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ASSESSMENT OF THE QUANTITIES AND DISTRIBUTION OF K EAST BASIN FLOOR SLUDGE CONSTITUENTS

S. L. Hecht

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Abstract: Floor sludge constituent masses and their spatial distribution within K East Basin were calculated based on results from recent laboratory chemical and radionuclides analyses of sludge sampled in K East main basin along with data previously generated from the analysis of measured sludge depths.

Results of these calculations, showed that the major gravimetric constituents of the sludge are iron, uranium, aluminum, sodium, and calcium. Significant amounts of fissionable materials ^{235}U and ^{239}Pu were also calculated. The calculated distribution of sludge constituent masses showed distinct patterns.

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**ASSESSMENT OF THE QUANTITIES AND DISTRIBUTION OF
K EAST BASIN FLOOR SLUDGE CONSTITUENTS**

S. L. Hecht
Spent Nuclear Fuel Evaluations

September 1996

CONTENTS

1.0	SUMMARY AND CONCLUSIONS	3
2.0	INTRODUCTION	5
3.0	ANALYSES AND RESULTS	7
3.1	ANALYSIS OF SLUDGE CONSTITUENTS CONCENTRATIONS	7
3.2	ANALYSIS OF SLUDGE CONSTITUENTS MASSES	10
4.0	DISCUSSION	13
4.1	UNCERTAINTIES	13
4.2	COMPARISON WITH PREVIOUS PREDICTIONS	13
4.3	GENERAL DISCUSSION	14
5.0	ACKNOWLEDGEMENTS	15
6.0	REFERENCES	17
	APPENDIX A VISUALIZATION PLOTS OF CONCENTRATIONS OF SELECTED CONSTITUENTS FOR K EAST FLOOR SLUDGE	19
	APPENDIX B VISUALIZATION PLOTS OF FLOOR SLUDGE DEPTH DATA FROM K EAST	71
	APPENDIX C VISUALIZATION PLOTS OF MASS DISTRIBUTIONS OF SELECTED CONSTITUENTS FOR K EAST FLOOR SLUDGE	75
	APPENDIX D COMPUTER CODE SOURCE LISTINGS	123

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ASSESSMENT OF THE QUANTITIES AND DISTRIBUTION OF K EAST BASIN FLOOR SLUDGE CONSTITUENTS

1.0 SUMMARY AND CONCLUSIONS

Floor sludge constituent masses and their spatial distribution within K East Basin were calculated. This information will be beneficial in the assessing the acceptability of K Basin sludge in the Tank Waste Remediation System and in the design and/or operational practices related to retrieval and handling of this K Basin sludge.

Calculations were made based on results from recent laboratory chemical and radionuclides analyses of sludge sampled from thirteen locations in K East main basin. This concentration data was mathematically processed to determine the various constituents concentration distribution throughout the basin floor. This data was further processed, along with data previously generated from the analysis of measured sludge depths, to give both basin total masses and associated spatial distribution of the various sludge constituents.

Results of these calculations, showed that the major gravimetric constituents of the sludge are iron (1505 kg), uranium (1387 kg), aluminum, sodium, and calcium. Significant amounts of fissionable materials were also calculated: ^{235}U (9.92 kg) and ^{239}Pu (3.42 kg).

The calculated distribution of sludge constituent masses showed distinct patterns. Sludge constituent associated with corroded spent nuclear fuel were concentrated near the north-west corner of the basin. Aluminum and iron, and many other elements are mainly located near the mouth of the South Load Out Pit. A value of 10,200 Ci of alpha (5%) + beta (95%) radioactivity was calculated for the total basin floor sludge, and was concentrated near the north-west corner of the basin and near the Dummy Elevator Pit.

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2.0 INTRODUCTION

It is currently estimated (Baker 1995) that 21.7 m^3 (765 ft^3) of particulate layered material, generally referred to as sludge, has accumulated on the floor of K East Basin. This sludge is believed to be generated from mainly spalled corrosion products from spent metallic uranium fuel elements (both fuel and cladding), from fuel canisters (primarily aluminum ones), and from fuel canister storage racks. Additional sludge constituents are believed to come from the concrete basin walls, paint chips, ion-exchange resins, and wind blown debris such as sand.

Removal from K Basin and interim safe storage of this sludge is a major part of the K Basin cleanup effort. In order to safely and effectively accomplish this goal, characterization of the sludge chemical make-up is required. More specifically, the amounts and distribution of key chemical constituents within K East (KE) Basin need be determined. Development of methods and design of equipment for retrieval, transportation, and processing require these aforementioned sludge characteristics. These characteristics have a direct bearing on such determinations as the personnel dose rates during handling, the accountability of Special Nuclear Materials, and the acceptability of K Basin sludge to the expected disposal path--the Tank Waste Remediation System.

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3.0 ANALYSES AND RESULTS

Calculations based on measured data were made for both total mass and spatial mass distributions for K East Basin floor sludge constituents, i.e., elements, isotopes. Additionally, in the process of calculating the spatial distribution of the constituents, concentration distributions were generated as an intermediate step, and these are also provided.

3.1 ANALYSIS OF SLUDGE CONSTITUENTS CONCENTRATIONS

These calculations were made by first performing spatial interpolation (surface mapping) of the concentration data given for the measured chemistry of as-settled sludge, as given in Makenas 1996, Appendix C. The interpolation algorithm used (because of the gradients in the sludge surface and the sparsity of data) was the inverse-distance method. These calculations, along with subsequent plotting were done using the TECPLOT scientific data visualization computer code running on a SUN workstation. Here the value of a variable at a data point in a destination (_d) zone is calculated as a function of the selected data points in the source (_s) zone. The value at each source data point is weighted by the inverse of the distance between the source data point and the destination data point raised to a power as shown below:

$$\varphi_d = (\sum w_s \varphi_s) / \sum w_s \text{ (summed over selected points in the source zone)}$$

where:

φ_d and φ_s are the values of the variables at the destination and source point respectively, and w_s is the weighing function defined as:

$w_s = D^{-n}$; where D is the distance between the source point and the destination point, and n is a exponent chosen as 3.5, to best fit the data (see Section 4.1).

The source points were chosen as the nearest point in each adjacent octant (unless at a boundary).

The basin was mathematically considered as continuous, i.e., not as three separate bays. This was done because of the sparsity of data points (locations). This approach is considered reasonable, though some error is inherent, as the majority of sampling locations are not near the interior walls, and hence their effect on interpolated values near the wall locations becomes less dominate. Previous interpolations for KE Basin sludge volume calculations evaluated each bay separately, however, there was considerably more data.

The interpolated data was then used for both subsequent analysis and as the data base for visualization plots. The concentration data was generally analyzed from all available measurement locations (i.e., 13 or less in some cases) in the K East Main Basin. These were mapped via interpolation to each basin cubical location (5,092 points).

Three-dimensional (3D) color contour plots were then created using TECPLOT. These plots, show the component concentration in either the appropriate unit of $\mu\text{g/ml}$ or $\mu\text{Ci/ml}$, and are provided in Appendix A. For reference, measurement data points are superimposed on these plots.

This data, along with the previously analyzed sludge depth data (see Appendix B and Baker 1995) which is also stored on a 5,092 cubical location basis, was then processed with the FORTRAN computer code DWAVG (see Appendix D) which calculates a depth (or volume) weighted average concentration, $\bar{C}_d$.

Here:

$$\bar{C}_d = \Sigma(c_i * d_i) / \Sigma d_i$$

Where, d is the sludge depth, c the local concentration, and i the index related to the 5092 cubical locations, which the expression is summed over. The resulting depth weighted average concentrations, for the sludge components evaluated, are given in Table 1.

For non-fuel/fission related elements (see lower part of Table 1) the largest depth-weighted average concentrations of as-settled sludge were calculated for the following:

Iron (Fe)	67,500 $\mu\text{g/cc}$
Aluminum (Al)	16,670 $\mu\text{g/cc}$
Sodium (Na)	1950 $\mu\text{g/cc}$
Calcium (Ca)	1750 $\mu\text{g/cc}$

For iron and aluminum, the maximum concentrations occur near the South Load Out Pit (cubical location 6720). The maximum concentrations for sodium and calcium occur near the North Load Out Pit (location 6750).

Fuel related isotopes (e.g., fission products), with the exception of cobalt-60, have their maximum concentrations located near cubical 6070, where a localized peak sludge depth of approximately 18 cm is found. Maximum activity depth-weighted average concentrations of as-settled sludge were calculated for the following:

Cesium-137 (^{137}Cs)	190 $\mu\text{Ci/cc}$
Strontium-90 (^{90}Sr)	179 $\mu\text{Ci/cc}$

Maximum gravimetric depth-weighted average concentrations of these isotopes were calculated for the following:

Uranium-238 (^{238}U)	61,700 $\mu\text{g/cc}$
Uranium-235 (^{235}U)	445 $\mu\text{g/cc}$
Plutonium-239/240 ($^{239/240}\text{Pu}$)	153 $\mu\text{g/cc}$

Table 1. K East Basin Floor Sludge Constituents: Calculated Masses and Related Parameters.

COMPONENT **	CONCENTRATION (DEPTH WEIGHTED AVERAGE) *****				TOTAL BASIN MASS/ RADIOACTIVITY	
	10e-6 g/cc	10e-6 Ci/cc	Conv. fac. Ci to g	10e-6 g/cc	kg	CI
Am 241 (AEA)	NA	10.7000	8.88E-03	0.10	0.00	249.31
Am 241 (GEA)	NA	10.7000	8.88E-03	0.10	0.00	249.31
Bi 212 **	NA	0.5040	6.82E-08	0.00	0.00	11.24
Ce 144 / Pr **	NA	4.0900	1.05E-04	0.00	0.00	91.21
Cm 243/244 **	NA	2.5100	1.23E-02	0.03	0.00	55.97
Co 60	NA	0.7040	8.81E-04	0.00	0.00	15.70
Ce 134 **	NA	0.3270	7.71E-04	0.00	0.00	7.29
Cs 137	NA	190.0000	1.16E-02	2.20	0.05	4237.00
Eu 152 **	NA	0.0823	5.51E-03	0.00	0.00	1.84
Eu 154	NA	1.7500	6.88E-03	0.01	0.00	39.03
Eu 155	NA	0.8910	7.83E-04	0.00	0.00	19.87
Nb 94 **	NA	0.2450	5.26E-00	1.29	0.03	5.46
Np 237 **	NA	0.0019	1.41E-03	2.69	0.06	0.04
Pu 238 **	NA	2.2300	5.83E-02	0.13	0.00	49.73
Pu 239/240	NA	9.5300	1.61E-01	153.15	3.42	212.52
Ra 226 **	NA	7.5100	1.01E-00	7.59	0.17	167.47
Ru 106 / Rh **	NA	5.4600	1.51E-04	0.00	0.00	121.76
Sb 125 **	NA	0.4770	9.42E-04	0.00	0.00	10.64
Sr 90	NA	179.0000	7.31E-03	1.31	0.03	3991.70
Ti 208 **	NA	1.5100	3.42E-09	0.00	0.00	33.67
U (PNNL)	62200.00	NA	NA	62200.00	1387.06	NA
U 233 **	0.61	NA	1.04E-02	0.61	0.01	0.13
U 234	4.81	NA	1.61E-02	4.81	0.11	0.67
U 235	444.90	NA	4.62E-05	444.90	9.92	0.02
U 236	33.70	NA	1.57E-04	33.70	0.75	0.05
U 238	61700.00	NA	3.00E-06	61700.00	1375.91	0.46
Total Alpha	NA	23.0000	NA	NA	NA	514.05
Total Beta	NA	432.0000	NA	NA	NA	9655.20
COMPONENT	CONCENTRATION (DEPTH WEIGHTED AVERAGE) *****				TOTAL BASIN MASS	
	10e-6 g/cc	10e-6 Ci/cc	Conv. fac. Ci to g	10e-6 g/cc	Kg	
Ag **	5.43	NA	NA	5.43	0.12	NA
Al	16670.00	NA	NA	16670.00	371.74	NA
B	66.50	NA	NA	66.50	1.48	NA
Ba **	75.60	NA	NA	75.60	1.69	NA
Be	13.40	NA	NA	13.40	0.30	NA
Ca	1750.00	NA	NA	1750.00	39.03	NA
Cd	36.10	NA	NA	36.10	0.81	NA
Cr	166.00	NA	NA	166.00	3.70	NA
Cu	183.00	NA	NA	183.00	4.08	NA
Fe	67500.00	NA	NA	67500.00	1505.25	NA
K **	412.00	NA	NA	412.00	9.19	NA
Mg	514.00	NA	NA	514.00	11.46	NA
Mn	150.00	NA	NA	150.00	3.35	NA
Na	1949.00	NA	NA	1949.00	43.46	NA
Pb	133.00	NA	NA	133.00	2.97	NA
Se **	54.30	NA	NA	54.30	1.21	NA
Sm **	54.30	NA	NA	54.30	1.21	NA
Ti **	108.00	NA	NA	108.00	2.41	NA
Zn	268.00	NA	NA	268.00	5.98	NA
Zr	129.00	NA	NA	129.00	2.88	NA
TIC	799.00	NA	NA	799.00	17.82	NA
TOC	1070.00	NA	NA	1070.00	23.86	NA
NOTES						
** Upper bound values						
TIC = Total inorganic carbon TOC = Total organic carbon						

3.2 ANALYSIS OF SLUDGE CONSTITUENTS MASSES

To determine the total mass of a particular component, the depth weighted average in mass/unit volume is multiplied by the average depth and the effective basin floor area (total basin area minus the area occupied by canisters). These total basin masses are given in Table 1. For radioisotopes, for which concentrations are given in units of radioactivity/volume, a conversion to mass/volume was made by multiplying the values by the inverse of the associated specific activity.

Here:

$$\text{g/Ci} = (\text{At.Wt.}) * (\text{half life in sec}) / 1.13 \times 10^{13} \text{ sec-Ci/g}$$

These conversions are given in Table 1.

To obtain spatial mass distributions, the FORTRAN programs MASDIS and MASDIS2 (see Appendix D) were written. These programs read in the sludge depth and concentration data files (plus conversion factors for radioisotopes), and multiply the depth by the mass concentration at each of 5,092 cubical location (the cubical being taken as calculational points). This value is then multiplied by the average effective floor area (assumes canisters are uniformly distributed taking up floor area within the basin) of a cubical location. MASDIS writes out a mass distribution data file which is read by TECPLOT, for subsequent processing and plotting. These mass distribution plots are provided in Appendix C.

The greatest total masses for the non-fuel related elements in the basin floor sludge were calculated for the following:

Fe at 1505 kg
Al at 372 kg
Na at 43 kg
Ca at 39 kg

For fissionable materials the total masses in the basin floor sludge were calculated as:

^{235}U at 9.92 kg
 ^{239}Pu at 3.42 kg
 ^{233}U at 0.01 kg

Total basin floor sludge mass calculated for other isotopes of significant amount or interest are as follows:

^{238}U at 1376 kg (total U is 1387 kg)
 ^{137}Cs at 0.05 kg
 ^{90}Sr at 0.03 kg

The calculated distribution of sludge constituent masses showed distinct patterns. Sludge constituent associated with corroded spent fuel were concentrated near the north-west corner of the basin. The north-west corner

is a region where significant amounts of degraded fuel are located and where the sampling location was between barrels of a canister in a particularly deep area of sludge. Another region of buildup of radionuclides is near the Dummy Elevator Pit. Aluminum and iron, and many other element are mainly located near the mouth of the South Load Out Pit. Significant amounts of Na, Ca, K and Mg are calculated near the mouth of the North Load Out Pit. A value of 10,200 Ci of alpha + beta radioactivity (~80% from ^{137}Cs and ^{90}Sr) were calculated for the total basin floor sludge, and this was concentrated near the north-west corner of the basin and near the north-east corner near Dummy Elevator Pit.

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4.0 DISCUSSION

4.1 UNCERTAINTIES

No attempt was made to statistically determine uncertainties. However, a qualitative discussion is provided here.

The main concern related to uncertainties is the choice of the basin sampling locations for chemical analysis. With only thirteen cubical locations, the choice becomes paramount. Rationale for selection of the sampling locations, based on the current *apriori* knowledge is discussed in Makenas 1996, and the Sampling Analysis Plan for this effort (Welsh 1994). For example, if the location (6070), where the greatest concentration of spent fuel related isotopes were found, was omitted from the sampling plan, significantly lower amounts of these isotopes would have been calculated by the current analysis.

The choice of interpolation method and the decay exponent in the present analysis affects uncertainties. For example, if the mathematical decay exponent was chosen higher than the 3.5 used, sharper peaks in local concentration and generally lower masses would have been calculated. The converse would lead to the calculation of higher masses. There is not enough data to fully assess this effect. The default TECPLOT exponent of 3.5, was chosen as it generally fits many natural systems.

The effect of considering the basin as one continuous pool is expected to cause little error. This conclusion is based on the fact that data values near the walls are consistently of low relative concentrations, i.e., not peak values (see Appendix A).

4.2 COMPARISON WITH PREVIOUS PREDICTIONS

Previously reported (Small 1995; Willis 1995) total basin masses/activities of sludge constituents were almost universally lower than those reported herein. For the most abundant chemical constituents, previous estimated mass values ranged from between a factor of four (4) to several orders of magnitude lower. For example, the amount of iron was previously report at 315 kg, whereas, this evaluation calculated 1505 kg. For aluminum it was 89 kg compared to 372 kg.

For fuel/fission products previously reported and (calculated herein) total basin masses were:

	<u>Old</u>	<u>New</u>
U (total)	150 kg	(1390 kg)
²³⁹ Pu	0.39 kg	(3.42 kg)

For total basin activities:

^{137}Cs	178 Ci	(4240 Ci)
^{90}Sr	321 Ci	(3990 Ci)

These totals are consistent with differences in measured concentration values on which they were based, as indicated in the comparisons shown in Table 4.6 of Makenas 1996.

4.3 GENERAL DISCUSSION

This analysis provides significant insight on the location and overall mass of constituents in the K East Basin sludge. The overall amount of materials in the sludge cannot be implied directly from the sample volumes. This follows because the volume of sludge sample taken was adjusted to obtain similar volume samples, even though the sludge depth varied from one location the next on the basin floor (see Makenas 1996).

Several interesting observations were made in the review of the results of this analysis. This analysis clearly shows a concentration of fuel/fission products near the north-west corner of the basin. Furthermore, the evaluation of the constituents shows that the ratio of ^{235}U to total U is 0.715%. This may suggest that this material had come from certain models of single pass reactor fuel, which was made from natural uranium (0.714% ^{235}U content), and not from N Reactor fuel which was all enriched.

The concentration of Na, Ca, K and Mg near the North Load Out Pit are indicative of trace elements in hard water (early operations) which likely was captured by the resin of the early ion exchange modules. These modules were know to have leaked in this region.

5.0 ACKNOWLEDGEMENTS

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APPENDIX A

**VISUALIZATION PLOTS OF CONCENTRATIONS OF SELECTED
CONSTITUENTS FOR K EAST FLOOR SLUDGE**

NOTE: The majority of plots are provided in monochrome form. Color plots are available upon request.

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(3D) || Print || 15 Jul 1996 || am241aea.plt ||

K-E BASIN SLUDGE Am-241 (AEA) CONCENTRATION BASIN FLOOR

(3D) || Print || 11 Jul 1996 || am241GEA.plt ||

K-E BASIN SLUDGE Am-241 (GEA) CONCENTRATION
BASIN FLOOR

3.50
3.33
3.15
2.97
2.80
2.62
2.45
2.27
2.10
1.92
1.75
1.57
1.40
1.23
1.05
0.88
0.70
0.52
0.35
0.17
0.00

K-E BASIN SLUDGE BI 212 CONCENTRATION
BASIN FLOOR

K-E BASIN SLUDGE Ce144/Pr CONCENTRATION BASIN FLOOR

(3D) || Print || 11 Jul 1996 || cm243_244.plt ||

K-E BASIN SLUDGE Cm243/244 CONCENTRATION BASIN FLOOR

K-E BASIN SLUDGE Co-60 CONCENTRATION
BASIN FLOOR

(3D) || Print || 20 Jun 1996 || cs134grd.plt || Cs-134 Concentration

K-E BASIN SLUDGE Cs-134 CONCENTRATION BASIN FLOOR

(3D) II Print II 20 Jun 1996 II cs137grid pit II Cs-137 Concentration

K-E BASIN SLUDGE Cs-137 CONCENTRATION

BASIN FLOOR

K-E BASIN SLUDGE EU-152 CONCENTRATION
BASIN FLOOR

K-E BASIN SLUDGE Eu154 CONCENTRATION
BASIN FLOOR

K-E BASIN SLUDGE EU155 CONCENTRATION BASIN FLOOR

K-E BASIN SLUDGE Nb-94 CONCENTRATION BASIN FLOOR

10 ci/ml
0.45
0.43
0.40
0.38
0.36
0.34
0.31
0.29
0.27
0.25
0.22
0.20
0.18
0.16
0.13
0.11
0.09
0.07
0.04
0.02
0.00

K-E BASIN SLUDGE Np-237 CONCENTRATION

BASIN FLOOR

K-E BASIN SLUDGE Pu-238 CONCENTRATION
BASIN FLOOR

(3D) || Print || 17 Jun 1996 || pu23940.plt ||

K-E BASIN SLUDGE PU 239+240 CONCENTRATION

BASIN FLOOR

K-E BASIN SLUDGE Ra-226 CONCENTRATION
BASIN FLOOR

K-E BASIN SLUDGE Ru-106/Rh CONCENTRATION
BASIN FLOOR

K-E BASIN SLUDGE Sb-125 CONCENTRATION
BASIN FLOOR

K-E BASIN SLUDGE Sr-90 CONCENTRATION
BASIN FLOOR

K-E BASIN SLUDGE T1-208 CONCENTRATION
BASIN FLOOR

(3D) // Print // 01 Jul 1996 // u_pnnl.plt //

K-E BASIN SLUDGE U CONCENTRATION (PNNL) BASIN FLOOR

10⁻¹ g/mL
400000
380000
360000
340000
320000
300000
280000
260000
240000
220000
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0

400000
350000
300000
250000
200000
150000
100000
50000
0

(3D) II Print II 21 Jun 1996 II u233.plt II

K-E BASIN SLUDGE U-233 CONCENTRATION BASIN FLOOR

K-E BASIN SLUDGE U-234 CONCENTRATION BASIN FLOOR

K-E BASIN SLUDGE U-235 CONCENTRATION BASIN FLOOR

10 g/mL
3200
3040
2880
2720
2560
2400
2240
2080
1920
1760
1600
1440
1280
1120
960
800
640
480
320
160
0

K-E BASIN SLUDGE U-236 CONCENTRATION
BASIN FLOOR

K-E BASIN SLUDGE U-238 CONCENTRATION
BASIN FLOOR

(3D) II Print II 23 Jul 1996 II atotal.plt II

K-E BASIN SLUDGE TOTAL ALPHA CONCENTRATION BASIN FLOOR

(3D) || Print || 22 Jul 1996 || btotai.plt ||

K-E BASIN SLUDGE TOTAL BETA CONCENTRATION BASIN FLOOR

K-E BASIN SLUDGE Ag CONCENTRATION
BASIN FLOOR

K-E BASIN SLUDGE Al CONCENTRATION
BASIN FLOOR

(3D) || Print || 08 Jul 1996 || b.plt ||

K-E BASIN SLUDGE B CONCENTRATION BASIN FLOOR

10⁻¹ g/mL

120	116	112	108	104	100	96	92	88	84	80	76	72	68	64	60	56	52	48	44	40
-----	-----	-----	-----	-----	-----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----

K-E BASIN SLUDGE Ba CONCENTRATION
BASIN FLOOR

K-E BASIN SLUDGE BE CONCENTRATION BASIN FLOOR

K-E BASIN SLUDGE Ca CONCENTRATION BASIN FLOOR

K-E BASIN SLUDGE Cd CONCENTRATION BASIN FLOOR

K-E BASIN SLUDGE Cr CONCENTRATION
BASIN FLOOR

K-E BASIN SLUDGE Cu CONCENTRATION
BASIN FLOOR

10 g/mL
450
427
405
382
360
337
315
292
270
247
225
202
180
157
135
112
90
67
45
22
0

K-E BASIN SLUDGE Fe CONCENTRATION
BASIN FLOOR

K-E BASIN SLUDGE K CONCENTRATION BASIN FLOOR

10⁻³ g/mL

1200	1140	1080	1020	960	900	840	780	720	660	600	540	480	420	360	300	240	180	120	60	0
------	------	------	------	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	----	---

K-B BATH SLODGE MG CONCENTRATION

BATH FLOOR

K-E BASIN SLUDGE Mn CONCENTRATION
BASIN FLOOR

10^{-6} g/mL

452
429
407
384
362
339
316
294
271
249
226
203
181
158
136
113
90
68
45
23
0

K-E BASIN SLUDGE Na CONCENTRATION
BASIN FLOOR

K-E BASIN SLUDGE Pb CONCENTRATION BASIN FLOOR

(3D) || Print || 10 Jul 1996 || pb.plt ||

K-E BASIN SLUDGE Se CONCENTRATION
BASIN FLOOR

K-E BASIN SLUDGE SM CONCENTRATION BASIN FLOOR

K-E BASIN SLUDGE Tl CONCENTRATION
BASIN FLOOR

K-E BASIN SLUDGE Zn CONCENTRATION
BASIN FLOOR

10 g/mL
650
617
585
552
520
487
455
422
390
357
325
292
260
227
195
162
130
97
65
32
0

K-E BASIN SLUDGE Zr CONCENTRATION
BASIN FLOOR

K-E BASIN SLUDGE TOTAL INORGANIC CARBON CONCENTRATION
BASIN FLOOR

K-E BASIN SLUDGE TOTAL ORGANIC CARBON CONCENTRATION
BASIN FLOOR

APPENDIX B

VISUALIZATION PLOTS OF FLOOR SLUDGE DEPTH DATA FROM K EAST

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K-E BASIN SLUDGE DEPTH MAP

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APPENDIX C

**VISUALIZATION PLOTS OF MASS DISTRIBUTIONS OF SELECTED
CONSTITUENTS FOR K EAST FLOOR SLUDGE**

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K-E BASIN SLUDGE AM 241 MASS DISTRIBUTION
BASIN FLOOR

g/Cubical Location

2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00

K-E BASIN SLUDGE Ba MASS DISTRIBUTION BASIN FLOOR

(3D) || Print || 16 Jul 1996 || bi212xxgrid-mass.plt || Bi212 Mass Grid

K-E BASIN SLUDGE BI 212 MASS DISTRIBUTION BASIN FLOOR

K-E BASIN SLUDGE Ce144/Pr MASS DISTRIBUTION
BASIN FLOOR

(3D) || Print || 19 Jul 1996 || cm243_244_mas.plt ||

K-K-E BASIN SLUDGE Cm 243/244 MASS DISTRIBUTION
BASIN FLOOR

K-E BASIN SLUDGE CO 60 MASS DISTRIBUTION
BASIN FLOOR

K-E BASIN SLUDGE Cs 134 MASS DISTRIBUTION BASIN FLOOR

K-E BASIN SLUDGE Cs 137 MASS DISTRIBUTION BASIN FLOOR

g/Cubical Location

0.250
0.237
0.225
0.213
0.200
0.188
0.175
0.163
0.150
0.138
0.125
0.113
0.100
0.087
0.075
0.062
0.050
0.038
0.025
0.013
0.000

K-E BASIN SLUDGE EU 152 MASS DISTRIBUTION BASIN FLOOR

K-E BASIN SLUDGE Eu 154 MASS DISTRIBUTION
BASIN FLOOR

g/Cubical Location

(3D) || Print || 16 Jul 1996 || nb94_mas.plt ||

K-E BASIN SLUDGE Nb 94 MASS DISTRIBUTION BASIN FLOOR

(3D) II Print II 16 Jul 1996 II np237_mas.plt II

K-E BASIN SLUDGE Np 237 MASS DISTRIBUTION BASIN FLOOR

K-E BASIN SLUDGE Pu 238 MASS DISTRIBUTION BASIN FLOOR

(3D) || Print || 26 Jun 1996 || pu23940_mas.plt ||

K-E BASIN SLUDGE Pu 239/240 MASS DISTRIBUTION

BASIN FLOOR

g/Cubical Location

12.00
12.35
11.70
11.05
10.40
9.75
9.10
8.45
7.80
7.15
6.50
5.85
5.20
4.55
3.90
3.25
2.60
1.95
1.30
0.65
0.00

(3D) II Print II 17 Jul 1996 II ra226_mas.plt II

K-E BASIN SLUDGE Ra 226 MASS DISTRIBUTION BASIN FLOOR

(3D) || Print || 18 Jul 1996 || ru106rh_mas.plt ||

K-E BASIN SLUDGE Ru106/Rh MASS DISTRIBUTION BASIN FLOOR

(3D) II Print II - 17 Jul 1996 II sb_mas.plt II

K-E BASIN SLUDGE Sb 125 MASS DISTRIBUTION BASIN FLOOR

(3D) || Print || 28 Jun 1996 || sr90_mas.plt ||

K-E BASIN SLUDGE Sr 90 MASS DISTRIBUTION BASIN FLOOR

BASIN FLOOR

(3D) II Print II 17 Jul 1996 II u_pnnl_mas.plt II

K-E BASIN SLUDGE U - TOTAL (PNNL) MASS DISTRIBUTION BASIN FLOOR

(3D) || Print || 17 Jul 1996 || u233_mas.plt ||

K-E BASIN SLUDGE U 233 MASS DISTRIBUTION BASIN FLOOR

(3D) || Print || 18 Jul 1996 || u234_mas.plt ||

K-E BASIN SLUDGE U 234 MASS DISTRIBUTION
BASIN FLOOR

K-E BASIN SLUDGE U 235 MASS DISTRIBUTION
BASIN FLOOR

g/Cubical Location

50.00
47.50
45.00
42.50
40.00
37.50
35.00
32.50
30.00
27.50
25.00
22.50
20.00
17.50
15.00
12.50
10.00
7.50
5.00
2.50
0.00

100

K-E BASIN SLUDGE U 236 MASS DISTRIBUTION
BASIN FLOOR

K-E BASIN SLUDGE U 238 MASS DISTRIBUTION
BASIN FLOOR

g/Cubical Location

6000
5700
5400
5100
4800
4500
4200
3900
3600
3300
3000
2700
2400
2100
1800
1500
1200
900
600
300
0

5000
4000
3000
2000
1000
0

MHC-SO-SNF-TI-038, Rev. 0

K-E BASIN SLUDGE Ag MASS DISTRIBUTION
BASIN FLOOR

g/Cubical Location

KE BASIN SLUDGE: AL MASS DISTRIBUTION
BASIN FLOOR

g/Cubical Location

(3D) II Print II 12 Jul 1996 II b_mas.plt II

K-E BASIN SLUDGE B MASS DISTRIBUTION BASIN FLOOR

(3D) || Print || 12 Jul 1996 || be_mas.plt ||

K-E BASIN SLUDGE Be MASS DISTRIBUTION BASIN FLOOR

(3D) II Print II 12 Jul 1996 II ca_mas.plt II

K-E BASIN SLUDGE Ca MASS DISTRIBUTION BASIN FLOOR

K-E BASIN SLUDGE Cd MASS DISTRIBUTION
BASIN FLOOR

(3D) II Print II 12 Jul 1996 II cd_mas.plt II

(3D) II Print II 12 Jul 1996 II cr_mas.plt II

K-E BASIN SLUDGE Cr MASS DISTRIBUTION BASIN FLOOR

K-E BASIN SLUDGE CU MASS DISTRIBUTION

BASIN FLOOR

K-E BASIN SLUDGE Fe MASS DISTRIBUTION
BASIN FLOOR

g/Cubical Location

(3D) || Print || 29 Jul 1996 || k_mas.plt ||

K-E BASIN SLUDGE K MASS DISTRIBUTION

BASIN FLOOR

g/Cubical Location

15.00
14.00
13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00

(3D) II Print II 12 Jul 1996 II mn_mas.plt II

K-E BASIN SLUDGE Mn MASS DISTRIBUTION BASIN FLOOR

(3D) || Print || 12 Jul 1996 || mg_mas.plt ||

K-E BASIN SLUDGE Mg MASS DISTRIBUTION BASIN FLOOR

g/Cubical Location

15.00
14.00
13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00

(3D) || Print || 12 Jul 1996 || na_mas.plt ||

K-E BASIN SLUDGE Na MASS DISTRIBUTION
BASIN FLOOR

(3D) Print II 12 Jul 1996 II pb_mas.plt II

K-E BASIN SLUDGE Pb MASS DISTRIBUTION BASIN FLOOR

(3D) II Print II 12 Jul 1996 II sm_mas.plt II

K-E BASIN SLUDGE Sm MASS DISTRIBUTION BASIN FLOOR

(3D) II Print II 29 Jul 1996 II tl_mas.plt II

K-E BASIN SLUDGE T1 MASS DISTRIBUTION BASIN FLOOR

(3D) || Print || 12 Jul 1996 || zn_mas.plt ||

K-E BASIN SLUDGE Zn MASS DISTRIBUTION

BASIN FLOOR

(3D) || Print || 12 Jul 1996 || zr_mas.plt ||

K-E BASIN SLUDGE Zr MASS DISTRIBUTION BASIN FLOOR

(3D) || Print || 29 Jul 1996 || tic_mas.plt ||

K-E BASIN SLUDGE TOTAL INORGANIC CARBON MASS DISTRIBUTION BASIN FLOOR

(3D) || Print || 29 Jul 1996 || toc_mas.plt ||

K-E BASIN SLUDGE TOTAL ORGANIC CARBON MASS DISTRIBUTION BASIN FLOOR

APPENDIX D
COMPUTER CODE SOURCE LISTINGS

DWAVG
MASDIS
MASDIS2

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davg.f

Tue Jun 18 15:37:04 1996

1

Program davg

```

c
c *** sludge depth weighted average grid data for k-basin ***
c *** set to cubical no. system
c *** on a cubical by cubical bases
c
c *** initializations and dimensions
c
    dimension depth(67,76), data(67,76)
    character*40 dfile, infile
c
    dsum =0.0
    psum =0.0
c ***
c *** open input files
c
    write(6,*) 'Enter name of depth data file'
    read(5,13) dfile
13    format(a40)
    write(6,*) 'Enter name of parameter data file'
    read(5,13) infile
    open(8,file=dfile,status='old')
    open(9,file=infile,status='old')
    rewind 8
    rewind 9
c
c *** constants
c
    imax = 67
    jmax = 76
    nrec = imax*jmax
c
c *** read data into array
c
    do 100 k = 1,nrec
c
c *** depth data
    read (8,*) itmp,jtmp,dtmp
    depth(itmp,jtmp) = dtmp
c
c *** input parameter file
    read (9,*) itmp,jtmp,ptmp
    data(itmp,jtmp) = ptmp
c
100  continue
c
c *** sums and products for averaging
c
    do 200 i = 1,imax
    do 150 j = 1,jmax
c
        dsum = dsum+depth(i,j)
        psum = psum + depth(i,j)*data(i,j)
c
150  continue
200  continue
c
c *** average and print
c
    pavg = psum/dsum
    write(6,250) pavg
250  format(2x,' The Depth weighted average is ',e15.5)
c

```

dwavg.f

Tue Jun 18 15:37:04 1996

2

stop
end

masdis.f

Thu Jun 20 14:08:21 1996

1

Program masdis

```

c
c *** sludge mass distribution/grid for elements for k-basin ***
c *** for g/mL input
c *** output in g/cubical
c *** set to cubical no. system
c *** on a cubical by cubical bases
c
c *** initializations and dimensions
c
c     dimension depth(67,76), data(67,76)
c     character*40 dfile, infile, outfile
c
c     dsum =0.0
c     psum =0.0
c
c     area = 881.
c     fac = area*1.e-6
c ***
c *** open input files
c
c     write(6,*) 'Enter name of depth data file'
c     read(5,13) dfile
13  format(a40)
c     write(6,*) 'Enter name of parameter data file'
c     read(5,13) infile
c     write(6,*) 'Enter name of output data file'
c     read(5,13) outfile
c     open(8,file=dfile,status='old')
c     open(9,file=infile,status='old')
c     open(10,file=outfile)
c     rewind 8
c     rewind 9
c     rewind 10
c
c *** constants
c
c     imax = 67
c     jmax = 76
c     nrec = imax*jmax
c
c *** read data into array
c
c     do 100 k = 1,nrec
c
c *** depth data
c     read (8,*) itmp,jtmp,dtmp
c     depth(itmp,jtmp) = dtmp
c
c *** input parameter file
c     read (9,*) itmp,jtmp,ptmp
c     data(itmp,jtmp) = ptmp
c
100  continue
c
c *** cal mass/locations , (i,j index)
c
c     do 200 i = 1,imax
c     do 150 j = 1,jmax
c
c         tot = depth(i,j)*data(i,j)*fac
c
c     write(10,201) i,j,tot
c

```

```
masdis.f      Thu Jun 20 14:08:21 1996      2

150  continue
200  continue
c
201  format(2i5,e12.4)
c
      stop
      end
```


masdis2.f

Tue Aug 27 12:21:50 1996

1

Program masdis2

```

c
c *** sludge mass distribution/grid for elements for k-basin ***
c *** for micro Ci/mL input
c *** output in g/cubical
c *** set to cubical no. system
c *** on a cubical by cubical bases
c
c *** initializations and dimensions
c
    dimension depth(67,76), data(67,76)
    character*40 dfile, infile, outfile
c
    dsun = 0.0
    psun = 0.0
c
    area = 881.
    fac = area*1.e-6
c ***
c *** open input files
c
    write(6,*) 'Enter name of depth data file'
    read(5,13) dfile
13  format(a40)
    write(6,*) 'Enter name of parameter data file'
    read(5,13) infile
    write(6,*) 'Enter name of output data file'
    read(5,13) outfile
    open(8,file=dfile,status='old')
    open(9,file=infile,status='old')
    open(10,file=outfile)
    rewind 8
    rewind 9
    rewind 10
c
c *** constants
c
    write(6,*) 'Enter conversion factor for isotope Ci to grams'
    read(5,*) confac
    fac = fac*confac
c
    imax = 67
    jmax = 76
    nrec = imax*jmax
c
c *** read data into array
c
    do 100 k = 1,nrec
c
c *** depth data
    read (8,*) itmp,jtmp,dtmp
    depth(itmp,jtmp) = dtmp
c
c *** input parameter file
    read (9,*) itmp,jtmp,ptmp
    data(itmp,jtmp) = ptmp
c
100 continue
c
c *** cal mass/locations , (i,j index)
c
    do 200 i = 1,imax
    do 150 j = 1,jmax
c

```

masdis2.f Tue Aug 27 12:21:50 1996 2

```
      tot = depth(i,j)*data(i,j)*fac
c
      write(10,201) i,j,tot
c
150  continue
200  continue
c
201  format(2i5,e12.4)
c
      stop
      end
```

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DISTRIBUTION SHEET

To Distribution	From Spent Nuclear Fuel Evaluations/8M710	Page 1 of 1 Date 09/06/96
Project Title/Work Order Spent Nuclear Fuel Project		EDT No. 617436 ECN No.

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
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U.S. Department of Energy.
Richland Operations Office

J. Shuen	S7-41	X			
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Mac Technical Services Company

G. Baston	R3-82	X			
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Pacific Northwest Laboratory

K. L. Silvers	K9-08	X			
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Westinghouse Hanford Company

C. J. Alderman	R3-48	X			
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R. B. Baker (2)	H0-40	X			
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L. D. Bruggeman	H0-40	X			
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J. C. Fulton	R3-11	X			
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S. L. Hecht (3)	H0-40	X			
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B. J. Makenas	H0-40	X			
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F. M. Mann	H0-31	X			
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R. P. Omberg	H0-40	X			
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M. J. Packer	R3-48	X			
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K. L. Pearce (3)	R3-48	X			
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D. J. Watson	X3-79	X			
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T. L. Welsh	T6-07	X			
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Central Files (orig + 1)	A3-88	X			
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BPC	A3-84	X			
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