Standard Inventories of Chemicals and Radionuclides in Hanford Site Tank Wastes

M. J. Kupfer, A. L. Boldt, K. M. Hodgson, L. W. Shelton, B. C. Simpson, and R. A. Watrous (LMHC); M. D. LeClair (SAIC); G. L. Borsheim (BA); R. T. Winward (MA); B. A. Higley and R. M. Orme (NHC); N. G. Colton (PNNL); S. L. Lambert and D. E. Place (SESC); and W. W. Schulz (W^2S)
Lockheed Martin Hanford Corporation, Richland, WA 99352
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Abstract: This report presents work performed to date to establish standard global and tank-by-tank component inventory estimates. This work includes: global inventory estimates for 30 nonradioactive components and 46 radionuclides that account for approximately 99 percent of the total tank waste inventory. To ensure that inventory values resulting from these evaluations are technically defensible and reproducible, every attempt is being made to document the bases, i.e., originating sources of assumptions, data, and background information, that support these values.

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Page 1 of 2

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13b. Design Baseline Document? [] Yes [X] No

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19. Change Impact Review: Indicate the related documents (other than the engineering documents identified on Side 1) that will be affected by the change described in Block 13. Enter the affected document number in Block 20.

SDD/DD	[]	Seismic/Stress Analysis	[]	Tank Calibration Manual	[]
Functional Design Criteria	[]	Stress/Design Report	[]	Health Physics Procedure	[]
Operating Specification	[]	Interface Control Drawing	[]	Spares Multiple Unit Listing	[]
Criticality Specification	[]	Calibration Procedure	[]	Test Procedures/Specification	[]
Conceptual Design Report	[]	Installation Procedure	[]	Component Index	[]
Equipment Spec.	[]	Maintenance Procedure	[]	ASME Coded Item	[]
Const. Spec.	[]	Engineering Procedure	[]	Human Factor Consideration	[]
Procurement Spec.	[]	Operating Instruction	[]	Computer Software	[]
Vendor Information	[]	Operating Procedure	[]	Electric Circuit Schedule	[]
OM Manual	[]	Operational Safety Requirement	[]	ICRS Procedure	[]
FSAR/SAR	[]	IEFD Drawing	[]	Process Control Manual/Plan	[]
Safety Equipment List	[]	Cell Arrangement Drawing	[]	Process Flow Chart	[]
Radiation Work Permit	[]	Essential Material Specification	[]	Purchase Requisition	[]
Environmental Impact Statement	[]	Fac. Proc. Samp. Schedule	[]	Tickler File	[]
Environmental Report	[]	Inspection Plan	[]	Other	[X]
Environmental Permit	[]	Inventory Adjustment Request	[]		[]

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STANDARD INVENTORIES OF CHEMICALS AND RADIONUCLIDES IN HANFORD SITE TANK WASTES

September 1998

M. J. Kupfer, A. L. Boldt, K. M. Hodgson,
L. W. Shelton, B. C. Simpson, and R. A. Watrous
Lockheed Martin Hanford Corporation
Richland, Washington

B. A. Higley and R. M. Orme
Numatec Hanford Corporation
Richland, Washington

M. D. LeClair
Science Applications International Corporation
Richland, Washington

G. L. Borsheim
Borsheim Associates
Richland, Washington

R. T. Winward
Meier Associates
Richland, Washington

N. G. Colton
Pacific Northwest National Laboratory
Richland, Washington

S. L. Lambert and D. E. Place
Cogema Engineering
Richland, Washington

W. W. Schulz
W^2S Corporation
Albuquerque, New Mexico

Prepared for
U.S. Department of Energy
Richland, Washington

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EXECUTIVE SUMMARY

This report presents global best-basis inventory estimates for chemical and radionuclide components in the 177 Hanford Site underground storage tanks. Tank-by-tank best-basis inventories have also been developed as part of the Standard Inventory task and will be published in the respective tank characterization report for each tank. In instances where a tank characterization report has not been issued, the best-basis inventory is issued as a preliminary tank characterization report. The methodology for deriving global chemical and radionuclide inventories, as well as individual tank inventories, is also presented in this report.

Tank-by-tank best-basis waste inventories include 25 chemical and 46 radionuclide components for each of the 177 single- and double-shell underground waste storage tanks on the Hanford Site. The global waste inventories include five chemicals that are in addition to the chemicals and radionuclides reported in the tank-by-tank inventories. The global waste inventories reported herein are an independent estimate of the total amount of each chemical or radionuclide component (e.g., metric tons of sodium, nitrate, aluminum, etc., and curies of $^{239/240}Pu$, ^{137}Cs, ^{90}Sr, *etc.) presently stored in the underground waste tanks. The chemical analytes selected represent over 99 weight percent of the tank contents, and the radionuclides represent over 99 percent of the activity. Global and tank-by-tank inventories now serve as waste composition data for Tank Waste Remediation System process flowsheet modeling work, safety analyses, risk assessments, and waste retrieval, treatment, and disposal system design.*

Information used to establish global inventories originated from key historical records (e.g., essential material purchase records), from various chemical flowsheets used in reprocessing of irradiated Hanford Site reactor fuels, and from calculations of radionuclide isotope generation and decay. Tank-by-tank inventories are most often based on sample analysis results.

In recent years, Los Alamos National Laboratory has revisited some of the historical information for the development of the Hanford Defined Waste model.[1],[2] *This model generates chemical and radionuclide inventory estimates for each of the underground tanks as well as global inventories for both single- and double-shell tanks. These Hanford Defined Waste model inventories are often inconsistent with the currently used Tank Waste Remediation System inventories.*

A major objective of the Standard Inventory task was to understand the underlying basis for the inconsistencies, to resolve the major inconsistencies and to establish standard global and tank-by-tank inventories that benefit a multitude of waste management and disposal

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[1]*Agnew, S. F., J. Boyer, R. A. Corbin, T. B. Duran, J. R. FitzPatrick, K. A. Jurgensen, T. P. Ortiz, and B. L. Young, 1996,* Hanford Tank Chemical and Radionuclide Inventories: HDW Model Rev. 3, *LA-UR-96-858, Los Alamos National Laboratory, Los Alamos, New Mexico.*

[2]*Agnew, S. F., J. Boyer, R. A. Corbin, T. B. Duran, J. R. FitzPatrick, K. A. Jurgensen, T. P. Ortiz, and B. L. Young, 1997,* Hanford Tank Chemical and Radionuclide Inventories: HDW Model Rev. 4, *LA-UR-96-3860, Los Alamos National Laboratory, Los Alamos, New Mexico.*

activities. Evaluations performed to resolve differences among reported values involved reviewing the bases, i.e., assumptions, data, background information, etc., that support these values. To ensure that inventory values resulting from these evaluations are technically defensible and reproducible, every attempt was made to document all bases that support these values.

A major effort in fiscal year 1998 involved a review and evaluation of the tank-by-tank inventories to improve the inventory bases where necessary. This effort provides the first major step toward reconciliation of differences between the global analyte inventories and those obtained by summation of the tank-by-tank inventories. Additional sample data were included where available, and improvements were made to the engineering bases for tanks without samples. A reconciliation team resolved numerous discrepancies, internal errors, and inconsistencies including:

- *Cases where the component inventory for a single tank comprised an unusually high fraction of the global (total) tank inventory*

- *Cases with components that exhibited unusually high concentrations*

- *Replacement of "less than" values, blanks, and "not reported" values with engineering or model values per established protocols.*

- *Improvement of the predictive basis for many of the 46 radionuclide isotopes. The distributions of all isotopes for uranium, plutonium, americium, and curium were predicted from analytical data or engineering based values using total uranium, total alpha and/or ^{238}Pu, $^{239/240}Pu$, ^{241}Am. The HDW Rev. 4 model isotopic distributions were normalized to these actual data.*

All changes/revisions to tank data were reviewed and approved by a Change Control Board with appropriate documentation. Issuance of the data was provided in Tank Characterization Reports (TCRs), revised TCRs, or preliminary TCRs. All data were entered into the Tank Characterization Database (TCD) (LMHC 1998).[1]

In parallel to the reconciliation effort, validation and review of the HDW model bases have continued and a report "Hanford Defined Waste Model Limitations and Improvements," will be issued in December 1998 to fulfill a Defense Nuclear Facility Safety Board (DNFSB) requirement (DNFSB 5.6.3.1.i, milestone TD1-99-113).

Global inventory values resulting from nonradioactive component evaluations are summarized in Table ES-1 along with the corresponding document section containing the evaluation discussion. Global inventory values resulting from the radionuclide component evaluation are summarized in Table ES-2. The global inventories were primarily developed

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[1]*LMHC, 1998,* Best-Basis Inventory for Tank 241-XX-XXX, Tank Characterization Database, Internet at http://twins.pnl.gov:8001/TCD/main.html, *Lockheed Martin Hanford Corporation, Richland, Washington.*

from purchase records and flowsheets. The summation of the tank-by-tank best-basis inventories is also included in Tables ES-1 and ES-2. A comparison of the global inventories to the summation of individual tank best-basis inventories for the 30 chemical components and 46 radionuclides is also provided in Appendix K. Appendix K additionally provides a strategy for further reconciliation of the global and tank summation inventories. As of September 1, 1998, 13 of the tank summation and global chemical inventories match within 25 percent. For these 13 components, seven match within 10 percent (Table ES-1). More than 50 percent of the tank summation inventory is based on sample data for 19 of the 30 chemicals. Comparison of radionuclide global and tank summation inventories (Table ES-2) is less meaningful since the two inventories are often derived from the Hanford Defined Waste model and therefore are not truly independent from each other.

It is recognized that the standard inventory, as reported in Tables ES-1 and ES-2, will not satisfy all users' needs. Expansion of the data set to include confidence intervals and other program-specific needs (liquid/solid split, soluble/insoluble split, etc.) is already being planned. Confidence intervals are now loaded into the TCD. Information on liquid/solid splits and soluble/insoluble splits have yet to be loaded. Users are referred to the Tank Characterization Database[1] for the most current Standard Inventory data set.

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[1] *PNL, 1994,* TWINS User Guide Tank Waste Characterization Information Network System Version 4.0, *PNL-8824-2, Pacific Northwest Laboratory, Richland, Washington.*

Table ES-1. Comparison of Global and Summation of Individual Tank Best-Basis Inventories for Nonradioactive Components. (2 Sheets)

Component	*Summation of individual tank best-basis inventories (MT)*[1]	*Global inventory (MT)*	*Corresponding document section*
Aluminum	*7,950*	*7,845*	*5.1*
Bismuth	*631*	*580*	*5.2*
Calcium	*319*	*214*	*5.3*
Carbonate	*9,390*	*4,830*	*5.4*
Chloride	*930*	*500*	*5.6*
Chromium	*670*	*785*	*5.7*
Fluoride	*1,190*	*1,360*	*5.8*
Hydroxide	*23,500*	*23,000*	*5.9*
Iron	*1,400*	*1,230*	*5.10*
Lanthanum	*51.3*	*51*	*5.11*
Lead	*84.0*	*279*	*5.12*
Manganese	*194*	*105*	*5.13*
Mercury	*1.81*	*2.1*	*5.14*
Nickel	*174*	*111*	*5.15*
Nitrite and Nitrate	*64,700*	*85,700*	*5.16*
Phosphate	*5,550*	*6,000*	*5.17*
Potassium	*874*	*481*	*5.18*
Silicon	*941*	*570*	*5.19*
Sodium	*48,800*	*54,200*	*5.20*
Sulfate	*3,330*	*5,000*	*5.21*
Strontium	*45.9*	*31.3*	*5.22*
Total organic carbon	*1,690*	*4,000*	*5.23*
U_{TOTAL}	*929*	*965*	*6.3*
Zirconium	*470*	*440*	*5.24*

Table ES-1. Comparison of Global and Summation of Individual Tank Best-Basis Inventories for Nonradioactive Components. (2 Sheets)

Component	*Summation of individual tank best-basis inventories (MT)*[1]	*Global inventory (MT)*	*Corresponding document section*
Minor components			
Cadmium	*NR*[2]	*8.2*	*7.3.1*
Cerium	*NR*[2]	*8.8*	*5.5*
Silver	*NR*[2]	*8.93*	*7.3.2*
Thorium	*NR*[2]	*25.6*	*7.3.3*
Tungsten	*NR*[2]	*15.9*	*7.3.4*

[1]*As of September 30, 1998*

[2]*NR = Not reported. Only small quantities of these chemicals are present in the waste and analytical data are limited.*

Table ES-2. Comparison of Global and Summation of Individual Tank Best-Basis Inventories for Radioactive Components (Decayed to January 1, 1994). (3 Sheets)

Radionuclide	*Summation of individual tank best-basis inventories (Ci)*[1]	*Global inventory (Ci)*	*Corresponding document section*
^{3}H	*2.45 E+04*	*3.40 E+04*	*6.1*
^{14}C	*3.87 E+03*	*4.81 E+03*	*6.1*
^{59}Ni	*8.76 E+02*	*9.34 E+02*	*6.1*
^{60}Co	*1.99 E+04*	*1.23 E+04*	*6.1*
^{63}Ni	*8.64 E+04*	*9.20 E+04*	*6.1*
^{79}Se	*7.11 E+02*	*7.73 E+02*	*6.1*
^{90}Sr	*5.86 E+07*	*7.16 E+07*	*6.1 and 6.2*
^{90}Y	*5.86 E+07*	*7.16 E+07*	*6.1*
^{93}Zr	*3.45 E+03*	*3.63 E+03*	*6.1*
^{93m}Nb	*2.53 E+03*	*2.69 E+03*	*6.1*
^{99}Tc	*2.83 E+04*	*3.26 E+04*	*6.1*
^{106}Ru	*1.26 E+05*	*1.04 E+05*	*6.1*

Table ES-2. Comparison of Global and Summation of Individual Tank Best-Basis Inventories for Radioactive Components (Decayed to January 1, 1994). (3 Sheets)

Radionuclide	Summation of individual tank best-basis inventories (Ci)[1]	Global inventory (Ci)	Corresponding document section
^{113m}Cd	1.66 E+04	1.69 E+04	6.1
^{125}Sb	2.52 E+05	2.08 E+05	6.1
^{126}Sn	1.17 E+03	1.19 E+03	6.1
^{129}I	9.91 E+01	6.30 E+01	6.1
^{134}Cs	8.68 E+04	8.89 E+04	6.1
^{137}Cs	5.29 E+07	4.64 E+07	6.1 and 6.2
^{137m}Ba	5.01 E+07	4.39 E+07	6.1
^{151}Sm	2.60 E+06	2.75 E+06	6.1
^{152}Eu	1.45 E+03	1.48 E+03	6.1
^{154}Eu	1.94 E+05	1.47 E+05	6.1
^{155}Eu	1.75 E+05	1.36 E+05	6.1
^{226}Ra	5.83 E-02	6.31 E-02	6.1
^{227}Ac	8.75 E+01	8.76 E+01	6.1
^{228}Ra	7.75 E+01	7.71 E+01	6.1
^{229}Th	1.80 E+00	1.81 E+00	6.1
^{231}Pa	1.56 E+02	1.56 E+02	6.1
^{232}Th	4.41 E+00	2.11 E+00	6.1
^{232}U	1.32 E+02	1.23 E+02	6.1
^{233}U	5.01 E+02	4.76 E+02	6.1
^{234}U	3.47 E+02	3.46 E+02	6.1
^{235}U	1.41 E+01	1.45 E+01	6.1
^{236}U	1.19 E+01	9.57 E+00	6.1
^{237}Np	1.84 E+02	1.41 E+02	6.1
^{238}Pu	2.69 E+03	2.77 E+03	6.1
^{238}U	3.10 E+02	3.22 E+02	6.1 and 6.3
^{239}Pu	5.52 E+04	3.91 E+04	6.1
^{240}Pu	1.11 E+04	8.93 E+03	6.1

Table ES-2. Comparison of Global and Summation of Individual Tank Best-Basis Inventories for Radioactive Components (Decayed to January 1, 1994). (3 Sheets)

Radionuclide	*Summation of individual tank best-basis inventories (Ci)*[1]	*Global inventory (Ci)*	*Corresponding document section*
^{241}Am	1.06 E+05	6.99 E+04	6.1
^{241}Pu	1.66 E+05	2.29 E+05	6.1
^{242}Cm	1.71 E+02	7.70 E+01	6.1
^{242}Pu	1.02 E+00	1.16 E+00	6.1
^{243}Am	1.76 E+01	9.34 E+00	6.1
^{243}Cm	3.28 E+01	1.00 E+01	6.1
^{244}Cm	7.82 E+02	2.42 E+02	6.1

[1]*As of September 30, 1998.*

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CONTENTS

1.0 INTRODUCTION 1-1
1.1 BACKGROUND 1-1
1.2 DOCUMENT OVERVIEW 1-3

2.0 STANDARD INVENTORY TASK OVERVIEW 2-1
2.1 STANDARD INVENTORY MAINTENANCE 2-3

3.0 DATA REQUIREMENTS 3-1
3.1 STANDARD INVENTORY CONTENT LIMITATIONS 3-1
3.2 EXPANSION OF THE STANDARD INVENTORY CONTENT 3-1

4.0 PROCESS-RELATED BASES AFFECTING GLOBAL INVENTORY ESTIMATES 4-1
4.1 PROCESS DESCRIPTIONS AND WASTE GENERATION 4-1
4.1.1 Bismuth Phosphate ($BiPO_4$) Process 4-3
4.1.2 Tri-Butyl Phosphate Uranium Recovery Process 4-4
4.1.3 Scavenging Program to Remove Cesium-137 and Strontium-90 From Aqueous Wastes 4-5
4.1.4 Reduction Oxidation (REDOX) Process 4-6
4.1.5 Plutonium-Uranium Extraction (PUREX) Process 4-7
4.1.6 B Plant Waste Fractionization 4-8
4.1.7 Evaporation of Waste Supernatants and the Formation of Salt Cake . . . 4-9
4.1.8 Other Processes 4-11
4.2 OVERVIEW OF FUEL PROCESSED 4-12
4.2.1 Separations Plant Fuel Processing History 4-12
4.2.2 Aluminum-Clad Fuel 4-13
4.2.3 Zirconium-Clad Fuel Fabrication 4-16
4.3 CAVEATS AND LIMITATIONS ON ESTIMATING CHEMICAL WASTES FROM FLOWSHEETS 4-17
4.3.1 Additional Data Needed to Accurately Extrapolate from Flowsheets . . 4-17
4.3.2 Status of Supplemental Information on Other Processes 4-19
4.4 OTHER BASES AND ASSUMPTIONS THAT IMPACT GLOBAL INVENTORIES 4-20
4.4.1 Product Losses 4-20
4.4.2 Wastes Discharged to Ground 4-21

5.0 BEST-BASIS GLOBAL INVENTORY EVALUATIONS 5-1
5.1 ALUMINUM 5-6
5.1.1 Identification of Aluminum Inventory Values 5-6
5.1.2 Aluminum Inventory Evaluation 5-8
5.1.3 Best-Basis Estimate for Aluminum Inventory Value 5-9
5.2 BISMUTH 5-9

5.2.1 Identification and Comparison of Bismuth Inventory Values 5-10
5.2.2 Bismuth Inventory Evaluation 5-11
5.2.3 Best-Basis Estimate for Bismuth Inventory Value 5-13
5.3 CALCIUM 5-13
5.3.1 Identification and Comparison of Calcium Inventory Values 5-14
5.3.2 Calcium Inventory Evaluation 5-14
5.3.3 Best-Basis Estimate for Calcium Inventory 5-17
5.4 CARBONATE 5-18
5.4.1 Identification of Carbonate Inventory Values 5-18
5.4.2 Carbonate Inventory Evaluation 5-18
5.4.3 Best-Basis Estimate for Carbonate Inventory 5-19
5.5 CERIUM 5-20
5.5.1 Identification of Cerium Values 5-20
5.5.2 Cerium Inventory Evaluation 5-21
5.5.3 Best-Basis Estimate for Cerium Inventory 5-21
5.6 CHLORIDE 5-22
5.6.1 Identification of Chloride Inventory Values 5-23
5.6.2 Chloride Inventory Evaluation 5-23
5.6.3 Best-Basis Estimate for Chloride Inventory Value 5-26
5.7 CHROMIUM 5-27
5.7.1 Identification and Comparison of Chromium Inventory Values 5-27
5.7.2 Chromium Inventory Evaluation 5-27
5.7.3 Best-Basis Estimate for Chromium Inventory Value 5-29
5.8 FLUORIDE 5-29
5.8.1 Identification and Comparison of Fluoride Inventory Values 5-30
5.8.2 Fluoride Inventory Evaluation 5-30
5.8.3 Best-Basis Estimate for Fluoride Inventory Value 5-37
5.9 HYDROXIDE 5-37
5.9.1 Identification of Hydroxide Inventory Values 5-37
5.9.2 Hydroxide Inventory Evaluation 5-38
5.9.3 Best-Basis Estimate for Hydroxide Inventory 5-39
5.10 IRON 5-40
5.10.1 Identification of Iron Inventory Values 5-40
5.10.2 Iron Inventory Evaluation 5-40
5.10.3 Best-Basis Estimate for Iron Inventory Value 5-50
5.11 LANTHANUM 5-51
5.11.1 Identification of Lanthanum Values 5-52
5.11.2 Lanthanum Inventory Evaluation 5-53
5.11.3 Best-Basis Estimate for Lanthanum Inventory 5-54
5.12 LEAD 5-55
5.12.1 Identification and Comparison of Lead Inventory Data 5-55
5.12.2 Lead Inventory Evaluation 5-55
5.12.3 Best-Basis Estimate for Lead Inventory Value 5-57
5.13 MANGANESE 5-57
5.13.1 Identification and Comparison of Manganese Inventory Data 5-58

5.13.2 Manganese Inventory Evaluation 5-58
5.13.3 Best-Basis Estimate for Manganese Inventory Value 5-60
5.14 MERCURY 5-60
5.14.1 Identification and Comparison of Mercury Inventory Values 5-61
5.14.2 Mercury Inventory Evaluation 5-61
5.14.3 Best-Basis Estimate for Mercury Inventory Value 5-63
5.15 NICKEL 5-64
5.15.1 Identification and Comparison of Nickel Inventory Values 5-64
5.15.2 Nickel Inventory Evaluation 5-65
5.15.3 Best-Basis Estimate for Nickel Inventory Value 5-69
5.16 NITRATE AND NITRITE 5-70
5.16.1 Identification of Nitrate/Nitrite Inventory Values 5-70
5.16.2 Nitrate/Nitrite Inventory Evaluation 5-71
5.16.3 Best-Basis Estimate for Nitrate/Nitrite Inventory Value 5-79
5.17 PHOSPHATE 5-81
5.17.1 Identification of Phosphate Inventory Values 5-81
5.17.2 Phosphate Inventory Evaluation 5-82
5.17.3 Best-Basis Estimate for Phosphate Inventory 5-89
5.18 POTASSIUM 5-91
5.18.1 Identification and Comparison of Potassium Inventory Values 5-92
5.18.2 Potassium Inventory Evaluation 5-92
5.18.3 Best-Basis Estimate for Potassium Inventory Value 5-95
5.19 SILICON 5-96
5.19.1 Identification of Silicon Values 5-96
5.19.2 Silicon Inventory Evaluation 5-97
5.19.3 Best-Basis Estimate for Silicon Value 5-106
5.20 SODIUM 5-107
5.20.1 Identification of Sodium Inventory Values 5-108
5.20.2 Sodium Inventory Evaluation 5-108
5.20.3 Best-Basis Estimate for Sodium Inventory 5-123
5.21 SULFATE 5-127
5.21.1 Identification of Sulfate Inventory Values 5-127
5.21.2 Sulfate Inventory Evaluation 5-127
5.21.3 Best-Basis Estimate for Sulfate Inventory Value 5-138
5.22 STRONTIUM 5-139
5.22.1 Identification and Comparison of Strontium Inventory Values 5-140
5.22.2 Strontium Inventory Evaluation 5-140
5.22.3 Best-Basis Estimate for Strontium Inventory 5-142
5.23 TOTAL ORGANIC CARBON 5-142
5.23.1 Identification of Total Organic Carbon Inventory Values 5-142
5.23.2 Total Organic Carbon Inventory Evaluation 5-143
5.23.3 Best-Basis Estimate for Total Organic Carbon Inventory 5-154
5.24 ZIRCONIUM 5-155
5.24.1 Identification of Zirconium Values 5-155
5.24.2 Zirconium Inventory Evaluation 5-156

5.24.3 Best-Basis Estimate for Zirconium Inventory Value 5-157

6.0 RADIONUCLIDES 6-1
6.1 ESTABLISH BEST INVENTORY FOR RADIONUCLIDES 6-1
6.1.1 Requirements for a Global Tank Radionuclide Inventory Model 6-2
6.1.2 Requirements for a Tank-by-Tank Radionuclide Inventory Model 6-3
6.1.3 Radionuclides to be Tracked 6-3
6.1.4 Requirements for Output Reporting 6-4
6.1.5 Model Architecture 6-4
6.1.7 Validation of Model Results from Tank Heat Measurements 6-17
6.1.8 Selection of Best-Basis Global Radionuclide Inventory 6-18
6.1.9 Summary of Errata and Accuracy Issues for Table 6.1-6 6-20
6.1.10 Tank-By-Tank Accuracy Issues 6-21
6.2 CESIUM AND STRONTIUM 6-27
6.2.1 Identification and Comparison of Cesium-137 and Strontium-90 Inventory Values 6-27
6.2.2 Cesium-137 and Strontium-90 Inventories Evaluation 6-28
6.3 URANIUM 6-38
6.3.1 Uranium Fuel Sources and Separation History 6-39
6.3.2 Calculation of Global Uranium Inventory 6-40
6.3.3 Best-Basis for Uranium-238 Global Inventory Value 6-42

7.0 MINOR ELEMENTS AND CHEMICALS 7-1
7.1 MINOR ELEMENTS INTRODUCED BY FUEL FABRICATION 7-1
7.1.1 Aluminum-Clad Fuel 7-1
7.1.2 Zirconium-Clad Fuel 7-6
7.2 MINOR ELEMENTS INTRODUCED BY FUEL FISSION AND ACTIVATION 7-10
7.3 MINOR ELEMENTS INTRODUCED BY CHEMICAL PROCESS OPERATIONS 7-11
7.3.1 Cadmium 7-11
7.3.2 Silver 7-16
7.3.3 Thorium 7-23
7.3.4 Tungsten 7-24
7.4 MINOR ELEMENTS INTRODUCED BY CHEMICAL IMPURITIES 7-25
7.4.1 Minor Elements Introduced by Tank Farm Actions 7-27
7.5 SUMMARY OF BEST-BASIS INVENTORY VALUES FOR MINOR COMPONENTS 7-29

8.0 METHODOLOGY FOR ESTIMATING INDIVIDUAL TANK WASTE INVENTORIES 8-1
8.1 CONTRIBUTING WASTE TYPES AND WASTE VOLUMES 8-2
8.1.1 Process History 8-2
8.1.2 Waste Sample Analytical Information 8-4
8.1.3 Surveillance Information 8-5

8.2 APPROACH FOR ESTIMATING WASTE INVENTORIES 8-5
8.2.1 Case 1: Waste Analyses Available and Process Flowsheets Known . . . 8-6
8.2.2 Case 2: Waste Analyses Available, Process Flowsheets Not Known . . 8-11
8.2.3 Case 3: Waste Analyses Not available; Process Flowsheets Known . . 8-12
8.2.4 Case 4: Waste Analyses Not Available, Process Flowsheets Not Known 8-12
8.2.5 Comparison and Reconciliation of Inventory Assessments 8-13

9.0 REFERENCES 9-1

APPENDIXES

A - SUMMARY OF DATA REQUIREMENTS A-1

B - SEPARATIONS PLANT RECONSTRUCTED FUEL PROCESS HISTORY . B-1

C - BISMUTH PHOSPHATE PROCESS FLOWSHEET C-1

D - REDOX PROCESS FLOWSHEETS D-1

E - SUPPORTING DATA FOR ALUMINUM (SECTION 5.1) E-1

F - SUPPORTING DATA FOR LEAD (SECTION 5.12) F-1

G - SAMPLE FUEL ACTIVITY RECORDS G-1

H - CORROSION PRODUCTS (IRON, NICKEL, AND CHROMIUM) H-1

I - STANDARD INVENTORY CONTENT LIMITATIONS I-1

J - GUIDELINES FOR PREPARING BEST-BASIS TANK-BY-TANK WRITE-UPS J-1

K - RECONCILIATION OF GLOBAL INVENTORY AND TANK SUM VALUES K-1

LIST OF FIGURES

2.0-1. Schematic of Task Plan 2-2

2.0-2. Standard Inventory Maintenance Process 2-4

2.0-3. Standard Inventory Change Control Operation 2-5

4.0-1. Major System Components That Impact Tank Inventories. 4-2

5.0-1. Methodology for Developing Global Inventory Values for Major Components . . 5-4

6.1-1. Data Flow Schematic--Generation of Fuel Activity Records from ORIGEN2. . . . 6-6

6.1-2. Data Flow Schematic--Generation of Tank Radionuclide Inventories. 6-7

6.1-3. Model Match--DKPRO and Hanford Defined Waste Versus DKPRO and Split. . . 6-16

6.1-4. Model/Sample/Estimate Correlation for Strontium-90. 6-23

6.1-5. Model/Sample/Estimate Correlation for Cesium-137. 6-24

6.1-6. Model/Sample/Estimate Correlation for Plutonium-239. 6-25

6.1-7. Model/Sample/Estimate Correlation for Americium-241. 6-26

6.2-1. Estimated Disposition of Cesium-137 and Strontium-90 Generated In Hanford Site Reactors 6-30

6.3-1. Estimated Disposition of ^{238}U Processed Through Hanford Separations Plants. . . 6-41

8.2-1. Waste Inventory Evaluation. 8-7

LIST OF TABLES

4.2-1. Separations Plant Fuel Processing Summary. 4-12

5.0-1. Comparison of Hanford Defined Waste and Tank Waste Remediation System Inventories 5-2

5.1-1. Estimated Metric Tons Aluminum in Tank Waste. 5-7

5.2-1. Reported Bismuth Inventory Values (MT Bismuth). 5-10

5.2-2. Comparison Between Allen[a] and Hanford Defined Waste Model Bismuth Inventories by Waste Stream 5-10

5.2-3. Bismuth Inventories Projected from Historical Process Information and from Analytical Data for the Bismuth Phosphate Process Waste Types 5-11

5.2-4. Bismuth Inventory Projected from Sample Analysis Data for Sort On Radioactive Waste Type Groups. 5-12

5.3-1. Current Reported Inventory Values for Calcium. 5-14

5.3-2. Summary of Calcium Sources 5-16

5.3-3. Calcium in Single-Shell Tanks Estimated From Sludge Samples. 5-17

5.3-4. Best-Basis Estimate of Calcium Inventory in Hanford Site Underground Tanks. . . 5-17

5.4-1. Estimated Amount of Carbonate in the Hanford Site Tank Wastes, MT 5-19

5.5-1. Reported Cerium Inventories 5-20

5.6-1. Double-Shell Tank Characterization Report Inventories for Sodium and Chloride 5-23

5.6-2. Single-Shell Tank Characterization Report Inventories for Sodium and Chloride 5-24

5.6-3. Distribution of Chloride in Hanford Site Tank Wastes 5-25

5.6-4. Estimated Amount of Chloride In Hanford Site Tank Wastes 5-26

5.7-1. Total Chromium Additions in REDOX Plant Operations 1952 to 1966 (MT of Chromium) 5-28

LIST OF TABLES (CONTINUED)

5.8-1. Currently Reported Inventories of Fluoride in Hanford Site Tanks. 5-30

5.8-2. Sources of Fluoride in Hanford Underground Tanks 5-31

5.9-1. Global Ion Balance 5-38

5.9-2. Estimated Amount of Hydroxide[a] in the Hanford Site Tank Wastes, MT 5-40

5.10-1. Amount of Iron in Bismuth Phosphate Process Wastes, MT 5-41

5.10-2. Estimated Amount of Iron in Bismuth Phosphate Process Tank Wastes, MT . . . 5-42

5.10-3. Estimated Amount of Iron in Tank Wastes from the Uranium Recovery Process, MT 5-44

5.10-4. Estimated Amount of Iron in Tank Wastes from the REDOX Process, MT 5-45

5.10-5. Estimated Amount of Iron in 1983 through 1989 PUREX Plant Tank Wastes, MT 5-46

5.10-6. Iron Use in PUREX Process from 1965 through 1982 5-47

5.10-7. Iron Use in PUREX Process from 1956 through 1964 5-48

5.10-8. Estimated Amount of Iron in PUREX Process Wastes, MT 5-49

5.10-9. Estimated Amount of Iron in the Hanford Site Tank Wastes, MT 5-50

5.11-1. Reported Lanthanum Inventories 5-52

5.11-2. Addition of Rare Earth Nitrate to the PUREX Process Decladding Wastes 5-54

5.13-1. Estimates of Manganese Added to Hanford Waste Tanks from Separations Plant Operations 5-59

5.14-1. Currently Reported Inventories of Mercury in Hanford Site Tanks 5-61

5.14-2. Best-Basis Estimate of Mercury Inventory. 5-63

5.15-1. Currently Reported Inventories of Nickel in Hanford Site Tanks (MT) 5-65

LIST OF TABLES (CONTINUED)

5.15-2. Inventory of Nickel in Aluminum- and Zircaloy®-Clad Fuel. 5-66

5.15-3. Estimates of Amounts of Corrosion-Generated Nickel in Hanford Site Tanks 5-68

5.15-4. Possible Inventories of Nickel in Hanford Site Waste Tanks. 5-69

5.16-1. Reported Nitrate/Nitrite Values (MT) 5-70

5.16-2. Amount of Nitrate/Nitrite in Bismuth Phosphate Wastes. 5-71

5.16-3. Estimated Amount of Nitrate/Nitrite in $BiPO_4$ Tank Wastes, MT. 5-73

5.16-4. Estimated Amount of Nitrate/Nitrite in Uranium Recovery Wastes, MT. 5-74

5.16-5. Amount of $NaNO_3$ and $NaNO_2$ Sent to Underground Storage Tanks from the REDOX Process. 5-76

5.16-6. Comparison of Nitrate/Nitrite Estimates in Neutralized Current Acid Waste 5-77

5.16-7. Nitrate/Nitrite Salts Contained in PUREX Plant Tanked Wastes from 1965 through 1972[a]. 5-78

5.16-8. Amount of Nitrate/Nitrite Sent to Underground Storage from the PUREX Process. 5-78

5.16-9. Estimated Amount of Total Nitrate/Nitrite in the Hanford Site Tank Wastes, MT. 5-80

5.17-1. Amount of Phosphate in $BiPO_4$ Process Wastes, MT. 5-83

5.17-2. Estimated Amount of Phosphate in $BiPO_4$ Tank Wastes, MT. 5-84

5.17-3. Estimated Amount of Phosphate in Uranium Recovery Wastes, MT. 5-85

5.17-4. Estimated Amount of Phosphate in PUREX Tank Wastes, MT. 5-87

5.17-5. Phosphate Use in B Plant from 1965 through 1977 5-88

5.17-6. Estimated Amount of Phosphate in the Hanford Site Tank Wastes, MT 5-90

LIST OF TABLES (CONTINUED)

5.18-1. Estimates of Total Potassium Added to Hanford Waste Tanks 5-93

5.19-1. Reported Silicon Inventory Values. 5-96

5.19-2. Summary of Silicon Sources. 5-104

5.20-1. Amount of Sodium in $BiPO_4$ Process Wastes, MT 5-109

5.20-2. Estimated Amount of Sodium in $BiPO_4$ Tank Wastes, MT. 5-111

5.20-3. Estimated Amount of Sodium in Uranium Recovery Wastes, MT. 5-112

5.20-4. NaOH Added to REDOX Process. 5-114

5.20-5. Comparison of REDOX Flowsheets to REDOX Plant Operations Synopsis for Sodium Hydroxide 5-115

5.20-6. Estimated Amount of Sodium in REDOX Wastes, MT. 5-116

5.20-7. Estimated Amount of Sodium in 1983 through 1989 PUREX Neutralized Current Acid Waste, MT. 5-117

5.20-8. Estimated Amount of Sodium in 1983 through 1989 PUREX Plant Wastes, MT. 5-118

5.20-9. Sodium Chemical Use in the PUREX Process from 1965 through 1982. 5-119

5.20-10. Sodium Chemical Use in the PUREX Process from 1956 through 1964 5-120

5.20-11. Estimated Amount of Sodium in the PUREX Plant Wastes, MT 5-121

5.20-12. Chemical Use in B Plant and Tank Farms from 1965 to 1982. 5-122

5.20-13. Estimated Amount of Sodium in the Hanford Site Tank Wastes, MT. 5-124

5.20-14. Estimated Amount of Sodium in the Hanford Site Tank Wastes based on Reported Waste volumes, MT. 5-126

5.21-1. Amount of Sulfate in Bismuth Phosphate Process Wastes, MT 5-129

5.21-2. Estimated Amount of Sulfate in Bismuth Phosphate Tank Wastes, MT 5-130

5.21-3. Estimated Amount of Sulfate in Uranium Recovery Wastes, MT 5-131

LIST OF TABLES (CONTINUED)

5.21-4. Estimated Amount of Sulfate in 1983 Through 1989 PUREX Process Neutralized Current Acid Waste, MT 5-132

5.21-5. Sulfate Use in PUREX Process From 1965 Through 1982 5-134

5.21-6. Sulfate Use in PUREX Process From 1956 Through 1964 5-135

5.21-7. Estimated Amount of Sulfate in PUREX Process Wastes, MT 5-136

5.21-8. Sulfate Chemical Use in B Plant from 1965 to 1984 5-136

5.21-9. Estimated Amount of Sulfate in Hanford Site Tank Wastes, MT 5-138

5.22-1. Current Reported Values for Strontium 5-140

5.22-2. Fission Product Strontium in 9 Percent Mark IV Fuel 5-141

5.23-1. Amount of Total Organic Carbon in $BiPO_4$ Process Wastes, MT. 5-144

5.23-2. Estimated Amount of Total Organic Carbon in $BiPO_4$ Tank Wastes, MT. 5-145

5.23-3. Estimated Amount of Total Organic Carbon in Uranium Recovery Wastes, MT. 5-146

5.23-4. Total Organic Carbon Discharged to Tank Farms by PUREX Process. 5-148

5.23-5. Total Organic Carbon Use in B Plant from 1965 through 1981. 5-151

5.23-6. Estimated Amount of Total Organic Carbon in the Hanford Site Tank Wastes, MT. 5-154

5.24-1. Reported Zirconium Inventory Values 5-155

5.24-2. Summary of Zirconium Sources 5-157

6.1-1. Key Radionuclides to be Added to the Hanford Defined Waste Model 6-4

6.1-2. Definition of Fuel Types and Fuel Codes for Radionuclide Inventory Modelling. . 6-8

6.1-3. Global Radionuclide Inventory Comparisons 6-10

6.1-4. Calculation of Global Uranium Isotopic Inventory from Accountability Records and Tank Samples. 6-13

LIST OF TABLES (CONTINUED)

6.1-5. Comparison of Measured Tank Decay Heat to Model Predicted Heat. 6-17

6.1-6. Best-Basis Global Radionuclide Inventory 6-18

6.2-1. Currently Reported Inventory Values for Cesium-137 and Strontium-90 in Hanford Site Tanks 6-28

6.2-2. Simplified Hanford Site Underground Tank Cesium-137 and Strontium-90 Material Balance 6-31

6.2-3. Inventory of Cesium-137 and Strontium-90 in Reactor Fuel Not Reprocessed at the Hanford 6-32

6.2-4. Inventory of Cesium-137 and Strontium-90 Removed from Tanks. 6-33

6.2-5. Material Balance for Cesium-137 and Strontium-90 in B Plant and Waste Encapsulation and Storage Facility 6-33

6.2-6. Comparison of Cesium-137 and Strontium-90 Accounting by Model. 6-35

6.2-7. Comparison of Tank Inventory Estimates for Cesium-137 and Strontium-90. . . . 6-37

6.2-8. Global Best-Basis Estimates of Cesium-137 and Strontium-90 Inventories in Hanford Underground Tanks 6-38

7.1-1. Elements Introduced by Fabrication of Aluminum-Clad Fuel. 7-2

7.1-2. Elements Introduced by Uranium Metal Used in Aluminum-Clad Fuel. 7-3

7.1-3. Elements Introduced by the Aluminum-Silicon Bond Layer 7-4

7.1-4. Minor Elements Introduced by the Aluminum Jacket Alloy. 7-5

7.1-5. Elements Introduced by Fabrication of Zirconium-Clad Fuel. 7-6

7.1-6. Elements Introduced by Uranium 601 Alloy 7-7

7.1-7. Elements Introduced by Zircaloy-2® Cladding 7-8

7.1-8. Elements from N Reactor Fuel Braze. 7-9

7.2-1. Radionuclides with Chemically Significant Mass[a]. 7-10

LIST OF TABLES (CONTINUED)

7.3-1. Fifty Percent Cadmium Nitrate Consumption. 7-13

7.3-2. Cadmium Inventory from Essential Material Consumption Records. 7-14

7.3-3. Summary of Tank Waste Remediation System Baseline Cadmium Inventory. 7-14

7.3-4. Best-Basis Cadmium Inventory. 7-16

7.3-5. Tank-By-Tank Inventory of Silver 7-21

7.3-6. Thorium Losses to the Waste Tanks (MT). 7-23

7.3-7. 92 percent Phosphotungstic Acid Consumption. 7-24

7.3-8. Best-Basis Tungsten Inventory. 7-25

7.4-1. Potential Impurities Introduced by Sodium Hydroxide 7-26

7.4-2. Trace Chemicals Introduced by 50 Wt% ANN Consumption 7-27

7.4-3. Portland Cement Inventory. 7-28

7.4-4. Diatomaceous Earth Inventory. 7-28

7.5-1. Best-Basis Inventory of Minor Components 7-29

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LIST OF TERMS

1C	First decontamination cycle of the bismuth phosphate process
2C	Second decontamination cycle of the bismuth phosphate process
1WW	Concentrated first cycle raffinate from PUREX process
224	Final decontamination/concentration cycle of the bismuth phosphate process
Al-Si	Aluminum-silicon (as in Al-Si bond layer)
ANN	Aluminum Nitrate Nonahydrate - $Al(NO_3)_3 \cdot 9H_2O$
$BiPO_4$	Bismuth phosphate
CAW	Current acid waste
CF	Concentration factor
CWZr2	REDOX process coating waste, zirconium cladding
CW	Cladding (coating) waste
D2EHPA	Di(2-ethylhexyl)phosphoric acid - $(C_8H_{17}O)_2POOH$
DKPRO	Computer code for radioactive decay and separations processing
DN	Dilute non-complexed
DOE	U.S. Department of Energy
DQO	Data Quality Objective
DSC	Differential scan calorimetry
DSSF	Double-shell slurry feed
DST	Double-shell tank
DTPA	Diethylene-triamine penta acetate
EB	Evaporator bottoms
EDTA	Ethylenediamine tetra acetic acid
EIS	Environmental Impact Statement
FEIS	Final Environmental Impact Statement
FIC	Food Instrument Company (FIC) Automatic Surface Level Gauge
Fuel Grade	Refers to plutonium material containing >6 wt% ^{240}Pu after irradiation
FY	Fiscal year
GWD	Gigawatt days
HAPO	Hanford Atomic Products Operation
HEDTA	N(2-hydroxyethyl)ethylenediamine tetra acetate
HDW	Hanford Defined Waste

LIST OF TERMS

HDW	Hanford Defined Waste
HEDR	Hanford Environmental Dose Reconstruction Project
HLW	High-level waste
HTCE	Hanford Tank Content Estimate
HSW	High-salt waste
ICP	Inductively coupled plasma spectroscopy
I&E	Internal & external (as in I&E cooled fuel elements)
IDB	Integrated database
ITS	In-tank solidification
LANL	Los Alamos National Laboratory
LAW	Low-activity waste
LLW	Low-level waste
LWPR	Light Water Pressure Reactor
MCi	Mega curie (1 E+06 Ci)
MT	Metric ton (1 MT = 1,000 kg)
MTHM	Metric ton of heavy metal
MTU	Metric ton of uranium
MUF	Material unaccounted for
MW	Metal waste
MWd	Megawatt days
NCAW	Neutralized current acid waste
NCRW	Neutralized cladding removal waste
NPH	Normal paraffin hydrocarbon
NPR	New Production Reactor (N Reactor)
NTA	Nitrilotriacetic acid
ORIGEN	Oak Ridge Isotope Generation (computer code)
ORNL	Oak Ridge National Laboratory
PCW	PUREX process cladding removal waste
P3	Aging waste from PUREX process high-level waste (1983 to 1988)
PF	Partitioning factor
PFP	Plutonium Finishing Plant (Z Plant)

LIST OF TERMS

PL1	PUREX process low-level waste (1956 to 1972)
PL2	PUREX process low-level waste (1983 to 1988)
PN	Partially neutralized
PNNL	Pacific Northwest National Laboratory
ppm	Parts per million
PRF	Plutonium Reclamation Facility
PRTR	Plutonium Recycle Test Reactor
PTA	Phosphotungstic acid - $P_2O_5 \cdot 24WO_3 \cdot 44H_2O$
PUREX	Plutonium-uranium extraction (process or plant)
RCRA	Resource Conservation and Recovery Act of 1976
RCW	Reduction and oxidation process cladding waste
REDOX	Reduction and oxidation (process or plant)
RIBD	Radioisotope buildup and decay
RMC	Remote Mechanical C
RSD	Relative standard deviation
S	Analytically determined inventories
SORWT	Sort on radioactive waste type
SST	Single-shell tank
TBP	Tri-butyl phosphate - $(C_4H_9O)_3PO$
TCD	Tank Characterization Database
TCR	Tank Characterization Report
TGA	Thermo-gravimetric analysis
TH1	Thoria high-level waste or cladding waste (1966 campaign)
TH2	Thoria high-level waste or cladding waste (1970 campaign)
TLM	Tank Layer Model
TOC	Total Organic Carbon
TRAC	Track Radioactive Components
Tri-Party Agreement	Hanford Federal Facility Agreement and Consent Order
TRU	Transuranic
TWRS	Tank Waste Remediation System
UNH	Uranyl Nitrate Hexahydrate - $UO_2(NO_3)_2 \cdot 6H_2O$

LIST OF TERMS

UR	Uranium recovery
UR/TBP	Uranium recovery/tri-butyl phosphate (process or plant)
WESF	Waste Encapsulation Storage Facility
WHC	Westinghouse Hanford Company
WSTRS	Waste Status and Transaction Record Summary

STANDARD INVENTORIES OF CHEMICALS AND RADIONUCLIDES IN HANFORD SITE UNDERGROUND TANK WASTES

1.0 INTRODUCTION

After the primary mission at the Hanford Site changed from plutonium production to environmental restoration, the U.S. Department of Energy (DOE) established the Tank Waste Remediation System (TWRS) in 1991 to safely manage and dispose of the radioactive wastes stored in underground tanks. Key activities for the TWRS include overseeing tank farm operations and identifying, monitoring, and resolving the safety issues associated with those operations and with the tank wastes. Disposal activities involve designing equipment, processes, and facilities for retrieving wastes, and processing waste into a form that is suitable for long-term storage/disposal. Safety analyses, engineering evaluations, risk assessments, and regulatory issues connected with these activities require information about the chemical and physical properties of tank wastes. To support these activities, chemical information usually is required in the form of tank waste component inventories, on either a global (total) or tank-specific basis.

There are multiple sources of tank waste inventory information, often with inconsistent data. A task was initiated in fiscal year (FY) 1996 to establish a best-basis standard inventory for chemicals and radionuclides in Hanford Site tank waste. The goal is to resolve differences among the many reported inventory values and to provide a consistent inventory basis for all waste management and disposal activities. This report summarizes the work performed to establish standard tank component inventories on a global basis.

1.1 BACKGROUND

Global tank waste inventory information was previously reported in several sources including the following:

- *Estimated Inventory of Chemicals Added to Underground Waste Tanks, 1944 Through 1975* (Allen 1976)
- *Hanford Defense Waste Final Environmental Impact Statement* (DOE 1987)
- *Tank Remediation System, Hanford Site, Washington, Final Environmental Impact Statement* (DOE 1996)
- *Chemical and Radionuclide Inventory for Single and Double-Shell Tanks* (Shelton 1996)

- The *Hanford Tank Content Estimate* (HTCE) documents (Brevick et al. 1997a, 1997b, 1997c, and 1997d)

- The *Hanford Tank Chemical and Radionuclide Inventories: HDW Model Rev. 3* (Agnew et al. 1996) and the *Hanford Tank Chemical and Radionuclide Inventories: HDW Model Rev. 4* (Agnew et al. 1997a), which report predictions of the Hanford Defined Waste (HDW) model developed by Los Alamos National Laboratory (LANL)

- National databases, such as the *Federal Facility Compliance Act Database* and *Integrated Database* (DOE 1997).

Each of the inventory reports listed contains the best inventory knowledge available at the time of publication. For example, inventories reported in the *Single-Shell and Double-Shell Tank Waste Inventory Data Package for the Tank Waste Remediation System Environmental Impact Statement* (Golberg and Guberski 1995) are based on those established by Allen (1976) but also include those chemicals used in process operations after 1975. The inventories reported by Shelton (1996), in support of TWRS process flowsheet modeling work, correspond with DOE (1987) values with two exceptions: (1) TWRS double-shell tank (DST) inventories were revised to reflect sampling data, and (2) TWRS single-shell tank (SST) component inventories for aluminum, chromium, phosphate, and chloride were revised as the result of a recent (1995) evaluation of these inventories. Finally, the HDW model predictions were based on historical data and do not directly correspond to any of the global inventory reports. Not surprisingly, the various global inventory sources provide inconsistent inventory values.

Several attempts have been made over the years to distribute global component inventories among individual waste tanks. The distribution is performed by: (1) estimating component inventories using results from sample analyses, or (2) predicting component inventories based on process knowledge and historical information. The result is that tank-specific inventory sources also often report inconsistent inventory values.

The major sources of tank-specific inventories include the following:

- Agnew et al. (1997a), which reports predictions of the HDW model developed by LANL

- Tank Characterization Reports (TCRs)

- The HTCE documents (Brevick et al. 1997a, 1997b, 1997c, and 1997d)

- *Radionuclide and Chemical Inventories for the Single-Shell Tanks* (Van Vleet 1993a) and *Radionuclide and Chemical Inventories for the Double-Shell Tanks* (Van Vleet 1993b)

- Multiple electronic databases, e.g., Tank Characterization Database (TCD) (PNL 1994), Braun Database (Forehand 1995), and ICF-Kaiser Hanford Company Database (Brevick et al. 1995).

The methodology used to establish a best-basis inventory on a global or tank-specific basis involves a thorough review of all pertinent information sources to identify errors, biases, inconsistencies, and missing information. The data sources typically include sample analyses, process flowsheets, waste transaction records, reactor fuel data, and essential material records. The process used to estimate a best-basis inventory is described in Sections 5.0, 8.0, and Appendix J of this report.

This report presents work performed to establish standard global component inventory estimates. This work includes: global inventory reconciliations for 26 nonradioactive components that account for approximately 99 percent of the total tank waste inventory, global inventory reconciliations for an additional four (4) minor chemical components, and global inventory values for 46 radionuclides. Tank-by-tank best-basis inventories that include the same suite of chemicals and radionuclides for each of the 177 Hanford Site underground storage tanks are published in TCRs and revised TCRs issued in fiscal year (FY) 1998, and as preliminary TCRs. The individual tank waste inventories are also now available in the TCD (LMHC 1998), which has been designated as the official source for the tank inventory values. To ensure that inventory values resulting from these evaluations are technically defensible and reproducible, every attempt was made to document the bases, i.e., originating sources of assumptions, data, and background information, that support the inventory values.

1.2 DOCUMENT OVERVIEW

Information in this report is presented as follows:

- Section 1.0 provides background information regarding tank inventories.
- Section 2.0 provides an overview of the Standard Inventory task plan and shows where the global component inventory work fits within this plan.
- Section 3.0 summarizes data requirements that served as the foundation for the global inventory work.
- Section 4.0 introduces the chemical processes that generated waste inventories, the types and amount of fuel processed, and the system inventory losses.
- Section 5.0 presents evaluations and global best-basis inventory values for individual components.

- Section 6.0 presents the methods used to establish global inventories for 46 radionuclides.

- Section 7.0 evaluates the sources of minor chemical components that contribute to the tank waste inventories and presents the global best-basis inventories for four minor components.

- Section 8.0 defines details of the methodology used to determine the tank-by-tank best-basis inventories for each of the 177 Hanford Site underground waste storage tanks.

- Section 9.0 lists the references used in this document.

- Appendix A provides a summary of the users' data needs for chemical and radionuclide inventories.

- Appendix B presents details of fuel processing history at the Hanford Site, including production data and fuel processing rates for the various separations facilities.

- Appendix C defines the flowsheet bases for the bismuth phosphate ($BiPO_4$) process wastes. This information is the standard basis for use in defining global and tank-by-tank inventories.

- Appendix D defines the flowsheet bases for the Reduction and Oxidation (REDOX) process wastes. This information is the standard basis for use in defining global and tank-by-tank inventories.

- Appendix E provides calculations supporting the global aluminum inventory evaluation (Section 5.1).

- Appendix F provides calculations supporting the global lead inventory evaluation (Section 5.12).

- Appendix G provides sample fuel activity records, supporting data and assumptions referred to in the global radionuclide inventory evaluation (Section 6.0).

- Appendix H defines the basis for corrosion product (iron, nickel, and chromium) inventories.

- Appendix I defines limitations on content of the Standard Inventory.

- Appendix J contains guidance for preparing tank-by-tank inventory evaluations (i.e., best-basis inventories).

- Appendix K describes how the sum of the individual tank best-basis inventories will be reconciled with the global (total) tank waste inventories.

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2.0 STANDARD INVENTORY TASK OVERVIEW

The primary objective of the Standard Inventory task was to establish best-basis waste inventory estimates that will provide consistent data for a multitude of activities related to the safe storage of the tank waste and its eventual treatment and disposal. Additional objectives within the work scope included ensuring that this information is incorporated into the TCD[1] (PNL 1994), documented in a published report, and maintained in a structured and controlled manner.

The approach used to implement the Standard Inventory task objectives is defined in the *Work Plan for Defining a Standard Inventory Estimate for Wastes Stored in Hanford Site Underground Tanks* (Hodgson and LeClair 1996) and is schematically depicted in Figure 2.0-1. Specific activities within this plan involved the following:

- Identification of waste components and characteristics, i.e., data requirements, that are important to waste management and disposal activities. The results from this activity are defined in Appendix A and further summarized in Appendix I and Section 3.0.

- Development and documentation of the methodology used to evaluate both global and tank-by-tank inventories. The global and tank-by-tank inventory evaluation methodologies are defined in Sections 5.0 and 8.0, respectively.

- Determination of standard global inventory values for specified waste components by evaluating the bases, i.e., assumptions, data, and background information, that support these values. The results of this effort are documented in Section 5.1 through Section 5.24.

- Determination of standard tank-by-tank waste inventories, in terms of these components, by evaluating available sampling data and historical information. The results of this effort are to be documented in each of the respective TCRs or preliminary TCRs.

- Publication of the results in a form that makes the data easily accessible to data users, makes it easy to update the data set, and also allows for archiving of the data and the associated pedigree (usually published as a supporting document). The TCD (PNL 1994) was recognized as an existing resource for providing these capabilities.

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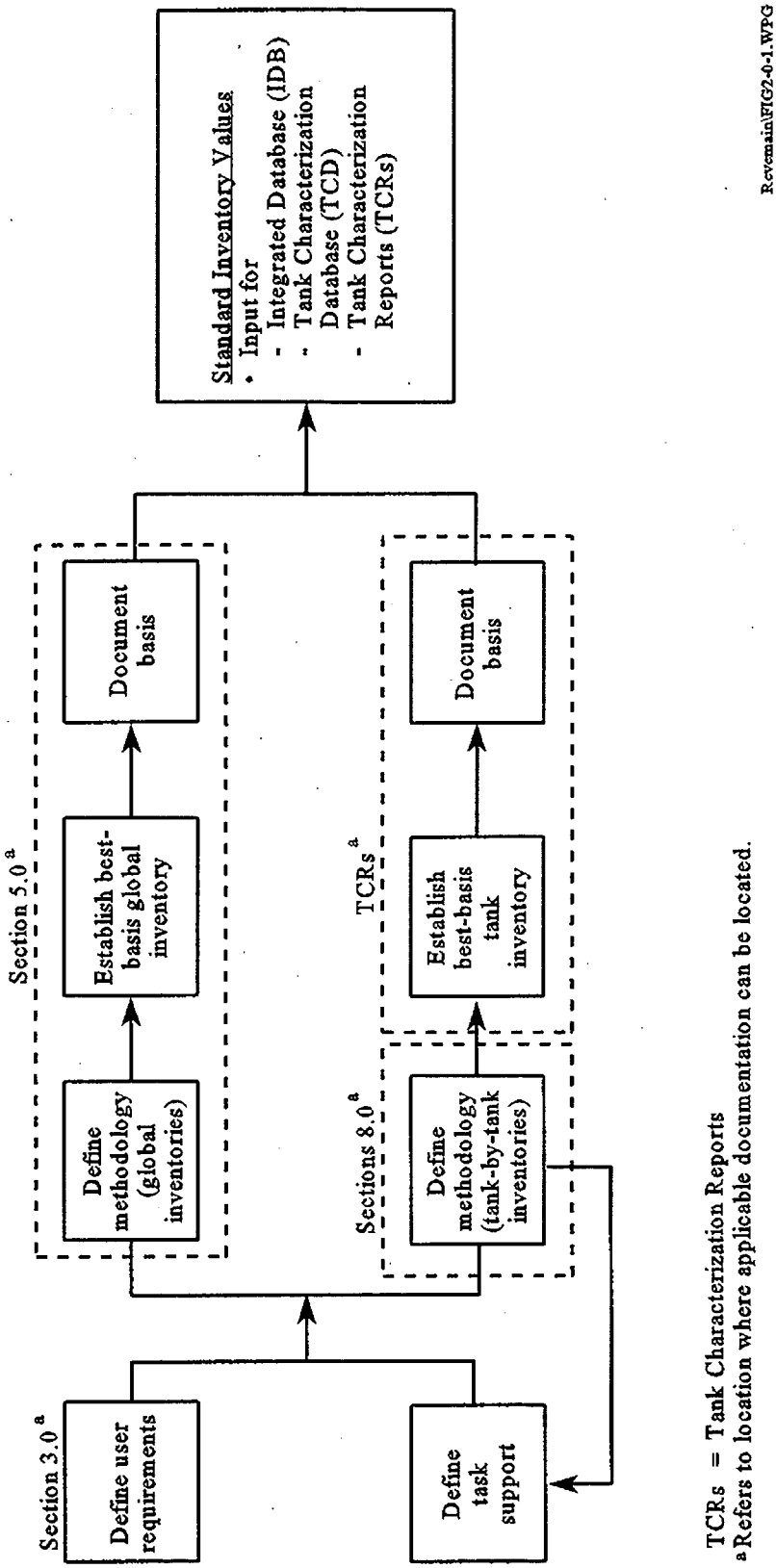
[1]Internet address is http://twins.pnl.gov:8001/TCD/main.htm/.

Figure 2.0-1. Schematic of Task Plan.



Revemain\FIG2-0-1.WPG

- Development of a mechanism for maintenance and update of the Standard Inventory. The results of this effort are discussed later in this section.

2.1 STANDARD INVENTORY MAINTENANCE

For the Standard Inventory values to remain useful, they must be periodically updated and modified to reflect current information available on tank contents. As sample analysis results, modeling data, and other information become available, it must be evaluated and reconciled with existing data in much the same fashion that the initial Standard Inventory values were derived. Revised Standard Inventory values and their associated pedigree (supporting documentation) must then be approved by the change control process and incorporated into the TCD. In instances where the prompt for update is new sample analysis results, the best-basis evaluation will also be documented in the respective TCR. Figure 2.0-2 illustrates the Standard Inventory maintenance process.

Figure 2.0-3 provides an overview of the Standard Inventory change control process developed during the Standard Inventory User and Policy Workshops conducted in July 1996 (LeClair 1996). This figure serves as a basis for developing the Standard Inventory change control procedures and policies. These procedures and policies will define protocol to be followed for proposing changes to the inventory, approving changes to the inventory, and updating the TCD to report revised Standard Inventory values. Responsibilities, authorities, methodology application, quality assurance practices, and database configuration control will also be addressed by these procedures and policies.

Figure 2.0-2. Standard Inventory Maintenance Process.

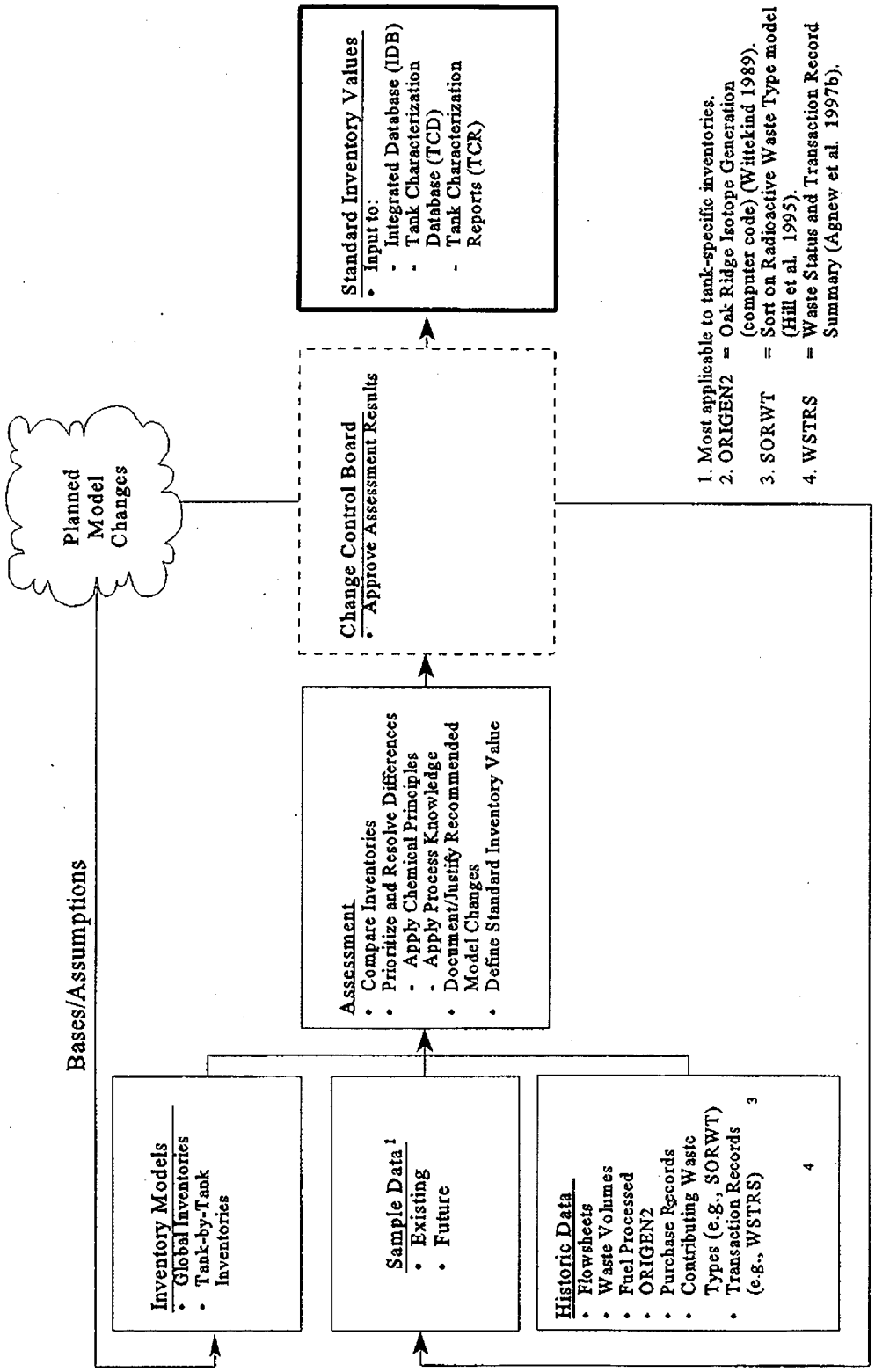
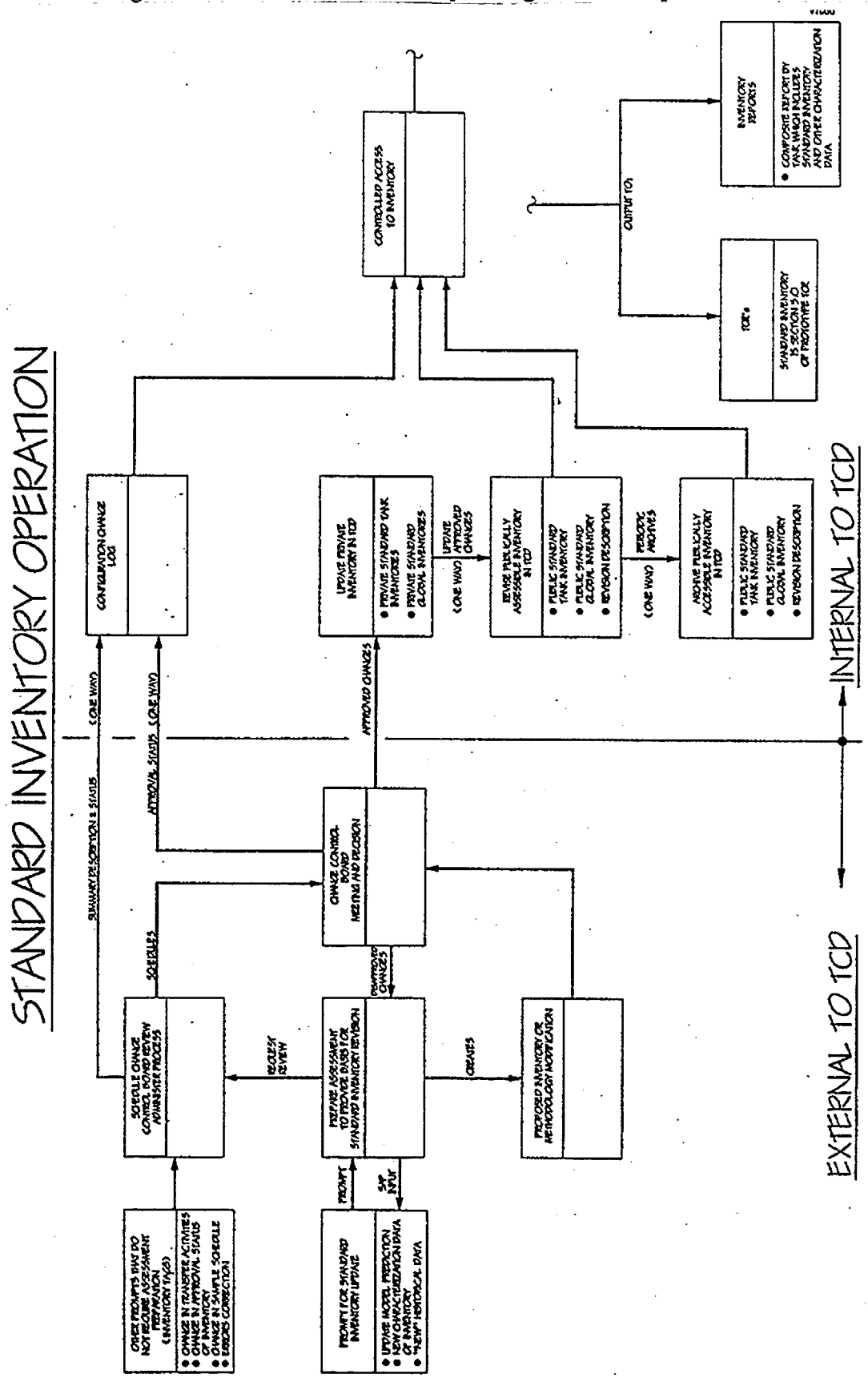


Figure 2.0-3. Standard Inventory Change Control Operation.



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APPENDIX K

RECONCILIATION OF GLOBAL INVENTORY AND TANK SUM VALUES

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APPENDIX K

RECONCILIATION OF GLOBAL INVENTORY AND TANK SUM VALUES

The standard inventory activity has produced a global inventory estimate and specific best basis inventories for 177 individual tanks. The summation of individual tank best-basis inventories and the global inventory estimates do not necessarily match due to differences in the way that the estimates were developed (See Section 8.0 of this document). Table K-1 compares the summation of individual tank best-basis inventories to the global inventory as of September 30, 1998. The second column shows the sum of individual tank values which consist of values based on samples (S)[1], engineering assessment (E), or the Hanford Defined Waste (HDW) model (M) or a combinations of these bases. Table K-1 also shows what fraction of the best-basis inventory that is derived from sample data. Data from tank sampling may be utilized directly, or may be modified based on process knowledge and engineering judgement. Thus the sample data in this column include the inventory from composite sources, i.e, sample/engineering assessment (S/E) values and sample/HDW model (S/M) values. The values in the last column include only the inventory that is directly from the HDW model (M values). The balance of the tank summation inventories is from engineering assessment (E) values and engineering assessment/HDW model (E/M) values. The engineering assessment (E and E/M) contributions are not shown in Table K-1.

Table K-1. Comparison of the Summation of Individual Tank Best-Basis Inventories to the Global Waste Inventory. (5 Sheets)

Analyte	Summation of individual tank best-basis inventories[c]	Global inventory basis	Ratio of tank sum inventory to global inventory (%)	Percent of tank sum based on sample data[a]	Percent of tank sum based on HDW Model[a]
Chemicals (MT)					
Ag	NR	8.93	NR	NR	NR
Al	7,950	7,845	101	61.1	0.01
Bi	631	580	109	76.6	0.75
Ca	319	214	149	53.1	8.56

[1]S, E, M, and combinations thereof, are designations used in the best-basis inventories to indicate the basis for a value: S = sample based, E = engineering assessment based, and M = Hanford Defined Waste model based. See Appendix J for further clarification of the inventory bases.

Table K-1. Comparison of the Summation of Individual Tank Best-Basis Inventories to the Global Waste Inventory. (5 Sheets)

Analyte	Summation of individual tank best-basis inventories[c]	Global inventory basis	Ratio of tank sum inventory to global inventory (%)	Percent of tank sum based on sample data[a]	Percent of tank sum based on HDW Model[a]
Cd	NR	8.20	NR	NR	NR
Cl	930	500	186	59.7	1.61
CO_3	9,390	4,830	194	62.8	7.17
Ce	NR	8.80	NR	NR	NR
Cr	670	785	85.4	59.0	1.21
F	1,190	1,360	87.8	67.9	0.92
Fe	1,400	1,230	114	77.7	4.75
Hg	1.81	2.10	86.1	11.1	0
K	874	481	182	69.6	0.88
La	51.3	51.0	101	82.1	0.10
Mn	194	105	185	66.8	0.77
Na	48,800	54,200	90.0	63.2	0.15
Ni	174	111	157	74.3	3.52
NO_2	12,400	NR	NR	NR	NR
NO_3	52,300	NR	NR	NR	NR
NO_2 and NO_3	64,700	85,700	75.5	55.1	0.75
OH_{TOTAL}	23,500	23,000	102	(b)	(b)
Pb	84.0	279	30.1	53.6	8.74
PO_4	5,550	6,000	92.6	61.3	0.19
Si	941	570	165	61.8	7.48
SO_4	3,330	5,000	66.7	57.6	1.51
Sr	45.9	31.3	147	58.8	0
Th	NR	25.6	NR	NR	NR

Table K-1. Comparison of the Summation of Individual Tank Best-Basis Inventories to the Global Waste Inventory. (5 Sheets)

Analyte	Summation of individual tank best-basis inventories[c]	Global inventory basis	Ratio of tank sum inventory to global inventory (%)	Percent of tank sum based on sample data[a]	Percent of tank sum based on HDW Model[a]
TOC	1,690	4,000	42.2	61.7	1.01
U_{TOTAL}	929	965	96.3	65.2	7.61
W	NR	15.9	NR	NR	NR
Zr	470	440	107	98.8	0.08
Radionuclides (Ci)					
^{3}H	2.45 E+04	3.40 E+04	72.2	0.68	86.8
^{14}C	3.87 E+03	4.81 E+03	80.6	3.81	93.0
^{59}Ni	8.76 E+02	9.34 E+02	93.8	1.09	92.6
^{60}Co	1.99 E+04	1.23 E+04	162	45.3	13.8
^{63}Ni	8.64 E+04	9.20 E+04	93.9	1.08	92.0
^{79}Se	7.11 E+02	7.73 E+02	92.0	0.48	85.4
^{90}Sr	5.86 E+07	7.16 E+07	81.9	59.6	6.94
^{90}Y	5.86 E+07	7.16 E+07	81.9	59.6	6.94
^{93}Zr	3.45 E+03	3.63 E+03	95.1	0	85.8
^{93m}Nb	2.53 E+03	2.69 E+03	94.0	0	89.6
^{99}Tc	2.83 E+04	3.26 E+04	86.9	30.6	60.8
^{106}Ru	1.26 E+05	1.04 E+05	121	39.1	0.35
^{113m}Cd	1.66 E+04	1.69 E+04	98.5	0	74.6
^{125}Sb	2.52 E+05	2.08 E+05	121	2.09	8.24
^{126}Sn	1.17 E+03	1.19 E+03	98.4	0	82.2
^{129}I	9.91 E+01	6.30 E+01	157	42.6	44.7
^{134}Cs	8.68 E+04	8.89 E+04	97.7	0.14	1.89
^{137}Cs	5.29 E+07	4.64 E+07	114	51.9	2.95

Table K-1. Comparison of the Summation of Individual Tank Best-Basis Inventories to the Global Waste Inventory. (5 Sheets)

Analyte	Summation of individual tank best-basis inventories[c]	Global inventory basis	Ratio of tank sum inventory to global inventory (%)	Percent of tank sum based on sample data[a]	Percent of tank sum based on HDW Model[a]
^{137m}Ba	5.01 E+07	4.39 E+07	114	51.9	2.95
^{151}Sm	2.60 E+06	2.75 E+06	94.5	0	86.4
^{152}Eu	1.45 E+03	1.48 E+03	97.9	0	68.1
^{154}Eu	1.94 E+05	1.47 E+05	132	25.4	31.9
^{155}Eu	1.75 E+05	1.36 E+05	129	14.6	42.6
^{226}Ra	5.83 E-02	6.31 E-02	92.5	0	95.8
^{227}Ac	8.75 E+01	8.76 E+01	99.9	0	100
^{228}Ra	7.75 E+01	7.71 E+01	101	0	96.2
^{229}Th	1.80 E+00	1.81 E+00	99.6	0	95.8
^{231}Pa	1.56 E+02	1.56 E+02	99.8	0	99.8
^{232}Th	4.41 E+00	2.11 E+00	209	0	92.1
^{232}U	1.32 E+02	1.23 E+02	107	64.8	11.6
^{233}U	5.01 E+02	4.76 E+02	105	64.7	11.6
^{234}U	3.47 E+02	3.46 E+02	100	66.6	7.71
^{235}U	1.41 E+01	1.45 E+01	97.1	67.2	7.8
^{236}U	1.19 E+01	9.57 E+00	124	76.8	7.15
^{237}Np	1.84 E+02	1.41 E+02	131	31.7	47.1
^{238}Pu	2.69 E+03	2.77 E+03	97.0	89.7	8.81
^{238}U	3.10 E+02	3.22 E+02	96.2	65.4	4.15
^{239}Pu	5.52 E+04	3.91 E+04	141	78.5	12.0
^{240}Pu	1.11 E+04	8.93 E+03	125	79.2	10.5
^{241}Am	1.06 E+05	6.99 E+04	152	49.7	7.27
^{241}Pu	1.66 E+05	2.29 E+05	77.3	90.0	8.53

Table K-1. Comparison of the Summation of Individual Tank Best-Basis Inventories to the Global Waste Inventory. (5 Sheets)

Analyte	Summation of individual tank best-basis inventories[c]	Global inventory basis	Ratio of tank sum inventory to global inventory (%)	Percent of tank sum based on sample data[a]	Percent of tank sum based on HDW Model[a]
^{242}Cm	1.71 E+02	7.70 E+01	222	59.4	7.55
^{242}Pu	1.02 E+00	1.16 E+00	87.8	80.4	7.74
^{243}Am	1.76 E+01	9.34 E+00	188	15.2	2.29
^{243}Cm	3.28 E+01	1.00 E+01	328	74.4	3.73
^{244}Cm	7.82 E+02	2.42 E+02	323	75.4	3.99

HDW = Hanford Defined Waste
NR = Not reported
[a]Values in the best-basis inventories are either based on sample data, engineering assessment, or from the HDW model. Sample data in this table contain S, S/E, and S/M values.
[b]The total hydroxide value is calculated by charge balance; includes oxides as hydroxides, not including CO_3, NO_3, NO_2, PO_4, SO_4, and SiO_3.
[c]Only three significant figures reported.

As of September 30, 1998, seven of the tank summation and global chemical inventories matched within 10 percent and 13 match within 25 percent out of a total of 30 chemical inventories. This is an improvement from September 1, 1997 when only four chemicals matched within 10 percent and seven matched within 25 percent. In 1998 more than 50 percent of the tank summation inventory is based on sample data for 19 of the 30 chemicals. Individual best-basis tank inventories were not developed for 5 chemicals (for which globals were estimated) that were determined to be present in small quantities and for which little analytical data exist.

The radionuclide inventories in many cases appear to reconcile very well. This conclusion is misleading. The tank summation of radionuclide inventories are often derived from model values and therefore are not truly independent from the global radionuclide inventories. This is the result of having limited analytical data for many of the radionuclides. With the exception of uranium and a few other radionuclides, those tank summation and global inventories that reconcile within 10 percent are in general 85 percent or more based on HDW model values.

The best-basis tank inventories and the global inventory for nonradioactive components were independently developed from different sources of information (See Section 8.0 of this report). Each of these methods may contain several possible sources of error. However, consideration of all sources is necessary to establish a standard inventory.

This appendix defines how the sum of the individual best-basis inventories will be further reconciled with the global inventory. The results of this additional reconciliation will be included in a future update of the best-basis inventories.

The global inventories, presented in Sections 5.0, 6.0, and 7.0, were developed from process knowledge. Although there are numerous reports and records on fuel fabrication, and reactor and separations plant operation, these records are highly variable in content. Many of the flowsheets and process records were not retained to the present. Often the data are not adequately correlated. In some cases the profusion of data must be screened and approximations made to facilitate interpretation. In other cases only very limited data are available. In general the global inventories are based on the nominal operating conditions for the facility. Typically process flowsheets and material consumption records were used to estimate separation plant waste discharges. These records did not capture times when the plants experienced high losses or were engaged in startup or shutdown activities. Uncertainty is also introduced by losses to cribs and to tank leaks. Although losses to cribs were estimated for some of the components there are large uncertainties in the quantity of chemicals sent to the cribs. Some uncertainty also exists in the radionuclide content of the reactor fuel elements due to uncertainty in the reactor neutron flux and the fission product yield. The global inventories, discussed in earlier sections of this report, contain numerous caveats and assumptions with respect to the uncertainty of these values.

The individual tank specific best-basis inventories are primarily derived from sample data and tank specific process history. When sample data exist for a tank the best-basis inventory is generally derived directly from these data. When sample data do not exist or data are considered suspect, the best-basis inventory is generally derived from a group of tanks, that process history indicates contain the same waste type. Tank sampling data contain uncertainties with respect to analytical error and the statistical distribution inherent in the analysis of a heterogeneous material. Results from a task to evaluate and quantify these factors indicate that the uncertainty limits are generally quite broad (Ferryman et al. 1998). In addition there are less quantifiable uncertainties introduced by analytical bias, poor sample recovery, and lack of samples from the very bottom of the tanks. Interpretive errors in the tank history are also possible owing to the imprecision of tank farm records with respect to waste type and volume. These uncertainty factors have not been evaluated.

For several of the tanks, it was possible to validate the sample data by comparison to separations plant process flowsheets through the tank process history. Validation by this method was impractical for the majority of the tanks due to their complex waste receipt and transfer history.

The tank specific best-basis inventories continue to evolve as new sample data are made available. The new data will be reviewed and used to revise inventory estimates that are currently based on engineering assessment or the HDW model. The new data will also be used to update the tank groups used to empirically estimate tanks without sample data. Updating of wastes compositions for the tank groups is expected to be the major source of change to the tank summation inventories in the next year. However once the empirically derived waste compositions are updated this year (FY 1999), the tank summation values should be less volatile. At this point it will be appropriate to initiate further reconciliation of the tank summation and global values. This reconciliation is necessary to assure that a single standardized inventory is in use by the Tank Waste Remediation System.

RECONCILIATION OF CHEMICAL INVENTORIES

The first step of reconciliation will be to determine whether of not the tank summation value is in agreement with the global value. In principle the tank summation value would be in agreement with the global value when the uncertainty limits of the two values overlapped. However the uncertainty limits on the best-basis inventories and the global inventories are quite broad. Thus to establish a single standard inventory engineering judgment must be applied. This can be accomplished by the use of a screening value negotiated with the end-users. For this discussion, a value of 15 percent was selected. Twelve of the 25 chemicals and 27 of the 46 radionuclides reported in the best-basis inventories fall within this limit. Best-basis inventories were not developed for 5 of the global chemicals for which the total inventory is small and the analytical data are limited.

For those analytes where the global and tank summation inventories agree within 15 percent, the summation value will be accepted as the global inventory. This will be acknowledged in the appropriate section of this document. Although coincidental agreement is a possibility, concurrence of the global and tank summation inventories will be re-checked in the future as new sample data are evaluated. Inventory data will also be checked by comparing tank inventories (and/or tank concentrations) to each other to identify suspect data.

For those analytes where the tank summation value and the global value do not agree within 15 percent, the tank summation inventory will be accepted when there is an acknowledged poor basis for determination of the global estimate. The global values for Ca, Cl, CO_3, K, Mn, Ni, Pb, Si, Sr, TOC, and U, for example are in general more uncertain than the other analytes. These analytes are ones that were present as trace impurities or that are difficult to quantify based on the available process records. In this event, a summary discussion of the tank summation inventory will be added to the appropriate section of this document.

For those analytes where the tank summation value and the global value do not agree within 15 percent, the global inventory will be accepted when there is an acknowledged lack of

sample data or the sample data consists largely of bounding values. In this case, that fraction of the global inventory not accounted for by sample data will be distributed to the remainder of the tanks using process knowledge or the HDW model distribution.

RECONCILIATION OF RADIONUCLIDE INVENTORIES

For the radionuclides, the global inventory is generally considered to be the most accurate basis. The exceptions to this are the isotopes of ^{3}H, ^{14}C, Cs, Sr, Pu, Np, Th, and U. The global estimates for these isotopes are somewhat less certain since recovery and loss factors of the various separations plants must also be considered in their computation.

For those radionuclides where the global and tank summation inventories agree within 15 percent, the sum of individual tank best-basis values will be accepted as the global inventory. This will be acknowledged in the appropriate section of this document. Note that agreement may occur due to a lack of analytical data and the dependence on the HDW model values.

When the tank summation radionuclide inventories no longer agree within 15 percent of the global radionuclide inventory, reconciliation is necessary. Reconciliation will be obtained by the following steps: (1) subtracting the sum of the sample and engineering based values from the global value, and (2) redistributing the remaining inventory in accordance with ratios defined by the HDW model or by process knowledge.

If redistribution of the remaining inventory in accordance with the HDW model becomes suspect due to the small number of tanks for which only model values exist, the basis for global inventory will be re-examined, and the individual tank best-basis inventories will be re-examined in order of the largest values first. Reconciliation will be complete once the tank summation value is within 15 percent of the global value.

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