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August 21, 1989

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WASTE ASSESSMENT RADIOLOGICAL CHARACTERIZATION OF THE WELDON SPRING SITE RAFFINATE PITS

Enclosed is a copy of the "Waste Assessment Radiological Characterization of the Weldon Spring Site Raffinate Pits" for your retention.

Sincerely,

R. R. Nelson

R. R. Nelson
Project Manager
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Enclosure:
As stated

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(CONTRACT NO. DE-AC05-86OR21548)

WASTE ASSESSMENT RADIOLOGICAL CHARACTERIZATION OF THE WELDON SPRING SITE RAFFINATE PITS

For The :
Weldon Spring Site Remedial Action Project
Weldon Spring, Missouri

Prepared By MK-Ferguson Company And Jacobs Engineering Group

AUGUST 1989 REV. 0

U.S. Department Of Energy
Oak Ridge Operations Office
Weldon Spring Site Remedial Action Project

Weldon Spring Site Remedial Action Project

WASTE ASSESSMENT RADIOLOGICAL CHARACTERIZATION OF THE WELDON SPRING SITE RAFFINATE PITS

August 1989

DOE/OR/21548-062 Rev. 0

Prepared by

MK-FERGUSON COMPANY
and
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7295 Highway 94 South
St. Charles, Missouri 63303

for

U.S. DEPARTMENT OF ENERGY
Oak Ridge Operations Office
Under Contract No. DE-AC05-86OR21548

RADSLUDG/TXTJOANN

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ABSTRACT

As part of the remedial investigation efforts conducted at the Weldon Spring Site Remedial Action Project (WSSRAP), it was recognized that an assessment of the nature and extent of the types of waste in the Weldon Spring Raffinate Pits (WSRP) was necessary to evaluate treatment and disposal alternatives. A sampling plan was developed, therefore, which detailed sample locations, sample parameters, and sampling techniques. The sampling effort consisted of collecting 145 samples from 42 locations. The sampling locations were evenly distributed across each of the four raffinate pits in terms of both area and depth.

The samples were analyzed for long-lived radionuclides from the natural uranium and natural thorium transformation series. The average, standard deviation, minimum, and maximum were determined for the selected radionuclides for each pit. The data were then evaluated and interpreted specific to each pit and for each radionuclide.

At a later date the surface waters of each pit were sampled and similarly analyzed. This type of information is available for non-radiological parameters in a companion report titled "Waste Assessment Chemical Characterization of the Weldon Spring Site Raffinate Pits, 1989."

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1 INTRODUCTION

This report presents the waste assessment radiological contamination data for the Weldon Spring Raffinate Pits (WSRP). Sample collection methods, sampling equipment decontamination techniques, analytical procedures and analytical results are also presented in this report, as well as interpretations of the results of sample analyses. The objective of this waste assessment was to supply data needed for sludge/sediment treatability studies which in turn will be necessary for the development and evaluation of remediation alternatives, design of the selected alternative, and verification of remedial effectiveness.

As part of the remedial investigation efforts conducted at the Weldon Spring Site Remedial Action Project (WSSRAP), it was recognized that an assessment of the nature and extent of the types of waste in the WSRP was necessary to evaluate treatment and disposal alternatives. In this regard a sampling plan was developed (Reference 5) which detailed sample locations, sample parameters, and sampling techniques. The final plan included input from the Environmental Protection Agency and the Missouri Department of Natural Resources. This report is a summary of the results obtained by implementing the sampling plan.

1.1 PURPOSE

The purpose of the radiological characterization of the sludge/sediment material within the pits is to define the degree of contamination and to help quantify the magnitude of the effort which will be required to ultimately dispose of the wastes. The variability of contaminant types within the sludges will determine the disposal alternatives to be evaluated. Knowledge of these contaminants is required to develop the

rationale behind liner engineering, compatibility testing, and radon barrier design.

1.2 SCOPE

This sampling effort consisted of collecting 145 samples from 42 locations. Sampling locations were evenly distributed with regard to area and depth across each pit.

This report reviews relevant historical data, summarizes previously identified data needs (Reference 5), describes sample collection procedures, interprets sample analytical results, and presents quality assurance data associated with sampling of the raffinate pit sludges. The sludges were analyzed for selected radionuclides from the natural uranium and thorium transformation series. A companion report assesses the chemical (nonradiological) characteristics of the sludges (Reference 6). A forthcoming report will assess the physical properties of the sludges (Reference 10). The scope of this report is limited to the radiological characterization of the raffinate pit sludges.

2 BACKGROUND

2.1 SITE HISTORY

In 1956, the Atomic Energy Commission (AEC) acquired about 89 hectares (ha) (220 acres) of the original Weldon Spring Ordnance Works property from the Department of the Army (DA) for use as the Weldon Spring Uranium Feed Materials Plant (WSUFMP). The WSUFMP operated between 1957 and 1966 and during that time processed uranium ore concentrates and recycled scrap to produce pure uranium trioxide, uranium tetrafluoride, and uranium metal. On average, 16,000 tons of uranium materials were processed at this plant per year. Thorium ore concentrates were also processed. These processes generated several chemical and radioactive waste streams, including raffinate streams from the refinery operation and magnesium fluoride slurry streams (washed slag) from the uranium recovery process. These streams were slurried to the pits where the solids settled out and the supernatant liquids drained to the plant process sewer which drained off site to a natural drainageway and ultimately to the Missouri River. The solids remaining in the pits consist of silica and other insolubles associated with the yellow cake ore feed materials, along with hydroxides and other precipitates formed from the pH neutralization of the raffinates with lime. Washed slag residues from the uranium metal production operation were also discharged to the pits. Figure 2-1 shows the location of the Weldon Spring Site. Figure 2-2 is a plan view of the Weldon Spring Raffinate Pit (WSRP) area.

After the plant was closed by the AEC, the DA acquired the facility in 1967 to convert it to herbicide production. The project was cancelled before it became operational.

The 21-ha (52-acre) portion of the site that contains the four raffinate pits was transferred back to the AEC in 1971. As

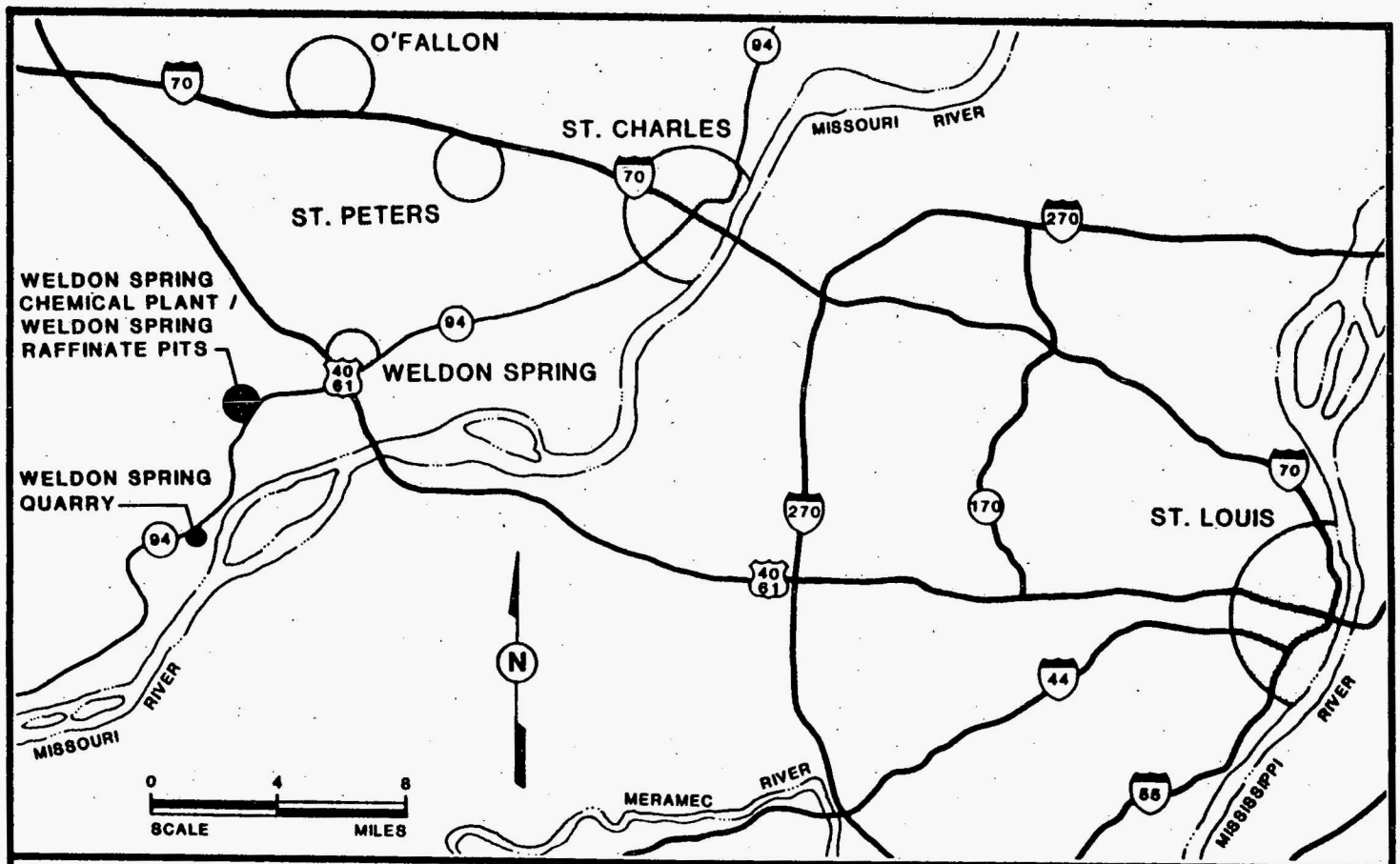


FIGURE 2-1

AREA AND VICINITY MAP, WELDON SPRING SITE, WELDON SPRING, MISSOURI

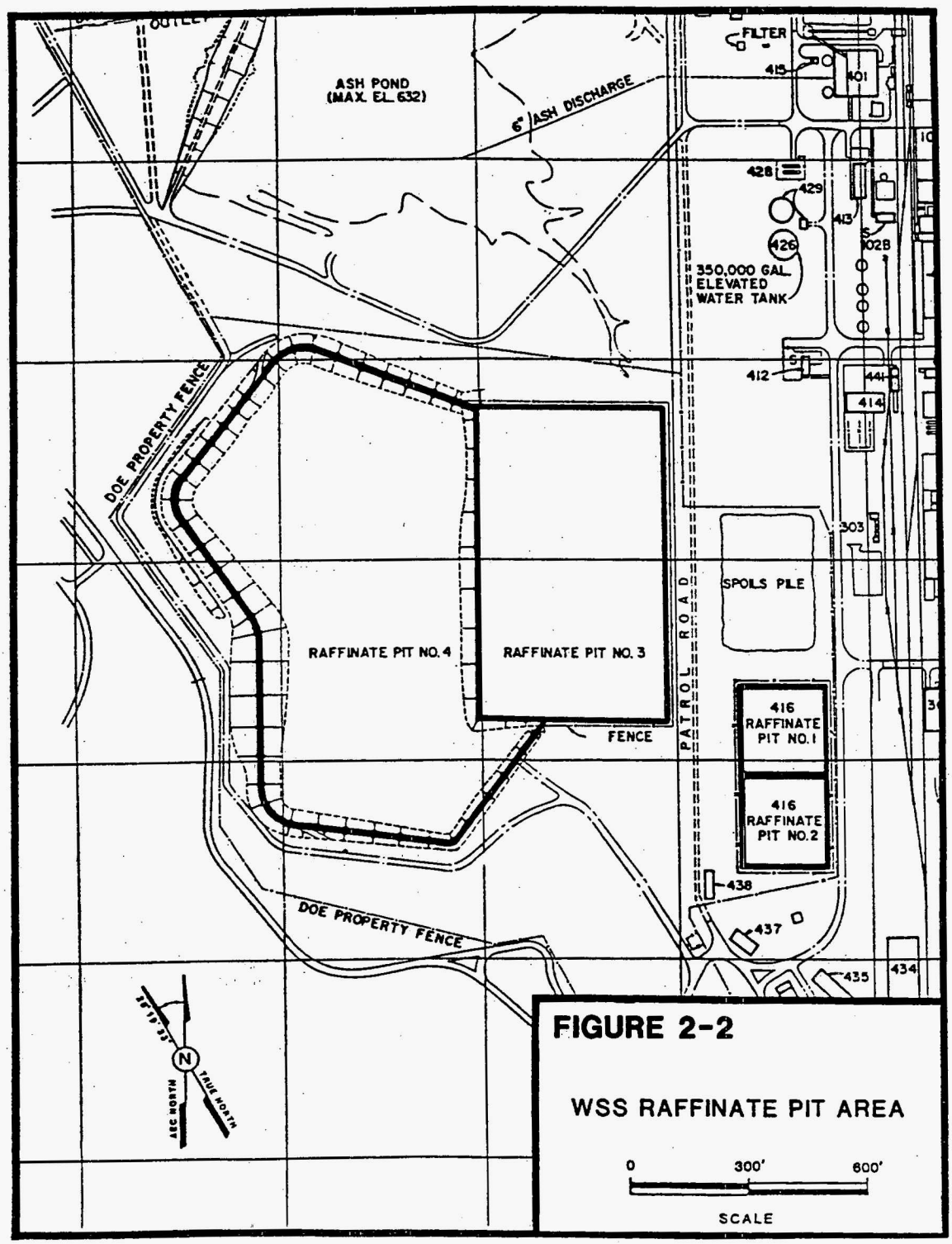


FIGURE 2-2

WSS RAFFINATE PIT AREA

the successor agency to the AEC, the U.S. Department of Energy (DOE) has assumed responsibility for maintenance of the entire site including the WSRP area. A more complete site and project history along with a description of the environmental setting and project plan can be found in the Weldon Spring Site Remedial Action Project (WSSRAP) RI/FS-EIS Work Plan (Reference 10).

2.2 PHYSICAL DESCRIPTION OF PITS

Raffinate Pits 1 and 2 were constructed in 1958 adjacent to each other on nearly level terrain. Each pit covers an area of about 0.5 ha (1.2 acres) and has a depth of about 4 m (13 ft). The dikes of these two pits are approximately 1 m (3 ft) above the surrounding grade. Pits 1 and 2 each contain approximately 13,700 m^3 (17,900 cy) and 14,500 m^3 (19,000 cy) of low-level radioactive residues from past uranium refining and metal production operations. These waste volumes represent 97% and 103% of the capacity of each of the two pits, respectively.

Pit 3 was constructed in 1959 with a design volume of 127,500 m^3 (166,700 cy), a surface area of approximately 3.4 ha (8.4 acres), and a depth of about 3.5 m (11 ft). The natural terrain slopes downward toward the west boundary so that the dikes around Pits 3 and 4, although approximately at the same elevation as those around Pits 1 and 2 are, in fact, much higher with respect to the original grade. A portion of the dike in the northeast corner of Pit 3 was constructed on existing terrain so that the dike is about 7 m (23 ft) above original grade in that area. Pit 3 contains approximately 98,800 m^3 (129,200 cy) of radioactive residues from past uranium refining and metal production operations and is 78% filled.

Pit 4 was constructed in 1964 with a design volume of 339,800 m^3 (444,400 cy) and is approximately 7% filled. The east dike of Pit 4 is common to the west dike of Pit 3. The west dike of Pit 4 extends to a maximum of about 11 m (35 ft) above the existing grade. Approximately 23,100 m^3 (30,200 cy) of radioactive materials are stored in Pit 4, and the residue fill is irregular across the pit. Pit 3 is designed to overflow into Pit 4 through a connecting pipe 2 m (7 ft) below the top of the common dike.

Table 2-1 presents the surface area, volume, and content of each of the four pits. The total waste volume for each pit was calculated as a result of the characterization effort described by this report. Volumes for Pits 1, 2, and 3 are near the values found in a previous report (Reference 1). However, the volume of Pit 4 was found to be considerably less than previously indicated. This discrepancy is attributed to the WSSRAP sampling effort providing better areal coverage of Pit 4 surface; i.e., more sample locations.

The sludge material in the pits is covered with water for most of the year. The amount of water in the pits varies depending on the climatic conditions of a given year. During the hot, dry summer months, the surface water in Pits 1 and 2 often evaporates, leaving the raffinate sludge with a dry and cracked surface. The level of water in Pits 3 and 4 also varies, but past observation has found some surface water always present.

Maintenance, surveillance, and environmental monitoring have been continually conducted at the WSRP site since the former DOE contractor, Bechtel National, Inc., began operation in 1981. The site is fenced, posted, and patrolled by security guards. The grass is mowed, brush is cleared for access to each pit, and the fences are repaired as necessary.

TABLE 2-1
Surface Area and Volume of the Weldon Spring Raffinate Pits

Pit	Year Constructed	Surface Area (acres)	Total Pit Volume (cy)	Total Waste Volume (cy)	Percent Filled (cy)
1	1958	1.2	18,500	17,900	97
2	1958	1.2	18,500	19,000	103
3	1959	8.4	166,700	129,200	78
4	1964	15.0	444,400	30,200	7
TOTALS		**25.0**	**648,100**	**196,300**	

Note: To convert acres to hectares, multiply by 0.4047.

To convert cubic yards to cubic meters, multiply by 0.7646.

To convert tons to kilograms, multiply by 0.9071.

Ref. BNI, 1984 with "Total Waste Volume (cy)" and "Percent Filled modified as a result of this characterization effort.

In 1982, a portion of the dike around Pit 4 was repaired to stabilize a shallow, circular arc slide. The slide occurred because of the steep (38-47%) side slopes of sections of the existing dikes. The side slopes of Pit 4 were constructed at undesirably steep slopes in this section because a perimeter road encroached on the space needed for construction.

2.3 PROCESS WASTE DESCRIPTION

Three major waste types are present at the WSRP site:

1. Neutralized raffinate liquors generated from uranium refining operations, including washed slag residues from uranium metal production operations and raffinate solids from the processing of thorium recycle materials. This is the material covered within the scope of this report.

2. Contaminated water ponded on each raffinate pit.

3. Contaminated rubble.

Each of these waste types is addressed in greater detail in the following text.

2.3.1 Neutralized Raffinate Liquors

Neutralized raffinate liquors were generated as follows: the Weldon Spring Uranium Feed Materials Plant (WSUFMP) received uranium ore concentrations from various uranium mills across the U.S. This yellow cake feed material was ultimately dissolved in a process stream containing nitric acid solution. This solution contained the dissolved uranium along with all the other impurities found in the ore concentrates. Once the uranium was stripped from the solution, the resulting waste was mixed with lime to produce what is referred to as neutralized raffinates.

These neutralized raffinates were discharged directly to the raffinate pits.

In the final stage of the uranium production process, uranium tetrafluoride was reacted with magnesium producing uranium metal and magnesium fluoride. The magnesium fluoride slag was then redissolved with yellow cake feed material to recover unreacted uranium contained in the slag. The remaining magnesium fluoride, or washed slag, was deposited in the pits. Neutralized raffinates and washed slag were processed in Building 103, the digestion and denitration building of the WSUFMP.

The residues contained in Pits 1, 2, and 3 consist of the neutralized raffinates and washed slag residues as described above.

Pit 4 contains the same types of residues that are present in Pits 1, 2, and 3 plus raffinate solids from processing of thorium-232 (Reference 7). It also contains recycle materials and significant quantities of drums and rubble placed during and after closure of the feed materials plant. Near the end of production at the feed materials plant, uranium was used to purge thorium wastes from all steps of the process. Wastes from this purge were disposed of in Pit 4.

Radium-226 is present in the raffinate pits due to both the decay of uranium to radium and trace amounts in the yellow cake. In addition, some feed materials processed in the early years of operation at the WSUFMP were high-grade uranium ore which would contribute both thorium-230 and radium-226 to the wastes in the raffinate pits. However, most of the radium was removed at the uranium mill and disposed of with the mill tailings (usually close to the source of the ore). Some

thorium-230 was retained with the uranium when raw uranium ore was processed into yellow cake. Processes at the feed materials plant were designed to remove as much metals, siliceous material, and other impurities (including thorium-230) from the uranium as possible and include them with waste sent to the raffinate pits.

2.3.2 Contaminated Water

Approximately 54 million gallons of water is currently ponded on the raffinate pits. Section 2.4.4 of this report provides a brief discussion of the analysis performed on these waters.

2.3.3 Contaminated Rubble

The contaminated rubble consists of drums and steel scrap dumped during closure of the WSUFMP and when the Army began conversion of a portion of the plant for herbicide production. The only known dumping was into Pit 4. All of the rubble is presumed to be radiologically contaminated since it originated from the WSUFMP.

2.4 PREVIOUS STUDIES

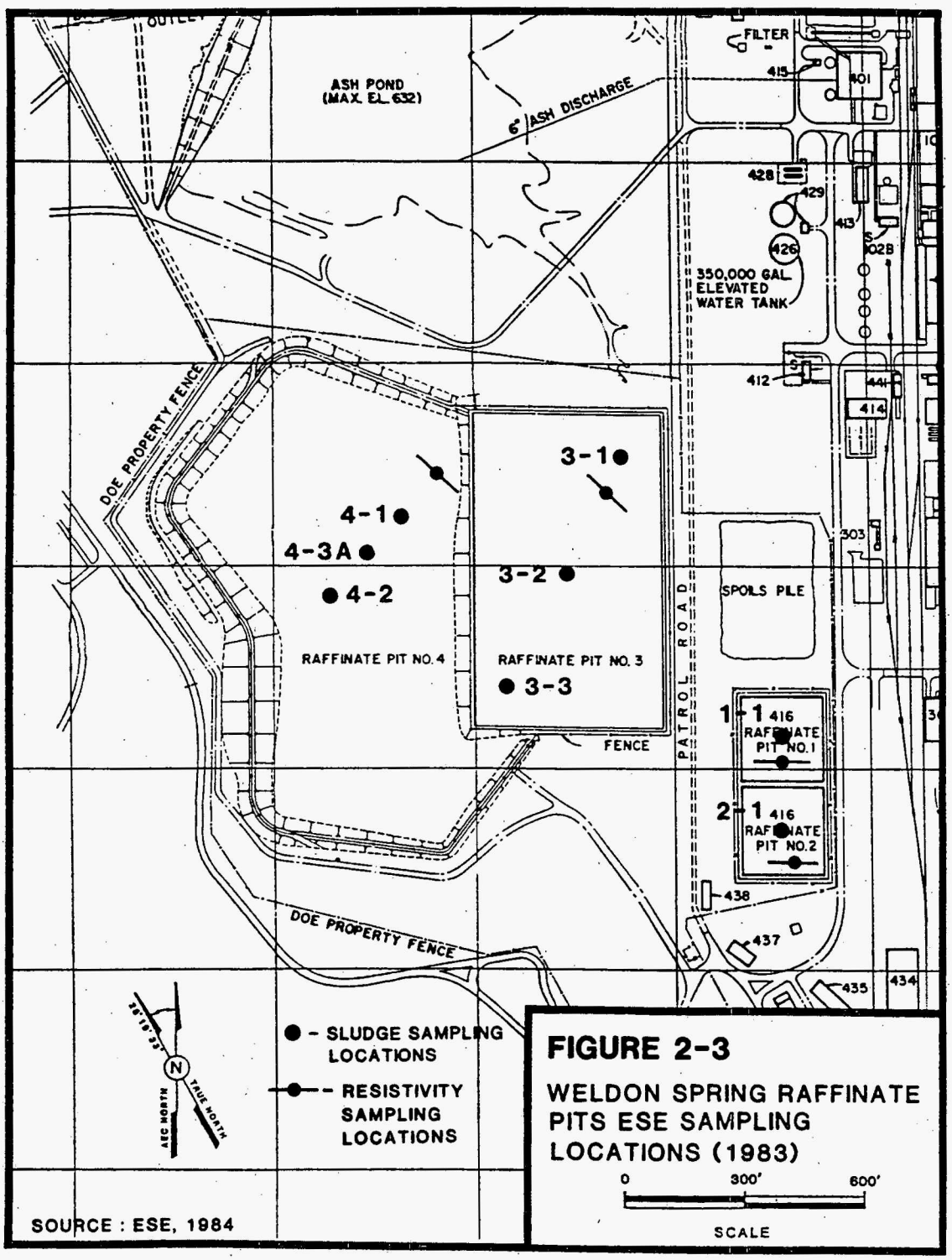
Two previous studies have been performed regarding various properties of the raffinate pit sludges and sediments. Bechtel National, Inc. (BNI) subcontracted with Eberline Instrument Corporation in 1983 to take samples of the waste in the raffinate pits and analyze them for stable metals and radionuclides. In 1986, BNI obtained samples of the raffinate pit sludges and subcontracted Thermoanalytic/Eberline Laboratory to perform radiological analysis and analysis for EP toxicity, PCBs and pesticides, reactivity, ignitability, and pH. In 1987

the current Project Management Contractor (PMC) performed a characterization of the raffinate pit surface waters.

2.4.1 Bechtel National, Inc. Study, 1983 (with Eberline)

The samples were collected and analyzed by Eberline instrument Corporation in 1983 (Reference 1). The data reported are analytical results on a single mixed composite sample prepared from multiple- location samples taken from each pit. A portion of the sample collection procedure included use of a Shelby tube driven from a polystyrene barge. Sample locations are depicted in Figure 2-3. No description of sampling rationale, method, depths, number of samples, or sample size is available.

Results of analyses conducted during that study of the radiological components of the raffinate sludge in each pit are presented in Table 2-2. The results of the chemical components analyses are presented in a companion report (Reference 6). No data validation information is currently available for that sampling exercise. Additionally, the sampling effort was severely limited by lack of sampling information and the small number of sampling locations; i.e. lack of representativeness. Given the later more extensive study performed by BNI in 1986 (Section 2.4.2) the data from the earlier study is probably of little use.



SOURCE : ESE, 1984

FIGURE 2-3

WELDON SPRING RAFFINATE PITS ESE SAMPLING LOCATIONS (1983)

TABLE 2-2
Raffinate Pits Radionuclide Contents From the BNI, 1983 Study
(pCi/g dry)

Radioisotope	Pit 1	Pit 2	Pit 3	Pit 4
Radium-226	430±130	440±130	460±130	11±3
Radium-228	850±85	200±20	100±10	60±10
Thorium-232	100±20	120±20	120±20	120±20
Thorium-230	24000±1000	24000±1000	14000±1000	1600±100
Uranium-238	710±70	470±40	520±50	620±60
Uranium-234	810±80	560±50	570±50	610±60
Uranium-235	40±5	30±4	30±4	30±4

(Reference 1)

Note: The ± values indicate measurement accuracy at an unknown sigma level.

2.4.2 Bechtel National, Inc. Study, 1986 (with Thermoanalytic/Eberline Laboratory)

BNI conducted an initial Resource Conservation and Recovery Act (RCRA) characteristic sampling program for the Weldon Spring Site (WSS) Raffinate Pits in 1986. The 28 sampling locations are shown on Figure 2-4. These locations were chosen using a random number generator method. At each location, as many as three samples were obtained and sent to Eberline's laboratory in Albuquerque, New Mexico for radiological analyses. Average concentrations are given in Table 2-3. The raw data may be found in Attachment C. No further information is available regarding sampling rationale or sampling method. Descriptions of sample locations, sample depths, sample sizes and number of samples is available from the laboratory analytical report. No information is available pertaining to either field or laboratory radiological data validation procedures or results. Because this data set is more or less complete, it is useful for qualitatively indicating the concentrations of radionuclides present in the sludges. The lack of data validation information, however, makes it difficult to quantitatively justify the data.

Eighteen of the samples were analyzed by Eberline Analytical Laboratories (EAL) for EP toxicity, reactivity, ignitability, PCBs and pesticides, and pH. All analytical results reported were below regulatory limits, and EAL concluded that the material did not exhibit any of the four characteristics of RCRA hazardous waste (Reference 2).

2.4.3 WSSRAP Project Management Contractor Study, 1987

Surface water samples were collected from the four raffinate pits as a part of the Phase I Water Quality Assessment conducted in April 1987 by the PMC. Representative samples for each pit

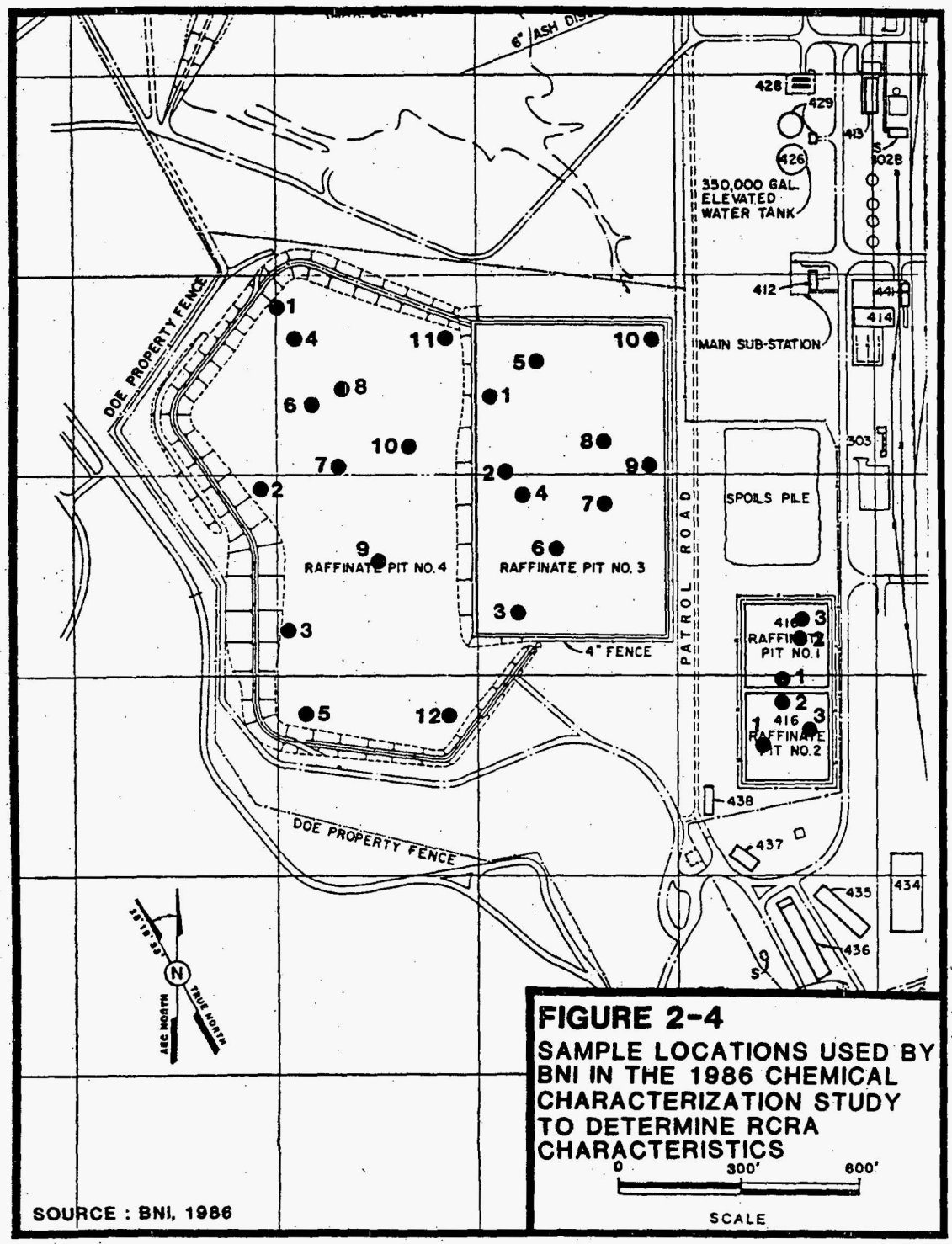


FIGURE 2-4

SAMPLE LOCATIONS USED BY BNI IN THE 1986 CHEMICAL CHARACTERIZATION STUDY TO DETERMINE RCRA CHARACTERISTICS

0 300' 600'

SCALE

SOURCE : BNI, 1986

TABLE 2-3
RAFFINATE PITS RADIONUCLIDE CONTENTS FROM THE BNI 1986 STUDY
(pCi/g dry)

RADIONUCLIDE	PIT 1	PIT 2	PIT 3	PIT 4
U-234	1057 ± 585	910 ±571	1588 ± 1465	318 ± 577
U-235	39 ± 25	35 ± 22	70 ± 64	13 ± 25
U-238	900 ± 567	844 ±561	1580 ± 1491	319 ± 577
Th-230	1541 ±1499	26673 ±30045	32897 ±52253	737 ± 964
Ra-226	2404 ± 932	1452 ±1245	1211 ± 905	50 ± 58
Pb-210	2657 ±1650	2384 ±1588	1785 ± 1132	114 ± 105
Po-210	2587 ±1550	2119 ±1513	1598 ± 1081	77 ± 101
Th-232	16 ± 17	108 ±139	357 ± 602	45 ± 46
Ra-228	98 ± 66	195 ±120	189 ± 85	182 + 235
LOCATIONS SAMPLED	3	3	10	12
TOTAL NO. SAMPLES	7	9	26	13

(Reference 1)
NOTE: The ± values indicate measurement accuracy at one standard deviation.

were collected from the shore and composited from at least four locations per pit. These samples were collected using a stainless steel bailer which was slowly lowered to a point just above the sediment. These samples were analyzed for nineteen radiological and nonradiological parameters. The radiological results are summarized in Table 2-4. A more detailed assessment, including nonradiological aspects, is available in the Phase I Water Quality Report (Reference 4).

On the basis of this analysis, further analysis was deemed necessary to characterize the waters ponded in the pits. The additional sampling effort as well as the results are described in Section 3.4.

2.4.4 Summary of Previous Characterization Activities

Radiological and chemical characterization from previous studies have indicated the types of radionuclides and chemicals present in the raffinate pit sludges. From a radiologic standpoint, further sampling was determined necessary to define the radioactive source term present in the raffinate sludge.

Physical characterization from previous studies is believed to be adequate to conclude that the sludges exist in a highly heterogeneous physical state and that the solids content is sufficiently high to preclude the effective use of mechanical dewatering techniques. Further testing was necessary, however, in connection with treatability studies. Previous physical characterization is summarized in the Weldon Spring Site Waste Assessment Raffinate Pit Sampling Plan (Reference 5).

Previous studies lacked either adequate sampling effort, data validation information, or both, making previous data sets unacceptable in terms of quantification of radionuclide

TABLE 2-4

Radionuclide Contents in
Raffinate Pits Ponded Water (pCi/L), 1987

Radionuclide	Pit 1	Pit 2	Pit 3	Pit 4
U-natural	45	300	130	2,400
Th-230	*	13	16	<5
Ra-226	61	28	42	3
Th-232	*	<6	<6	<5
Ra-228	<3	6	32	13

* No data available

(Reference 4)

concentrations. The prior studies also did not satisfy the accuracy requirements set forth in the sampling plan developed by the WSSRAP (Reference 5). Previous studies did, however, give ample information regarding the heterogeneity of the sludges as well as sludge constituents and therefore were useful in developing a sampling rationale and sampling scope.

For the reasons discussed above, the data used exclusively in the following sections of this report have been derived from the most recent study conducted by the PMC as presented in the WSSRAP Raffinate Pit Sampling Plan (Reference 5). Also, the WSSRAP sampling effort provides more representative sampling results than previous sampling efforts with regard to number of samples and sample locations. It should be noted, however, that some differences exist between the WSSRAP data set and the BNI 1986 data set. In 17 cases the mean radionuclide concentration from the BNI 1986 data set could be compared to the mean radionuclide concentration from the WSSRAP data set. Mean concentrations could not be compared for Th-228 because the BNI 1986 data set did not include this radionuclide. Mean concentrations could not be compared for Th-232 in Pits 1, 2, and 3 for reasons discussed later in Section 3.3.5. In 10 of 17 estimates of mean radionuclide concentrations, there is a statistically significant difference of the mean values between the two data sets. The test used was the standard two-tailed t-test for differences between means for sample sizes less than 30 and a t-critical value at 90% confidence level. There was no discernible overall pattern of bias between the data sets with regard to concentration value, concentration heterogeneity, or radionuclide.

3 SAMPLING

Sampling was accomplished by a PMC subcontractor in one phase for Pits 1, 2, and 4 and in two phases for Pit 3. The first sampling phase occurred from July 1988 through October 1988 and the second sampling phase during January 1989. Figure 3-1 exhibits the sample location layout.

Field activities began with the first phase sampling of Pit 3 which consisted of obtaining samples from nine locations. The sampling operation was then moved to Pit 4 where nineteen locations were sampled. The operation then moved to Pits 1 and 2 respectively where six locations were sampled in each pit. Sampling for the second phase consisted of collecting samples from two locations in Pit 3. These locations were sampled from a shore-based platform due to lack of water in the pit.

3.1 RADIOLOGICAL SAMPLING RATIONALE

The purpose of the radiological characterization of the raffinate pit sludges was to accurately determine the concentrations of radionuclides in the sludges. The importance of accurately determining these concentrations is twofold. First, the radium-226 source term must be estimated to design an effective radon-222 barrier as part of an engineered cover for a disposal cell. Second, the concentrations must be determined to help assess the feasibility of recovering constituents (e.g. radionuclides or metals) from the sludges.

The radon barrier of a disposal cell will likely be designed for a 1,000-year design life (40 CFR 192). Significant concentrations of Ra-226 exist in the sludge today and, in 1,000 years, 35% of the Th-230 will transform into Ra-226. Sixty-five percent of the original Ra-226 will also still be present. It is important, then, to estimate as accurately as possible the

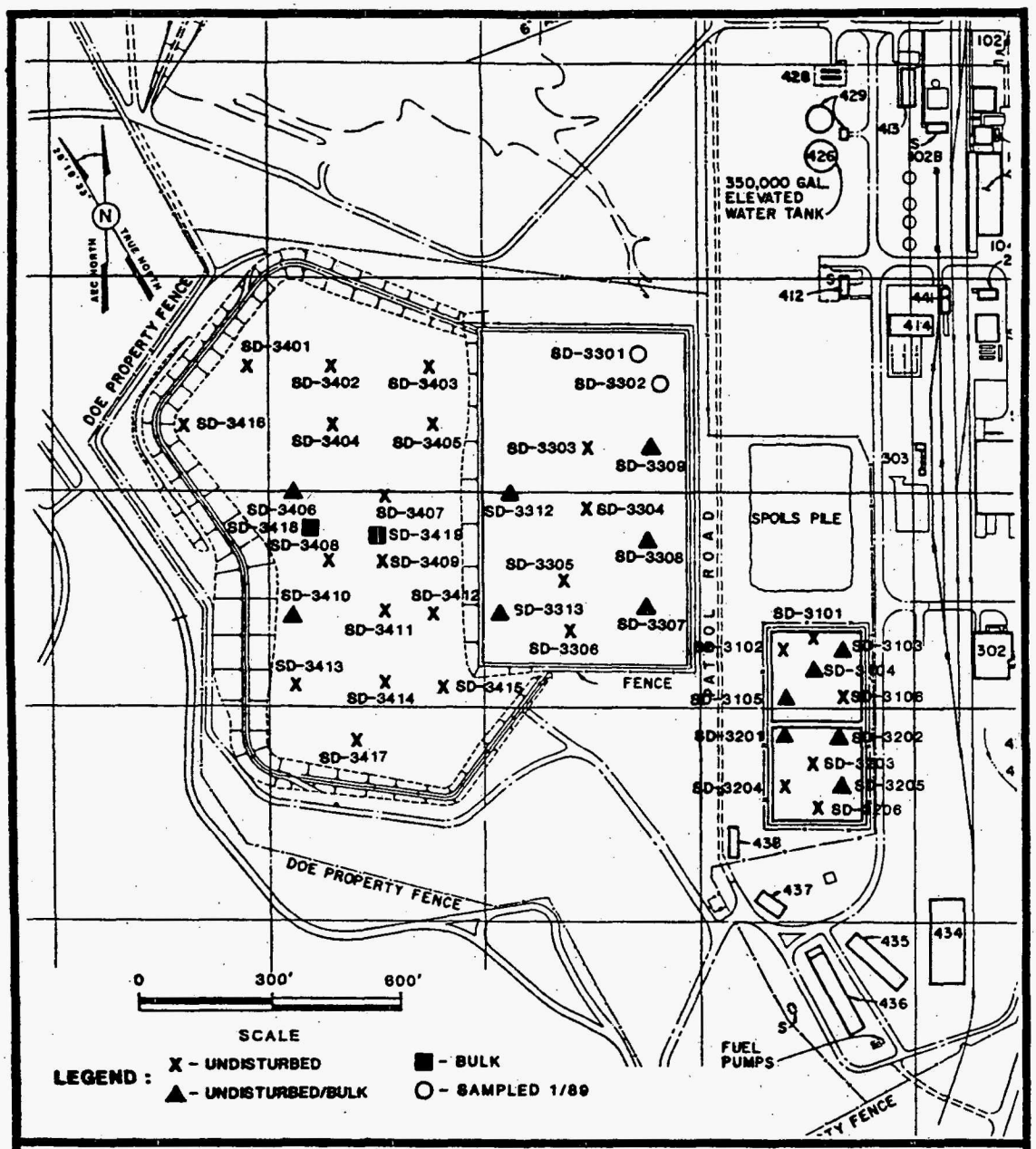


FIGURE 3-1

SAMPLING LOCATIONS FOR THE WSS RAFFINATE PITS CHARACTERIZATION

concentrations of these two radionuclides in the raffinate pit sludges in order to maximize the accuracy of subsequent radon barrier thickness calculations.

In 1986, the raffinate pit sludges were sampled by Bechtel National, Inc. (BNI). Prior to the current sampling effort this is the most recent, most comprehensive sampling effort of the sludges that has been performed. That effort showed that there was large pit-to-pit variability for all radiologic species.

In order to design a more comprehensive sampling plan, the BNI data were used to determine the number of samples per pit necessary to characterize the average radionuclide concentrations of each pit at a given level of statistical confidence. Details of this technique are given in the raffinate pit sampling plan (Reference 5). The accuracy determined to be adequate for this characterization was a 90% confidence interval about the mean with a relative error of the mean of 30%. The BNI data for Th-230 and Ra-226 were tabulated and the averages and standard deviations calculated. Only Th-230 was evaluated further because this radionuclide dominates (for the 1,000-year design-life of the disposal cell) the Ra-226 source term. Additionally, the statistical variability of the Ra-226 concentration was less than the statistical variability of the Th-230 concentration. The statistical variability of the uranium species concentrations was also less than the Th-230 concentration variability. Thus the number of sampling locations needed in each pit was a direct result of the estimate of Th-230 variability based on the 1986 BNI data set.

For completeness, among other reasons, it was planned that the sludge samples be analyzed for total uranium, thorium-232, thorium-230, thorium-228, radium-226, and radium-228. Six samples were also designated to be analyzed for uranium-238, uranium-235, and uranium-234. In all cases results will be

reported as activity per unit weight on a dry weight basis. The analysis results for each radionuclide will then be used to develop specific radionuclide source terms (total activity and concentration) for each pit. These source terms will then be used in various pathway calculations and associated risk assessments. The source term values will also be considered with regard to handling and stabilization of the sludges in the final disposal cell design.

The derived sample requirements were then scaled volumetrically relative to Pit 3. More specifically, each pit was planned to be sampled at a rate of 2.6 samples per thousand cubic yards of sludge. Considering that Pit 3 was estimated to contain approximately two-thirds the total sludge volume, the number of samples needed for the other pits could be volumetrically scaled relative to Pit 3 without significant increase in error but with significant cost savings. This caused the number of samples to be reduced for Pits 1 and 2 and slightly increased for Pit 4. Because of the reduced number of samples in Pits 1 and 2, the sludges in those pits may be characterized at a lower level of accuracy than discussed above as being adequate. However, approximately 85% of the total sludge volume (i.e. all four pits) would still be characterized with at least the desired level of accuracy. Finally, the number of samples collected by BNI in 1986 was subtracted from the scaled number of samples (see above) to derive the number of samples to be collected.

As sampling proceeded, additional changes were made in the number of samples required from Pits 3 and 4. Due to a lack of sludge in Pit 4 (it was shallower than estimated) the number of samples was decreased from 49 to 20. Due to shallow water limiting access in Pit 3 the number of samples was initially decreased from 50 to 34. During the second phase of sampling, seven samples were collected from Pit 3 making the total number

of samples collected from Pit 3 equal to 41. The implications of these changes are discussed in Section 3.3.3.

In March 1989 the surface water contained in each pit was sampled. The method of sampling and results are contained in Section 3.4 for this operation.

3.2 SAMPLE COLLECTION

3.2.1 Sample Location Access

The samples were collected using a barge-mounted drilling rig. The barge rig was maneuvered to specific sample locations by means of cables and two electric winches mounted on the barge. Water had to be pumped from Pit 4 to Pits 1 and 2 to raise the water level to the minimum needed to float the barge. Due to the summer drought, the water level above the sludge in these two pits had dropped to six inches. The depth of ponded water was increased to two feet to float the barge. The sampling crew transferred from barge to shore through the use of a 14-foot john boat powered by a gasoline motor. Sample locations were located by line-of-sight cross reference between survey grid stakes on each bank of the pits.

In the second phase sampling of Pit 3, a wooden platform was constructed. The platform was pulled into position by a truck driven on the pit berm. The two sample locations were in approximately six inches of water.

3.2.2 Method of Collection

The barge used during the first phase of sampling consisted of four steel sections with dimensions of 15 feet by 7.5 feet by 4 feet. The sections were connected together with a hole in the center from which to obtain samples. During the second phase of

sampling, a cathead and a tripod of aluminum poles were used in place of the motorized drilling rig. Undisturbed samples were collected with a piston sampler consisting of an outer tube and a coaxial piston that created a suction pressure within the tube. The tube was two feet long and three inches in diameter and made from steel. The samples were obtained by lowering the tube two feet followed by lowering 10-inch PVC casing around the tube to assure integrity of the hole. Bulk samples for physical tests were obtained by cleaning out a 10-inch PVC casing with a bailer. Samples at intervals of two feet were taken continuously through the sludge from surface to clay during the first phase of sampling. The sample interval was four feet during the second phase of sampling.

Undisturbed samples were extruded from the tubes to a stainless steel tray where pictures were taken. The sludge was then placed in appropriate containers with the use of funnels, spatulas, spoons, and probes. Parafilm was wrapped around the containers to prevent outside contamination.

3.2.3 Quantity/Containers/Preservation

Analysis of sludge materials required that samples be properly packaged to maintain sample integrity. Table 3-1 details the chemical container types, volumes used, and parameters tested as specified for different locations on aliquots from each container. The table also lists the methods by which the samples were preserved.

3.2.4 Decontamination of Sampling Equipment

Equipment that could possibly influence the chemical or radiologic character (either concentration or substance) of the samples through direct or indirect contact was decontaminated between uses. Each discrete undisturbed sample was collected

Table 3-1
Sample Containers Chemical Analysis

Parameters	Containers	Preservatives
Volatile Organics	2-40ml vials	Refrigeration
Organics--Semi-Volatile, Pesticides, PCBs, Nitroaromatics, Total Organic Carbon, Total Organic Halogens, Cyanides, Phenols	2-250ml wide-mouth amber glass jars	Refrigeration
Inorganics--Metals, Radiologic, Ionic Species	2-250ml wide-mouth amber glass jars	Refrigeration
Oil/Grease	1-1000ml wide-mouth amber glass jar	Refrigeration

with a sampler that had been decontaminated with pressure steam followed by a triple rinse with distilled water. Other sampling equipment that potentially could have come in contact with the sample material was decontaminated with pressure steam between sampling locations. The barge and drilling rig were decontaminated with pressure steam following sampling in each pit. The barge and drilling rig were also rinsed as needed with water from a tank placed on the barge. All equipment (funnels, trays, etc.) used in transporting the sludge from the piston tube to the sampling containers was washed with Alconox soap and water followed by a rinse of water.

No effort was made to decontaminate the wooden platform and it was not removed from the pit area.

The effectiveness of the decontamination was verified by the following methods: 1) visual inspection of the sampling components; 2) radiologic scan through the use of an alpha probe or GM probe (as appropriate); and 3) occasional collection of rinsate samples from the sampling tools.

3.2.5 Sample Container Labeling

All samples were assigned a specific number and all samples were labeled. A description of the numbering system and field report abbreviations is located in Appendix A of this report. Information included on the labels was the site name and address, sample number, sampling personnel, and date. Following completion of each label with the specific sample data, the labels were taped with clear plastic to protect the information and ensure that it remained legible.

3.3 SAMPLE ANALYSIS AND RESULTS

All sample analyses were performed according to industry standard testing protocols. Specific analysis criteria (procedures) are listed in Table 3-2 according to parameter of interest. The analytical method used for radium determinations followed "Prescribed Procedures for Measurement of Radiation in Drinking Water," August 1986 (Reference 8). The analytical method used for uranium and thorium followed "Eastern Environmental Radiation Facility Radiochemistry Procedures Manual," August 1984 (Reference 9). A list of approximate analysis detection limits can be found in Appendix B. It should be noted that no specific analytical procedures exist for determination of radionculides in raffinate sludges. The analytical laboratory determined that the procedures cited above were those most appropriate to adapt to the sludge analyses. It should also be noted that, contrary to Section 3.1, the analysis results were reported as activity per unit weight on a wet weight basis.

Tables 3-3, 3-4, 3-5, 3-6, and 3-7 show the locations and types of samples collected from each pit for the WSSRAP sampling effort. Table 3-8 provides a summary of sampling parameters and number of samples collected per pit. The chemical and physical parameters are included in Tables 3-2 through 3-8 for completeness. Discussion of rationale, procedures, and results for the chemical and physical parameters are available elsewhere (Reference 6).

The following sections summarize the data obtained from the WSSRAP raffinate pit sampling effort. The data is evaluated and interpreted specific to each pit and for each radionuclide. The raw data obtained from the WSSRAP sampling effort and discussed in the following sections may be found in Appendix B.

3.3.1 Pit 1

Nine samples were collected from three locations in Pit 1. The sample depths ranged from an interval of two to four feet to an interval of ten to twelve feet. The minimum, maximum, average, and standard deviation of the concentrations of each radionuclide are presented in Table 3-9.

For each radionuclide except Th-228 and Ra-226 the estimate of the mean meets the sampling plan requirement of 30% relative error at the 90% confidence level. The relative error for Th-228 is 38% and for Ra-226 is 33%. Noting that both the average concentration of Th-228 and Ra-226 in Pit 1 and the volume in Pit 1 are comparatively small, this occurrence is considered acceptable. Additionally, since the Th-230 concentrtion increasingly controls the Ra-226 concentration over extended time periods, this lack of accuracy in the Ra-226 estimate of the mean is considered acceptable.

3.3.2 Pit 2

Five samples were collected from three locations in Pit 2. The sample depths ranged from an interval of two to four feet to an interval of eight to ten feet. The minimum, maximum, average, and standard deviations of the concentrations are presented in Table 3-9.

For each radionuclide except Ra-228, Th-228 and Ra-226 the estimate of the mean meets the sampling plan requirements of 30% relative error at the 90% confidence level. The relative error for Ra-228 is 32%, for Th-228 is 39%, and for Ra-226 is also 39%. Noting that both the average concentrations of these radionuclides in Pit 2 and the volume in Pit 2 are comparatively small, this occurrence is considered acceptable. Additionally, since the Th-230 concentration increasingly controls the Ra-226

TABLE 3-2
Sample Analysis Criteria

Parameter	Standard Method of Analysis
Radiologic:	
Uranium and Thorium	EPA 520/5-84-006, Procedure 00-07
Radium	EPA 600/4-80-032
Chemical:	
Volatile Organics	CLP SOW #WA-87-J002
Semi-Volatile Organics	CLP SOW #WA-87-J002
PCBs	CLP SOW #WA-87-J002
Pesticides	CLP SOW #WA-87-J002
Metals (plus Li, Mo and Zi)	CLP SOW #WA-87-K026
Nitroaromatics	EPA Method 609 and USATHAMA Methodology
Inorganic Anions	EPA Method 300.0
Cyanides	CLP SW-846-9010
Phenols	EPA Method 420.2
Physical:	
Sludge Moisture Content	ASTM D2216
Sludge and Solid Specific Gravity	SMEWW Method 213E and ASTM D854
Sludge Capillary Moisture	ASTM D3152
Sludge Particle Size Analysis	ASTM D422
Sludge Viscosity and Gel Strength	See Note 1
Sludge Surface Charge	Zeta Meter
Atterberg Limits	ASTM 4318
Sludge Centrifuge Moisture Yield	ASTM D425
Sludge Consolidation	ASTM D2435
Sludge Phase Separation	See Note 2

Note 1: Viscosity and Gel Strength

Viscosity was be measured according to ASTM D4016. To measure gel strength, the viscometer was turned off and the grout or sludge allowed to stand for ten (10) minutes. The viscometer was then turned on at a low rate of shear (5 s^{-1} for a Fann viscometer) and the gel strength was read directly as the maximum deflection on the scale.

Note 2: Phase Separation

Phase separation, a measurement of drainable water, was determined by a settling test in a 250-ml graduate cylinder. A sludge sample (200 ml) was poured into the graduate and allowed to stand. Phase separation was calculated as the volume of clear, drainable surface water divided by the total initial volume X 100.

TABLE 3-3
Pit 1
Sampling Parameters

DEPTH LOCATION	0 - 2 ft.	2 - 4 ft.	4 - 6 ft.	6 - 8 ft.	8 - 10 ft.	10-12 ft.
1 - 1	V N S I P M	V N S I P M R	V N S I P M R	V N S I P M R	V N S I P M R	R
1 - 2	V N S I P M	V N S I P M R	V N S I P M	V N S I M	V N S I P M R	R
1 - 3	V N S M	V N S I P M	V N S I M R	V N S I M	V N S I M	
1 - 4	V N S I M	V N S I M	V N S I M	V N S I M	V N S I M	
1 - 5	S I M	S	S I M	S I M	S I M	
1 - 6	S I O M T X	S I O M T X	S I O M T X	S I O M T X	S O T X	

V = VOLATILES
S = SEMI-VOLATILES
P = PCBs/PESTICIDES
M = METALS
N = NITROAROMATICS
I = INORGANIC ANIONS
R = RADIOLOGICAL
O = OIL/GREASE
T = TOTAL ORGANIC CARBON
X = TOTAL ORGANIC HALOGENS

TABLE 3-4
Pit 2
Sampling Parameters

DEPTH LOCATION	0 - 2 ft.	2 - 4 ft.	4 - 6 ft.	6 - 8 ft.	8 - 10 ft.	10 - 12 ft.
2 - 1	V N S I P M	V N S I P M R	V N S I P M R	V N S I P M	V N S I P M	
2 - 2	V N S I P M	V N S I P M R	V N S I P M	V N S I M R	V N S I P M	
2 - 3	V N S I P M	V N S I P M	V N S I M	V N S I M	V N S I M R	
2 - 4	V N S I M	V N S I M	V N S I M	V	V	V
2- 5	S I O M T X	S I O M T X	S I M T X	S I O M T X	S I O M T X	
2- 6	S I M	S I M	S I M	S I M	S I M	S I M

V = VOLATILES
S = SEMI-VOLATILES
P = PCBs/PESTICIDES
M = METALS
N = NITROAROMATICS
I = INORGANIC ANIONS
R = RADIOLOGICAL
O = OIL/GREASE
T = TOTAL ORGANIC CARBON
X = TOTAL ORGANIC HALOGENS

TABLE 3-5
Pit 3
Sampling Parameters Phase 1

Depth Location	0 - 2 ft.	2 - 4 ft.	4 - 6 ft.	6 - 8 ft.	8 - 10 ft.	10 - 12 ft.	UPPER COMP.	MIDDLE COMP.	LOWER COMP.
3-3	V R	R	R	V R	R	R	N S I P M	N S I P M	N S I P M
3-4	V R	R	R	V R	I M R	V	N S I P M		N S I P M
3-5	R	V R		R	V R		N S I P M		N S I P M
3-6	R	V R	R	R			N S I P M		N S I P M
3-7	S N X P O R T	O V T R X	I O M T R X	O V T R X					
3-8	V P I R M	V N P S R	V I R M	S P N R	R				
3-9	V R	S I R M	V R	S I R M	V R	R			
3-12	V I M	S I M	S P I N M	S	V				
3-13	S I M	V I M	S I M						

V = VOLATILES
S = SEMI-VOLATILES
P = PCBs/PESTICIDES
M = METALS
N = NITROAROMATICS
I = INORGANIC ANIONS
R = RADIOLOGICAL

O = OIL/GREASE
T = TOTAL ORGANIC CARBON
X = TOTAL ORGANIC HALOGENS

Table 3-6
Pit 3
Sampling Parameters Phase 2

Depth Location	0 - 4 ft.	4 - 8 ft.	8 - 12 ft.	12 - 16 ft.
3-1	V, C, H S, P, I M, R	 P, I M, R	V, C, H S, P, I M, R	V, C, H S, P, I M, R, N
3-2	 M, R	V, C, H S, P, I M, R	V, P, I M, R, N	

V = VOLATILES
S = SEMI-VOLATILES
P = PCBs/PESTICIDES
M = METALS
N = NITROAROMATICS
I = INORGANIC ANIONS
R = RADIOLOGICAL

O = OIL/GREASE
T = TOTAL ORGANIC CARBON
X = TOTAL ORGANIC HALOGENS
C = CYANIDES
H = PHENOLS

TABLE 3-7
Pit 4 Sludge Sampling Parameters

DEPTH LOCATION	0 - 2 ft.	2 - 4 ft.
4 - 3	R S M I V P N	
4 - 4	R S M I V P N	
4 - 5	R S M I V P N	
4 - 6	R S M I V P N O T X	*R S M I V P N
4 - 7	R S M I V P N T X	
4 - 8	*R S M I V P N	
4 - 9	R S M I V P N	
4 - 10	*R S M I V P N	R V
4 - 11	R S M I V P N	
4 - 12	R S M I V P N	
4 - 13	R S M I V P N	
4 - 14	R S M I V P N	
4 - 15	R S M I V P N	
4 - 16	R S M I V P N	
4 - 17	R S M I V P N	
4 - 18	**R	
4 - 19	**R	

V = VOLATILES
S = SEMI-VOLATILES
P = PCBs/PESTICIDES
M = METALS
N = NITROAROMATICS
I = INORGANIC ANIONS
R = RADIOLOGICAL
O = OIL/GREASE
T = TOTAL ORGANIC CARBON
X = TOTAL ORGANIC HALOGENS

* Two radiological samples collected and analyzed, one undisturbed and one bulk.

** Radiological samples were aliquots from bulk samples.

TABLE 3-8
Sampling Summary

	Pit 1	Pit 2	Pit 3	Pit 4	Total
# Locations	6	6	11	19	42
# Samples	33	32	59	21	145
Particle Size	7	2	7	4	15
Moisture Content	9	6	21	10	43
Specific Gravity	9	6	21	10	43
Phase Separation	9	6	21	10	43
Viscosity	9	6	21	10	43
Atterberg Limits	9	6	21	10	43
5-gal. composite	23	15	49	10	92
Volatiles	20	21	23	17	81
Semi-Volatiles	30	29	23	16	98
PCBs/Pesticides	10	11	21	16	58
Metals	28	29	28	16	101
Nitroaromatics	20	18	15	16	69
Inorganic Anions	27	29	28	16	100
Radiological	9	5	41	22	77
De-con Rinsates *	1	1	2	1	5
Field Blanks *	0	0	0	0	0
Field Duplicates *	1	0	5	1	7
Total Organic Carbon	5	5	4	2	16
Total Organic Halogens	5	5	4	2	16
Oil/Grease	5	4	4	1	14
Phenols	0	0	4	0	4
Cyanides	0	0	4	0	4

* For this table these parameters refer only to radiological analyses.

concentration over extended time periods, this lack of accuracy in the Ra-226 estimate of the mean is considered acceptable.

3.3.3 Pit 3

Forty-one samples were collected from nine locations in Pit 3. For those samples collected during the first sampling phase the sample depths ranged from a sample interval of zero to two feet, to a sample interval of ten to eleven feet. The sample depths for the samples collected during the second phase of sampling ranged from an interval of zero to four feet, to an interval of 12 to 16 feet. The minimum, maximum, average, and standard deviations of the concentrations are presented in Table 3-9. For each radionuclide the averages meet the sampling plan requirement of 30% relative error at the 90% confidence level.

3.3.4 Pit 4

Twenty-two samples were collected from 19 locations in Pit 4. The sample depths ranged from an interval of zero to two feet, to an interval of two to four feet. At no location did sludge depth exceed four feet. During sampling of Pit 4 some sample locations were found to be absent of sludge. In an attempt to collect the greatest number of samples possible, aliquots of bulk samples were collected and analyzed at five locations (see Table 3-7). The minimum, maximum, average, and standard deviations of the concentrations for Pit 4 are presented in Table 3-9.

Only for Ra-226 does the average concentration meet the sampling plan goals of 30% relative error at the 90% confidence level. This indication of sludge heterogeneity is also reflected in the nonradiological parameter concentrations (Reference 6) and historical actions described in sections 2.2. and 2.3. The relative error for Th-230 is 34%. Since the average Th-230

TABLE 3-9

Raffinate Pits Radionuclide Contents From the WSSRAP Project Management Contractor Study 1987

Radionuclide		Concentrations (pCi/g - wet)*			
		Pit 1	Pit 2	Pit 3	Pit 4
Total Uranium	low	620	340	110	10
	high	1200	680	1100	3400
	avg.	840	540	600	570
	std.	190	140	220	790
Thorium-230	low	12000	22000	3300	8
	high	34000	33000	28000	6800
	avg.	27000	27000	17000	2500
	std.	6200	3600	5700	2300
Radium-226	low	140	300	18	1
	high	1700	900	610	200
	avg.	840	540	320	72
	std.	420	200	150	58
Thorium-232***	low				4
	high				1400
	avg.				320
	std.				340
Radium-228**	low	19	56	9	4
	high	110	170	160	1400
	avg.	61	130	64	230
	std.	23	40	41	310

TABLE 3-9 (Continued)

Raffinate Pits Radionuclide Contents From the WSSRAP Project Management Contractor Study 1987

Radionuclide		Concentrations (pCi/g - wet)*			
		Pit 1	Pit 2	Pit 3	Pit 4
Thorium-228**	low	18	47	18	3
	high	120	160	200	1100
	avg.	60	100	91	300
	std.	35	37	44	310
Locations Sampled		3	3	9	19
Total No. Samples		9	5	41	22

* This table includes results of samples collected during the second phase of sampling.

** The analysis date for these samples was August 1988 for Pit 3, September 1988 for Pit 4, and October 1988 for Pit 1 and Pit 2.

*** The Th-232 values for Pits 1, 2, and 3 are not reported here because they are considered erroneous due to interferences during laboratory analysis caused by high Th-230 concentrations (see Section 3.3.5).

concentration and sludge volume for Pit 4 are small compared with the other pits, this is considered acceptable.

3.3.5 Summary

Several conclusions can be drawn from the results of this study. First, the sludge has been characterized to the level indicated in the sampling plan (Reference 5). Regarding the source term (in units of total activity and concentration) for Ra-226 and Th-230, the total sludge volume (all four pits) has been characterized to within the accuracy specified in the sampling plan. Tables 3-10 and 3-11 show the Ra-226 total activity levels and concentrations for each pit at the time of sampling and 200 and 1,000 years after sampling.

The fact that the relative error of the Ra-226 concentration in Pit 2 and the Th-230 concentration in Pit 4 do not meet the sampling plan requirement of less than 30% does not appreciably affect the characterization of the total sludge volume. The average concentrations are relatively low as are the respective volumes. Neither of these parameters is likely to change significantly as a result of further characterization; i.e., considering the standard deviations of the current data sets and/or sampling density.

Thorium-232 values are not reported here for reasons related to data validity. The high concentrations of Th-230 in Pits 1, 2, and 3 caused excessive analytical interference with the Th-232 results. The Th-230 alpha spectroscopy peak significantly overlapped the Th-232 peak. This interference did not affect Pit 4 due to the lower Th-230 concentrations. However, the Th-232 concentrations for Pits 1, 2, and 3 can be estimated based on the assumption of transient equilibrium between Th-232 and its daughters Ra-228 and Th-228. This assumption is based on the following:

Table 3-10

Total activity inventory (curies) of Ra-226 per pit at the time of sampling, and at 200 years and 1000 years after sampling*

Ra-226 (Ci)

	Current	200 Years	1000 Years
Pit 1	14	48	160
Pit 2	10	48	170
Pit 3	39	210	740
Pit 4	2	8	26

* Sampling occurred in mid 1988

Table 3-11

Average concentration (picocuries per gram) of Ra-226 per pit at the time of sampling and at 200 years and 1000 years after sampling

Ra-226 Concentration (pCi/g)

	Current	200 Years	1000 Years
Pit 1	840	3000	10000
Pit 2	540	2700	10000
Pit 3	320	1700	6200
Pit 4	76	290	1000

* Sampling occurred in mid 1988.

1) The Ra-228 and Th-228 are in equilibrium in Pits 1, 2 and 4.

2) The majority (>90%) of radium was removed at the mill site and so unsupported Ra-228 (i.e., radium-228 removed from parent source material) has transformed to 6% of original levels given an average of 27 years since Pits 1, 2, and 3 were filled. Supported Ra-228 has grown to 94% of secular equilibirum with Th-232.

3) Unsupported Th-232 daughters below Ra-228 (namely Th-228), due to their short half-life relative to the long storage time of the sludges in the pits, would not be present.

Besides Th-232, estimates may also be made of the concentrations of U-238 daughters below Ra-226, and Th-232 daughters from Ra-224 through the remainder of the transformation series. Refer to Figures 3-2 and 3-4 for descriptions of the U-238 and Th-232 transformation series, respectively.

It would have been very difficult to analyze for these other radionuclides. In each series there is a radionculide present as an isotope of the noble gas radon. During sampling, an unquantifiable amount of this insoluble gas escaped, thereby disrupting the equilibrium state of the radionuclides in the sludges. This effect, coupled with the short half-lives of the daughter radionuclides, except Pb-210 and Po-210, would severely affect the precision of laboratory analyses.

In fact, some radon is always escaping from the sludges and therefore alters assumption of equilibrium from a theoretical aspect. However, through the determination of the emanation fraction and diffusion coefficient, the "escaping" radon can be accounted for and equilibrium assumptions adjusted accordingly.

Radionuclide	Half Life	Radiation Type
Uranium -238	4.5 Billion Years	Alpha
Thorium -234	24 Days	Beta (5% Gamma)
Protactinium -234	1 Minute	Beta (1% Gamma)
Uranium -234	250,000 Years	Alpha
Thorium -230	80,000 Years	Alpha (1% Gamma)
Radium -226	1,600 Years	Alpha (4% Gamma)
Radon -222	4 Days	Alpha
Polonium -218	3 Minutes	Alpha
Lead -214	27 Minutes	Beta (60% Gamma)
Bismuth -214	20 Minutes	Beta (100% Gamma)
Polonium -214	0.00016 Seconds	Alpha
Lead Pb-210	21 Years	Beta
Bismuth Bi-210	5 Days	Beta
Polonium Po-210	140 Days	Alpha
Lead Pb-206	Stable	

FIGURE 3-2

TRANSFORMATION SERIES FOR URANIUM-238

Radionuclide	Half Life	Radiation Type
Uranium U-235	0.7 Billion Years	Alpha
Thorium Th-231	26 Hours	Beta
Protactinium Pa-231	34,000 Years	Alpha
Actinium Ac-227	22 Years	Beta (1% Alpha)
Thorium Th-227	18 Days	Alpha
Radium Ra-223	12 Days	Alpha
Radon Rn-219	4 Seconds	Alpha
Polonium Po-215	0.002 Seconds	Alpha
Lead Pb-211	36 Minutes	Beta
Bismuth Bi-211	2 Minutes	Alpha (0.3% Beta)
Polonium Po-211	0.5 Seconds	Alpha
Thallium Tl-207	5 Minutes	Beta
Lead Pb-207	Stable	

FIGURE 3-3

TRANSFORMATION SERIES FOR URANIUM-235

Radionuclide	Half Life	Radiation Type
Thorium Th -232	14 Billion Years	Alpha
Radium Ra -228	7 Years	Beta
Actinium Ac-228	6 Hours	Beta (45% Gamma)
Thorium Th -228	2 Years	Beta (2% Gamma)
Radium Ra -224	4 Days	Alpha (4% Gamma)
Radon Rn -220	55 Seconds	Alpha
Polonium Po -216	0.16 Seconds	Alpha
Lead Pb -212	11 Hours	Beta (40% Gamma)
Bismuth Bi -212	60 Minutes	Alpha (66% Beta)
Polonium Po -212	0.0000003 Seconds	Alpha
Lead Pb -208	Stable	

FIGURE 3-4

TRANSFORMATION SERIES FOR THORIUM-232

The emanation fraction is that fraction of radon that physically escapes the particle with which the parent radium is associated and thus is available to diffuse through and escape from the sludge. The diffusion coefficient is a measure of how fast the radon diffuses through the sludge and so at a given depth allows assessment of how much radon actually escapes the sludge before transformation to a solid particle daughter. These parameters will be measured as part of the physical testing of the sludges. Should it be required, reasonable estimates may be made of the concentrations of these other radionculides at a later date.

No analyses were performed for U-235 daughters (Figure 3-3). Because of the chemical processing of the ore, the concentrations of the U-235 daughte radionuclides are expected to be greater than estimates based on the assumption of secular equilibrium with U-235. This "increase" (daughter concentration greater than parent) in concentration will be the same for each radionuclide as seen in the U-238 transformation series and as exhibited in Table 3-9.

In Pit 4 several biased locations were sampled. Locations SD-3412 and SD-3415 were near regions of debris and rubble. The samples from these locations exhibited no radiological characteristics that would indicate the sludge at these locations is any different from the sludge at other locations in Pit 4. Locations SD-3401, SD-3402, SD-3416, and SD-3417 generally defined the sludge boundaries. Sludge was absent at SD-3401 and SD-3402, and was very shallow (less than six inches) at SD-3416 and SD-3417.

The sample results are consistent with implied and documented history of the pits. The sample data indicate a greater degree of concentration homogeneity in Pits 1, 2, and 3 than in Pit 4. The rate of fill of Pits 1, 2, and 3 (implied from Table 3-8), lack of significant changes in process

operations, and material balance records for the time period prior to construction of Pit 4 (Reference 7), support assumptions of sludge homogeneity within Pits 1, 2, and 3. Other historical factors support the lack of homogeneity in Pit 4 and are discussed in sections 2.2 and 2.3.

As part of the sludge sampling effort, six sludge samples were analyzed for isotopic uranium. The results are presented in Appendix B. U-238 and U-234 are found in nature in a state of secular equilibrium. Uranium ore mining and further processing, up to and including that which occurred at the WSUFMP were not designed to separate the uranium isotopes. Therefore secular equilibrium can be assumed between U-238 and U-234 activity concentrations found in the sludge samples. Three of the six samples analyzed for isotopic uranium had equal mean activity concentrations of U-238 and U-234. The remaining three samples exhibited mean activity concentrations of U-238 and U-234 equal at plus or minus one standard deviation.

The other uranium isotope comprising natural uranium, U-235, is present at low activity concentrations relative to U-238 and U-234 both in nature, and in the sludge. The U-235 activity concentration data in Appendix B might be construed to indicate the presence of depleted uranium. However, this condition has been interpreted to laboratory error. The reason for this is that uranium depleted in U-235 would also be depleted in U-234. This is because the enrichment/depletion mechanism is a direct function of the isotopes masses. In fact, if the uranium in the sludges were depleted the U-238 activity concentration would be approximately 85 percent of the total uranium activity concentration. This is not the case as stated above; i.e., the U-238 and U-234 activity concentrations are equal. It should be noted that both slightly enriched (<1%) and depleted uranium were sometimes processed at the WSUFMP. Total discards of slightly enriched and depleted uranium to the raffinate pits amounted to

less than 2% by mass of the total uranium discards (Reference 7). It is concluded that the uranium in the raffinate pits is adquately defined as being natural uranium and not enriched or depleted uranium.

This report characterizes the sludge without regard to any vertical, horizontal, or other stratification or segmentation characteristics. However, the selection of sample locations was intended to provide uniform coverage of sludge area and depth. If necessary, Pits 3 and 4 could be characterized by layer. Any such subsequent analysis of the results for Pits 1 and 2 probably would not allow any characterization beyond total volume due to the small number of samples collected in each of these pits. However, archived samples are available from Pits 1, 2 and 3. These samples could be used to allow for a more thorough characterization of Pits 1, 2, and 3.

3.4 PIT SURFACE WATER SAMPLING

As part of the WSRP characterization it was determined necessary to identify and quantify the concentration of radionuclides in the waters ponded in the pits. The scope of the sampling effort included estimating average radionuclide concentrations in the ponded water and evaluating whether vertical stratification of radionuclide concentrations exist.

Sampling of surface water was performed from a 14-foot john boat with the use of a peristaltic pump. Water was collected from four locations in each pit to make one composite sample for each pit. A similar composite sample was also collected near the bottom of Pit 4. Sampling occured during March of 1989. Table 3-12 contains the results of the radiological analyses. All samples collected for radionuclide analyses were unfiltered.

The radionuclides analyzed were chosen based on knowledge of the sludge constituents. The parameters gross alpha and gross beta were not reported here. These parameters are highly dependent on the solids content of the water sample. Solids suspended in the water cause unquantifiable variation in analysis due to alpha and beta absorption within the prepared sample. The sampling results shown in Table 3-12 indicate uranium to be the primary radionuclide present in the water. Uranium is the more water soluble of the radionuclides analyzed with radium the next most soluble. From a qualitative sense the data in Table 3-12 are as expected. The greater uranium concentration for the water in Pit 4 is explained by the equipment dumped along the edges and into the water of Pit 4 (see Section 2.4.4). This equipment likely contributed loose material to the water in Pit 4. The sample from the bottom of Pit 4 indicates that no stratification, relative to radionuclide concentration, occurs in the waters ponded on the raffinate pits. Table 3-12 is considered to show data consistent with that shown in Table 2-4.

Table 3-12

Radiological Analyses Results of Surface Water from the Weldon Spring Raffinate Pits as Determined from WSSRAP Project Management Contractor Study 1989

	Pit 1	Pit 2	Pit 3	Pit 4 Surface	Pit 4 Bottom
Total Uranium	400 ± 40	600 ± 60	180 ± 20	2400 ± 300	2900 ± 300
Thorium-230	3 ± 0.6	2.3 ± 0.5	1.4 ± 0.5	1 ± 0.3	ND
Radium-226	35 ± 4	4.4 ± 0.2	54 ± 6	2.1 ± 0.1	2.9 ± 0.1
Lead-210	1.8 ± 0.9	<1	<1	<1	ND
Thorium-232	<1	<1	<1	<1	ND
Radium-228	2.5 ± 0.8	<2	25 ± 2	8.2 ± 1.1	ND
Thorium-228	<1	<1	<1	<1	ND

NOTE: Errors expressed at two standard deviations.
ND - Not determined

4 QUALITY ASSURANCE MEASURES

All aspects of the site characterization, field investigations, and data collection complied with the required practices of the WSSRAP Quality Assurance Project Plan (QAPP). The QAPP presents the policies, organizations, objectives, functional activities, and specific quality assurance (QA) and quality control (QC) activities designed to achieve the data quality goals of WSSRAP. Detailed below are the specific practices which were employed as QA measures during characterization of the wastes in the raffinate pits.

The general QA objectives for analytical data are to acquire data of known and acceptable quality. To provide a check of the quality of the data, a number of blank and duplicate samples were submitted to the analytical laboratory. Blank samples were analyzed to check for container contamination and the adequacy of the field decontamination procedures. Duplicate samples provided a check of sampling and analytical error. The frequency of submittal and results of these QA/QC samples is detailed in the following sections.

The laboratory also performed certain QA/QC tests. A copy of the Quality reports received from the analytical laboratory may be found in Appendix D. These reports present and interpret data from laboratory duplicate and spiked samples.

4.1 FIELD BLANKS

One sample for each 20 samples collected was acquired as a field blank by filling a sample container with distilled, deionized water and exposing it to the sampling environment to detect accidental or incidental contamination.

Considering the nature and concentrations of radionuclides in the sludges, the use of field blanks was not considered necessary from a radiological standpoint and so they were not collected. Field blanks were collected only to support the non-radiological aspects of the sludge sampling effort (Reference 6).

4.2 DECONTAMINATION (RINSATE) BLANK

One rinsate blank sample was prepared for every 20 sludge samples collected. Following decontamination, the sample was prepared by rinsing the sampling apparatus with distilled water and collecting the rinsate to check for residual contamination on the sampling tools. The radiological results of the decontamination blanks are shown in Table 4-1. Given the levels of radionuclides present in the sludge, the results shown in Table 4-1 are not surprising and are acceptable.

4.3 BLIND FIELD DUPLICATES

One sample for every 11 collected for radiological analysis was split and both splits were analyzed by the same laboratory to determine data reproducibility. These samples were labelled with different sample numbers to disguise their relationship. The results of these duplicate samples are shown in Table 4-2.

TABLE 4-1

Radiological Analyses Results of Decontamination (Rinsate) Blank Samples

	Radionuclide (pCi/L)					
Sample I.D.	Total Uranium	Th-232	Th-230	Th-228	Ra-228	Ra-226
SD-3101-0204-FC	1	<1	35	<1	<1	<1
SD-3203-0810-FC	5.2 ± 1.1	<1	10 ± 1	<1	<1	<1
SD-3306-0204-FC	<1	<1	6 ± 0.7	<1	13 ± 2	<0.1
SD-3308-0608-FC	<1	<1	1.6 ± 0.5	<1	<1	<1
SD-3406-0204-FC	<1	*	*	*	<1	<1

* This portion of the sample was lost during analysis.

Error is expressed at two standard deviations

TABLE 4-2

Radiological Analyses Results of Blind Field Duplicate Samples

	Radionuclide (pCi/g)					
Sample I.D.	Total Uranium	Th-232	Th-230	Th-228	Ra-228	Ra-226
SD-3101-0406	910 ±100	310 ±40	12000 ±1200	24 ± 5	19 ±7	810 ± 90
-FD	880 ± 90	510 ±60	18000 ±2000	28 ± 4	30 ±9	1400 ±200
SD-3301-0812	440 ± 40	140 ±18	11000 ±1100	86 ±15	86 ±16	230 ± 20
-FD	370 ± 40	160 ±20	12000 ±1200	91 ±15	81 ±12	200 ± 20
SD-3304-0002	1100 ±100	270 ±70	11000 ±2000	70 ±43	<15	270 ± 30
-1	1100 ±200	340 ±70	18000 ±2000	130 ±50	25 ±12	560 ± 60
SD-3304-0204	940 ±100	200 ±60	14000 ±2000	<67	<15	470 ± 50
-1	930 ±100	260 ±70	15000 ±2000	83 ±43	<18	390 ± 40
SD-3304-0406	640 ±70	320 ±80	20000 ±2000	55 ±37	14 ±9	610 ± 70
-1	570 ±60	360 ±80	20000 ±2000	62 ±33	<26	530 ± 60
SD-3307-0204	650 ±70	200 ±20	14000 ±2000	26 ±6	50 ±9	220 ± 20
-FD	840 ±90	440 ±50	2800 ± 300	<31	50 ±10	95 ± 10
SD-3410-0002	760 ±80	580 ± 60	4600 ±500	600 ±60	350 ±40	150 ± 20
-FD	660 ±70	500 ± 50	3700 ±400	530 ±60	300 ±30	100 ±10

Note: Error expressed at two standard deviations.

Sample SD-3301-0812 collected during second phase of sampling.

4.4 DATA DOCUMENTATION

4.4.1 Sample Transfer/Chain-Of-Custody Records

All raffinate pit samples leaving the Weldon Spring Site were in Department of Transportation regulated and approved containers. All sludge samples were handled and shipped according to WSSRAP Environmental Safety and Health (ES&H) Standard Operating Procedure (SOP) 2.03.10.

4.4.2 Field Reports

The construction engineer responsible for monitoring field activities, as outlined in Standard Operation Procedure numbers ENP-12 and ENP-18, filled out a field activity report and made appropriate entries into the field daily diary. Appropriate entries included date, time, sample number, location sketch, physical description, analyses requested, recovery and any problems encountered in obtaining the sample. Logs of stratification breaks, color, texture, etc., were also recorded for the undisturbed samples (i.e., those collected with Shelby tubes).

4.4.3 Photographs

Following extrusion from the sampling tool, all sludge samples were photographed. A legible sample identification card was placed in each frame to identify the sample in the picture.

5 REFERENCES

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3. Environmental Science and Engineering, Inc., et. al., Oct. 1983, Material Test Report, Sludge Sampling and Testing Services, Weldon Spring Storage Site, Missouri, Subcontract No. 14501-AA-SC-46.

4. Project Management Contractor, MK-Ferguson Company, 1987, WSSRAP Water Quality Phase I Assessment Report, Section 5.3 Surface Water-WSRP, DOE/OR.21548-003.

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7. U.S. Department of Energy, Oak Ridge Operations Office, July 1986, Historical Nuclear Materials Balance Report for the Former AEC-Owned Weldon Spring Chemical Plant, Weldon Spring, Missouri, DOE/OR-872.

8. U.S. Environmental Protection Agency, Described Procedures for Measurement of Radioactivity in Drinking Water, Environmental Monitoring and Support Laboratory, Office of Research and Development, Cincinnati, OH, EPA-600/4-80-032, August 1980.

9. U.S. Environmental Protection Agency, Eastern Environmental Radiation Facility Radiochemistry Procedures Manual, Eastern Environmental Radiation Facility, Office of Radiation Programs, Montgomery, AL, EPA 520/5-84-006, August 1984.

10. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, November 1986, Test Methods for Evaluating Solid Wastes Volume II - Field Manual Physical/ Chemical Methods, EPA Doc. No. SW-846 Third Edition.

11. U.S. Department of Energy, Work Plan for the Remedial Investigation/Feasibility Study - Environmental Impact Statement for the Weldon Spring Site, Weldon Spring, Missouri, prepared by Energy and Environmental Systems Division, Argonne National Laboratory, Argonne, IL, DOE/OR-21548-033, August 1988.

APPENDIX A

WSSRAP Raffinate Pit Sample Numbering System And WSSRAP Raffinate Pit Sample Field Report Abbreviations

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WSSRAP RAFFINATE PIT SAMPLE NUMBERING SYSTEM

SAMPLE NUMBERING SYSTEM: SD-3101-0002-V-A-MS

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|__|____|____|_|_|__|
 1   2    3   4 5  6
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1. Indicates the sample type, i.e. SD refers to Sediment (See SOP No. 4.01.01 page 2).

2. Indicates the location number, pit number and sample location number, i.e. 3 refers to the Raffinate Pits, 1 refers to Pit 1 and 01 refers to sample location 1 (see SOP No. 4.01.01 page 2).

3. Indicates the upper and lower limits of the sample interval, i.e. sample interval is between 0 to 2 ft. (see SOP No. 4.01.01 page 4).

4. Indicates the category of analysis:

   V=Volatile
   O=Organic
   I=Inorganic
   B=Bulk
   P=Physical
   R=Radiological

5. Indicates the container number:

   A=First of two containers per sample
   B=Second of two containers per sample
   C=One container per sample

6. Indicates QA/QC samples: MS=Matrix Spike
   MD=Matrix Duplicate

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FD=Field Duplicate
FC=Field De-con Rinsate
EA=EPA Samples

Notes:

1) Note the following composite samples:

SD-3100-0010-P	Composite of Pit 1
SD-3200-0010-P	Composite of Pit 2
SD-3300-0010-P	Composite of Pit 3
SD-3400-0010-P	Composite of Pit 4
SD-3000-0014-P	Composite of All Pits

2) Note U.C.=Upper Composite
M.C.=Middle Composite
L.C.=Lower Composite

3) Note the abbreviations used in the sample numbering system may not correspond to those used in the field report (See WSSRAP Raffinate Pit Sample Field Report Abbreviations).

WSSRAP RAFFINATE PIT SAMPLE FIELD REPORT ABBREVIATIONS

FIELD REPORT ABBREVIATIONS:

Sample Type:	U=Undisturbed	
	D=De-con Rinsate	
	B=Field Blank	
	Bu=Bulk	
	Ph=Physical	
Analysis:	Z=Particle Size	ASTM D422
	W=Moisture Content	ASTM D2216
	G=Specific Gravity	SMEWW Method 213E & ASTM D854
	H=Phase Separation	Settling Test
	C=Viscosity	ASTM D4016
	A=Atterberg Limits	ASTM 4318
	So=Solidification	
	V=Volatile Organics	CLP SOW #WA-87-J002
	S=Semi-Volatiles	CLP SOW #WA-87-J002
	P=PCBs/Pesticides	CLP SOW #WA-87-J002
	M=Metals	CLP SOW #WA-87-K026
	N=Nitroaromatics	EPA Method 609 & USATHAMA Methodology
	I=Inorganic Anions	EPA Method 300.0
	R=Radiological	EPA 520/5-84-006, Procedure 00-07 and EPA 600/4-80-032
	O=Oil/Grease	
	T=TOC	
	X=TOX	
	Y=Centr. Mois. Yield	ASTM D425
	E=Capillary Moisture	ASTM D3152
	F=Surface Charge	Zeta Meter
	J=Consolidation	ASTM D2435

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Ship To: MT = metaTRACE
CH = Chen & Associates
ORNL = Oak Ridge National Laboratory
SITE = Weldon Springs Site Radiation Control

* Note the abbreviations used in the field report may not correspond to those used in the sample numbering system (See WSSRAP Raffinate Pit Sample Numbering System).

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APPENDIX B

Results of Radiochemical Analyses Performed on Raffinate Pit Sludge Samples Collected by WSSRAP 1988

The sample locations are shown in Figure 3-1.

Raffinate Pit Sludge Data - Radiochemicals

WSSRAP ID	DATE SAM	PARAMTR1 Radium 226 0.1 * pCi/G	PARAMTR2 Radium 228 1 pCi/G	PARAMTR3 Thorium 228 1 pCi/G	PARAMTR4 Thorium 230 1 pCi/G	PARAMTR5 Thorium 232 1 pCi/G	PARAMTR6 Total Uranium 1 pCi/G	PARAMTR7 Uranium 234 1 pCi/G	PARAMTR8 Uranium 235 1 pCi/G	PARAMTR9 Uranium 238 1 pCi/G
SD-3101-0204-I.C.	09/12/88	930 +/- +-100	53 +/- +-7	32 +/- +-5	31000 +/- +-4000	740 +/- +-80	970 +/- +-100			
SD-3101-0406-I.C.	09/12/88	810 +/- +- 90	19 +/- +-7	24 +/- +-5	12000 +/- +-2000	310 +/- +-40	910 +/- +-100			
SD-3101-0608-I.C.	09/12/88	1700 +/- +-200	60 +/- +-11	45 +/- +-6	3000 +/- +-3000	700 +/- +-70	1000 +/- +-100			
SD-3101-0810-I.C.	09/12/88	1200 +/- +-200	62 +/- +-10	84 +/- +-9	27000 +/- +-3000	350 +/- +-40	620 +/- +-70			
SD-3101-1012-I.C.	09/12/88	690 +/- +-70	64 +/- +-10	78 +/- +-8	23000 +/- +-3000	340 +/- +-40	720 +/- +-80			
SD-3102-0204-I.C.	09/12/88	450 +/- +-50	66 +/- +-11	18 +/- +8	25000 +/- +-3000	420 +/- +-50	800 +/- +-80			
SD-3102-0810-I.C.	09/12/88	660 +/- +-66	110 +/- +-20	120 +/- +-12	34000 +/- +-3400	490 +/- +-50	730 +/- +-73			
SD-3102-1012-I.C.	09/12/88	140 +/- +-20	74 +/- +-10	100 +/- +-10	25000 +/- +-3000	380 +/- +-40	650 +/- +-70			
SD-3103-0406-R.C.	09/14/88	990 +/- +-100	45 +/- +-9.3	36 +/- +-6.4	32000+/- 4000	570 +/- +-60	1200 +/- +-120	830 +/- +-90	<3	770 +/- +-80
SD-3201-0204-I.C.	09/16/88	470+/- +-50	140 +/- +-20	160 +/- +-20	26000 +/- +-3000	470 +/- +-50	470 +/- +-56	290 +/- +-30	<4	300 +/- +-30
SD-3201-0406-I.C.	09/15/88	510 +/- +-60	56 +/- +-12	47 +/- +-16	22000 +/- +-3000	280 +/- +-30	340 +/- +-34			
SD-3202-0204-I.C.	09/22/88	900 +/- +- 90	160 +/- +-20	83 +/- +-21	26000 +/- +-3000	330 +/- +-40	590 +/- +-60			
SD-3202-0608-I.C.	09/22/88	300 +/- +- 30	170 +/- +-20	100 +/- +-20	26000 +/- +-3000	380 +/- +-40	630 +/- +-70			
SD-3203-0810-I.C.	09/21/88	520 +/- +-50	140 +/- +-20	110 +/- +-20	33000 +/- +-4000	510 +/- +-60	680 +/- +-70	640 +/- +-6	<3	640 +/- +-6
**SD-3301-0004-I	01/04/89	160 +/- 20	57 +/- 10	90 +/- 15	13000 +/- 1300	160 +/- 20	840 +/- 80			
**SD-3301-0408-I	01/04/89	320 +/- 30	47 +/- 8	42 +/- 9.7	16000 +/- 1600	160 +/- 20	520 +/- 50			
**SD-3301-0812-I	01/04/89	230 +/- 20	86 +/- 16	86 +/- 15	11000 +/- 1100	140 +/- 18	440 +/- 40			
**SD-3301-1216-I	01/04/89	600 +/- 60	72 +/- 14	86 +/- 15	28000 +/- 2800	290 +/- 30	660 +/- 60	360 +/- 40	<4	350 +/- 40
**SD-3301-0004-I	01/04/89	340 +/- 30	51 +/- 8.4	80 +/- 8	14000 +/- 1400	220 +/- 20	580 +/- 60	260 +/- 30	<2	260 +/- 30
**SD-3302-0408-I	01/04/89	260 +/- 30	33 +/- 6.5	18 +/- 4.3	20000 +/- 2000	200 +/- 20	210 +/- 30			
**SD-3302-0812-I	01/04/89	210 +/- 20	38 +/- 6.5	47 +/- 6.8	8900 +/- 890	460 +/- 50	540 +/- 50			
SD-3303-0002-I.C.	07/29/88	50 +/- +-5	160 +/- +-17	140 +/- +-30	15000 +/- +-2000	320 +/- +-40	1000 +/- +-100			
SD-3303-0204-I.C.	07/29/88	95 +/- +-10	82 +/- +-10	140 +/- +-30	22000 +/- +-3000	440 +/- +-60	820 +/- +-90			
SD-3303-0406-I.C.	07/29/88	320 +/- +-40	90 +/- +-11	200 +/- +-40	28000 +/- 3000	450 +/- +-+60	510 +/- +-60			
SD-3303-0608-I.C.	07/29/88	390 +/- +-40	70 +/- +-9	94 +/- +-24	21000 +/- +-3000	370 +/- +-50	1000 +/- +-100			
SD-3303-0810-I.C.	07/29/88	350 +/- +-40	30 +/- +-5	33 +/- +-17	21000 +/- +-3000	300 +/- +-40	560 +/- +-60			
SD-3303-1011-I.C.	07/29/88	390 +/- +-40	90 +/- +-12	130 +/- +-30	22000 +/- +-3000	340 +/- +-50	290 +/- +-30			
SD-3304-0002	07/27/88	270 +/- +-30	<15	70 +/- +-43	11000 +/- +-2000	270 +/- +-70	1100 +/- +-100			
SD-3304-0204	07/27/88	470 +/- +-50	<15	<67	14000 +/- +-2000	200 +/- +-60	940 +/- +-100			
SD-3304-0406	07/27/88	610 +/- +-70	14 +/- +-9	55 +/- +-37	20000 +/- +-2000	320 +/- +-80	640 +/- +-70			
SD-3304-0608	07/27/88	18 +/- +-2	80 +/- +-9	75 +/- +-28	21000 +/- +-3000	210 +/- +-40	480 +/- +-50	320 +/- +-40	<2	310 +/- +-40

RADSLUDG/TXTJOANN

Raffinate Pit Sludge Data - Radiochemicals

WSSRAP ID	DATE SAM	PARAMTR1 Radium 226 0.1* pCi/G	PARAMTR2 Radium 228 1 pCi/G	PARAMTR3 Thorium 228 1 pCi/G	PARAMTR4 Thorium 230 1 pCi/G	PARAMTR5 Thorium 232 1 pCi/G	PARAMTR6 Total Uranium 1 pCi/G	PARAMTR7 Uranium 234 1 pCi/G	PARAMTR8 Uranium 235 1 pCi/G	PARAMTR9 Uranium 238 1 pCi/G
SD-3304-0810	07/27/88	380 +/- +-40	<16	<57	14000 +/- +-2000	180 +/- +-60	680 +/- +-70			
SD-3305-0002	07/27/88	310 +/- +-40	<14	170 +/- +-60	21000 +/- +-3000	460 +/- +-90	660 +/- +-70			
SD-3305-0204	07/27/88	570 +/- +-60	15 +/- +-6	170 +/- +-60	21000 +/- +-3000	460 +/- +-90	660 +/- +-70			
SD-3305-0608	07/27/88	360 +/- +-40	15 +/- +-6	130 +/- +-50	20000 +/- +-2000	460 +/- +-90	420 +/- +-50			
SD-3305-0810	07/27/88	510 +/- +-60	18 +/- +-11	100 +/- +-50	24000 +/- +-3000	350 +/- +-80	380 +/- +-40			
SD-3306-0002-I.C.	07/28/88	160 +/- +-20	44 +/- +-8	59 +/- +-25	5800 +/- +-600	88 +/- +-30	750 +/- +-80	600 +/- +-60	<2	570 +/- +-60
SD-3306-0204-I.C.	07/28/88	180 +/- +-20	30 +/- +-7	82 +/- +-26	8600 +/- +-900	130 +/- +-40	610 +/- +-70			
SD-3306-0406-I.C.	07/28/88	300 +/- +-30	31 +/- +-6	80 +/- +-30	9800 +/- +-1000	180 +/- +-40	950 +/- +-100			
SD-3306-0608-I.C.	07/28/88	470 +/- +-50	8.7 +/- +-4.7	130 +/- +-40	19000 +/- +-2000	330 +/- +-60	610 +/- +-70			
SD-3307-0002-I.C.	08/03/88	160 +/- +-20	70 +/- +-7	54 +/- +-8	3300 +/- +-400	590 +/- +-60	550 +/- +-60			
SD-3307-0204-I.C.	08/03/88	220 +/- +-20	50 +/- +-9	26 +/- +-6	14000 +/- +-2000	200 +/- +-20	650 +/- +-70			
SD-3307-0406-I.C.	08/03/88	390 +/- +-40	130 +/- +-20	110 +/- +-30	9200 +/- +-100	180 +/- +-40	760 +/- +-70			
SD-3307-0608-I.C.	08/03/88	290 +/- +-30	130 +/- +-20	55 +/- +-37	16000 +/- +-2000	280 +/- +-30	470 +/- +-50			
SD-3308-0002-I.C.	08/03/88	150 +/- +-20	53 +/- +-7	79 +/- +-27	13000 +/- +-2000	280 +/- +-47	770 +/- +-80			
SD-3308-0204-I.C.	08/03/88	450 +/- +-50	130 +/- +-20	160 +/- +-40	17000 +/- +-2000	290 +/- +-50	490 +/- 50			
SD-3308-0406-I.C.	08/03/88	260 +/- +-30	120 +/- +-20	150 +/- +-40	20000 +/- +-2000	250 +/- +-50	380 +/- +-40			
SD-3308-0608-I.C.	08/03/88	410 +/- +-50	130 +/- +-20	55 +/- +-37	24000 +/- +-3000	360 +/- +-70	450 +/- +-50			
SD-3308-0810-I.C.	08/03/88	480 +/- +-50	130 +/- +-20	80 +/- +-25	14400 +/- +-2000	290 +/- +-40	400 +/- +-40			
SD-3309-0002-I	08/02/88	550 +/- +-60	80 +/- +- 17	140 +/- +-40	16000 +/- +-2000	240 +/- +-50	850 +/- +-90			
SD-3309-0204-R.C.	08/02/88	520 +/- +-60	65 +/- +- 18	62 +/- +- 24	23000 +/- +-3000	440 +/- +-60	560 +/- +-60			
SD-3309-0406-R.C.	08/02/88	380 +/- +-40	100 +/- +-30	68 +/- +- 26	24000 +/- 3000	440 +/- +-60	520 +/- +-60			
SD-3309-0608-R.C.	08/02/88	300 +/- +-30	55 +/- +- 17	29 +/- +- 16	17000 +/- +-1700	330 +/- +-50	440 +/- +-50			
SD-3309-0810-R.C.	08/02/88	250 +/- +-30	79 +/- +-16	140 +/- +-40	17000 +/- +-2000	430 +/- +-60	460 +/- +-50			
SD-3309-1011-R.C.	08/02/88	100 +/- +-10	100 +/- +-20	100 +/- +-30	17000 +/- +-2000	260 +/- +-40	110 +/- +-20			
SD-3403-0002-I.C.	08/26/88	4.0 +/- +-0.5	<1	11 +/- +-3	47 +/- +-7	4.6 +/- +-2.5	37 +/- +-6			
SD-3404-0002-I.C.	08/26/88	150 +/- +-20	270 +/- +-30	390 +/- +-40	250 +/- +-30	400 +/- +-40	160 +/- +-20			
SD-3405-0002-I.C.	08/17/88	60 +/- +-6	230 +/- +-320	450 +/- +-540	280 +/- +-500	450 +/- +-50	30 +/- +-7			
SD-3406-0002-I.C.	08/24/88	100 +/- +-10	170 +/- +-20	310 +/- +-4031	4900 +/- +-700	350 +/- +-40	690 +/- +-70			
SD-3406-0204-I	08/24/88	90 +/- +-9.0	70 +/- +-8	80 +/- +-9	6100 +/- +-700	280 +/- +-30	560 +/- +-60			
SD-3406-0204-I.C. BU	08/26/88	80 +/- +-8	110 +/- +-20	110 +/- +-20	3700 +/- +-400	160 +/- +-20	330 +/- +-40			
SD-3407-0002-I.C.	08/18/88	120 +/- +-20	190 +/- +-20	230 +/- +-30	5300 +/- +-600	260 +/- +-30	960 +/- +-100			
SD-3408-0002-I.C.	08/25/88	<1	50+/- +-8	80 +/- +-12	340 +/- +-40	70 +/- +-11	590 +/- +-60	40 +/- +-10	<4	40 +/- +- 12

RADSLUDG/TXTJOANN

Raffinate Pit Sludge Data - Radiochemicals

WSSRAP ID	DATE SAM	PARAMTR1 Radium 226 0.1 * pCi/G	PARAMTR2 Radium 228 1 pCi/G	PARAMTR3 Thorium 228 1 pCi/G	PARAMTR4 Thorium 230 1 pCi/G	PARAMTR5 Thorium 232 1 pCi/G	PARAMTR6 Total Uranium 1 pCi/G	PARAMTR7 Uranium 234 1 pCi/G	PARAMTR8 Uranium 235 1 pCi/G	PARAMTR9 Uranium 238 1 pCi/G
SD-3408-0002-I.C. BU	08/31/88	96 +/- +-10	590 +/- +-60	1100 +/- +-200	2100 +/- +-300	900 +/- +-90	530 +/- +-60			
SD-3409-0002-I.C.	08/25/88	1.4 +/- +-0.2	<6	<3	13 +/- +-3	3.7 +/- +-1	10 +/- +-3			
SD-3410-0002-I.C.	08/26/88	150 +/- +-20	350 +/- +-40	600 +/- +-60	4600 +/- +-500	580 +/- +-60	760 +/- +-80			
SD-3410-0002-I.C. BU	08/26/88	42 +/- + 5	480 +/- +-50	830 +/- +-90	1700 +/- +-200	680 +/- +-70	56 +/- +-9			
SD-3410-0204-I.C.	08/26/88	200 +/- +-20	120 +/- +-20	200 +/- +-20	3300 +/- +-400	210 +/- +-30	330 +/- +-40			
SD-3411-0002-I.C.	08/16/88	24 +/- +-2.4	230 +/- +-30	400 +/- +-40	5200 +/- +-600	460 +/- +-50	3400 +/- +-400			
SD-3412-0002-I.C.	08/26/88	32 +/- +-3.2	15 +/- +-2	<15	190 +/- +-20	14 +/- +-2	67 +/- +-7			
SD-3413-0002-I.C.	08/16/88	130 +/- +-20	1400 +/- +-200	850 +/- +-90	3000 +/- +-300	1400 +/- +-200	2000 +/- +-200			
SD-3414-0002-I.C.	08/26/88	2.2 +/- +-1.0	16 +/- +-4.3	40 +/- +-6.0	120 +/- +-20	40 +/- +-6.0	44 +/- +-5.5			
SD-3415-0002-I.C.	08/17/88	130 +/- +-20	230 +/- +-30	230 +/- +-30	4500 +/- +-500	290 +/- +-30	1100 +/- +-200			
SD-3416-0002-I.C.	08/18/88	30 +/- +-3	4.0 +/- +-2.3	6.2 +/- +-1.7	12 +/- +-2.3	5.2 +/- +-1.6	30 +/- +-6			
SD-3417-0002-I.C.	08/26/88	2.3 +/- +-0.3	<8	3.2 +/- +-1.9	7.9 +/- +-3.4	<4	32 +/- +-5.0			
SD-3418-0002-I.C. BU	08/31/88	55 +/- +-6	90 +/- +-9	450 +/- +-50	2500 +/- +-300	360 +/- +-40	390 +/- +-40			
SD-3419-0002-I.C. BU	08/31/88	94 +/- +-10	320 +/- +-40	160 +/- +-20	6800 +/- +-700	200 +/- +-20	450 +/- +-50	420 +/- +-50	<4	420 +/- +-50

* Analytical procedure detection limit.

NOTE:
1) Error is expressed at two standard deviations.
2) BU = Bulk sample (as opposed to undisturbed sample taken with a Shelby tube)
3) The Th-232 values are considered erroneous for Pits 1, 2, and 3. Excessive interference during laboratory analysis was caused by the high Th-230 concentrations. Section 3.3.5 explains the problem in more detail as well as the resolution.
4) ** Designates samples collected during second phase of sampling.
5) Those samples collected but determined to not be sludge (i.e., samples collected where sludge was absent) are not included in this table.

RADSLUDG/TXTJOANN

APPENDIX C

Results of Radiochemical Analyses Performed

on Raffinate Pit Sludge Samples Collected by

Bechtel National Inc. 1986

The sample locations are shown in Figure 2-4

RADSLUDG/TXTJOANN

CUSTOMER Bechtel National, Inc.-Weldon Springs
ATTENTION Jeff Brown
ADDRESS P.O. Box 350
CITY Oak Ridge, TN 37830
S.O. NO. E-5507

REPORT OF ANALYSIS

Radiochemical analysis of sediment — TYPE OF ANALYSIS
23-531 — CUSTOMER ORDER NUMBER
SAMPLES RECEIVED 1/3/86

CORRECTED REPORT

Customer Identification	Date Collected	Type of Analysis	pCi/g (dry)
W50727N99074	12/19/85	Th-230	810±30
LOC #2		Th-232	30±5
3-1/4 - 5-1/2			
W50675N98875	12/20/85	Th-230	100,000±10,000
LOC #3		Th-232	440±40
4-6			

☐ REPORTED VIA TELEPHONE
☐ REPORTED VIA TWX

Eberline — A DIVISION OF Thermo Electron CORPORATION
P. O. BOX 3874 ALBUQUERQUE, NEW MEXICO 87190
PHONE (505) 345-3461 twx: 910-985-0678

APPROVED BY R. Melgard 4/1/86 DATE
Rod Melgard, Mgr.

CUSTOMER Bechtel National, Inc.-Weldon Springs
ATTENTION Jeff Brown
ADDRESS P.O. Box 350
CITY Oak Ridge, TN 37830
S.O. NO. E-5507

RECEIVED MAR 19 1986

REPORT OF ANALYSIS

TYPE OF ANALYSIS: Radiochemical analysis of sediment
CUSTOMER ORDER NUMBER: 23-531
SAMPLES RECEIVED: 1/3/86

Customer Identification	Date Collected	Type of Analysis	Total Wt. wet/dry(g)	pCi/g (dry)
Pπ 1				
W50775N98975	12/19/85	U-234	518/217	2100±100
LOC #1		U-235		90±20
0-2 1/2		U-238		1800±100
		Th-230		2000±100
		Th-232		6±4
		Ra-226		3600±100
		Ra-228		<200
		Pb-210		4500±200
		Po-210		5400±400
W50727N99074	12/19/85	U-234	483/125	790±10
LOC #2		U-235		28±3
0-2		U-238		630±10
		Th-230		70±20
		Th-232		<1
		Ra-226		2000±100
		Ra-228		<40
		Pb-210		1200±100
		Po-210		2200±100
W50727N99074	12/19/85	U-234	456/136	920±20
LOC #2		U-235		32±3
3-1/4 - 5-1/2		U-238		630±20
		Th-230		460±110*
		Th-232		<40*
		Ra-226		2600±100
		Ra-228		<100
		Pb-210		2300±100
		Po-210		1900±100
W50727N99074	12/19/85	U-234	582/166	900±20
LOC #2		U-235		32±3
6-1/2 - 8-2/3		U-238		730±10
		Th-230		4400±100
		Th-232		24±5
		Ra-226		2200±100
		Ra-228		90±40
		Pb-210		2100±100
		Po-210		2200±100

☐ REPORTED VIA TELEPHONE
☐ REPORTED VIA TWX

*Being reanalyzed to verify original results.

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APPROVED BY Kathy Burnham for Rod Melgard, Mgr.

3/18/86

CUSTOMER Bechtel National, Inc.-Weldon Springs

ATTENTION

ADDRESS

CITY

S.O. NO. E-5507

REPORT OF ANALYSIS

TYPE OF ANALYSIS | CUSTOMER ORDER NUMBER | SAMPLES RECEIVED

Customer Identification	Date Collected	Type of Analysis	Total Wt. wet/dry(g)	pCi/g (dry)
W50826N98825	12/20/85	U-234	515/201	510±20
LOC #1		U-235		21±4
3-1/2 - 5-1/2		U-238		550±20
		Th-230		40±10
		Th-232		<1
		Ra-226		950±10
		Ra-228		<100
		Pb-210		1300±100
		Po-210		960±70
W50826N98825	12/20/85	U-234	531/214	310±30
LOC #1		U-235		18±8
7-9-1/4		U-238		290±30
		Th-230		31,000±1000
		Th-232		120±10
		Ra-226		640±10
		Ra-228		140±90
		Pb-210		850±100
		Po-210		830±100
W50775N98925	12/20/85	U-234	560/151	1400±100
LOC #2		U-235		40±20
0-2		U-238		1200±100
		Th-230		33,000±1000
		Th-232		80±10
		Ra-226		3600±100
		Ra-228		<200
		Pb-210		3200±100
		Po-210		3600±300
W50775N98925	12/20/85	U-234	573/207	380±30
LOC #2		U-235		14±6
3-5		U-238		280±30
		Th-230		21,000±1000
		Th-232		200±20
		Ra-226		740±10
		Ra-228		<100
		Pb-210		630±100
		Po-210		840±100

☐ REPORTED VIA TELEPHONE

☐ REPORTED VIA TWX

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P. O. BOX 3874 · ALBUQUERQUE, NEW MEXICO 87190
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APPROVED BY Kathy Burnham for Rod Melgard, Mgr. DATE 3/18/86

CUSTOMER Bechtel National, Inc.-Weldon Springs
ATTENTION
ADDRESS
CITY
S.O. NO. E-5507

REPORT OF ANALY

TYPE OF ANALYSIS | CUSTOMER ORDER NUMBER | SAMPLES RECEIVED

Customer Identification	Date Collected	Type of Analysis	Total Wt. wet/dry(g)	pCi/g (dry)
W50775N98925	12/20/85	U-234	566/247	410±20
LOC #2		U-235		16±4
6-8-1/3		U-238		440±20
		Th-230		25,000±1000
		Th-232		24±3
		Ra-226		770±10
		Ra-228		<100
		Pb-210		480±50
		Po-210		540±40
W50675N98875	12/20/85	U-234	509/152	1500±100
LOC #3		U-235		60±10
0-2		U-238		1500±100
		Th-230		820±20
		Th-232		10±2
		Ra-226		270±10
		Ra-228		430±60
		Pb-210		3800±100
		Po-210		4400±100
W50675N98875	12/20/85	U-234	491/143	1400±100
LOC #3		U-235		60±10
4-6		U-238		1400±100
		Th-230		7900±1000*
		Th-232		390±40*
		Ra-226		3200±100
		Ra-228		300±100
		Pb-210		4700±200
		Po-210		3700±200
W50675N98875	12/20/85	U-234	563/258	1700±100
LOC #3		U-235		70±10
8-10		U-238		1700±100
		Th-230		21,000±1000
		Th-232		35±3
		Ra-226		2300±100
		Ra-228		<100
		Pb-210		2800±100
		Po-210		1300±100

☐ REPORTED VIA TELEPHONE
REPORTED VIA TWX *Being reanalyzed to verify original results.

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APPROVED BY Kathy Burnham for Rod Melgard, Mgr. 3/18/86

CUSTOMER Bechtel National, Inc.-Weldon Springs
ATTENTION Jeff Brown
ADDRESS P.O. Box 350
CITY Oak Ridge, TN 37830
S.O. NO. E-5505

Raffinate Pit #3

REPORT OF ANALYSIS

Radiochemical analysis of sediment — TYPE OF ANALYSIS
23-531 — CUSTOMER ORDER NUMBER
SAMPLES RECEIVED 1/3/86

Customer Identification	Date Collected	Type of Analysis	Total Wt. wet/dry(g)	pCi/g (dry)
N99675 W51476 Loc #1 0-2'	12/17/85	U-234	550/163	820±40
		U-235		28±9
		U-238		850±40
		Th-230		130±20
		Th-232		<2
		Ra-226		610±20
		Ra-228		200±100
		Pb-210		1400±100
		Po-210		860±60
N99479 W51425 Loc #2	12/14/85	U-234	242/56	1800±100
		U-235		73±17
		U-238		1800±100
		Th-230		33,000±1000
		Th-232		370±30
		Ra-226		1100±100
		Ra-228		150±100
		Pb-210		1300±100
		Po-210		850±70
N99479 W51425 Loc #2 4-6	12/14/85	U-234	220/68	1700±100
		U-235		74±9
		U-238		1700±100
		Th-230		30,000±1000
		Th-232		880±60
		Ra-226		730±10
		Ra-228		300±100
		Pb-210		780±60
		Po-210		1000±100
N99479 W51425 Loc #2 8-10	12/14/85	U-234	256/55	570±60
		U-235		21±11
		U-238		590±60
		Th-230		1600±100
		Th-232		280±30
		Ra-226		3400±100
		Ra-228		<200
		Pb-210		3800±300
		Po-210		3300±200

☐ REPORTED VIA TELEPHONE
☐ REPORTED VIA TWX

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APPROVED BY R. Melgard 3/21/86 DATE
Rod Melgard, Mgr.

CUSTOMER Bechtel National, Inc.-Weldon Springs

ATTENTION

ADDRESS

CITY

S.O. NO. E-5505

REPORT OF ANALYSIS

TYPE OF ANALYSIS | CUSTOMER ORDER NUMBER | SAMPLES RECEIVED

Customer Identification	Date Collected	Type of Analysis	Total Wt. wet/dry(g)	pCi/g (dry)
N99174 W51375 Loc #3 0-2	12/16/85	U-234	572/115	880±20
		U-235		43±3
		U-238		710±20
		Th-230		5300±100
		Th-232		68±7
		Ra-226		260±10
		Ra-228		70±10
		Pb-210		260±20
		Po-210		*
N99174 W51375 Loc #3 3-5	12/16/85	U-234	571/120	580±40
		U-235		32±9
		U-238		570±40
		Th-230		27,000±1000
		Th-232		420±30
		Ra-226		920±10
		Ra-228		200±100
		Pb-210		1400±100
		Po-210		940±10
N99174 W51375 Loc #3 6-8 1/4	12/16/85	U-234	503/165	500±30
		U-235		24±8
		U-238		470±30
		Th-230		23,000±1000
		Th-232		190±20
		Ra-226		990±20
		Ra-228		200±100
		Pb-210		1100±100
		Po-210		940±100
N99424 W51375 Loc #4 0-2	12/14/85	U-234	276/80	2100±100
		U-235		120±10
		U-238		1700±100
		Th-230		7100±100
		Th-232		130±10
		Ra-226		550±10
		Ra-228		200±100
		Pb-210		580±50
		Po-210		310±20

☐ REPORTED VIA TELEPHONE

☐ REPORTED VIA TWX *Being reanalyzed and will be reported later.

Eberline A DIVISION OF Thermo Electron CORPORATION

APPROVED BY R. Melgard 3/21/86
Rod Melgard, Mgr.

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CUSTOMER Bechtel National, Inc.-Weldon Springs

ATTENTION

ADDRESS

CITY

S.O. NO. E-5505

REPORT OF ANALYSIS

TYPE OF ANALYSIS | CUSTOMER ORDER NUMBER | SAMPLES RECEIVED

Customer Identification	Date Collected	Type of Analysis	Total Wt. wet/dry(g)	pCi/g (dry)
N99424 W51375	12/14/85	U-234	329/90	3200±100
Loc #4		U-235		150±30
3 3/4-5 3/4		U-238		3300±100
		Th-230		44,000±1000
		Th-232		470±40
		Ra-226		660±10
		Ra-228		200±100
		Pb-210		2700±200
		Po-210		2200±200
N99424 W51375	12/14/85	U-234	266/62	900±20
Loc #4		U-235		42±5
7 1/2-9 1/2		U-238		930±20
		Th-230		820±20
		Th-232		12±2
		Ra-226		1400±100
		Ra-228		300±100
		Pb-210		2800±100
		Po-210		*
W51375 N99774	12/17/85	U-234	606/220	3900±100
Loc #5		U-235		160±20
0-2		U-238		4300±100
		Th-230		52,000±1000
		Th-232		710±150
		Ra-226		450±10
		Ra-228		<200
		Pb-210		2600±200
		Po-210		1800±200
W51375 N99774	12/17/85	U-234	558/112	610±40
Loc #5		U-235		25±7
4-6		U-238		670±40
		Th-230		63,000±1000
		Th-232		360±30
		Ra-226		1700±100
		Ra-228		300±100
		Pb-210		3200±200
		Po-210		*

☐ REPORTED VIA TELEPHONE

REPORTED VIA TWX *Being reanalyzed and will be reported later.

Eberline A DIVISION OF Thermo Electron CORPORATION

P. O. BOX 3874 ALBUQUERQUE, NEW MEXICO 87190
PHONE (505) 345-3461 twx: 910-985-0678

APPROVED BY R. Melgard 3/21/86 DATE

Rod Melgard, Mgr.

CUSTOMER Bechtel National, Inc.-Weldon Springs

ATTENTION

ADDRESS

CITY

S.O. NO. E-5505

REPORT OF ANALY

TYPE OF ANALYSIS CUSTOMER ORDER NUMBER SAMPLES RECEIVED

Customer Identification	Date Collected	Type of Analysis	Total Wt. wet/dry(g)	pCi/g (dry)
W51375 N99774	12/17/85	U-234	594/184	740±60
Loc #5		U-235		36±15
8-10.25		U-238		650±60
		Th-230		29,000±1000
		Th-232		130±20
		Ra-226		1300±100
		Ra-228		200±100
		Pb-210		1700±100
		Po-210		1300±100
W51326 N99326	12/16/85	U-234	584/168	1400±100
Loc #6		U-235		58±13
0-2		U-238		1400±100
		Th-230		19,000±1000
		Th-232		240±30
		Ra-226		840±10
		Ra-228		200±100
		Pb-210		1100±100
		Po-210		930±70
W51326 N99326	12/16/85	U-234	565/136	5900±100
Loc #6		U-235		240±20
3.75-5.75		U-238		6000±100
		Th-230		35 000±1000
		Th-232		390±30
		Ra-226		1300±100
		Ra-228		200±100
		Pb-210		2600±200
		Po-210		2900±100
W51326 N99326	12/16/85	U-234	550/157	1200±100
Loc #6		U-235		48±15
7.5-9.5		U-238		1200±100
		Th-230		61,000±2000
		Th-232		510±140
		Ra-226		3600±100
		Ra-228		200±100
		Pb-210		4400±300
		Po-210		4000±200

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CUSTOMER Bechtel National, Inc.-Weldon Springs

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S.O. NO. E-5505

REPORT OF ANALYSIS

TYPE OF ANALYSIS | CUSTOMER ORDER NUMBER | SAMPLES RECEIVED

Customer Identification	Date Collected	Type of Analysis	Total Wt. wet/dry(g)	pCi/g (dry)
N99425 W51172	12/18/85	U-234	566/158	1100±100
Loc #7		U-235		35±6
0-2		U-238		1100±100
		Th-230		14,000±1000
		Th-232		190±10
		Ra-226		2100±100
		Ra-228		300±100
		Pb-210		1600±100
		Po-210		1200±100
N99425 W51172	12/18/85	U-234	479/121	840±60
Loc #7		U-235		30±16
4-6		U-238		810±60
		Th-230		270,000±10,000
		Th-232		3100±200
		Ra-226		2100±100
		Ra-228		300±100
		Pb-210		3300±300
		Po-210		3000±100
W51172 N99425	12/18/85	U-234	538/135	950±20
Loc #7		U-235		51±5
8-10.4		U-238		980±20
		Th-230		3400±100
		Th-232		25±4
		Ra-226		2500±100
		Ra-228		300±100
		Pb-210		2800±100
		Po-210		*
W51173 N99574	12/17/85	U-234	758/448	1200±100
Loc #8		U-235		47±7
0-2		U-238		1200±100
		Th-230		26,000±1000
		Th-232		190±20
		Ra-226		500±10
		Ra-228		50±40
		Pb-210		510±50
		Po-210		390±20

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APPROVED BY R. Melgard DATE 3/21/86

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ALBUQUERQUE LABORATORY

CUSTOMER Bechtel National, Inc.-Weldon Springs

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REPORT OF ANALYSIS

TYPE OF ANALYSIS | CUSTOMER ORDER NUMBER | SAMPLES RECEIVED

Customer Identification	Date Collected	Type of Analysis	Total Wt. wet/dry(g)	pCi/g (dry)
W51173 N99574 Loc #8 5.75-6.75	12/17/85	U-234	568/127	680±20
		U-235		29±3
		U-238		670±20
		Th-230		320±10
		Th-232		2.1±0.9
		Ra-226		1200±100
		Ra-228		60±20
		Pb-210		1400±100
		Po-210		*
W51173 N99574 Loc #8 9.5-11.5	12/17/85	U-234	505/124	730±80
		U-235		28±19
		U-238		720±80
		Th-230		640±20
		Th-232		11±2
		Ra-226		430±10
		Ra-228		70±20
		Pb-210		970±40
		Po-210		*
W51076 N99523 Loc #9 0-2	12/18/85	U-234	554/154	5400±200
		U-235		250±40
		U-238		5200±200
		Th-230		18,000±1000
		Th-232		140±10
		Ra-226		86±5
		Ra-228		<90
		Pb-210		1700±100
		Po-210		1600±100
W51076 N99523 Loc #9 3 3/4-5 3/4	12/18/85	U-234	548/110	810±60
		U-235		47±13
		U-238		820±60
		Th-230		61,000±1000
		Th-232		270±20
		Ra-226		1500±100
		Ra-228		200±100
		Pb-210		1600±100
		Po-210		1700±100

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ATTENTION

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S.O. NO. E-5505

REPORT OF ANALYSIS

TYPE OF ANALYSIS CUSTOMER ORDER NUMBER SAMPLES RECEIVED

Customer Identification	Date Collected	Type of Analysis	Total Wt. wet/dry(g)	pCi/g (dry)
W51076 N99523	12/18/85	U-234	574/165	380±20
Loc #9		U-235		18±4
7 1/2-9 1/2		U-238		350±20
		Th-230		15,000±100
		Th-232		50±5
		Ra-226		340±10
		Ra-228		<20
		Pb-210		350±30
		Po-210		400±20
W51079 N99795	12/17/85	U-234	657/417	2400±100
Loc #10		U-235		120±20
0-1.5		U-238		2400±100
		Th-230		16,000±1000
		Th-232		140±10
		Ra-226		910±20
		Ra-228		<200
		Pb-210		460±50
		Po-210		890±60

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ATTENTION Jeff Brown
ADDRESS P.O. Box 350
CITY Oak Ridge, TN 37830
S.O. NO. E-5505

Raffinate Pit #3

REPORT OF ANALYSIS

Radiochemical analysis of sediment — TYPE OF ANALYSIS
23-531 — CUSTOMER ORDER NUMBER
SAMPLES RECEIVED 1/3/86

SUPPLEMENTAL REPORT

Customer Identification	Date Collected	Type of Analysis	pCi/g (dry)
N99174 W51375 Loc #3 0-2	12/16/85	Po-210	130±10
N99424 W51375 Loc #4 7 1/2 - 9 1/2	12/14/85	Po-210	3500±400
W51375 N99774 Loc #5 4-6	12/17/85	Po-210	3000±100
W51172 N99425 Loc #7 8-10.4	12/18/85	Po-210	2100±200
W51173 N99574 Loc #8 5.75-6.75	12/17/85	Po-210	1200±100
W51173 N99574 Loc #9 9.5-11.5	12/17/85	Po-210	1100±100

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APPROVED BY R. Melgard 3/27/86
Rod Melgard, Mgr.

CUSTOMER Bechtel National, Inc.-Weldon Springs
ATTENTION Jeff Brown
ADDRESS P.O. Box 350
CITY Oak Ridge, TN 37830
S.O. NO. E-5524

(Raffinate Pit #4)

REPORT OF ANALYSIS

TYPE OF ANALYSIS Radiochemical analysis of sediment
CUSTOMER ORDER NUMBER 23-531
SAMPLES RECEIVED 1/13/86

Customer Identification	Date Collected	Type of Analysis	Total Wt. wet/dry(g)	pCi/g (dry)
N99875W51975	1/7/86	U-234	622/366	28±1
Loc #1		U-235		1.2±0.3
0-9"		U-238		28±1
		Th-230		110±10
		Th-232		12±1
		Ra-226		50±5
		Ra-228		44±4
		Pb-210		34±3
		Po-210		10±1
W51926N99430	1/8/86	U-234	547/90	320±10
Loc #2		U-235		13±2
0-2.5'		U-238		300±10
		Th-230		130±10
		Th-232		24±2
		Ra-226		7±1
		Ra-228		80±20
		Pb-210		110±10
		Po-210		71±4
W51926N99430	1/8/86	U-234	526/134	100±10
Loc #2		U-235		5±3
2.5'-5'		U-238		120±10
		Th-230		1800±100
		Th-232		59±3
		Ra-226		26±3
		Ra-228		60±10
		Pb-210		95±12
		Po-210		72±7
W51875N99123	1/8/86	U-234	391/116	73±4
Loc #3		U-235		3±1
0-6"		U-238		72±4
		Th-230		480±20
		Th-232		64±4
		Ra-226		16±2
		Ra-228		210±20
		Pb-210		93±2
		Po-210		120±10

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ATTENTION

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S.O. NO. E-5524

REPORT OF ANALYSIS

TYPE OF ANALYSIS | CUSTOMER ORDER NUMBER | SAMPLES RECEIVED

Customer Identification	Date Collected	Type of Analysis	Total Wt. wet/dry(g)	pCi/g (dry)
W51875N99828	1/7/86	U-234	421/205	270±10
Loc #4		U-235		6±2
0-15		U-238		280±10
		Th-230		2400±100
		Th-232		100±10
		Ra-226		190±20
		Ra-228		350±70
		Pb-210		350±40
		Po-210		340±20
W51824N98926	1/9/86	U-234	634/413	27±1
Loc #5		U-235		1.1±0.2
0-6		U-238		28±1
		Th-230		36±4
		Th-232		3.3±0.4
		Ra-226		40±4
		Ra-228		16±3
		Pb-210		27±3
		Po-210		10±1
W51825N99626	1/7/86	U-234	449/129	530±10
Loc #6		U-235		23±3
0-2		U-238		530±10
		Th-230		2900±100
		Th-232		160±10
		Ra-226		160±20
		Ra-228		270±20
		Pb-210		180±10
		Po-210		67±4
W51776N99475	1/8/86	U-234	401/97	120±10
Loc #7		U-235		4±1
0-25		U-238		120±10
		Th-230		74±7
		Th-232		15±1
		Ra-226		71±7
		Ra-228		310±10
		Pb-210		55±3
		Po-210		27±2

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APPROVED BY Kathy Burnham for Rod Melgard, Mgr. 4/7/86

ALBUQUERQUE LABORATORY

REPORT OF ANALYSIS

CUSTOMER Bechtel National, Inc.-Weldon Springs

ATTENTION

ADDRESS

CITY

S.O. NO. E-5524

TYPE OF ANALYSIS | CUSTOMER ORDER NUMBER | SAMPLES RECEIVED

Customer Identification	Date Collected	Type of Analysis	Total Wt. wet/dry(g)	pCi/g (dry)
W51772N99676	1/7/86	U-234	620/283	2200±100
Loc #8		U-235		90±10
0-2.5		U-238		2200±100
		Th-230		500±30
		Th-232		73±10
		Ra-226		21±3
		Ra-228		870±80
		Pb-210		230±30
		Po-210		240±30
W51720N9927	1/9/86	U-234	595/242	40±1
Loc #9		U-235		1.8±0.3
0-6		U-238		41±1
		Th-230		820±20
		Th-232		55±5
		Ra-226		0.8±0.1
		Ra-228		120±10
		Pb-210		250±10
		Po-210		22±2
				19±2*
W51623N99573	1/7/86	U-234	537/368	9±1
Loc #10		U-235		0.3±0.1
0-0.5		U-238		9±1
		Th-230		82±2
		Th-232		1.2±0.3
		Ra-226		15±2
		Ra-228		4±2
		Pb-210		15±2
		Po-210		9±2
W51544N99809	1/7/86	U-234	695/600	390±10
Loc #11		U-235		25±1
0-6		U-238		390±10
		Th-230		250±10
		Th-232		13±1
		Ra-226		53±5
		Ra-228		35±3
		Pb-210		35±3
		Po-210		13±1

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REPORTED VIA TWX *Reanalysis

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REPORT OF ANALYSIS

TYPE OF ANALYSIS | CUSTOMER ORDER NUMBER | SAMPLES RECEIVED

Customer Identification	Date Collected	Type of Analysis	Total Wt. wet/dry(g)	pCi/g (dry)
W51578N98935	1/9/86	U-234	685/418	23±1
Loc #12		U-235		0.8±0.2
0-6		U-238		23±1
		Th-230		1.8±0.2
		Th-232		0.8±0.2
		Ra-226		1.6±0.2
		Ra-228		<2
		Pb-210		5±2
		Po-210		2±1

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APPROVED BY Kathy Burnham for Rod Melgard, Mgr. 4/7/86

APPENDIX D

QA/QC Data in the Form of Quality Reports

from Analytical Laboratory Regarding Blank, Duplicate,

and

Matrix Spike Analyses.

RADSLUDG/TXTJOANN

WELDON SPRING SITE REMEDIAL ACTION PROJECT

QUALITY CONTROL REPORT

RAFFINATE SLUDGE

metaTRACE, Inc. 13715 Rider Trail North • Earth City, MO 63045 • (314) 298-8566

CLIENT: MK Ferguson
PROJECT #'s: 100-03
SAMPLE #'s: All samples analyzed for radiochemical constituents (Raffinate Sludge)

RADIOCHEMICAL ANALYSIS CONFORMANCE SUMMARY

1) GAS PROPORTIONAL COUNTER

a) BACKGROUND ACCEPTABLE ALPHA ☒

b) BACKGROUND ACCEPTABLE BETA ☒

c) PERFORMANCE CHECK ACCEPTABLE ALPHA ☒

d) PERFORMANCE CHECK ACCEPTABLE BETA ☒

2) ALPHA SPECTROMETER

a) BACKGROUND ACCEPTABLE ☒

b) CALIBRATION (KeV/CHANNEL) VERIFICATION ☐

3) ALPHA SCINTILLATION COUNTER

a) BACKGROUND ACCEPTABLE ☒

b) PERFORMANCE CHECK ACCEPTABLE ☐

4) METHOD SPECIFIC PARAMETERS

a) BLANK IN CONTROL ☒

b) SPIKED BLANK IN CONTROL ☒

c) RPD FOR DUPLICATES IN CONTROL ☒

ADDITIONAL COMMENTS: Th 232 duplicates RPD may be out of line. Due to Th 230 interference. Thorium blanks may be >1, but not at a level to be significant compared to the level of activity present in the samples.

Jerry R. Isabe
PROJECT MANAGER

metaTRACE, Inc. 13715 Rider Trail North • Earth City, MO 63045 • (314) 298-8566

WSSRAP PROJECT NO: 100-03
Radiological - Raffinate Sludge
Duplicate Results and Blank Spike Recovery

SAMPLE # AA15850
SITE ID: SD-3309-0002-I

ANALYTE	RESULT #1(pCi/G)	RESULT #2(pCi/G)
Radium 226	550 +/- 55	660 +/- 70
Radium 228	80 +/- 17	190 +/- 25
Thorium 228	140 +/- 40	240 +/- 50
Thorium 230	.16000 +/- 1600	21000 +/- 2100
Thorium 232	240 +/- 45	450 +/- 60
Total Uranium	850 +/- 85	1200 +/- 120

BLANK SPIKE RECOVERY

ANALYTE	PERCENT RECOVERY
Radium 226	67
Radium 228	130
Thorium 228	95
Thorium 230	*
Thorium 232	84
Total Uranium	88

* Unable to quantitate due to other Th interferences.

metaTRACE, Inc. 13715 Rider Trail North • Earth City, MO 63045 • (314) 298-8566

WSSRAP PROJECT NO: 100-03
Radiological - Raffinate Sludge
Duplicate Results and Blank Spike Recovery

SAMPLE # AA15936
SITE ID: SD-3307-0608-I

ANALYTE	RESULT #1(pCi/G)	RESULT #2(pCi/G)
Radium 226	290 +/- 30	130 +/- 15
Radium 228	130 +/- 15	120 +/- 12
Thorium 228	130 +/- 40	150 +/- 33
Thorium 230	14000 +/- 1400	17000 +/- 1700
Thorium 232	250 +/- 50	300 +/- 47
Total Uranium	475 +/- 50	410 +/- 40

BLANK SPIKE RECOVERY

ANALYTE	PERCENT RECOVERY
Radium 226	74
Radium 228	136
Thorium 228	80
Thorium 230	*
Thorium 232	76
Total Uranium	88

* Unable to quantitate due to other Th interferences.

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RADSLUDG/TXTJOANN

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Building 1916-T2
Oak Ridge, TN 37831-0117

Repositories

Cobbs Hall
Lindenwood College
St. Charles, MO 63301

Kathryn Linneman Branch
St. Charles City/County Library
2323 Elm Street
St. Charles, MO 63301

RADSLUDG/TXTJOANN

Spencer Creek Branch
St. Charles City/County Library
425 Spencer Road
St. Peters, MO 63376

Mr. Dan Brown
Francis Howell High School
7001 Highway 94 South
St. Charles, MO 63303

Administrative Record

WSSRAP Public Document Room
7295 Highway 94 South
St. Charles, MO 63303

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