STAGING

The Phase 1 Case 3 LAW feeds listed in Table 4-1 represent the Phase 1 waste to be processed as indicated by DOE on April 1, 1999 (Taylor 1999). Table 4-1 lists the tank wastes to be delivered, order of delivery, waste envelope, units of waste, and liquid and solids volumes for delivery. Case 3 uses 241-AN Farm tanks as feed staging tanks.

Table 4-1. Tank Wastes in Phase 1, Case 3 Low-Activity Waste Processing[1]. (2 Sheets)

Tank	Batch Number (and order of delivery)	Envelope	Values Projected by HTWOS				
				Liquid Volume		Solids Volume	
			Units	kL	(kgal)	kL	(kgal)
241-AN-107	1	C	652	3,669	(969.2)	13.60	(3.592)
241-AN-104	2	A	532	3,402	(898.7)	4.79	(1.265)
	3	A	566	3,516	(928.9)	16.59	(4.382)
241-AN-102	4	C	548	2,964	(782.9)	4.815	(1.272)
	5	C	532	2,959	(781.6)	4.459	(1.178)
241-AN-105	6	A	519	3,318	(876.4)	4.187	(1.106)
	7	A	534	3,318	(876.4)	3.948	(1.043)
241-SY-101	8	A	421	2,732	(721.8)	0.027	(0.007)
	9	A	306	1,554	(410.6)	0.148	(0.039)
241-AN-103	10	A	548	3,402	(898.8)	4.501	(1.189)
	11	A	701	4,016	(1,061)	21.610	(5.710)
241-AZ-101/-102	12	B	637	3,460	(914)	n/a	n/a
241-AW-101	13	A	515	3,283	(867.2)	4.611	(1.218)
	14	A	516	3,283	(867.2)	4.611	(1.218)
241-AW-104	15	C	475	2,648	(699.6)	4.081	(1.078)
241-AP-105	16	C	574	3,181	(840.4)	4.974	(1.314)
	17	C	574	3,181	(840.4)	4.974	(1.314)
241-AP-104	18	C	499	2,701	(713.6)	0.155	(0.041)
	19	C	499	2,701	(713.6)	0.155	(0.041)
241-AP-101	20	C	513	2,772	(732.4)	0.155	(0.041)
	21	C	513	2,774	(732.8)	0.008	(0.002)

Table 4-1. Tank Wastes in Phase 1, Case 3 Low-Activity Waste Processing[1]. (2 Sheets)

Tank	Batch Number (and order of delivery)	Envelope	Units	Values Projected by HTWOS			
				Liquid Volume		Solids Volume	
				kL	(kgal)	kL	(kgal)

Note:

HTWOS = Hanford Tank Waste Operations Simulator
n/a = not available

[1]Kirkbride et al. (1999)

The Case 3 compositions of waste to be delivered have been determined by means of the Hanford Tank Waste Operation Simulator (HTWOS) computer code (Kirkbride et al. 1999). This code uses the best-basis inventory, the operational waste volume projection code (Strode and Boyles 1998), and updated estimates for tank inventory and tank space availability. The HTWOS code accounts for tank heels and flushes of the line, pump, and tank necessary to prepare the waste for delivery. The volumes, specific gravities, and analyte compositions for liquids and solids of the waste batches to be delivered are listed in Tables A-1 and A-2, respectively, in Appendix A.

The data in the Appendix A tables may be used to determine if the presence of non-uniformly distributed insoluble particulates in the feed could affect an at-tank determination of homogeneity. If an at-tank method for determining homogeneity responds to soluble and insoluble forms of the measured species, then the presence of non-uniformly distributed particulates in the liquid phase may complicate the at-tank determination of homogeneity. In this case, and for most feed batches, the suspended solids must be evenly distributed throughout the height of the feed before the at-tank method can reliably indicate feed homogeneity.

For example, the data in Appendix A indicates that batch 1 has a projected average solids content of about 1 volume percent. If there were 0.5 volume percent solids at the top of the LAW slurry and 3 volume percent in the bottom portion, the in-situ bulk Na and Al content and specific gravity would be significantly different at these locations (161 g Na/L versus 190 g Na/L, 1.95 g Al/L versus 7.0 g Al/L, and 1.37 versus 1.41, respectively). The ^{137}Cs concentration would be 10 percent greater at the bottom than the top.

This example indicates that for an at-tank method to reliably determine homogeneity when the method responds to soluble and insoluble forms of the measured species, a tank mixing pump must uniformly suspend the solids in the feed, or the method must be capable of screening out or accounting for the solids contribution. Adjustments could be made for solids content based upon laboratory analysis of centrifuged samples but this would result in homogeneity determination after sampling instead of before. The ICD-19-required certification grab samples do not suffer this limitation because these samples are to be centrifuged to remove the solids prior to analyzing the supernatant (BNFL 2000b).

4.2 LOW-ACTIVITY WASTE FEED PREPARATION AND DELIVERY

Waste form, analyte content, and staging have been considered in developing the Case 3 scenario. Some LAW feed is to be transferred to staging tanks and mixed. Waste tanks with significant quantities of solids are scheduled for decanting and delivery of the LAW feed to the WTP.

4.3 HIGH-LEVEL WASTE FEED STAGING

The HLW slurry in (or transferred from a source tank to) the staging tank is mixed, sampled, and certified before delivery to the WTP. The certification process and requirements for feed transfer from the HLW staging tanks to the WTP are specified in ICD-20 (BNFL 2000b). Interface Control Document (ICD)-20 requires that the HLW have an unwashed solids content of 10 to 200 grams per liter. Verification of homogeneity for the HLW feed to the WTP is not currently required by ICD-20. However, a representative sample must be obtained from each waste batch, including wastes that rapidly settle such as the waste in tank 241-AZ-101 (Carlson et al. 2000). The waste sample must represent the waste that is transferred to the WTP.

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5.0 AT-TANK HOMOGENEITY SCREENING METHODS

The current ICD-19 requires that eight grab samples be acquired from a single riser in the feed staging tank after the tank contents have been mixed and the mixing pump has been shut off. The analysis of these samples provides the verification of feed composition and homogeneity prior to shipment of the feed to the WTP. To minimize the risk of sampling the tank when the tank contents are not completely homogeneous, at-tank or in-tank-screening methods could be used to determine that the tank contents are homogeneous prior to grab sampling. At a minimum, these screening measurements should indicate when the staging tank contents are mixed to a steady state even if the tank contents are not completely homogeneous. The screening methods discussed in this section are intended to provide a first indication of feed homogeneity. These methods may not necessarily directly detect the homogeneity indicators discussed in Section 3.0. Therefore, these methods would not provide the data needed to certify a tank waste batch as currently required by ICD-19.

- The criterion used to choose homogeneity screening methods was that each method be correlated either to an important chemical/radiochemical species that must be measured (such as sodium or ^{137}Cs) or a physical parameter that must be measured (such as suspended solids).

The following waste measurement methods are recommended as potential candidates for determining LAW feed homogeneity:

- gamma activity profiling,
- conductivity,
- specific gravity, and
- total suspended solids or turbidity.

The feasibility of these methods will depend on other issues, such as the availability of suitable sensors and measurement configuration. These issues will be examined in future work.

Measurements would be performed as a function of depth within the waste feed. Because temperature affects several of these measurements, tank waste temperature should also be measured in conjunction with the screening methods. The ICD-19 requires the measurement of waste feed temperature at the time of sampling (BNFL 2000a), and two of the recommended measurements, conductivity and specific gravity, are temperature dependent. The following sections discuss these waste properties as candidates for assessing homogeneity.

5.1 GAMMA ACTIVITY PROFILING

Tank waste is routinely profiled using a gamma activity detector as a function of depth in the waste. The predominant species detected in such profiling is ^{137}Cs. These profiles frequently reveal an inhomogeneous distribution of ^{137}Cs in the tank waste that may indicate layering in the tank waste. Because ^{137}Cs is generally water-soluble, a uniform gamma profile in the waste feed should indicate that the waste is reasonably homogeneous.

Should significant amounts of ^{137}Cs exist in the suspended solids in the feed, gamma activity profiling may reveal the distribution of suspended solids in the tank. Because particulates will have a tendency to settle to the tank bottom, greater gamma count rates near the tank bottom may indicate the presence of settled solids.

Gamma profiling was used to monitor the distribution of gamma-emitting radionuclides in tank waste during the fiscal year (FY) 2000 tank 241-AZ-101 mixing pump test (Carlson et al. 2000). The results of the gamma profiling suggests that this method is indeed sensitive to the distribution of solids in the tank.

5.2 SOLUTION CONDUCTIVITY

Solution conductivity is a measure of ionic content in solution and is dependent on the identity and concentration of the ionic species in solution. Conductivity is defined as:

$$\text{Conductivity} = k\sum \upsilon_i C_i \lambda_i$$

where: k is a probe-specific coefficient determined during probe calibration, and for ionic species i in solution,

v_i is the absolute value of the ionic charge,

C_i is the concentration, and

λ_i is the ionic conductivity.

Those solution species with high concentrations, large ionic charges, and/or large ionic conductivities will contribute most to the overall solution conductivity. Table 5-1 lists the ionic conductivities for some species of interest in LAW feed.

Table 5-1. Ionic Conductivities at Infinite Dilution and 25 °C[1]

Cation	λ^0 (S cm^2 mol^{-1})	Anion	λ^0 (S cm^2 mol^{-1})
Na^+	50.1	OH^-	199.1
K^+	73.5	Cl^-	76.3
Mg^{2+}	106.0	NO_3^-	71.4
Ca^{2+}	119.0	SO_4^{2-}	160.0

Note:
[1]Noyes et al. (1996)

The ionic conductivities in Table 5-1 were determined at "infinite dilution" and 25 °C. While these are obviously far from the conditions of actual tank waste, the information in the table provides trends from which we can predict those waste species that will contribute most to the measured conductivity of the waste. From Table 5-1 and from the relative concentrations shown in Table 2-1, the species contributing most to the overall solution-phase conductivity should be sodium, hydroxide, and nitrate. Because conductivity is dependent upon the major ionic solutes in the waste feed, a uniform conductivity profile throughout the liquid waste should indicate a homogenous feed. Conversely, a non-uniform conductivity profile will indicate non-uniform distribution of the liquid waste.

The ionic conductivity, λ, is temperature dependent; therefore, conductivity measurements will either need to be temperature compensated, or will require a thermostated measurement cell. Conductivity measurements should not be affected by the LAW feed suspended solids at the less than two weight percent specification of DOE (1998).

5.3 WASTE FEED SPECIFIC GRAVITY

For many liquid tank wastes, plots of sodium and nitrate ion versus specific gravity of the waste reveal a correlation between the specific gravity of the waste and the sodium and nitrate content of the waste (Reynolds 1999). Figures 5-1 and 5-2 show correlations between specific gravity and sodium and nitrate ion in liquid tank waste. These plots indicate that monitoring LAW feed specific gravity may indicate the distribution of sodium and nitrate throughout the liquid waste in the feed staging tank. Because specific gravity is temperature dependent, specific gravity must be measured using a thermostated cell. The presence of suspended solids may also affect the determination of specific gravity.

5.4 WASTE FEED SUSPENDED SOLIDS

Measurement of suspended solids is important both for LAW feed and HLW feed. Specification 7 of DOE (1998) limits the suspended solids concentration in LAW feed to less than two weight percent (dry weight) suspended solids. Specification 8 of DOE (1998) limits the concentration of unwashed solids to between 10 and 200 g/L. At-tank profiling of the suspended solids content of the waste feed could potentially provide an estimate of:

- how homogeneously the suspended solids are distributed in the liquid feed, and
- the concentration of suspended solids in the liquid feed assuming the suspended solids measurements can be appropriately calibrated.

Furthermore, if the concentration of suspended solids affects other at-tank measurements, such as gamma activity profiling or specific gravity measurements, the suspended solids profile in the staging tank may be used to determine the existence of a correlation between suspended solids content and gamma activity.

Finally, if measurement of suspended solids shows these to be uniformly distributed throughout the tank, then it seems safe to assume that the supernatant is homogeneously mixed as well. However, this assumption would need to be demonstrated to be true prior to using suspended solids as an indicator of homogeneity in the LAW feed soluble fraction.

Ultrasonic probes and a suspended solids profiler (turbidity measurement instrument) were used to monitor the distribution of sludge and suspended solids in liquid tank waste during the FY 2000 tank 241-AZ-101 mixing pump test (Carlson et al. 2000). Data from the ultrasonic probes allowed determinations of sludge settling rates in the tank. The suspended solids profiler successfully acquired relative turbidity profiles from the tank waste although some operational difficulties were encountered.

Figure 5-1. Correlation between Sodium Ion and Specific Gravity in Liquid Tank Waste

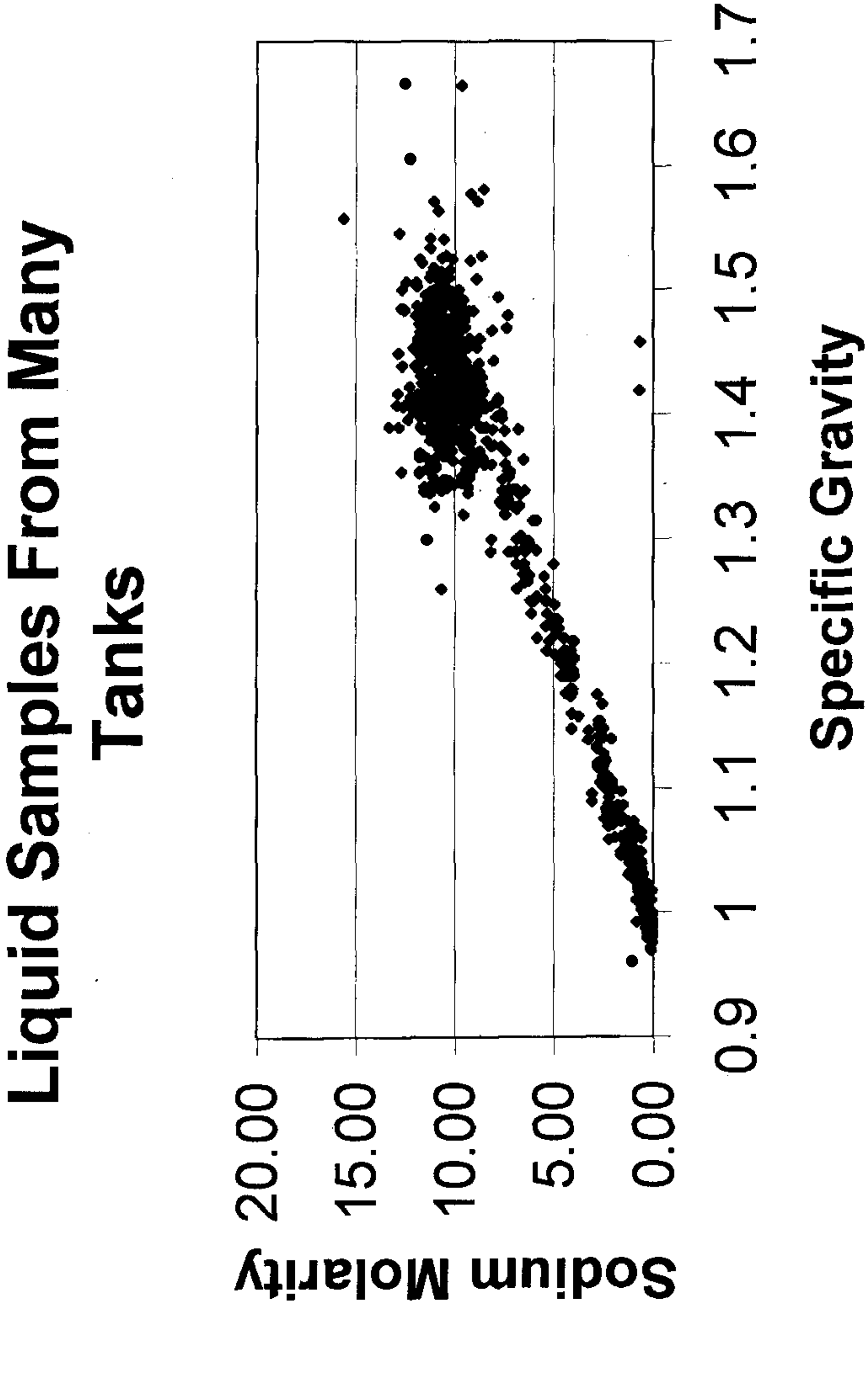
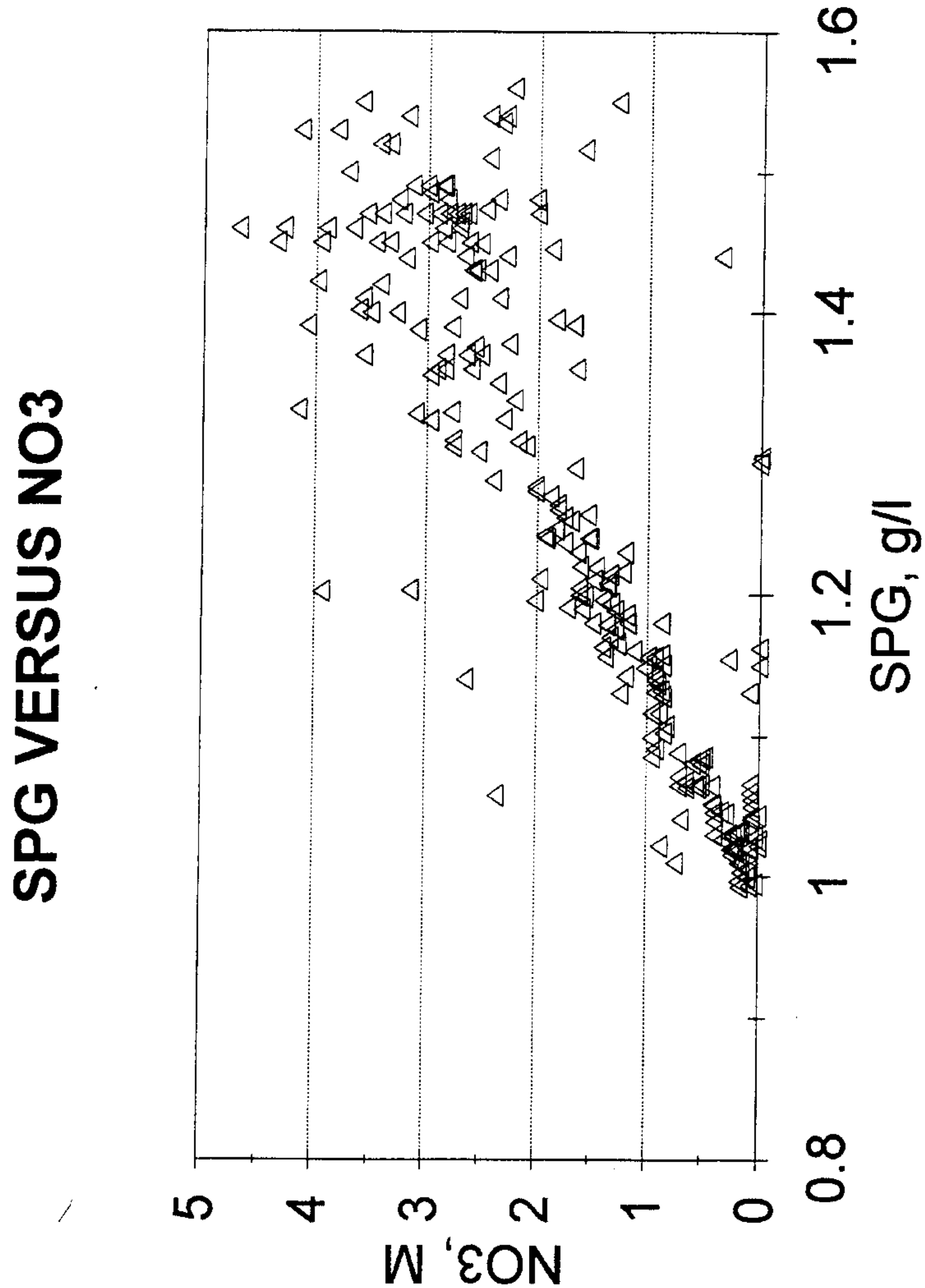


Figure 5-2. Correlation between Nitrate Ion and Specific Gravity in Liquid Tank Waste



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APPENDIX A

COMPOSITION OF LIQUIDS AND SOLIDS FOR LOW-ACTIVITY WASTE FEED BATCHES TO THE WASTE TREATMENT PLANT

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Table A-1. Waste Treatment Plant Feed Delivery Concentrations for Low-Activity Waste Phase 1 Case 3 Liquids (3 sheets)

Species	Units	LAW-1	LAW-2	LAW-3	LAW-4	LAW-5	LAW-6	LAW-7	LAW-8	LAW-9	LAW-10	LAW-11	LAW-12	LAW-13	LAW-14	LAW-15	LAW-16	LAW-17	LAW-18	LAW-19	LAW-20	LAW-21
Volume	Liters	3.67E+06	3.40E+06	3.52E+06	2.96E+06	2.96E-06	3.32E+06	3.32E+06	2.73E+06	1.55E+06	3.40E+06	4.02E+06	3.46E+06	3.28E+06	3.28E+06	2.65E+06	3.18E+06	3.18E+06	2.70E+06	2.70E+06	2.77E+06	2.77E+06
Density	sp gr	1.36	1.3	1.3	1.28	1.27	1.34	1.35	1.28	1.36	1.26	1.28	1.38	1.29	1.29	1.29	1.31	1.31	1.31	1.31	1.3	1.3
106-Ru	bq/Liter	4.85E-03	1.09E-02	7.01E-03	1.51E-05	1.44E-05	3.22E-03	2.38E-03	7.16E-05	1.31E-05	8.74E-04	6.60E-04	1.11E+01	5.07E-04	2.51E-04	4.85E-02	1.11E-01	7.69E-02	8.45E-04	1.59E-03	7.85E-03	4.94E-03
113m-Cd	bq/Liter	1.08E+06	7.65E+05	7.62E+05	2.57E+05	2.23E+05	1.34E+06	1.35E+06	2.01E+05	2.08E+05	6.15E+05	6.29E+05	2.30E+02	7.74E+05	7.37E+05	5.27E+05	5.86E+05	5.72E+05	7.11E+05	6.98E+05	7.32E+05	7.21E+05
125-Sb	bq/Liter	7.48E+04	1.15E+05	9.96E+04	2.91E+04	2.39E+04	1.11E+05	1.01E+05	1.33E+04	1.28E+04	4.29E+04	3.99E+04	1.34E+07	4.87E-04	3.78E+04	1.46E+04	1.50E+04	1.32E+04	1.58E+04	1.41E+04	1.21E+04	1.09E+04
126-Sn	bq/Liter	6.79E+04	7.33E+04	1.06E+05	2.17E+04	2.01E+04	1.88E+05	1.88E+05	2.25E+04	2.19E+04	7.33E+04	9.31E+04		1.14E+05	1.14E-05	1.41E+05	1.57E+05	1.57E+05	1.38E+05	1.38E+05	1.80E+05	1.80E+05
129-I	bq/Liter	1.29E+04	6.09E+03	6.13E+03	1.29E+04	1.23E+04	4.12E+04	4.25E+04	8.80E+03	1.12E+04	3.92E+04	4.25E+04	5.34E+04	6.23E+04	6.23E+04	7.82E+03	1.17E+04	1.17E+04	1.07E+04	1.10E+04	1.22E+04	1.19E+04
134-Cs	bq/Liter	4.62E+03	5.68E+03	4.66E+03	1.61E+03	1.25E+03	4.14E+03	3.63E+03	3.33E+02	2.36E+02	1.92E+03	1.73E+03	7.37E+06	2.06E+03	1.46E+03	1.45E+02	4.85E+02	4.05E+02	2.01E+02	1.80E+02	6.16E+01	4.94E+01
137-Cs	bq/Liter	7.45E+09	2.58E+10	2.62E+10	6.10E+09	5.81E+09	8.91E+09	9.04E+09	5.97E+09	8.23E+09	7.13E-09	7.57E+09	2.15E+01	6.85E+09	6.58E+09	4.16E+09	3.88E+09	3.88E+09	3.59E+09	3.43E+09	4.45E+09	4.45E+09
137m-Ba	bq/Liter																					
14-C	bq/Liter	1.08E+06	5.31E+05	5.46E+05	1.34E+06	1.34E+06	1.19E+06	1.19E+06	1.45E+06	1.20E+06	5.41E+05	4.93E-05	7.31E+03	6.03E+05	6.03E-05	7.48E+05	1.25E+06	1.25E+06	7.33E+05	7.33E+05	7.14E+05	7.14E+05
151-Sm	bq/Liter	1.15E+06	1.72E+08	2.08E+08	3.80E+04	1.01E+06	3.53E+08	3.53E+08	1.65E+07	5.04E+06	1.72E+08	1.82E+08	2.21E+04	2.23E+08	2.23E+08	1.66E+08	9.21E+07	9.21E+07	2.17E+08	2.17E+08	2.64E+08	2.64E+08
152-Eu	bq/Liter	2.48E+02	3.64E+04	3.62E+04	7.04E+00	1.82E-02	6.16E+04	6.19E+04	2.52E+03	7.09E+02	3.01E+04	3.09E+04	2.26E+04	3.59E+04	3.41E+04	2.19E+04	1.07E+04	1.04E+04	3.07E+04	2.97E+04	2.98E+04	2.98E+04
154-Eu	bq/Liter	2.58E+04	5.99E+05	5.79E+05	6.60E+02	2.82E+03	3.55E+05	3.45E+05	1.97E+05	6.83E+04	6.36E+05	6.71E+05	2.52E+06	5.46E+05	5.02E+05	1.82E+06	8.47E-05	8.11E+05	2.34E+06	2.22E+06	2.32E+06	2.29E+06
155-Eu	bq/Liter	5.26E+03	1.59E+06	1.49E+06	1.09E+02	6.61E+03	4.38E+05	4.20E+05	3.25E+04	8.99E+03	9.95E+05	1.02E+06	1.37E+06	7.53E+05	6.53E+05	2.05E+05	1.95E+05	1.81E+05	2.44E+05	2.29E+05	2.24E+05	2.12E+05
226-Ra	bq/Liter	1.58E+00	2.35E+00	2.42E+00	7.94E-01	7.54E-01	4.84E+00	4.98E+00	8.32E-01	8.76E-01	2.78E+00	2.94E+00	1.66E-02	3.40E+00	3.40E+00	1.30E+05	4.05E+05	4.04E+05	6.14E+03	1.63E+04	1.12E+05	9.79E+04
227-Ac	bq/Liter	6.16E-02	9.36E+00	9.43E+00	1.87E-03	4.88E-02	1.77E+01	1.80E+01	8.38E-01	2.50E-01	9.57E+00	9.95E+00	4.23E-04	1.16E+01	1.13E+01	7.71E+00	3.68E+00	3.62E+00	1.03E+01	1.00E+01	1.09E+01	1.09E+01
228-Ra	bq/Liter	1.79E+03	1.24E+03	1.19E+03	3.70E+02	3.11E+02	1.94E+03	1.90E+03	1.36E+02	1.45E+02	7.73E+02	7.66E+02	3.01E-07	9.43E+02	8.48E+02	2.55E+02	3.67E+02	3.48E+02	3.93E+02	3.79E+02	3.09E+02	2.96E+02
229-Th	bq/Liter	2.71E+00	1.22E+02	1.25E+02	1.24E+00	1.83E+00	2.50E+02	2.58E+02	5.58E+00	1.91E+00	1.18E+02	1.23E+02	4.00E-04	1.63E+02	1.63E+02	5.22E+01	3.72E+01	3.72E+01	9.21E+01	9.15E+01	7.97E+01	8.17E+01
231-Pa	bq/Liter	6.57E+00	6.55E+01	6.74E+01	3.72E+01	3.73E+01	1.33E+02	1.37E+02	3.60E+01	4.18E+01	6.94E+01	7.29E+01	2.34E-03	9.21E+01	9.21E+01	6.83E+01	3.80E+01	3.80E+01	9.66E+01	9.55E+01	1.05E+02	1.07E+02
232-Th	bq/Liter	1.31E+01	5.58E+02	5.75E+02	5.72E+00	8.28E+00	1.13E+03	1.16E+03	1.69E+01	6.06E+00	5.04E+02	5.25E+02	5.50E-06	6.84E+02	6.84E+02	1.62E+02	1.58E+02	1.58E+02	3.17E+02	3.17E+02	2.38E+02	2.43E+02
232-U	bq/Liter	1.79E+02	8.07E+02	8.05E+02	3.72E+01	3.55E+01	5.20E+02	5.12E+02	8.23E+02	2.41E+02	5.12E+02	5.52E+02	1.23E+01	2.54E+03	2.51E-03	8.59E+03	2.97E+03	2.96E+03	1.37E+04	1.34E+04	1.35E+04	1.38E+04
233-U	bq/Liter	4.12E+02	3.53E+03	3.55E+03	1.53E+02	1.59E+02	2.36E+03	2.33E+03	3.74E+03	1.13E+03	2.34E-03	2.53E+03	5.12E+01	1.17E+04	1.17E+04	3.22E+04	1.40E+04	1.40E+04	6.31E+04	6.31E+04	6.15E+04	6.15E+04
234-U	bq/Liter	1.76E+02	1.03E+03	1.05E+03	3.47E-01	3.45E+01	5.49E+02	5.32E+02	1.13E+03	3.91E+02	8.20E+02	8.98E+02	2.62E+03	6.83E+03	6.82E+03	1.74E+04	4.91E+03	4.91E+03	1.76E+04	1.71E+04	1.98E+04	1.98E+04
235-U	bq/Liter	5.19E+00	3.92E+01	4.33E+01	1.38E+00	1.37E+00	2.30E+01	2.29E+01	4.88E+01	1.22E+01	3.36E+01	3.32E+01	9.71E+01	2.61E+02	2.61E+02	6.97E+02	1.97E+02	1.97E+02	7.12E+02	6.91E+02	8.10E+02	8.30E+02
236-U	bq/Liter	9.02E+00	5.51E+01	5.63E+01	1.33E+00	1.33E+00	2.43E+01	2.40E+01	3.68E-01	1.20E+01	4.77E+01	5.24E+01	2.15E+02	5.21E+02	5.21E+02	8.61E+02	1.66E+02	1.66E+02	6.33E+02	6.33E+02	6.16E+02	6.16E+02
237-Np	bq/Liter	3.43E+02	1.82E+03	1.76E+03	3.28E+01	3.15E+01	1.41E+03	1.41E+03	1.48E+03	6.83E+02	1.31E+05	1.46E-05	1.17E-03	1.69E+04	1.69E+04	1.63E+04	1.36E+04	1.36E+04	2.06E+04	2.06E+04	2.23E+04	2.23E+04
238-Pu	bq/Liter	2.42E+03	1.75E+03	1.77E+03	2.47E+03	2.38E+03	1.17E+03	1.03E+03	1.79E+03	2.28E+03	2.19E+03	2.40E+03	6.18E+04	2.79E+04	2.77E-04	3.16E+04	1.22E+04	1.22E+04	2.79E+04	2.71E+04	3.04E+04	3.08E+04
238-U	bq/Liter	1.65E+02	8.38E+02	8.43E+02	3.10E+01	3.00E+01	4.67E+02	4.43E+02	1.29E+03	4.36E+02	6.42E+02	7.03E+02	1.80E+03	5.07E+03	5.06E+03	1.76E+04	5.35E+03	5.35E+03	2.09E+04	2.04E+04	2.29E+04	2.34E+04
239-Pu	bq/Liter	1.20E+06	4.65E+03	3.75E+03	1.72E+05	1.30E+05	5.16E+03	2.33E+03	7.47E+04	5.12E+04	4.43E+04	4.95E+04	6.59E-02	4.34E+04	4.33E+04	8.30E+05	3.46E+05	3.46E+05	1.02E+06	1.02E+06	1.19E+06	1.19E+06
240-Pu	bq/Liter	1.42E+04	2.47E+03	2.37E+03	2.46E+03	2.00E+03	2.00E+03	1.33E+03	1.27E+04	9.93E+03	1.88E+02	1.65E+02	1.12E+05	8.75E+04	8.75E+04	1.60E+05	5.14E+04	5.14E+04	1.83E+05	1.79E+05	1.99E+05	2.04E+05
241-Am	bq/Liter	1.68E+07	3.01E+04	2.98E+04	3.46E+06	2.92E+06	1.80E+04	5.29E+03	2.16E+05	4.25E+05	9.23E+04	1.03E+05	2.20E+00	3.07E+05	3.08E+05	1.03E+06	6.28E+05	6.28E+05	1.25E+06	1.24E+06	1.47E+06	1.49E+06
241-Pu	bq/Liter	1.10E+05	8.29E+04	8.17E+04	1.56E+04	1.24E+04	4.18E+04	4.04E+04	5.91E+04	2.59E+04	8.83E+04	9.50E+04	2.24E+06	1.27E+06	1.21E+06	1.02E+06	1.80E+05	1.76E+05	7.47E+05	7.02E+05	7.60E+05	7.62E+05
242-Cm	bq/Liter	2.04E-06	2.20E-07	7.88E-08	1.92E-08	6.46E-09	8.56E-10	3.98E-10	1.83E-09	1.16E-09	9.79E-11	4.80E-11	8.93E-05	4.52E-11	9.29E-12	1.75E-11	2.98E-12	1.30E-12	2.56E-12	1.23E-12	6.38E-13	3.13E-13
242-Pu	bq/Liter	1.02E+00	7.53E-01	7.65E-01	1.75E-01	1.44E-01	6.78E-01	4.57E-01	7.59E-01	2.88E+00	1.00E+00	1.10E+00	3.07E+01	1.24E+01	1.24E+01	1.48E+01	5.87E+00	5.87E+00	1.22E+01	1.18E+01	1.41E+01	1.43E+01
243-Am	bq/Liter	2.45E+01	1.42E+01	1.46E+01	5.75E+00	4.99E+00	2.58E+00	2.57E+00	5.32E+00	4.53E+00	6.78E+00	7.49E+00	5.09E+03	2.53E+01	2.53E+01	3.29E+01	1.07E+01	1.07E+01	4.65E+01	4.57E+01	5.02E+01	5.15E+01
243-Cm	bq/Liter	1.58E+01	1.28E+03	1.30E+03	1.33E+00	7.60E+00	4.42E+02	4.32E+02	8.07E+01	2.82E+02	2.55E+01	1.44E+01	4.36E+03	7.72E+02	7.54E+02	4.22E+02	8.65E+02	8.54E+02	2.47E+02	2.60E+02	4.16E+02	3.91E+02
244-Cm	bq/Liter	1.07E+02	2.52E+04	2.53E+04	7.52E+03	7.45E+03	2.32E+03	2.07E+03	6.51E+02	3.95E+03	1.29E+02	7.64E+01	9.12E+04	1.41E+04	1.36E+04	3.33E+03	6.69E+03	6.55E+03	2.31E+03	2.39E+03	3.05E+03	2.85E+03
3-H	bq/Liter	3.95E+06	1.03E+05	1.00E+05	3.40E+06	3.16E+06	7.91E+03	3.69E+03	2.35E+06	2.95E+06	1.53E+04	1.65E-04	9.23E+06	3.75E+04	3.83E+04	1.25E+06	6.03E+05	5.85E+05	1.50E+06	1.44E+06	1.64E+06	1.63E+06
59-Ni	bq/Liter	3.16E+04	2.87E+04	2.95E+04	1.01E+04	9.20E+03	5.29E+04	5.29E+04	1.10E+04	1.14E+04	3.64E+04	3.86E+04	3.83E+01	3.87E-04	3.87E+04	3.66E+04	2.44E+04	2.44E+04	4.98E+04	4.93E+04	5.58E+04	5.67E+04
60-Co	bq/Liter	2.03E+05	4.50E+04	4.23E+04	5.14E+05	4.65E+05	8.20E+03	7.75E+03	1.87E+04	3.69E+04	1.57E+04	1.62E+04	7.09E+05	6.65E+04	5.82E+04	3.86E+04	2.35E+04	2.19E+04	4.73E+04	4.41E+04	4.37E+04	4.19E+04
63-Ni	bq/Liter	2.86E+06	2.54E+06	2.60E+06	8.95E+05	8.11E+05	5.14E+06	5.27E+06	9.46E+05	9.83E+05	3.12E+06	3.30E+06	4.03E+03	3.30E+06	3.27E+06	3.06E-06	2.04E+06	2.03E+06	4.12E+06	4.07E+06	4.58E+06	4.64E+06
79-Se	bq/Liter	1.11E+05	5.78E+04	5.79E+04	1.37E+05	6.88E+04	1.23E+05	1.23E+05	7.45E+04	1.03E+05	5.98E+04	5.07E+04	4.72E+05	6.20E+04	6.20E-04	5.63E+04	5.16E+04	5.16E+04	7.53E+04	7.53E+04	7.34E+04	7.34E+04
90-Sr	bq/Liter	2.60E+09	6.04E+06	4.46E+06	1.23E+09	1.23E+09	3.15E+07	2.90E-07	1.66E+08	2.10E+08	2.29E+07	2.43E+07	1.42E+02	1.96E+07	1.92E+07	1.03E+09	4.28E-08	4.28E+08	1.51E+09	1.51E+09	1.64E+09	1.64E+09
90-Y	bq/Liter																					
93-Zr	bq/Liter	3.01E+04	2.84E+05	2.92E+05	5.72E+04	5.73E+04	5.65E+05	5.83E+05	6.52E+04	6.55E+04	2.89E+05	3.04E+05	1.44E+02	3.85E+05	3.85E+05	2.72E+05	1.84E+05	1.84E+05	3.93E+05	3.89E+05	4.19E+05	4.28E+05

Table A-1. Waste Treatment Plant Feed Delivery Concentrations for Low-Activity Waste Phase 1 Case 3 Liquids (3 sheets)

Species	Units	LAW-1	LAW-2	LAW-3	LAW-4	LAW-5	LAW-6	LAW-7	LAW-8	LAW-9	LAW-10	LAW-11	LAW-12	LAW-13	LAW-14	LAW-15	LAW-16	LAW-17	LAW-18	LAW-19	LAW-20	LAW-21
93m-Nb	bq/Liter	3.87E-04	1.01E+05	1.00E+05	3.28E+04	3.11E+04	1.78E+05	1.78E+05	2.86E+04	3.00E+04	8.38E+04	8.57E+04	9.63E+04	1.05E+05	9.92E+04	6.86E+04	4.07E+04	3.96E+04	9.05E+04	8.75E+04	9.27E+04	9.22E+04
99-Tc	bq/Liter	9.97E+05	1.20E+06	1.23E+06	8.37E+05	8.17E+05	5.95E+06	6.11E+06	5.81E+06	7.14E+06	2.24E+06	2.32E+06	1.92E+00	4.29E+06	4.31E+06	4.94E+06	2.77E+06	2.77E+06	5.65E+06	5.58E+06	6.19E+06	6.31E+06
Ag+	g/Liter	3.40E-06	5.61E-03	5.80E-03	1.15E-07	3.13E-05	6.57E-03	6.76E-03	9.87E-06	1.97E-06	1.90E-04			4.98E-08	9.91E-09	4.07E-05	1.02E-04	1.02E-04	3.29E-06	4.42E-06	3.73E-05	3.42E-05
Al(OH)4-	g/Liter												3.19E+01									
Al+3	g/Liter	9.24E-01	3.91E+01	4.03E+01	9.12E+00	9.30E+00	4.28E+01	4.41E+01	1.59E+01	2.03E+01	3.03E+01	3.23E+01	9.63E+00	1.91E+01	1.91E+01	1.60E+01	9.34E+00	9.34E+00	2.16E+01	2.13E+01	1.59E+01	1.64E+01
As+5	g/Liter	6.75E-08			2.28E-09				8.90E-06					4.49E-08		1.37E-05	2.12E-04	2.12E-04	7.51E-07	7.68E-06	1.52E-05	7.94E-06
B+3	g/Liter						2.75E-02	2.83E-02	6.33E-08	2.78E-04	3.06E-02	3.32E-02		3.20E-10	1.41E-06	5.96E-04	4.63E-03	4.63E-03	3.60E-05	1.84E-04	4.29E-04	2.65E-04
Ba+2	g/Liter	1.04E-05			3.51E-07				4.38E-05					2.21E-07		1.56E-04	3.02E-04	3.02E-04	7.39E-06	1.30E-05	9.90E-05	9.90E-05
Be+2	g/Liter																					
Bi+3	g/Liter		2.17E-02	2.23E-02		1.41E-04	2.17E-02	2.24E-02	4.52E-06	4.22E-05	6.76E-04			8.78E-03	8.78E-03	7.89E-05	1.31E-04	1.31E-04	3.87E-04	3.87E-04	1.51E-04	1.51E-04
Ca+2	g/Liter	4.55E-01	2.19E-02	2.25E-02	2.88E-01	2.73E-01	4.48E-02	4.61E-02	1.13E-01	1.59E-01	5.39E-02	5.87E-02	1.67E-02	1.72E-02	1.74E-02	5.05E-02	2.63E-02	2.64E-02	5.42E-03	4.51E-03	1.49E-02	1.41E-02
Cd+2	g/Liter	6.13E-05			1.57E-06				7.41E-04		1.12E-03	1.26E-03		3.64E-06		9.34E-04	2.05E-03	2.05E-03	8.32E-05	1.25E-04	5.67E-04	5.27E-04
Ce+3	g/Liter	5.77E-17	1.83E-17		1.95E-18	1.02E-19	6.81E-06		2.56E-04	8.06E-05				1.23E-06	4.07E-07	3.07E-03	1.32E-03	1.32E-03	5.45E-03	5.34E-03	5.46E-03	5.61E-03
Cl-	g/Liter	1.68E+00	4.22E+00	4.34E+00	2.41E+00	2.38E+00	5.91E+00	6.08E+00	6.36E+00	8.04E+00	3.57E+00	3.79E+00	1.82E-01	3.38E+00	3.39E+00	4.19E+00	2.67E+00	2.67E+00	4.01E+00	3.95E+00	4.06E+00	4.11E+00
CN-	g/Liter																					
Co+3	g/Liter																					
CO3-2	g/Liter	7.26E+01	2.99E+01	3.08E+01	4.54E+01	4.31E+01	2.84E+01	2.93E+01	3.07E+01	3.99E+01	1.22E+01	1.27E+01	6.43E+01	1.28E+01	1.29E+01	2.85E+01	1.56E+01	1.56E+01	2.42E+01	2.37E+01	2.50E+01	2.53E+01
Cr(OH)4-	g/Liter												9.78E-01									
Cr(Total)	g/Liter	1.18E-01	8.02E-01	8.26E-01	1.88E-01	1.89E-01	5.43E-01	5.53E-01	1.75E+00	2.19E+00	3.50E-01	3.73E-01	1.32E+00	1.50E-01	1.53E-01	1.49E+00	5.90E-01	5.90E-01	1.77E+00	1.73E+00	2.08E+00	2.12E+00
Cs+	g/Liter	8.07E-03	3.21E-02	3.30E-02	7.21E-03	7.13E-03	1.03E-01	1.20E-02	6.52E-04	1.08E+00	9.50E-03	1.02E-02	5.09E-02	9.14E-03	1.46E-02	7.90E-01	1.34E+00	1.34E+00	6.07E-02	8.09E-02	5.72E-01	5.26E-01
Cu+2	g/Liter	3.51E-06			1.19E-07				4.74E-08					2.39E-10		4.80E-05	1.57E-05	1.57E-05	1.98E-06	1.16E-06	2.19E-05	2.14E-05
F-	g/Liter	4.51E-01	3.35E-01	3.45E-01	1.16E+00	1.14E+00	5.70E-01	5.86E-01	8.73E-01	1.12E+00	4.95E-01	5.34E-01	2.61E+00	6.76E-01	6.77E-01	5.29E+00	3.84E+00	3.84E+00	1.05E+00	9.93E-01	1.04E+00	9.44E-01
Fe+3	g/Liter	1.11E+00	1.04E-02	1.08E-02	6.82E-02	3.09E-02	1.77E-02	1.82E-02	2.14E-01	2.74E-01	2.98E-02	3.27E-02	7.64E-02	1.77E-02	1.80E-02	2.01E-02	5.35E-03	5.35E-03	3.60E-03	3.04E-03	2.24E-02	2.23E-02
H+	g/Liter																					
H2O	g/Liter	8.23E+02	7.06E+02	6.97E+02	7.94E+02	7.98E+02	7.51E+02	7.43E+02	8.45E+02	8.01E+02	7.64E+02	7.45E+02	8.01E+02	7.89E+02	7.89E+02	8.06E+02	7.78E+02	7.78E+02	7.74E+02	7.74E+02	7.75E+02	7.75E+02
Hg+2	g/Liter	2.19E-04			6.54E-06		3.02E-04	2.42E-04	2.20E-04	2.58E-04	7.97E-06			1.06E-06	1.22E-06	3.94E-03	1.32E-03	1.32E-03	4.75E-03	4.68E-03	6.22E-03	6.36E-03
K+	g/Liter	1.54E+00	3.31E+00	3.40E+00	2.39E+00	2.35E+00	3.63E+00	3.74E+00	2.35E+00	2.73E+00	5.83E+00	6.39E+00	6.98E+00	2.23E+01	2.23E+01	6.56E+00	1.29E+01	1.29E+01	2.34E+00	2.58E+00	3.35E+00	2.96E+00
La+3	g/Liter	2.61E-06	1.89E-02	1.95E-02	8.83E-08	9.39E-05	9.21E-03	9.50E-03	6.85E-10	7.29E-06	2.31E-02	2.55E-02	1.04E-03	3.46E-12	3.68E-08	2.10E-04	4.37E-05	4.37E-05	8.19E-06	2.82E-06	3.10E-05	2.96E-05
Li+	g/Liter		3.73E-03	3.85E-03		2.11E-05	1.68E-06		1.78E-05	1.30E-06				8.33E-08	6.57E-09	6.81E-05	1.33E-04	1.33E-04	5.14E-06	7.71E-06	4.75E-05	4.25E-05
Mg+2	g/Liter	2.60E-06			8.78E-08				1.78E-05					2.35E-02	2.35E-02	1.01E-04	2.03E-03	2.03E-03	1.80E-05	9.00E-05	1.40E-04	7.01E-05
Mn+4	g/Liter	3.77E-01	2.07E-02	2.14E-02	3.70E-02	2.44E-02	1.68E-02	1.71E-02	1.65E-02	1.24E-02	5.09E-03	5.12E-03	1.01E-04	7.00E-02	7.00E-02	1.52E-01	3.79E-02	3.79E-02	1.70E-01	1.65E-01	2.43E-01	2.47E-01
Mo+6	g/Liter	5.23E-05	2.56E-02	2.64E-02	2.11E-06	1.30E-04	3.57E-02	3.68E-02	1.27E-08	8.93E-06	1.10E-03			2.59E-02	2.59E-02	5.07E-04	1.51E-04	1.51E-04	2.43E-05	1.02E-05	2.77E-04	2.77E-04
Na+	g/Liter	1.55E+02	1.56E+02	1.61E+02	1.61E+02	1.56E+02	1.57E+02	1.61E+02	1.54E+02	1.97E+02	1.61E+02	1.74E+02	1.84E+02	1.57E+02	1.57E+02	1.56E+02	1.57E+02	1.57E+02	1.61E+02	1.61E+02	1.61E+02	1.61E+02
Nd+3	g/Liter																					
NH3	g/Liter	7.10E-01	1.94E+00	1.99E+00	9.26E-01	9.13E-01	1.19E+00	1.23E+00	1.31E+00	1.12E+00	3.53E+00	3.90E+00	3.87E-01	8.86E+00	8.86E+00	2.55E+00	4.70E+00	4.70E+00	8.92E-01	9.72E-01	2.20E+00	2.06E+00
Ni+2	g/Liter	3.99E-01	8.92E-03	9.18E-03	2.38E-01	2.25E-01	8.12E-03	8.26E-03	6.70E-01	8.65E-01	9.41E-03	1.02E-02	1.77E-04	1.62E-02	1.72E-02	6.89E-02	7.18E-03	7.20E-03	3.40E-02	3.18E-02	7.58E-02	7.67E-02
NO2-	g/Liter	5.52E+01	6.28E+01	6.45E+01	5.26E+01	5.13E+01	7.28E+01	7.48E+01	8.42E+01	1.07E+02	6.34E+01	6.83E+01	9.15E+01	6.39E+01	6.40E+01	6.23E+01	7.09E+01	7.09E+01	6.21E+01	6.24E+01	5.98E+01	5.95E+01
NO3-	g/Liter	2.03E+02	9.41E+01	9.68E+01	1.46E+02	1.39E+02	1.05E+02	1.08E+02	1.03E+02	1.30E+02	9.90E+01	1.07E+02	8.77E+01	1.10E+02	1.10E+02	1.39E+02	2.00E+02	2.00E+02	1.57E+02	1.59E+02	1.63E+02	1.61E+02
OH (bound)	g/Liter	9.90E-01	1.56E+02	1.61E+02	3.08E+01	3.16E+01	1.12E+02	1.16E+02	3.38E+00	4.63E+00	8.57E+01	9.19E+01	2.89E+01	4.81E+01	4.81E+01	2.57E+01	2.83E+01	2.83E+01	5.24E+01	5.25E+01	4.21E+01	4.30E+01
OH-	g/Liter	1.63E+00	2.23E+01	2.29E+01	2.36E+00	2.48E+00	3.52E+01	3.62E+01	1.39E+01	1.73E+01	2.51E+01	2.68E+01	2.87E+01	4.41E+01	4.42E+01	1.30E+01	9.92E+00	9.92E+00	1.80E+01	1.79E+01	1.47E+01	1.50E+01
Pb+2	g/Liter	2.74E-01	4.31E-02	4.44E-02	5.37E-02	4.47E-02	2.49E-02	2.56E-02	3.03E-02	3.99E-02	5.07E-02	5.58E-02		6.57E-02	6.58E-02	1.17E-02	1.09E-02	1.09E-02	2.30E-02	2.29E-02	1.78E-02	1.82E-02
Pd+2	g/Liter																					
PO4-3	g/Liter	9.11E-01	2.30E+00	2.37E+00	3.02E+00	3.00E+00	2.67E+00	2.73E+00	4.76E+00	6.08E+00	1.29E+00	1.35E+00	1.38E+00	1.23E+00	1.23E+00	4.19E+00	3.37E+00	3.37E+00	6.44E+00	6.41E+00	6.18E+00	6.29E+00
Pr+3	g/Liter																					
Pu+4	g/Liter																					
Rb+	g/Liter																					
Rh+3	g/Liter																					
Ru+3	g/Liter																					

Table A-1. Waste Treatment Plant Feed Delivery Concentrations for Low-Activity Waste Phase 1 Case 3 Liquids (3 sheets)

Species	Units	LAW-1	LAW-2	LAW-3	LAW-4	LAW-5	LAW-6	LAW-7	LAW-8	LAW-9	LAW-10	LAW-11	LAW-12	LAW-13	LAW-14	LAW-15	LAW-16	LAW-17	LAW-18	LAW-19	LAW-20	LAW-21
Sb+5	g/Liter																					
Se+6	g/Liter	1.25E-07			4.22E-09				2.54E-11					1.50E-05	1.50E-05	1.11E-06	2.48E-05	2.48E-05	5.25E-08	9.82E-07	1.55E-06	6.01E-07
Si+4	g/Liter	4.19E-01	1.71E-01	1.76E-01	5.07E-02	3.75E-02	8.64E-02	8.89E-02	3.33E-01	4.26E-01	2.72E-01	3.00E-01	9.79E-01	2.17E-01	2.17E-01	2.31E-01	9.80E-02	9.80E-02	7.16E-02	6.67E-02	4.30E-02	4.20E-02
SO4-2	g/Liter	8.80E+00	4.85E+00	5.00E+00	1.02E+01	9.94E+00	2.93E+00	3.00E+00	3.65E+00	4.54E+00	1.71E+00	1.81E+00	3.25E+01	1.05E+00	1.05E+00	8.87E+00	5.21E+00	5.21E+00	7.48E+00	7.34E+00	1.10E+01	1.11E+01
Sr+2	g/Liter	3.43E-04	4.29E-03	4.40E-03	2.73E-04	3.04E-04	2.33E-03	2.39E-03	6.59E-05	5.01E-05	4.81E-03	5.31E-03	4.74E-04	1.56E-03	1.56E-03	6.80E-05	1.13E-04	1.13E-04	6.66E-05	6.66E-05	3.24E-05	3.09E-05
Ta+5	g/Liter																					
Tc+7	g/Liter																					
Te+6	g/Liter																					
Th+4	g/Liter																					
Ti+4	g/Liter	3.28E-06			1.11E-07				6.68E-10					2.13E-03	2.13E-03	1.81E-05	1.11E-05	1.11E-05	1.26E-06	6.83E-07	1.48E-05	1.45E-05
Tl+3	g/Liter																					
TOC	g/Liter	3.16E+01	9.21E+00	9.49E+00	1.67E+01	1.57E+01	1.61E+01	1.66E+01	7.50E+00	9.82E+00	1.93E+00	1.61E+00	2.72E+00	2.66E+00	2.67E+00	7.36E+00	3.69E+00	3.69E+00	9.22E+00	9.08E+00	9.27E+00	9.47E+00
U(total)	g/Liter		3.23E-06	3.33E-06	1.16E-01	1.16E-01	1.23E-06	1.06E-07	8.89E-03	1.65E-02	3.14E-09		1.35E+00	7.25E-05	1.45E-04	1.77E-02	3.40E-02	3.40E-02	3.70E-03	4.23E-03	1.85E-02	1.74E-02
V+5	g/Liter																					
W+6	g/Liter																					
Y+3	g/Liter																					
Zn+2	g/Liter	8.83E-06	4.50E-03	4.63E-03	2.98E-07	2.21E-05	1.15E-02	1.19E-02	2.71E-02	3.45E-02	4.98E-03	5.16E-03		1.42E-01	1.42E-01	2.44E-03	1.18E-02	1.18E-02	4.84E-04	8.23E-04	3.23E-03	2.80E-03
Zr+4	g/Liter	7.96E-04	1.56E-02	1.61E-02	4.12E-03	4.16E-03	9.85E-03	1.01E-02	2.14E-03	2.29E-03	4.99E-03	5.25E-03	2.37E-04	2.85E-02	2.85E-02	4.25E-02	7.94E-03	7.94E-03	1.96E-02	1.83E-02	1.65E-02	1.69E-02

Table A-2. *Waste Treatment Plant Feed Delivery Concentrations for Low-Activity Waste Phase 1 Case 3 Solids* (3 sheets)

Species	Units	LAW-1	LAW-2	LAW-3	LAW-4	LAW-5	LAW-6	LAW-7	LAW-8	LAW-9	LAW-10	LAW-11	LAW-12	LAW-13	LAW-14	LAW-15	LAW-16	LAW-17	LAW-18	LAW-19	LAW-20	LAW-21
Solids Vol	Liters	1.36E+04	4.79E+03	1.66E+04	4.81E+03	4.46E+03	4.19E+03	3.95E+03	2.67E+01	1.47E+02	4.50E+03	2.16E+04		4.61E+03	4.61E+03	4.08E+03	4.98E+03	4.98E+03	1.54E+02	1.57E+02	1.57E+02	5.73E+00
Density	g/cc	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
106-Ru	Bq/Liter	3.01E+00	0.00E+00	0.00E+00	1.68E+00	1.11E+00	1.58E-03	0.00E+00	3.70E-01	3.01E-01	0.00E+00	0.00E+00		3.66E-06	1.87E-05	2.45E+00	4.49E-09	3.20E-08	8.68E-01	1.57E-09	1.17E-08	3.31E-01
113m-Cd	Bq/Liter	3.55E+07	0.00E+00	0.00E+00	3.19E+08	3.30E+08	7.54E+05	0.00E+00	2.87E+08	3.02E+08	0.00E+00	0.00E+00		9.25E+03	9.10E+04	3.14E+04	1.42E+08	1.39E+08	2.92E+04	1.32E+08	1.29E+08	2.73E+04
125-Sb	Bq/Liter	1.30E+07	0.00E+00	0.00E+00	3.00E+07	2.68E+07	4.65E+04	0.00E+00	1.73E+07	1.67E+07	0.00E+00	0.00E+00		3.83E+02	3.05E+03	3.81E+03	1.10E+00	9.89E+00	2.61E+03	7.51E-01	6.86E+00	1.84E+03
126-Sn	Bq/Liter	5.01E+06	0.00E+00	0.00E+00	2.59E+07	2.80E+07	1.08E+05	0.00E+00	3.86E+07	4.12E+07	0.00E+00	0.00E+00		1.36E+03	1.40E+04	4.72E+03	5.01E+07	5.01E+07	4.72E+03	5.82E+07	5.82E+07	4.72E+03
129-I	Bq/Liter	3.05E+05	5.19E+05	5.50E+05	1.38E+06	1.49E+06	1.37E+07	1.49E+07	1.38E+06	1.47E+06	3.68E+05	0.00E+00		4.85E+01	4.98E+02	2.12E+03	2.26E-01	2.32E+00	2.12E+03	2.26E-01	2.32E+00	2.12E+03
134-Cs	Bq/Liter	1.59E+05	0.00E+00	0.00E+00	1.06E+05	8.73E+04	2.41E+02	0.00E+00	5.06E+04	4.62E+04	0.00E+00	0.00E+00		2.13E+03	1.52E+03	1.13E+01	5.17E+00	4.34E+00	6.82E+00	3.09E+00	2.66E+00	4.26E+00
137-Cs	Bq/Liter	3.24E+10	0.00E+00	0.00E+00	3.00E+10	2.83E+10	2.68E+09	0.00E+00	2.85E+10	2.70E+10	2.63E+09	2.67E+09		7.31E+09	7.14E+09	2.08E+09	3.26E+07	3.22E+07	2.01E+09	3.15E+07	3.12E+07	1.95E+09
137m-Ba	Bq/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
14-C	Bq/Liter	4.49E+06	0.00E+00	0.00E+00	7.14E+05	3.96E+05	9.70E+02	0.00E+00	7.14E+05	3.96E+05	0.00E+00	0.00E+00		2.51E+01	1.34E+02	5.25E-03	1.17E-01	6.27E-01	5.25E-03	1.17E-01	6.26E-01	5.25E-03
151-Sm	Bq/Liter	1.08E+10	0.00E+00	0.00E+00	9.12E+10	9.85E+10	2.31E+08	0.00E+00	8.85E+10	9.39E+10	0.00E+00	0.00E+00		3.06E+06	3.12E+07	9.30E+06	1.18E+11	1.18E+11	9.19E+06	1.15E+11	1.14E+11	9.09E+06
152-Eu	Bq/Liter	3.58E+06	0.00E+00	0.00E+00	1.72E+07	1.77E+07	3.81E+04	0.00E+00	1.54E+07	1.60E+07	0.00E+00	0.00E+00		4.92E+02	4.80E+03	4.32E+03	1.61E+07	1.57E+07	4.00E+03	1.49E+07	1.46E+07	3.72E+03
154-Eu	Bq/Liter	3.79E+08	1.72E+08	1.63E+08	1.68E+09	1.69E+09	3.63E+08	3.67E+08	1.41E+09	1.45E+09	1.08E+07	1.87E+06		4.26E+04	4.03E+05	1.85E+05	1.70E+02	1.67E+03	1.64E+05	1.50E+02	1.49E+03	1.46E+05
155-Eu	Bq/Liter	7.52E+07	0.00E+00	0.00E+00	2.63E+08	2.54E+08	3.44E+08	3.47E+08	1.94E+08	1.95E+08	6.25E+07	5.22E+07		5.26E+03	4.68E+04	3.28E+05	1.87E+01	1.78E+02	2.66E+05	1.51E+01	1.45E+02	2.19E+05
226-Ra	Bq/Liter	1.19E+02	0.00E+00	0.00E+00	9.08E+02	9.68E+02	3.01E+00	0.00E+00	9.07E+02	9.68E+02	0.00E+00	0.00E+00		3.18E-02	3.28E-01	1.14E-01	1.48E-04	1.53E-03	1.13E-01	1.48E-04	1.53E-03	1.13E-01
227-Ac	Bq/Liter	7.45E+02	0.00E+00	0.00E+00	4.14E+03	4.31E+03	1.20E+01	0.00E+00	3.86E+03	4.06E+03	0.00E+00	0.00E+00		1.28E-01	1.27E+00	3.85E-01	5.13E+03	5.04E+03	3.67E-01	4.88E+03	4.81E+03	3.51E-01
228-Ra	Bq/Liter	1.24E+05	0.00E+00	0.00E+00	4.04E+05	3.99E+05	4.46E+02	0.00E+00	3.22E+05	3.28E+05	0.00E+00	0.00E+00		9.35E+00	8.61E+01	2.81E+01	2.43E+05	2.30E+05	2.40E+01	2.07E+05	1.98E+05	2.08E+01
229-Th	Bq/Liter	1.49E+04	0.00E+00	0.00E+00	5.53E+04	5.83E+04	6.41E+01	0.00E+00	5.53E+04	5.83E+04	0.00E+00	0.00E+00		1.94E+00	1.98E+01	4.76E+00	6.41E+04	6.41E+04	4.76E+00	6.41E+04	6.41E+04	4.76E+00
231-Pa	Bq/Liter	5.10E+03	0.00E+00	0.00E+00	2.36E+04	2.50E+04	8.09E+01	0.00E+00	2.36E+04	2.50E+04	0.00E+00	0.00E+00		8.28E-01	8.48E+00	2.54E+00	4.09E+04	4.09E+04	2.54E+00	4.10E+04	4.09E+04	2.54E+00
232-Th	Bq/Liter	7.23E+04	0.00E+00	0.00E+00	2.54E+05	2.68E+05	1.57E+03	0.00E+00	2.47E+05	2.69E+05	0.00E+00	0.00E+00		8.92E+00	9.08E+01	2.09E+01	3.19E+05	3.19E+05	2.09E+01	3.19E+05	3.19E+05	2.09E+01
232-U	Bq/Liter	3.89E+05	0.00E+00	0.00E+00	8.99E+05	9.31E+05	6.84E+03	0.00E+00	8.80E+05	9.15E+05	0.00E+00	0.00E+00		3.04E+01	3.03E+02	2.71E+03	1.04E+05	1.04E+05	2.67E+03	1.03E+05	1.02E+05	2.63E+03
233-U	Bq/Liter	1.67E+05	0.00E+00	0.00E+00	3.87E+06	4.16E+06	2.82E+05	0.00E+00	3.87E+06	4.16E+06	0.00E+00	0.00E+00		1.36E+02	1.41E+03	8.50E+03	4.90E+05	4.90E+05	8.49E+03	4.90E+05	4.90E+05	8.49E+03
234-U	Bq/Liter	2.13E+05	0.00E+00	0.00E+00	8.13E+05	8.59E+05	1.71E+04	0.00E+00	8.13E+05	8.59E+05	0.00E+00	0.00E+00		2.86E+01	2.91E+02	4.98E+06	4.49E+05	4.49E+05	4.98E+06	4.49E+05	4.49E+05	4.98E+06
235-U	Bq/Liter	8.40E+03	0.00E+00	0.00E+00	3.16E+04	3.42E+04	8.83E+02	0.00E+00	3.25E+04	3.43E+04	0.00E+00	0.00E+00		1.14E+00	1.16E+01	1.87E+05	1.91E+04	1.91E+04	2.47E+05	1.72E+04	1.72E+04	1.89E+05
236-U	Bq/Liter	7.55E+03	0.00E+00	0.00E+00	2.90E+04	3.06E+04	9.84E+02	0.00E+00	2.90E+04	3.06E+04	0.00E+00	0.00E+00		1.02E+00	1.04E+01	4.19E+05	3.28E+04	3.28E+04	4.10E+05	3.28E+04	3.28E+04	4.10E+05
237-Np	Bq/Liter	1.36E+06	3.87E+06	4.10E+06	7.45E+05	7.16E+05	1.08E+08	1.17E+08	7.45E+05	7.16E+05	6.87E+06	3.43E+06		2.62E+01	2.43E+02	3.47E+04	1.22E-01	1.13E+00	3.47E+04	1.22E-01	1.13E+00	3.47E+04
238-Pu	Bq/Liter	2.02E+06	0.00E+00	0.00E+00	1.37E+07	1.45E+07	2.36E+07	0.00E+00	1.34E+07	1.43E+07	0.00E+00	0.00E+00		4.66E+02	4.75E+03	5.34E+07	2.14E+00	2.19E+01	5.28E+07	2.11E+00	2.17E+01	5.22E+07
238-U	Bq/Liter	1.85E+05	0.00E+00	0.00E+00	7.18E+05	7.59E+05	1.63E+04	0.00E+00	6.65E+05	7.67E+05	0.00E+00	0.00E+00		2.52E+01	2.57E+02	3.40E+06	3.24E+05	3.24E+05	3.40E+06	3.22E+05	3.21E+05	3.62E+06
239-Pu	Bq/Liter	2.44E+07	1.24E+07	1.24E+07	3.73E+07	3.82E+07	2.63E+08	2.34E+07	3.73E+07	3.82E+07	1.26E+06	6.55E+05		2.38E+08	2.38E+08	5.39E+08	1.19E+06	1.19E+06	5.11E+08	1.19E+06	1.19E+06	5.11E+08
240-Pu	Bq/Liter	1.22E+07	1.93E+06	1.93E+06	1.22E+07	1.21E+07	8.24E+07	3.66E+06	1.22E+07	1.21E+07	2.91E+06	2.89E+06		4.28E+02	4.11E+03	1.56E+08	1.99E+00	1.92E+01	1.56E+08	1.99E+00	1.92E+01	1.56E+08
241-Am	Bq/Liter	2.07E+08	7.25E+07	7.24E+07	3.96E+08	4.10E+08	1.02E+09	4.36E+07	3.95E+08	4.09E+08	2.38E+06	1.25E+06		1.38E+04	1.38E+05	2.66E+05	6.43E+01	6.43E+02	2.65E+05	6.41E+01	6.42E+02	2.64E+05
241-Pu	Bq/Liter	8.92E+07	0.00E+00	0.00E+00	7.64E+07	7.36E+07	4.06E+05	0.00E+00	6.87E+07	6.71E+07	0.00E+00	0.00E+00		2.21E+03	2.02E-04	2.36E+09	1.23E+07	1.19E+07	2.19E+09	1.14E+07	1.11E+07	2.05E+09
242-Cm	Bq/Liter	1.92E-02	0.00E+00	0.00E+00	3.13E-05	9.02E-06	1.42E-08	0.00E+00	1.03E-06	4.78E-07	0.00E+00	0.00E+00		2.08E-12	3.50E-12	4.57E-12	9.52E-11	4.16E-11	4.41E-13	8.91E-12	4.33E-12	5.00E-14
242-Pu	Bq/Liter	8.55E+02	0.00E+00	0.00E+00	8.60E+02	8.56E+02	2.35E+04	0.00E+00	8.60E+02	8.56E+02	0.00E+00	0.00E+00		3.02E-02	2.90E-01	2.41E+04	1.41E+02	1.41E+02	2.41E+04	1.41E+02	1.41E+02	2.41E+04
243-Am	Bq/Liter	3.17E+04	0.00E+00	0.00E+00	4.49E+04	4.58E+04	2.77E+02	0.00E+00	4.49E+04	4.58E+04	0.00E+00	0.00E+00		1.58E+00	1.55E+01	4.37E+01	2.01E+03	2.01E+03	4.37E+01	2.02E+03	2.01E+03	4.37E+01
243-Cm	Bq/Liter	1.49E+05	1.68E+05	1.65E+05	1.17E+04	2.00E+03	1.51E+05	1.57E+05	1.11E+04	1.91E+03	4.06E+03	0.00E+00		3.71E-01	6.09E-01	7.63E+01	1.65E-03	2.74E-03	7.36E+01	1.59E-03	2.65E-03	7.11E+01
244-Cm	Bq/Liter	9.66E+05	3.30E+06	3.22E+06	9.88E+06	1.03E+07	7.80E+06	8.07E+06	9.08E+06	9.59E+06	2.26E+05	2.02E+04		2.97E+02	2.96E+03	1.29E+03	1.29E+00	1.31E+01	1.22E+03	1.21E+00	1.24E+01	1.15E+03
3-H	Bq/Liter	1.53E+07	0.00E+00	0.00E+00	9.71E+05	0.00E+00	0.00E+00	0.00E+00	8.58E+05	0.00E+00	0.00E+00	0.00E+00		2.72E+01	0.00E+00	0.00E+00	1.14E-01	0.00E+00	0.00E+00	1.04E-01	0.00E+00	0.00E+00
59-Ni	Bq/Liter	1.11E+06	0.00E+00	0.00E+00	1.35E+07	1.45E+07	2.90E+04	0.00E+00	1.36E+07	1.45E+07	0.00E+00	0.00E+00		4.76E+02	4.92E+03	2.60E+03	1.54E+07	1.54E+07	2.60E+03	1.54E+07	1.54E+07	2.60E+03
60-Co	Bq/Liter	6.29E+06	2.50E+07	2.28E+07	1.46E+07	1.41E+07	5.31E+07	5.39E+07	1.09E+07	1.10E+07	1.89E+06	6.25E+05		3.01E+02	2.70E+03	1.10E+04	1.09E+00	1.04E+01	9.04E+03	8.89E-01	8.59E+00	7.52E+03
63-Ni	Bq/Liter	9.65E+07	0.00E+00	0.00E+00	1.20E+09	1.28E+09	2.53E+06	0.00E+00	1.18E+09	1.26E+09	0.00E+00	0.00E+00		4.09E+04	4.20E+05	2.35E+05	1.29E+09	1.28E+09	2.33E+05	1.27E+09	1.27E+09	2.30E+05
79-Se	Bq/Liter	1.06E-06	0.00E+00	0.00E+00	4.07E+06	4.29E+06	4.82E+03	0.00E+00	4.07E+06	4.29E+06	0.00E+00	0.00E+00		1.43E+02	1.46E+03	3.57E+02	6.66E-01	6.80E+00	3.57E+02	6.66E-01	6.80E+00	3.57E+02
90-Sr	Bq/Liter	2.96E+10	9.49E+10	1.10E+11	5.86E+10	6.04E+10	7.54E+10	7.89E+10	5.56E+10	5.78E+10	2.55E+09	5.12E+08		1.87E+06	1.85E+07	2.45E+08	8.32E+03	8.33E+04	2.36E+08	8.02E+03	8.04E+04	2.28E+08
90-Y	Bq/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
93-Zr	Bq/Liter	2.25E+07	0.00E+00	0.00E+00	1.29E+08	1.37E+08	3.41E+05	0.00E+00	1.29E+08	1.16E+08	0.00E+00	0.00E+00		4.52E+03	4.65E+04	1.25E+04	1.57E+08	1.57E+08	1.25E+04	1.63E+08	1.62E+08	1.25E+04
93m-Nb	Bq/Liter	7.79E+06	0.00E+00	0.00E+00	3.88E+07	3.98E+07	9.76E+04	0.00E+00	3.47E+07	3.61E+07	0.00E+00	0.00E+00		1.11E+03	1.08E+04	3.04E+03	4.14E+07	4.03E+07	2.81E+03	3.83E+07	3.74E+07	2.62E+03

Table A-2. Waste Treatment Plant Feed Delivery Concentrations for Low-Activity Waste Phase 1 Case 3 Solids (3 sheets)

Species	Units	LAW-1	LAW-2	LAW-3	LAW-4	LAW-5	LAW-6	LAW-7	LAW-8	LAW-9	LAW-10	LAW-11	LAW-12	LAW-13	LAW-14	LAW-15	LAW-16	LAW-17	LAW-18	LAW-19	LAW-20	LAW-21
99-Tc	Bq/Liter	3.65E+07	1.81E+08	1.87E+08	2.58E+07	2.78E+07	2.52E+08	2.67E+08	3.01E+07	3.02E+07	1.14E+07	5.74E+06		1.06E+03	1.03E+04	6.09E+06	4.93E+00	4.79E+01	6.10E+06	4.93E+00	4.79E+01	6.10E+06
Ag+	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.12E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Al(OH)4-	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Al+3	g/Liter	2.05E+02	0.00E+00	0.00E+00	1.58E+02	1.53E+02	4.36E+01	0.00E+00	1.58E+02	1.53E+02	1.41E+02	1.45E+02		5.54E-03	5.27E-02	1.18E+02	2.59E-05	2.42E-04	1.18E+02	2.59E-05	2.42E-04	1.18E+02
As+5	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.77E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B+3	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.82E-03	0.00E+00	0.00E+00	0.00E+00	1.04E+01	1.07E+01		0.00E+00	0.00E+00	5.56E-02	0.00E+00	0.00E+00	5.53E-02	0.00E+00	0.00E+00	5.53E-02
Ba+2	g/Liter	0.00E+00	0.00E+00	0.00E+00	4.85E-01	5.24E-01	1.64E-01	0.00E+00	4.75E-01	5.12E-01	0.00E+00	0.00E+00		1.67E-05	1.74E-04	0.00E+00	7.78E-08	8.10E-07	0.00E+00	7.78E-08	8.11E-07	0.00E+00
Be+2	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.61E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bi+3	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.34E+00	5.66E+00	0.00E+00	0.00E+00	1.39E-01	0.00E+00		3.97E+01	3.97E+01	8.03E-04	1.68E-01	1.68E-01	8.03E-04	1.85E-01	1.85E-01	8.03E-04
Ca+2	g/Liter	3.42E+00	2.54E+01	2.54E+01	3.38E+01	3.62E+01	1.17E+02	1.26E+02	3.30E+01	3.63E+01	3.51E+00	1.46E-01		7.51E+01	7.51E+01	4.30E+01	1.96E+01	1.96E+01	4.29E+01	1.95E+01	1.97E+01	4.20E+01
Cd+2	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.59E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce+3	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cl-	g/Liter	2.86E+01	0.00E+00	0.00E+00	2.22E+00	1.59E-02	1.15E-03	0.00E+00	2.66E+00	1.52E-02	0.00E+00	0.00E+00		7.81E-05	5.14E-06	0.00E+00	3.64E-07	2.40E-08	0.00E+00	3.64E-07	2.40E-08	0.00E+00
CN-	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Co+3	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO3-2	g/Liter	9.74E+01	1.65E+00	1.65E+00	7.75E+00	2.69E-01	3.17E+00	3.11E+00	6.74E+00	2.69E-01	2.93E-01	2.19E-01		5.34E-01	5.34E-01	5.44E-01	2.50E-03	2.50E-03	3.89E-01	2.50E-03	2.50E-03	5.43E-01
Cr(OH)4-	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cr(total)	g/Liter	7.69E+00	0.00E+00	0.00E+00	2.32E+01	2.44E+01	2.75E+02	2.91E+02	2.34E+01	2.44E+01	1.26E+01	4.94E+00		5.74E+00	5.74E+00	1.87E+01	6.31E+01	6.31E+01	1.89E+01	6.31E+01	6.31E+01	1.82E+01
Cs+	g/Liter	9.07E-02	0.00E+00	0.00E+00	1.71E-01	1.84E-01	6.31E-03	0.00E+00	1.66E-01	1.71E-01	9.13E-02	9.51E-02		2.67E-01	2.67E-01	6.72E-02	1.25E-03	1.25E-03	7.91E-02	1.25E-03	1.25E-03	7.91E-02
Cu+2	g/Liter	0.00E+00	0.00E+00	0.00E+00	1.10E+00	1.17E+00	4.86E-01	0.00E+00	1.09E+00	1.30E+00	0.00E+00	0.00E+00		3.83E-05	3.99E-04	0.00E+00	1.79E-07	1.86E-06	0.00E+00	1.79E-07	1.86E-06	0.00E+00
F-	g/Liter	4.31E+00	1.46E+00	1.46E+00	6.59E-01	3.62E-01	7.24E+00	7.77E+00	6.61E-01	3.88E-01	7.14E-01	5.21E-01		2.32E-05	1.23E-04	2.84E+01	2.21E-01	2.21E-01	2.83E+01	2.43E-01	2.43E-01	2.99E+01
Fe+3	g/Liter	4.81E+01	1.14E+01	1.14E+01	3.46E+01	3.34E+01	3.33E+01	2.28E+01	3.56E+01	3.35E+01	1.08E+01	1.04E+01		7.61E+01	7.61E+01	8.01E+01	7.24E+00	7.24E+00	8.01E+01	7.14E+00	7.13E+00	7.80E+01
H-	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H2O	g/Liter	1.04E-12	0.00E+00	0.00E+00	8.06E-14	0.00E+00	0.00E+00	0.00E+00	8.06E-14	0.00E+00	0.00E+00	0.00E+00		2.83E-18	0.00E+00	0.00E+00	1.32E-20	0.00E+00	0.00E+00	1.32E-20	0.00E+00	0.00E+00
Hg+2	g/Liter	5.15E-03	0.00E+00	0.00E+00	3.97E-04	0.00E+00	4.45E-02	4.86E-02	3.97E-04	0.00E+00	1.30E-03	0.00E+00		1.40E-08	0.00E+00	6.91E-06	6.51E-11	0.00E+00	6.91E-06	6.51E-11	0.00E+00	6.92E-06
K+	g/Liter	7.29E+00	4.50E+01	4.50E+01	1.23E+01	1.29E+01	2.67E+01	2.74E+01	1.17E+01	1.30E+01	7.11E+00	6.55E+00		5.68E-01	5.76E-01	3.22E+01	9.93E+01	9.93E+01	3.22E+01	9.94E+01	9.93E+01	3.41E+01
La+3	g/Liter	8.48E-01	2.47E+00	2.45E+00	5.77E-02	1.28E-02	7.73E+00	8.33E+00	6.51E-02	1.28E-02	1.04E+01	1.05E+01		2.28E-06	4.33E-06	6.81E-02	1.07E-08	2.02E-08	5.54E-02	1.07E-08	2.02E-08	5.54E-02
Li+	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mg+2	g/Liter	0.00E+00	0.00E+00	0.00E+00	2.16E+00	2.33E+00	2.23E+00	0.00E+00	1.82E+00	2.32E+00	0.00E+00	0.00E+00		7.58E-05	7.89E-04	0.00E+00	3.53E-07	3.68E-06	0.00E+00	3.53E-07	3.68E-06	0.00E+00
Mn+4	g/Liter	4.98E+00	0.00E+00	0.00E+00	8.90E+00	9.18E+00	4.19E+00	0.00E+00	8.23E+00	9.36E+00	2.08E-01	2.19E-01		9.41E-01	9.41E-01	2.61E+01	1.84E+00	1.84E+00	2.60E+01	1.76E+00	1.75E+00	2.88E+01
Mo+6	g/Liter	0.00E+00	0.00E+00	0.00E+00	7.37E-01	7.96E-01	4.58E-02	0.00E+00	7.33E-01	6.54E-01	0.00E+00	0.00E+00		2.57E-05	2.68E-04	0.00E+00	1.20E-07	1.25E-06	0.00E+00	1.20E-07	1.25E-06	0.00E+00
Na+	g/Liter	1.32E+03	2.73E+03	2.73E+03	4.70E+02	4.11E+02	1.72E+03	1.84E+03	4.70E+02	4.11E+02	1.84E+02	1.38E+02		1.75E+00	1.87E+00	1.77E+01	2.43E+03	2.43E+03	1.76E+01	2.43E+03	2.43E+03	1.61E+01
Nd+3	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.41E-01	0.00E+00	0.00E+00	0.00E+00	4.35E-01	4.46E-01		0.00E+00	0.00E+00	2.58E+00	0.00E+00	0.00E+00	2.54E+00	0.00E+00	0.00E+00	2.58E+00
Ni+2	g/Liter	3.92E+00	6.12E+00	6.12E+00	7.28E+00	7.56E+00	8.50E+00	9.14E+00	6.60E+00	7.60E+00	6.65E-01	4.37E-01		5.35E+00	5.35E+00	3.40E+01	2.36E-02	2.36E-02	3.39E+01	2.50E-02	2.50E-02	3.08E+01
NO2-	g/Liter	1.30E+02	0.00E+00	0.00E+00	1.31E+01	3.31E+00	5.60E-01	0.00E+00	1.38E+01	3.45E+00	6.65E-01	6.79E-01		9.98E-03	9.98E-03	1.57E+00	7.66E+01	7.66E+01	1.49E+00	7.67E+01	7.66E+01	1.56E+00
NO3-	g/Liter	3.47E+02	9.98E+00	9.99E+00	3.00E+01	3.57E+00	1.86E+01	1.74E+01	3.02E+01	3.38E+00	3.17E+00	2.78E+00		5.78E-01	5.78E-01	3.33E+00	1.64E+02	1.64E+02	3.22E+00	1.64E+02	1.63E+02	3.33E+00
OH (bound)	g/Liter	4.27E+02	0.00E+00	0.00E+00	1.76E+03	1.86E+03	1.13E+02	0.00E+00	1.76E+03	1.86E+03	2.56E+03	2.63E+03		2.77E+03	2.77E+03	2.11E+03	1.29E+01	1.29E+01	2.11E+03	1.29E+01	1.29E+01	2.11E+03
OH-	g/Liter	1.29E+01	0.00E+00	0.00E+00	9.93E-01	0.00E+00	0.00E+00	0.00E+00	1.27E+00	0.00E+00	0.00E+00	0.00E+00		3.49E-05	0.00E+00	0.00E+00	1.63E-07	0.00E+00	0.00E+00	1.63E-07	0.00E+00	0.00E+00
Pb+2	g/Liter	4.18E+00	3.20E+00	3.19E+00	3.86E+01	4.14E+01	1.15E+01	1.15E+01	3.88E+01	4.09E+01	2.44E+00	2.20E+00		8.99E-02	8.99E-02	4.57E-01	1.47E+01	1.47E+01	4.42E-01	1.46E+01	1.45E+01	4.42E-01
Pd+2	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PO4-3	g/Liter	8.29E+01	2.31E+01	2.31E+01	1.39E+01	8.25E+00	2.31E+02	2.39E+02	1.42E+01	8.41E+00	8.13E+00	1.80E+00		9.48E+00	9.47E+00	8.26E+00	3.82E-02	3.82E-02	8.01E+00	4.42E-02	4.42E-02	8.27E+00
Pr+3	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pu+4	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb+	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh+3	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.23E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru+3	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.99E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb+5	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table A-2. Waste Treatment Plant Feed Delivery Concentrations for Low-Activity Waste Phase 1 Case 3 Solids (3 sheets)

Species	Units	LAW-1	LAW-2	LAW-3	LAW-4	LAW-5	LAW-6	LAW-7	LAW-8	LAW-9	LAW-10	LAW-11	LAW-12	LAW-13	LAW-14	LAW-15	LAW-16	LAW-17	LAW-18	LAW-19	LAW-20	LAW-21
Se+6	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Si+4	g/Liter	4.95E+01	5.53E+01	5.53E+01	2.32E+01	2.12E+01	4.15E+01	4.37E+01	2.31E+01	2.12E+01	7.78E+00	6.79E+00		8.15E-04	6.09E-03	1.56E+01	3.80E-06	3.36E-05	1.55E+01	3.80E-06	3.36E-05	1.47E+01
SO4-2	g/Liter	2.22E+01	8.87E+01	8.87E+01	1.95E+01	1.96E+01	3.07E+02	3.35E+02	1.80E+01	1.96E+01	1.28E+01	3.92E+00		7.08E-01	7.08E-01	1.29E+01	3.30E-03	3.33E-03	1.31E+01	3.30E-03	3.33E-03	1.29E+01
Sr+2	g/Liter	5.96E-02	3.01E-01	2.93E-01	2.06E-01	2.22E-01	1.07E+00	1.12E+00	2.14E-01	2.27E-01	2.00E-01	1.71E-01		3.65E+00	3.65E+00	1.23E-03	3.62E-02	3.62E-02	1.23E-03	2.96E-02	2.96E-02	1.23E-03
Ta+5	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tc+7	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Te+6	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.10E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Th+4	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ti+4	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.89E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tl+3	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOC	g/Liter	1.60E+02	0.00E+00	0.00E+00	2.07E+02	2.10E+02	6.62E+00	0.00E+00	2.07E+02	2.10E+02	1.45E+01	1.49E+01		5.44E+00	5.51E+00	1.57E+02	2.66E-02	2.66E-02	1.57E+02	2.54E-02	2.57E-02	1.57E+02
U(total)	g/Liter	7.00E-02	9.39E-03	9.39E-03	4.93E-03	4.89E-05	9.44E-03	1.03E-02	4.93E-03	4.89E-05	2.75E-04	0.00E+00		3.61E-01	3.61E-01	1.46E-06	1.66E-03	1.66E-03	1.46E-06	1.66E-03	1.66E-03	1.46E-06
V+5	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.65E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
W+6	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y+3	g/Liter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zn+2	g/Liter	0.00E+00	0.00E+00	0.00E+00	1.51E+00	1.63E+00	1.30E+00	0.00E+00	1.51E+00	1.78E+00	3.14E+00	3.22E+00		5.30E-05	5.52E-04	1.60E-02	2.47E-07	2.58E-06	1.67E-02	2.47E-07	2.58E-06	1.67E-02
Zr+4	g/Liter	4.03E-01	0.00E+00	0.00E+00	9.36E+00	1.01E+01	6.54E-02	0.00E+00	1.02E+01	9.94E+00	1.82E-01	1.81E-01		3.29E-04	3.41E-03	1.16E+01	1.39E+00	1.39E+00	1.18E+01	1.17E+00	1.16E+00	1.16E+01