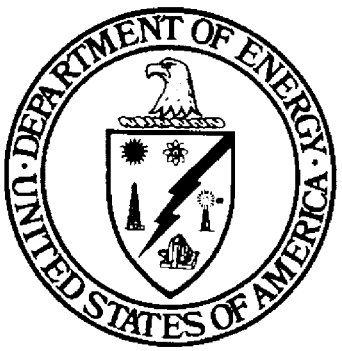
DOE/OR/21548-702
CONTRACT NO. DE-AC05-86OR21548

BUSCH LAKE 36 SUMMARY CLOSEOUT REPORT

WELDON SPRING SITE REMEDIAL ACTION PROJECT
WELDON SPRING, MISSOURI

OCTOBER 1997 **REV. 1**



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

Prepared by MK-Ferguson Company and Jacobs Engineering Group

DOE/OR/21548-702

Weldon Spring Site Remedial Action Project

Busch Lake 36 Summary Closeout Report

Revision 1

October1997

Prepared by

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and
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for the

U.S. DEPARTMENT OF ENERGY
Oak Ridge Operations Office
Under Contract DE-AC05-86OR21548

MK-FERGUSON
A MORRISON KNUDSEN COMPANY

Weldon Spring Site Remedial Action Projec
Contract No. DE-AC05-86OR21548

Rev. No. 1

PLAN TITLE: Busch Lake 36 Summary Closeout Report

APPROVALS

Project Manager - Quarry/Vicinity Properties — Date: 24 OCT 97

Engineering Department Manager — Date: 10-24-97

Data Administration Manager — Date: 10/24/97

Quality Assurance Manager — Date: 10/24/97

Deputy Project Director — Date: 10-24-97

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1. INTRODUCTION

1.1 Purpose

The purpose of this report is to document the assessment of the need for, and the results of, the Busch Lake 36 sediment removal project.

1.2 Scope

This report discusses characterization work performed to provide a basis for a decision on whether engineering design was needed to remediate the Lake 36 sediments. On the basis of the characterization results, it was determined that remediation design was not needed, but a small quantity of sedimentary materials was contaminated with U-238 at levels slightly above background but below cleanup criteria. At the request of the Missouri Department of Natural Resources, these materials were removed and transported to the Weldon Spring Site Remedial Action Project (WSSRAP) chemical plant site.

1.3 Background

Busch Lake 36 is a 15.5 acre man-made lake located in the southeast portion of the August A. Busch Memorial Conservation Area immediately north of State Highway D and approximately 1 mile west of Francis Howell High School. Water flows to the lake via springs and a drainage from the Weldon Spring Chemical Plant site. Water flows from the lake through an overflow structure into another drainage that eventually leads to Busch Lake 35. The lake was constructed while the chemical plant was in operation. The Department of Energy (DOE) had the opportunity to sample the lake sediments after it was drained by the Department of Conservation for scheduled restoration. These data were obtained to evaluate remediation decisions and support engineering design.

2. CHARACTERIZATION

The *Engineering Design and Characterization Sampling Plan for Soils and Sediments from Busch Lake 36* (Ref.. 1) was the guiding document for sediment characterization activities. The plan required sampling crews to take walkover readings and surface radioactivity measurements 10 meters apart at previously surveyed locations. At-depth samples were taken at previously surveyed locations on a five point pattern 50 meters apart at the corners. Each at-depth sample was 1 ft long with the last sample at each location ending in the engineered clay lake bottom. The plan also called for biased depth sampling at walkover locations where the reading was 1.5 times background for areas greater than 100 sq ft. Biased sampling was also conducted in areas outside the 50 meter grid where additional information was needed. A total of six biased locations were sampled. Three of these sites were located on the dam to determine if the materials used to build the dam were contaminated. The results were negative. Two biased locations (062 and 063) were sampled to recheck walkover readings, and one location (P7) was sampled because a survey marker had been washed away. The characterization activities were complete as of February 14, 1997. A summary of sample locations, sample identifications, dates sampled, and final concentrations is in Appendix A. In total, 136 samples were obtained from 58 locations with the following results:

- 12 samples above the post remediation ALARA (As Low As Reasonably Achievable) goal of 30 pCi/g of U-238.
- 124 samples below the ALARA goal of 30 pCi/g of U-238.
- 0 samples exceeded 120 pCi/g of U-238 above which remediation is mandated.

2.1 Statistical Results

Characterization produced the following statistical results.

	Above ALARA	Below ALARA	Total
No. of Samples	12	124	136
% of Total	9.4	90.6	100
Mean (pCi/g)	48.2	8.1	11.5
Range (pCi/g)	28.3 - 91.0	1.3 - 26.6	1.3 - 91.0
Standard Deviation (pCi/g)	18.7	6.4	14.1
95% Conf. Interval (pCi/g)	39 - 59	6 - 9	10 - 13

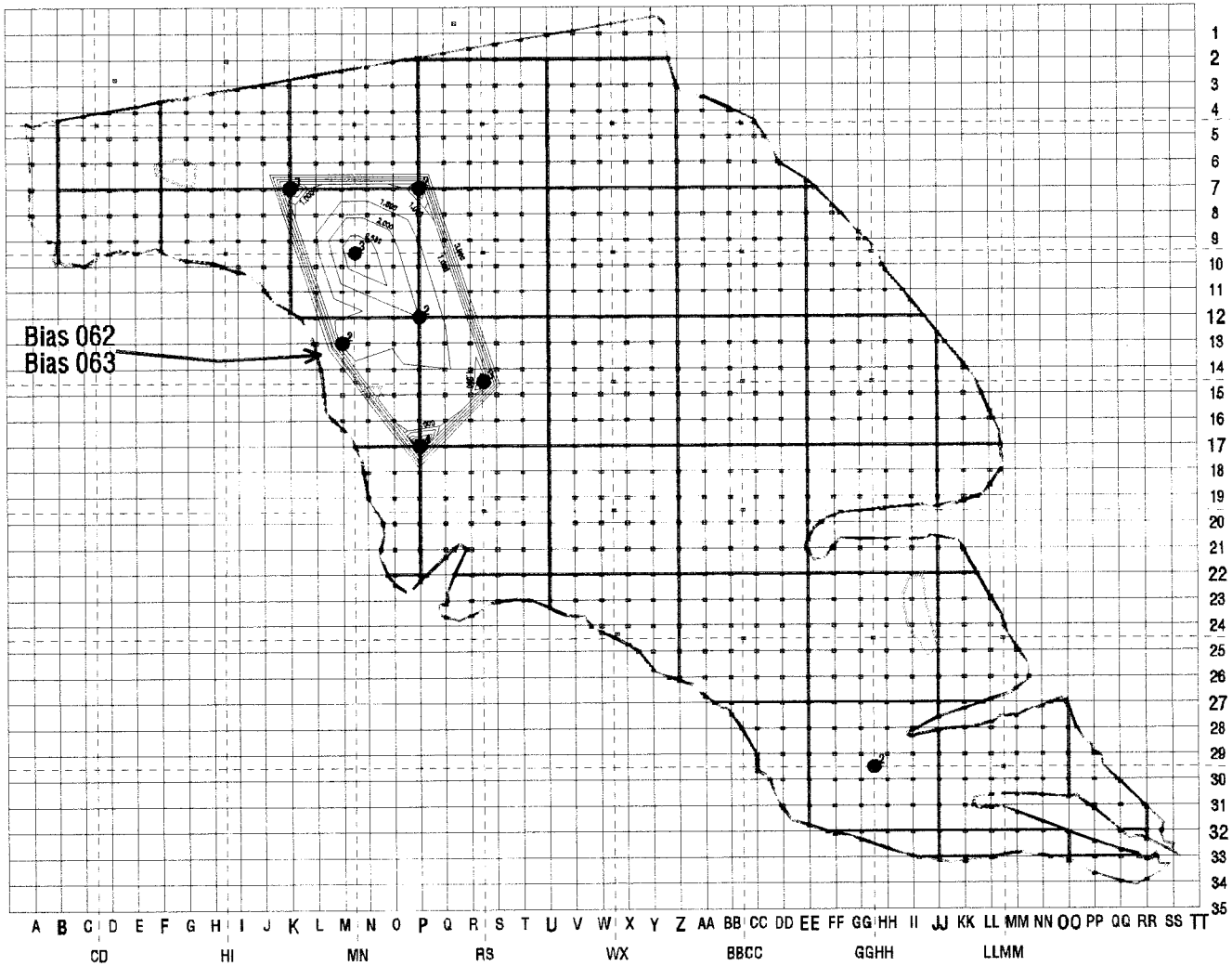
The characterization indicated that approximately 10,000 bank cu yd of sediment within Lake 36 was identified as above the ALARA goal (30 pCi/g) but below criteria (120 pCi/g). The total volume of sediment within Lake 36 is estimated to be approximately 80,000 bank cu yd.

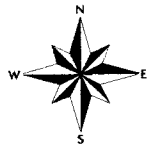
The locations indicating sample results above the ALARA goal are shown on Figure 1.

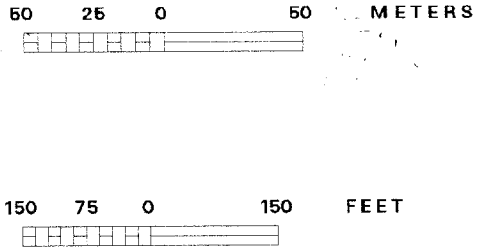
2.2 Quality Control Sampling Summary

Samples of soil and sediment were taken from the lake bed of Busch Lake 36 in accordance with the quality sampling criteria established in ES&H 4.1.4, *Quality Control Samples for Aqueous and Solid Matrices: Definitions, Identification Codes, and Collection Procedures.* Samples were collected from January 29, 1997, through February 13, 1997. A total of 62 samples were collected from the lake bed and adjacent north berm at Busch Lake 36 (sample identification numbers 496005 through 496067).

Eight quality control samples (see table in Appendix B) were taken during this sample collection (13% of sample total). These included blanks (equipment blanks) and duplicate/replicate samples. The equipment blanks indicated that there was no significant cross contamination during sample collection which could result from radioactively contaminated sampling equipment. The measured precision or Relative Percent Difference (RPD) between sample duplicate measurements was within the 50% tolerance specified in the *WSSRAP Sample Management Guide* (Ref. 4).







BUSCH LAKE 36

LOCATION OF SEDIMENTS

ABOVE ALARA GOAL

Figure: 1

EXHIBIT NO.: G/QY/013/0697		REPORT NO.: DOE/OR/21548-702	
ORIGINATOR: GLV	DRAWN BY: WSSRAP GIS	DATE: 08/20/97	

3. REGULATORY REVIEW

The Weldon Spring Site Remedial Action Project (WSSRAP) is a DOE managed project that utilizes the CERCLA process as guidance for remediation decisions. A Record of Decision (ROD) is the summary decision document that records the agreement between the DOE and the regulatory agencies concerning remediation goals and standards. The Lake 36 area is governed by the Chemical Plant ROD (Ref. 2) signed by the DOE and Region VII of the U.S. Environmental Protection Agency (EPA) on September 13, 1993, and September 28, 1993, respectively. The ROD is based upon data contained in supporting documents such as the Feasibility Study (FS) (Ref. 3). Concerning Lake 36, the ROD and FS state the following:

- For off-site soils and sediments (i.e., Busch Lakes 34, 35, and 36), the cleanup criteria developed for on-site soil will be used. (ROD, pg. 42)

- Radionuclides are included within the soils and sediments as a result of past spills and releases from the site, but chemicals are not. Consequently, the radiological cleanup criteria for soils should be applied to this material. (FS, pg. 2-8)

- The DOE will remove the portion of sediment and shoreline soils contaminated in excess of cleanup criteria for the site. (FS, pg. 4-5) Once contamination levels in excess of criteria have been identified, the remediation design and quantities to be removed to attain the ALARA goal will be determined.

3.1 Dose Estimates

Dose estimates have been calculated for workers removing the Lake 36 sediments above ALARA. The dose estimate to the equipment operators is slightly under 9 mrem (committed effective dose equivalent). For comparison, listed below are everyday activities and the doses:

- Chest x-ray - 8 mrem.
- CT scan (head and body) - 111 mrem.
- Transatlantic flight (one way) - 5 mrem.
- Living one year near a lead smelter - 5 mrem.
- Smoking one cigarette per day for one year - 64 mrem.
- Annual average background radiation in the St. Charles County area - 300 mrem.

3.2 Estimate of Potential Human Health Risk

Potential human health risks were estimated using data collected from Lake 36. Uranium was identified as the only contaminant elevated above background. Concentrations ranged from 1.29 pCi/g to 91 pCi/g. Only 10 of 136 samples collected were reported at concentrations greater

than the ALARA goal of 30 pCi/g. Note that two additional samples within the +/- error range of 30 pCi/g were used in the statistical analysis data base. Samples showing concentrations above the ALARA goal were primarily collected from the northwest portion of the lake. Risk estimates were performed using a hypothetical case in which uranium contaminated soil is removed from the lake and used as top cover for a 10-acre area nearby. Calculations were based on methodology and assumptions similar to those presented in other documents prepared for the chemical plant area. Potential health risks for a recreational visitor and a resident are estimated to be at 1×10^{-6} and 5×10^{-5}, respectively. Potential health risk estimated from background concentrations is about 8×10^{-6}. A summary of risk calculations is contained in Appendix C.

3.3 Transportation Impacts

The nonexposure-related impacts of transporting excavated or dredged soil from Lake 36 to the chemical plant area were calculated. To perform this calculation, the Missouri Department of Transportation provided traffic flow data for Highway D and Highway 94. Based upon information regarding possible routes, number of trips, and distances traveled, no accident or fatality is expected. That is, using an accident rate of 1.97×10^{-6} per vehicle-km and a fatality rate of 1.72×10^{-8} per vehicle-km, the accident rate for a distance traveled of about 500 miles would result in 0.002 accident and 0.00002 fatality.

4. REMEDIATION DECISION

On April 25, 1997, representatives of the DOE and PMC met to review the Lake 36 characterization results and to identify future work at Lake 36. The following decisions were made:

- The existing remediation design efforts were canceled because characterization results indicated that site cleanup criteria had not been exceeded.

- Characterization efforts for the remainder of the off-site properties, including Busch Lakes 34 and 35, will continue.

- Remediation activities will be performed on off-site properties that exceed site cleanup criteria for at least one contaminant of concern.

5. ADDITIONAL ACTIONS

In accordance with an agreement reached between the State of Missouri and the DOE on July 25, 1997, approximately 429 cu yd of sediment were removed from Lake 36 and transported to the WSSRAP on September 11 and 12, 1997. Although the results of characterization and health risk evaluation indicated that removal of sediment was not required, the DOE agreed to remove sediments to a depth of 1 ft within an area measuring approximately 150 ft by 65 ft and encompassed by location MN910 (U-238; 91 pCi/g) and nearby location P12 (U-238; 75 pCi/g). These sediments targeted for removal were stockpiled by the Department of Conservation utilizing equipment engaged in the lake restoration project. Loading and transportation efforts were performed by a PMC subcontractor. These materials were then delivered to the WSSRAP and placed in the clean unsuitable soil stockpile area for future use as construction material within the geochemical or select soil layer in the disposal cell. Prior to transportation to the site, six samples of the sediment were taken yielding the following results (U-238):

Average pCi/g	Minimum pCi/g	Maximum pCi/g
31.14	14.41	62.23

6. REFERENCES

1. MK-Ferguson Company and Jacobs Engineering Group. *Engineering Design and Characterization Sampling Plan for Soils and Sediments from Busch Lake 36*. Rev. 1. DOE/OR/21548-662. Prepared for the U. S. Department of Energy, Oak Ridge Operations Office. St. Charles, MO. January 1997.

2. Department of Energy. *Record of Decision for Remedial Action at the Chemical Plant Area of the Weldon Spring Site*. Rev. 0. DOE/OR/21548-376. Oak Ridge Field Office. St. Charles, MO. September 1993.

3. Department of Energy. *Feasibility Study for Remedial Action at the Chemical Plant Area of the Weldon Spring Site*, 2 Vols. DOE/OR/21548-148. Oak Ridge Field Office, Weldon Spring Site Remedial Action Project. St. Charles, MO. November 1992.

4. MK-Ferguson Company and Jacobs Engineering Group. *Sample Management Guide*. Rev. 1. DOE/OR/21548-499. Prepared for the U. S. Department of Energy, Oak Ridge Operations Office. St. Charles, MO. August 1997.

APPENDIX A
Lake 36 Data Report

LAKE 36 DATA REPORT

Sample Identification #	Sample Location	Date Sampled	Conc.(pci/g)	REQUEST #	
SO-496022-01	MN910	1/29/97	91	257	
SO-496027-01	P12	1/29/97	75.1	257	
SO-496036-01	P17	2/12/97	54.17	266	
SO-496015-02	K7	1/30/97	52.8	257	
SO-496064-01	Bias (P7)	1/30/97	51.3	257	
SO-496032-02	RS1415	2/13/97	43.57	266	
SO-496056-01	GGHH2930	2/7/97	42.1	261	
SO-496063-01	Bias	1/29/97	41.2	257	
SO-496032-01	RS1415	2/13/97	35.26	266	
SO-496036-03	P17	2/12/97	33.84	266	
SO-496015-01	K7	1/30/97	29.5	257	
SO-496022-02	MN910	1/29/97	28.3	257	
SO-496051-01	BBCC2425	2/11/97	26.62	265	
SO-496048-01	EE22	2/10/97	26.31	265	
SO-496052-02	GGHH2425	2/11/97	23.34	265	
SO-496041-01	RS1920	2/12/97	22.95	266	
SO-496047-01	Z22	2/5/97	22.8	261	
SO-496017-02	U7	2/14/97	21.93	267	
SO-496057-02	LLMM2930	2/11/97	21.63	265	
SO-496028-02	U12	2/13/97	21.5	266	
SO-496029-01	Z12	2/14/97	21.5	267	
SO-496013-01	B7	1/30/97	21.2	257	
SO-496056-02	GGHH2930	2/7/97	21	261	
SO-496014-01	F7	2/13/97	20.64	266	
SO-496007-01	CD45	2/13/97	19.89	266	
SO-496057-01	LLMM2930	2/11/97	19.52	265	
SO-496008-02	HI45	2/14/97	19.29	267	
SO-496052-01	GGHH2425	2/11/97	18.4	265	
SO-496017-01	U7	2/14/97	16.76	267	
SO-496048-02	EE22	2/10/97	16.28	265	
SO-496054-01	EE27	2/7/97	15.7	261	
SO-496008-01	HI45	2/14/97	15.35	267	
SO-496047-02	Z22	2/5/97	15	261	
SO-496046-01	U22	2/10/97	14.92	265	
SO-496048-03	EE22	2/10/97	12.83	265	
SO-496009-01	MN45	2/14/97	12.34	267	
SO-496032-03	RS1415	2/13/97	12.29	266	
SO-496036-02	P17	2/12/97	12.27	266	
SO-496045-02	P22	2/7/97	12.1	261	
SO-496037-01	U17	2/12/97	12.04	266	
SO-496006-01	U2	1/8/97	11.4	249	
SO-496033-01	WX1415	2/13/97	10.63	266	
SO-496033-02	WX1415	2/13/97	10.41	266	
SO-496009-03	MN45	2/14/97	10.11	267	
SO-496034-01	BBCC1415	2/13/97	10	266	
SO-496027-02	P12	1/29/97	9.95	257	

SO-496030-01	EE12	1/14/97	9.83	250	
SO-496055-01	JJ27	2/10/97	9.72	265	
SO-496006-02	U2	1/8/97	9.58	249	
SO-496010-01	RS45	2/14/97	9.55	267	
SO-496028-01	U12	2/13/97	9.45	266	
SO-496038-01	Z17	2/12/97	9.15	266	
SO-496015-03	K7	1/30/97	8.85	257	
SO-496049-02	JJ22	2/10/97	8.56	265	
SO-496009-02	MN45	2/14/97	7.6	267	
SO-496025-01	BBCC910	1/14/97	7.16	250	
SO-496041-02	RS1920	2/12/97	7.14	266	
SO-496044-01	GGHH1920	2/13/97	7.03	266	
SO-496035-01	GGHH1415	1/14/97	7.02	250	
SO-496039-01	EE17	2/13/97	6.8	266	
SO-496064-03	Bias (P7)	1/30/97	6.49	257	
SO-496024-02	WX910	2/14/97	6.44	267	
SO-496018-01	Z7	1/8/97	6.15	249	
SO-496007-02	CD45	2/13/97	6	266	
SO-496049-01	JJ22	2/10/97	5.83	265	
SO-496043-01	BBCC1920	2/10/97	5.18	265	
SO-496043-02	BBCC1920	2/10/97	5.07	265	
SO-496028-03	U12	2/13/97	4.96	266	
SO-496029-02	Z12	2/14/97	4.96	267	
SO-496037-03	U17	2/12/97	4.87	266	
SO-496034-02	BBCC1415	2/13/97	4.84	266	
SO-496037-02	U17	2/12/97	4.81	266	
SO-496006-04	U2	1/8/97	4.59	249	
SO-496020-01	CD910	2/10/97	4.35	265	
SO-496053-02	LLMM2425	2/10/97	4.3	265	
SO-496011-02	WX45	1/8/97	4.27	249	
SO-496031-01	MN1415	2/13/97	4.22	266	
SO-496021-02	HI910	2/10/97	4.05	265	
SO-496022-03	MN910	1/29/97	4.04	257	
SO-496022-04	MN910	1/29/97	4.04	257	
SO-496024-01	WX910	2/14/97	4.03	267	
SO-496030-03	EE12	1/14/97	4.03	250	
SO-496038-02	Z17	2/12/97	4.03	266	
SO-496005-01	P2	2/14/97	3.97	267	
SO-496035-03	GGHH1415	1/14/97	3.97	250	
SO-496025-03	BBCC910	1/14/97	3.95	250	
SO-496012-01	BBCC45	1/8/97	3.92	249	
SO-496055-02	JJ27	2/10/97	3.92	265	
SO-496040-02	JJ17	1/14/97	3.88	250	
SO-496063-02	Bias	1/29/97	3.88	257	
SO-496012-02	BBCC45	1/8/97	3.86	249	
SO-496005-02	P2	2/14/97	3.85	267	
SO-496042-01	WX1920	2/11/97	3.74	265	
SO-496005-03	P2	2/14/97	3.71	267	
SO-496041-03	RS1920	2/12/97	3.71	266	

SO-496020-02	CD910	2/10/97	3.67	265	
SO-496026-02	GGHH910	1/14/97	3.67	250	
SO-496010-02	RS45	2/14/97	3.55	267	
SO-496006-03	U2	1/8/97	3.54	249	
SO-496053-01	LLMM2425	2/10/97	3.53	265	
SO-496058-01	JJ32	2/11/97	3.47	265	
SO-496021-01	HI910	2/10/97	3.46	265	
SO-496027-03	P12	1/29/97	3.4	257	
SO-496027-04	P12	1/29/97	3.4	257	
SO-496045-01	P22	2/7/97	3.4	261	
SO-496050-01	WX2425	2/5/97	3.4	261	
SO-496054-02	EE27	2/7/97	3.4	261	
SO-496054-03	EE27	2/7/97	3.4	261	
SO-496062-02	Bias	1/29/97	3.4	257	
SO-496063-03	Bias	1/29/97	3.4	257	
SO-496064-02	Bias (P7)	1/30/97	3.4	257	
SO-496011-01	WX45	1/8/97	3.33	249	
SO-496042-03	WX1920	2/11/97	3.33	265	
SO-496062-03	Bias	1/29/97	3.26	257	
SO-496011-03	WX45	1/8/97	3.24	249	
SO-496013-03	B7	1/30/97	3.21	257	
SO-496018-02	Z7	1/8/97	3.21	249	
SO-496051-02	BBCC2425	2/11/97	3.18	265	
SO-496019-01	EE7	1/8/97	3.14	249	
SO-496019-02	EE7	1/8/97	3.14	249	
SO-496044-02	GGHH1920	2/13/97	3.14	266	
SO-496039-02	EE17	2/13/97	3.11	266	
SO-496058-02	JJ32	2/11/97	3.11	265	
SO-496025-02	BBCC910	1/14/97	3.1	250	
SO-496046-02	U22	2/10/97	3.09	265	
SO-496030-02	EE12	1/14/97	3.07	250	
SO-496013-02	B7	1/30/97	3	257	
SO-496035-02	GGHH1415	1/14/97	2.99	250	
SO-496026-03	GGHH910	1/14/97	2.98	250	
SO-496026-01	GGHH910	1/14/97	2.97	250	
SO-496040-03	JJ17	1/14/97	2.92	250	
SO-496040-01	JJ17	1/14/97	2.86	250	
SO-496050-02	WX2425	2/5/97	2.63	261	
SO-496042-02	WX1920	2/11/97	2.14	265	
SO-496051-03	BBCC2425	2/11/97	1.74	265	
SO-496062-01	Bias	1/29/97	1.29	257	
STANDARD DEVIATION			14.04824498		
MEAN			11.47838235		
MODE			3.4	*DUE TO N/D	
PERCENT ABOVE ALARA			8.60%		
MEAN FOR THOSE > ALARA			48.17833333		
MEAN FOR THOSE < ALARA			8.08976		
SURFACE AREA ABOVE ALARA			15.30%		

APPRENDIX B
Quality Control Sampling Summary Table

APPRENDIX B
Quality Control Sampling Summary Table

WSSRAP SAMPLE ID	SAMPLE CONCEN-TRATION	SAMPLE UNITS	ANALYTICAL PARAMETER	SAMPLE DETECTION LIMIT
SO-496005-01	ND	pCi/g	U-238	3.97
SO-496005-01-DU	ND	pCi/g	U-238	3.11
SO-496005-01-EB	(0.0137)	pCi/L	Total U	0.0677
SO-496005-01-FR	3.02	pCi/g	U-238	2.26
SO-496005-01-SD	1.48	pCi/g	U-238	0.258
SO-496008-01	15.35	pCi/g	U-238	3.53
SO-496008-01-DU	12.9	pCi/g	U-238	4.64
SO-496008-01-EB	0.0678	pCi/L	Total U	0.0677
SO-496008-01-EB-DU	0.0716	pCi/L	Total U	0.0677
SO-496008-01-FR	16.7	pCi/g	U-238	5.53
SO-496008-01-SD	18.4	pCi/g	U-238	0.258
SO-496018-01	6.15	pCi/g	U-238	2.32
SO-496018-01-DU	4.51	pCi/g	U-238	2.66
SO-496018-01-EB	(0.10)	pCi/L	Total U	0.2
SO-496018-01-FR	(3.24)	pCi/g	U-238	3.41
SO-496018-01-SD	4.9	pCi/g	U-238	0.4
SO-496025-01	7.16	pCi/g	U-238	3.62
SO-496025-01-DU	7.30	pCi/g	U-238	3.51
SO-496025-01-FR	8.50	pCi/g	U-238	2.70
SO-496029-01-ED	21.5	pCi/g	U-238	0.0677
SO-496029-01-DU	19.5	pCi/g	U-238	5.93
SO-496029-01-EB	0.512	pCi/L	Total U	0.677
SO-496029-01-FR	24.8	pCi/g	U-238	3.47
SO-496029-01-SD	25.6	pCi/g	U-238	0.258
SO-496059-15	ND	pCi/g	U-238	3.31
SO-496059-15-DU	ND	pCi/g	U-238	3.79
SO-496059-15-EB	0.5	pCi/L	Total U	0.2
SO-496059-15-FR	ND	pCi/g	U-238	3.01
SO-496059-15-SD	1.0	pCi/g	U-238	0.4
SO-496060-10	ND	pCi/g	U-238	4.39
SO-496060-10-DU	ND	pCi/g	U-238	3.85
SO-496060-10-EB	(0.10)	pCi/L	Total U	0.2
SO-496060-10-FR	ND	pCi/g	U-238	3.15
SO-496060-10-SD	1.3	pCi/g	U-238	0.4
SO-496061-27	ND	pCi/g	U-238	3.94
SO-496061-27-DU	ND	pCi/g	U-238	3.65
SO-496061-27-EB	0.5	pCi/L	Total U	0.2
SO-496061-27-FR	ND	pCi/g	U-238	2.92
SO-496061-27-SD	0.9	pCi/g	U-238	0.4

APPENDIX C
Risk Evaluation for Busch Lake 36

ATTACHMENT 1: RISK EVALUATION FOR BUSCH LAKE 36

Risk calculations relative to soil/sediment contaminant levels in Lake 36 were performed for a range of scenarios, including recreational and residential. The pathways evaluated included external irradiation, incidental ingestion of soil, and inhalation of air particulates. The primary contaminant of concern in Lake 36 soil/sediment is uranium. An exposure point concentration for uranium was calculated using the one-tailed 95% upper confidence limit of the arithmetic average (UCL); a value of 13 pCi/g was calculated for U-238.

Two methods for evaluating human health risk are shown in this attachment. For the first method, presented in Part 1, radiation doses are calculated using dose conversion factors (DCFs), and multiplied by a risk factor to estimate risk of cancer incidence. Calculations are also performed using the EPA slope factor methodology presented in Part 2. EPA recommends using slope factors to estimate cancer risks from radionuclide exposures. The dose conversion factor (DCF) methodology was used in the Baseline Assessment for the Chemical Plant area (DOE 1992) because at the time, slope factors for radionuclides were not widely accepted. Because the lakes are included in the chemical plant area operable unit, both methods are presented in this attachment.

Part I. Dose Conversion Factor Methodology

For the DCF method, radiation doses are calculated for each pathway of exposure. Exposure to radioactive contaminants is expressed in terms of the 50-yr committed effective dose equivalent (CEDE) for internal exposures, a concept that was developed by the International Commission on Radiological Protection (ICRP 1977). For external pathways, there is no long-term residence of radionuclides in the body and the appropriate measure of dose is the effective dose equivalent (EDE). The sum of the CEDE and EDE is termed the total CEDE. The equations used to calculate the EDE and CEDE are provided below.

The dose associated with external irradiation was calculated using the following equation:

$$EDE = R_{soil} \times ET \times EF \times ED \times DCF_{ext}$$

where:

EDE = Effective dose equivalent (mrem);

R_{soil} = Radionuclide soil concentration (pCi/g);

ET = Exposure time (h);

EF = Exposure frequency (d/yr);

ED = Exposure duration (yr); and

DCF_{ext} = External radiation dose conversion factor (mrem/h)/(pCi/g).

For indoor exposures, a shielding factor was applied to account for the reduction in indoor exposure to external gamma radiation compared with outdoor exposure as a result of attenuation by the structure (i.e., the EDE was multiplied by the shielding factor).

The dose associated with ingestion of contaminated soil was calculated as follows:

$$CEDE = R_{soil} \times IR_{soil} \times CF_1 \times EF \times ED \times DCF_{ing}$$

where:

CEDE = Committed effective dose equivalent (mrem);

IR_{soil} = Soil ingestion rate (mg/d);

CF_1 = Conversion factor (10^{-3} g/mg); and

DCF_{ing} = Ingestion dose conversion factor (mrem/pCi).

The dose associated with inhalation of radioactive air particulates was calculated as follows:

$$CEDE = R_{soil} \times (1/PEF) \times CF_2 \times IR_{air} \times ET \times EF \times ED \times DCF_{inh}$$

where:

IR_{air} = Inhalation rate (m^3/h);

CF_2 = conversion factor (10^3 g/kg);

PEF = particulate emission factor (m^3/kg);

DCF_{inh} = Inhalation dose conversion factor (mrem/pCi).

For indoor exposures, a filtration factor was also applied to account for the reduction of airborne dust from outdoor soil as a result of the filtration effect of the structure (i.e., the CEDE was multiplied by the filtration factor).

Risk calculations for U-238 include the contribution from U-234, U-235, Pa-231, and Ac-227, as determined by a source term analysis for chemical plant soil. The activity ratios and dose conversion factors used for the risk calculations are summarized in Table 1. The exposure assumptions used are summarized in Table 2; parameters are those used in the BA and FS for the Chemical Plant Area (DOE 1992).

The risk of cancer induction from exposure to radiation was calculated by multiplying the sum of the EDE and CEDEs by a risk factor of 6×10^{-7} per mrem (EPA 1989a). As shown in Table 3, the estimated risk for the recreational visitor is 1×10^{-6}, and 5×10^{-5} for the resident.

Table 1 Activity Concentration Ratios and Dose Conversion Factors[a]

Radionuclide[b]	Activity Ratio[c]	DCF External (mrem/h)/(pCi/g)	DCF Ingestion (mrem/pCi)	DCF Inhalation (mrem/pCi)
Actinium-227+D	0.019	3.1×10^{-4}	1.5×10^{-2}	6.7
Protactinium-231	0.038	2.5×10^{-5}	1.1×10^{-2}	1.3
Uranium-234	1	1.4×10^{-7}	2.6×10^{-4}	2.7×10^{-3}
Uranium-235+D	0.046	1.0×10^{-4}	2.5×10^{-4}	2.5×10^{-3}
Uranium-238+D	1	1.4×10^{-5}	2.5×10^{-4}	2.4×10^{-3}

a Source: Yu 1993.
b. The +D designation indicates that decay products with radioactive half-lives less than or equal to 6 months are included.
c. Activity ratios based on chemical plant area soil (BA 1992).

Table 2 Exposure Assumptions[a]

Parameter	Recreational Visitor	Resident
Exposure Time ET (hr)		
Indoor	--	23
Outdoor	4	1
Exposure Frequency EF (d/yr)	20	350
Exposure Duration ED (yr)	30	30
Inhalation Rate IR_{air} (m^3/hr)		
Indoor	--	0.8
Outdoor	2.1[d]	1.6
Filtration Factor[a]	--	0.8
Soil Ingestion Rate IR_{soil} (mg/d)	120[e]	120[e]
Shielding Factor[b]	--	0.7
Particulate emission factor (m3/kg)[f]	$4.63\ 10^9$	$4.63\ 10^9$

a. Source for exposure parameters is EPA (1991a) unless otherwise noted.
b. This factor accounts for reduction in indoor concentration of airborne dust from outdoor soil as a result of the filtration effect of the structure (Stern 1976, Ozkaynak 1991).
c. This factor accounts for reduction in indoor exposure to external gamma radiation as a result of shielding from structure (Yu 1993).
d. Scenario-specific inhalation rate calculated on the basis of average inhalation rates for male adults at various activity levels and information on outdoor activity patterns given by the EPA (1989b) (see the BA).
e. This receptor is assumed to incidentally ingest 200 mg/d for 6 years and 100 mg/d for 24 years (EPA 1991a).
f. EPA 1991b.

Table 3. Dose and Health Risk for the Recreational Visitor and Resident

Radionuclide	Recreational Visitor		Resident	
	Dose (mrem)	Risk	Dose (mrem)	Risk
Actinium-227	0.45	2.7 E-7	18	1.1 E-5
Protactinium-231	0.42	2.5 e-7	9.1	5.5 E-6
Uranium-235	0.15	9.0 e-8	11	6.6 E-6
Uranium-238[a]	0.91	5.5 e-7	41	2.5 E-5
Total	1.9	1 E-6	79	5 E-5

a. Includes contribution from uranium-234.

Part II: Slope Factor Methodology

Calculations were also performed using the EPA slope factor methodology using the same exposure parameters provided in Table 2. Using the slope factor methodology, intakes and health risks were calculated for each pathway of exposure. For the external gamma pathway, the intake for radionuclide I (in units of pCi -yr/g) were calculated as follows:

$$I_{i(ext)} = R_{soil} \times ET \times EF \times ED \times 1/8760\ h$$

where:

$I_{i(ext)}$ = intake for radionuclide I from external irradiation (pCi - yr/g);

R_{soil} = Radionuclide soil concentration (pCi/g);

ET = Exposure time (h);

EF = Exposure frequency (d/yr); and

ED = Exposure duration (yr).

For indoor exposures, a shielding factor was applied to account for the reduction in indoor exposure to external gamma radiation compared with outdoor exposure as a result of attenuation by the structure (i.e., the intake was multiplied by the shielding factor).

The intake of radionuclide I from ingestion of soil was calculated as follows:

$$I_{i(ing)} = R_{soil} \times IR_{soil} \times CF_1 \times EF \times ED$$

where:

$I_{i(ing)}$ = intake for radionuclide I from ingestion (pCi);
IR_{soil} = Soil ingestion rate (mg/d); and
CF_1 = Conversion factor (10^{-3} g/mg).

The intake of radionuclide I from inhalation of soil was calculated as follows:

$$I_{i(inh)} = R_{si} \times (1/PEF) \times CF_2 \times IR_{air} \times ET \times EF \times ED$$

where:

$I_{i(inh)}$ = intake for radionuclide I from inhalation (pCi);
CF_2 = conversion factor (10^3 g/kg);
IR_{air} = Inhalation rate (m^3/h); and
PEF = particulate emission factor (m^3/kg).

For indoor exposures, a filtration factor was also applied to account for the reduction of airborne dust from outdoor soil as a result of the filtration effect of the structure (i.e., the intake was multiplied by the filtration factor).

The estimated intakes for uranium and associated radionuclides are presented in Table 4. Health risks were calculated by multiplying the estimated intake for each radionuclide and pathway by the appropriate slope factor provided in Table 5. Estimated risks are presented in Table 6. For the recreational scenario a total risk from all pathways was estimated to be 5×10^{-7}. A total risk of 3×10^{-5} was estimated for the residential scenario. As is observed for this assessment, risks computed by the slope factor methodology are generally lower than those using the DCF method. The differences between the methods is attributed to factors such as the consideration of competing mortality risks and age-dependent radiation risk models in the development of slope factors, different distributions of relative weights assigned to individual organ risks in the two methods, and differences in dosimetric and toxicological assumptions.

Table 4. Estimated Intakes for the Recreational Visitor and Resident[a]

Radionuclide	Recreational Visitor			Resident		
	$I_{(ing)}$	$I_{(ing)}$	$I_{(ext)}$	$I_{(ing)}$	$I_{(ing)}$	$I_{(ext)}$
Actinium-227+D	18	0.00027	0.068	310	0.0091	5.1
Protactinium-231	36	0.00054	0.14	620	0.018	10
Uranium-235	43	0.00065	0.16	750	0.022	12
Uranium-238+D[b]	940	0.014	3.6	16,000	0.48	270
Total	1,000	0.016	3.9	18,000	0.53	290

a. Units for inhalation and ingestion are pCi, and for external irradiation pCi-yr/g.
b. Includes contribution from uranium-234.

Table 5 Slope Factors

Radionuclide[a]	External Gamma (risk/yr)/(pCi/g)	Ingestion (risk/pCi)	Inhalation (risk/pCi)
Actinium-227+D	9.30×10^{-7}	6.26×10^{-10}	7.87×10^{-8}
Protactinium-231	2.71×10^{-8}	1.49×10^{-10}	2.42×10^{-8}
Uranium-234	2.14×10^{-11}	4.44×10^{-11}	1.4×10^{-8}
Uranium-235+D	2.65×10^{-7}	4.7×10^{-11}	1.3×10^{-8}
Uranium-238+D	6.57×10^{-8}	6.20×10^{-11}	1.24×10^{-8}

Source: HEAST 1995

a. The +D designation indicates that decay products with radioactive half-lives less than or equal to 6 months are included.

Table 6 Estimated Health Risks for the Recreational Visitor and Resident

Radionuclide	Recreational Visitor	Resident
Actinium-227	7.4e-8	4.9e-6
Protactinium-231	9.0e-9	3.7e-7
Uranium-235	4.5e-8	3.3e-6
Uranium-238[a]	3.3e-7	1.9e-5
Total	5e-7	3e-5

a. Includes contribution from uranium-234.

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