Environmental Information Center Document Review

Doc. Title:	RIA for WAG 22 BG SWMU 2 and 3 @ PGDP				Location: EIC
Doc. Date:	Sept 1994	Doc. No.	DOE/OR/07-1141&D2	Accession No.	I-00309-0029

Review 2.1 ☐ Review 2.2 ☑ Determined by: Date: 11-3-10

2.1 Review Coordination
Corporate or Agency Author:

Agency/Site/Contact: ______ Date: ______ By: ______

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Agency/Site/Contact: ______ Date: ______ By: ______

Decision: ______

2.2 Review (Paducah Document)

Review Decision:	A ☐	B.1 ☑ ~~[illegible]~~ 1/6/11	B.2 ☐	B.3 ☐	C ☑

A1: ______ Initial/Date	B 1.2: ______ Initial/Date	B 1.6: ______ Initial/Date	**Notify CO**: B.2.1/B.3.1 ______ Date/Time
A2: ______ Initial/Date	B 1.3: ______ Initial/Date	B 1.7: ______ Initial/Date	CO Review: B.2.2/B.3.2 ______
A3: ______ Initial/Date	B 1.4: ______ Initial/Date	B 1.8: ______ Initial/Date	CO Decision: B.1 ☐ B.2.3 ☐ B.3.3 ☐ C ☐
	B 1.5: ______ Initial Date	B 1.9: ______ Initial/Date	

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NOTES: TO Kevil for copy of fig 2-1

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DOE/OR/07-1141 & D2
KY/ER-32 & D2

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Remedial Investigation Addendum for Waste Area Grouping 22, Burial Grounds, Solid Waste Management Units 2 and 3, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

DEPARTMENT OF ENERGY • UNITED STATES OF AMERICA •

SEPTEMBER 1994
REVISION 2

CLEARED FOR
PUBLIC RELEASE

I-00309-0029

Department of Energy
Oak Ridge Operations
Paducah Site Office
P.O. Box 1410
Paducah, KY 42001

September 7, 1994

Mr. Tony Able
Remedial Project Manager
United States Environmental Protection Agency
Region IV
345 Courtland Street, N. E.
Atlanta, Georgia 30365

Ms. Caroline Patrick Haight, Director
Division of Waste Management
Kentucky Department for Environmental Protection
14 Reilly Road, Frankfort Office Park
Frankfort, Kentucky 40601

D2 REMEDIAL INVESTIGATION (RI) ADDENDUM - WASTE AREA GROUPING (WAG) 22 SOLID WASTE MANAGEMENT UNITS (SMWUs) 2 AND 3

Dear Mr. Able and Ms. Haight:

Enclosed for your review is the referenced document. SWMUs 2 and 3 are two of the four burial grounds that are included in WAG 22. SWMU 2 is the C-749 Uranium Burial Ground and SWMU 3 is the C-404 Low-Level Radioactive Waste Burial Ground. As was agreed, SWMUs 2 and 3 have been removed from WAG 22 because SWMUs 7 and 30 need additional field work.

If you have any questions or require additional information, please call David W. Dollins at (502) 441-6819.

Sincerely,

Robert C. Edwards
for Jimmie C. Hodges, Site Manager
Paducah Site Office

EF-22:Dollins

cc: J. Stickney, KDEP/Frankfort
T. Taylor, KDEP/Frankfort

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CERTIFICATION

Document Identification: D2 Waste Area Grouping 22 Remedial Investigation Addendum

I certify under penalty of law that I have personally examined and am familiar with the information submitted in this application and all attachments and that, based on my inquiry of those persons immediately responsible for obtaining the information contained in the application, I believe that the information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment.

U. S. Department of Energy
Owner and Operator

Jimmie C Hodges

Jimmie C. Hodges, Paducah Site Manager
Paducah Site Office
U. S. Department of Energy

9-2-94
Date Signed

The Department of Energy has signed as "owner and operator" and Martin Marietta Energy Systems, Inc., has signed as "co-operator" this application for the permitted facility. The Department has determined that dual signatures best reflect the actual apportionment of responsibility under which the Department's RCRA responsibilities are for policy, programmatic, funding, and scheduling decisions, as well as general oversight, and the contractor's RCRA responsibilities are for day-to-day operations (in accordance with general directions given by the Department of Energy as part of its general oversight responsibility), including but not limited to, the following responsibilities: waste analyses and handling, monitoring, record keeping, reporting, and contingency planning. For purposes of the certification required by 40 CFR Section 270.11(d), the Department of Energy's representatives certify, to the best of their knowledge and belief, the truth accuracy and completeness of the application for their respective areas of responsibility.

CERTIFICATION

Document Identification: D2 Waste Area Grouping 22 Remedial Investigation Addendum

I certify under penalty of law that I have personally examined and am familiar with the information submitted in this application and all attachments and that, based on my inquiry of those persons immediately responsible for obtaining the information contained in the application, I believe that the information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment.

Martin Marietta Energy Systems, Inc.
Co-Operator

Martin Marietta Energy Systems, Inc.

5/2/94
Date Signed

The Department of Energy has signed as "owner and operator" and Martin Marietta Energy Systems, Inc., has signed as "co-operator" this application for the permitted facility. The Department has determined that dual signatures best reflect the actual apportionment of responsibility under which the Department's RCRA responsibilities are for policy, programmatic, funding, and scheduling decisions, as well as general oversight, and the contractor's RCRA responsibilities are for day-to-day operations (in accordance with general directions given by the Department of Energy as part of its general oversight responsibility), including but not limited to, the following responsibilities: waste analyses and handling, monitoring, record keeping, reporting, and contingency planning. For purposes of the certification required by 40 CFR Section 270.11(d), Martin Marietta Energy Systems, Inc.'s; representatives certify, to the best of their knowledge and belief, the truth accuracy and completeness of the application for their respective areas of responsibility.

DOE/OR/07-1141&D2
KY/ER-32&D2

Remedial Investigation Addendum for Waste Area Grouping 22, Burial Grounds Solid Waste Management Units 2 and 3 at the Paducah Gaseous Diffusion Plant Paducah, Kentucky

Prepared for
U.S. Department of Energy

PADUCAH GASEOUS DIFFUSION PLANT

Managed by
Martin Marietta Energy Systems

Date Issued – September 1994

Revision 2

Contents

Section **Page**

Contents

Section **Page**

Tables

Number **Page**

Figures

Number **Page**

Acronyms and Initialisms

AFIRO	available for infiltration or runoff
AOC	Area of Concern
ARAR	Applicable or Relevant and Appropriate Requirement
AWQC	ambient water quality criteria
BEIAS	Biomedical and Environmental Analysis Section
BEIR	Biological Effects of Ionizing Radiation
bgs	below ground surface
bls	below land surface
BMP	Biological Monitoring Program
BTEX	benzene, toluene, ethylbenzene, xylenes
CEC	cation exchange capacity
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CNS	central nervous system
cpm	counts per minute
DCE	dichloroethene
DNA	deoxyribonucleic acid
DNAPL	dense non-aqueous phase liquid
DOE	Department of Energy
dpm	disintegrations per minute
EM	electromagnetic
EP	Extraction Procedure
EPRI	Electric Power Research Institute
EPA	Environmental Protection Agency
FDA	Food and Drug Administration
f_{oc}	fraction of organic carbon
FS	feasibility study
FSL	Field Support Laboratory
FY	fiscal year
GC	gas chromatography
GM	Geiger-Mueller
HEAST	Health Effects Assessment Summary Tables
HI	hazard index
HpCDD	heptachlorodibenzo-p-dioxin
HpCDF	heptachlorodibenzofuran
HQ	hazard quotient
HxCDD	hexachlorodibenzo-p-dioxin
HxCDF	hexachlorodibenzofuran
IRIS	Integrated Risk Information System
KAR	Kentucky Administrative Record
K_d	distribution coefficient
K_{oc}	organic carbon partition coefficient
KPDES	Kentucky Pollutant Discharge Elimination System

Acronyms and Initialisms

(Continued)

LET	low-linear energy transfer
LLRWBG	Low-Level Radioactive Waste Burial Ground
MCL	maximum concentration level
MCLG	maximum concentration level goal
MDA	Minimum Detectable Activity
mgd	millions of gallons per day
MMES	Martin Marietta Energy Systems, Inc.
mph	miles per hour
MS	mass spectrometry
msl	mean sea level
MW	monitor well
NAS	National Academy of Sciences
NCP	National Contingency Plan
NESHAPS	National Emission Standards for Hazardous Air Pollutants
NOV	notices of violation
NPDWS	National Primary Drinking Water Standard
OCDD	octachloro-dibenzo-p-dioxin
OCDF	octachlorodibenzofuran
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
OU	operable unit
PAH	polycyclic aromatic hydrocarbons
PARCC	precision, accuracy, representativeness, completeness, and comparability
PCB	polychlorinated biphenyl
PCDD	polychlorinated dibenzodioxin
PCDF	polychlorinated dibenzofuran
PEF	particulate emission factor
PGDP	Paducah Gaseous Diffusion Plant
ppb	parts per billion
ppm	parts per million
QC	quality control
RAGS	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation and Recovery Act
RfC	reference concentration
RfD	reference dose
RFI	RCRA Facility Investigation
RGA	Regional Gravel Aquifer
RGO	Remediation Goal Option
RI	remedial investigation
RME	Reasonable Maximum Exposure
SAIC	Science Applications International Corporation

Acronyms and Initialisms
(Continued)

SDWA	Safe Drinking Water Act
SF	slope factor
SVE	soil vapor extraction
SVOC	semivolatile organic compound
Tc-99	technetium-99
TAL	Target Analyte List
TBC	to-be-considered
TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
TCE	trichloroethene
TCL	Target Compound List
TCLP	Toxicity Characteristic Leaching Procedure
TEF	Toxicity Equivalency Factor
THI	Target Hazard Index
TIC	tentatively identified compounds
TM	technical memorandum
TNT	trinitrotoluene
TOC	total organic carbon
TSCA	Toxic Substances Control Act
TVA	Tennessee Valley Authority
U-235	uranium-235
U-238	uranium-238
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
VOC	volatile organic compound
UCRS	Upper Continental Recharge System
WAG	waste area grouping
WKWMA	West Kentucky Wildlife Management Area
WMU	waste management unit

Response to Comments

for the
June 1993
Preliminary Draft

Remedial Investigation Addendum
for
Waste Area Grouping 22, Burial Grounds
Solid Waste Management Units 2 & 3
at the
Paducah Gaseous Diffusion Plant
Paducah, Kentucky

Prepared for
U.S. Department of Energy
Environmental Restoration Division

CH2M HILL

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
U.S. EPA–General Comments			
1.	N/A	The remedial alternatives addressed for the two groups of WMUs should take care of any leaching or contamination control from the surface, but as stated in the report, may not prevent lateral or vertical migration below the surface. It is not clear from the discussion in the two sections on "Potential Remedial Action Technologies," that additional capping will make any difference in the primary exposure pathways and associated risk. There's little evidence of the current caps integrity breaking down.	Comment noted. The effect of remedial alternatives on exposure pathways will be addressed in the feasibility study.
2.	N/A	A continual problem is that the site characterization activities were not designed to characterize the contaminant sources. Therefore, the risk assessment is based upon data collected from the fringe of WMUs 2 and 3 and only limited data from 7 and 30. As acknowledged in the RI Addendum a quantitative assessment of risks cannot be made for the waste pits themselves.	Agree.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
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Comment Number	Section/ Page	Comment	Response
3.	N/A	The RI Addendum and its risk assessment avoids the real issue and distracts attention from the true risks associated with the "principle threat" source-material in SWMUs 2, 3, 7 and 30. The results and evaluations described focus on the impacts associated with the present and future exposures to contaminated soil and groundwater. The real issue is not soil and groundwater impacts, but the impacts and source terms from the thousands of tons of uranium and other hazardous wastes buried in the four WMUs. For SWMUs 2 and 3, a future residential scenario must be evaluated for the "principle threat" source-material and the associated releases impacting the adjacent environmental media. If insufficient data are available, the risk assessment may be performed qualitatively; however, the uncertainty section must clearly describe the limitations of such a qualitative risk assessment. Greater emphasis must be placed on the risk associated with the "principle threat" associated with these SWMUs. The risk assessment focuses on the risk associated with the media for which limited data is available and confuses the "principle threat" associated with these SWMUs. The risk associated with the "principle threat" should then be compared to the risks from contaminated media resulting from source releases. This analysis will highlight the critical need for proceeding with FS and RD/RA activities for these principle threats even though a high level of uncertainty may remain regarding how to proceed with RI/FS activities for the releases from these sources.	Agree. Sufficient data are not available for good quantitative modelling and analysis. This would require sampling of the waste material itself. The future residential receptor was not evaluated in the RIA per instructions from the Oak Ridge National Laboratory (ORNL) Risk Analysis Section. (Also, the onsite residential scenario is not feasible given the DOE land use policy at this facility.) Detailed source term modelling was outside the original scope of work for this document. However, a qualitative assessment of the risks to potential future residents from the "principle threat," the source material at SWMUs 2 and 3, will be addressed qualitatively under a reasonable worst-case scenario in Section 2.6.1. Uncertainties associated with the qualitative risk assessment will be clearly outlined in the uncertainty section.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
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Comment Number	**Section/ Page**	**Comment**	**Response**
4.	N/A	Table 2-1 presents the estimated inventory of uranium in WMU 2, but this information was never used to model the possible leach rate and offsite transport of uranium to future receptor residents. Such an estimate may be included in the baseline risk assessment. A scoping analysis, for example, reveals the following: The total inventory of uranium in the 52 pits of WMU 2 is about 250 million grams in an area of about 200 ft by 160 ft (32,000 ft^2), a depth ranging from 7 to 17 ft, with 2 to 4 feet of cover soil. Accordingly, the average concentration of uranium in WMU 2 is about 650 g/ft^3 or about 5000 pCi/g.[1] Using a Kd of 45 for uranium (from Table 2-22), the uranium concentration in leachate would be about 100 pCi/cc or 10^5 pCi/L. Once the leachate reaches the groundwater, it will be diluted. According to Table 2-22, the dilution factor is .039. Using this dilution factor, the uranium concentration in drinking water is estimated to be about 4000 pCi/L. Using a drinking water rate of 2 L/d for 30 years and a uranium ingestion slope factor of 1.6E-11 risk of cancer per *(Continued on next page...)*	Agree. As noted in response to comment 3, residential risk evaluation was not performed due to DOE land use policy. The back calculation of cleanup goals for soil used a simple model (MULTIMED or SUMMERS) to determine concentrations in soil that could cause exceedance of a maximum contaminant level (MCL) or 10^{-5} risk. This approach was agreed to by EPA during the March 9, 1993, meeting. Two reasons exist for not using modelled data originally: 1) Uranium in the waste pits was considered to be primarily uranium oxide and would not, therefore, have been soluble; 2) To use modelled data requires the prior approval of the EPA project manager (per RAGS, 1989). Modeling of leachate from WMU 2 was performed by SAIC as part of the F.S. This model has been included in Appendix D and is discussed in Section 2.5.3.5.

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[1] $\frac{2.58E8\ g}{(32{,}000\ ft2 \times 12\ ft)} \times \frac{6.023E23\ atoms/mole}{238\ g/mole} \times \frac{.693/4.5E9\ y}{3.15E7\ sec/yr} \times 1\ pCi/.037\ dis/sec$

x 1 ft3/28.31 L x 1 L/1000 cc x 1 cc/1.6 g = 4806 pCi/g

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Comment Number	Section/ Page	Comment	Response
4. (Cont'd.)	N/A	pCi ingested, the lifetime risk of cancer is approximately 10^{-3}. If credit for the dilution is not taken, which could be the case if the well is assumed to be located immediately downgradient from the buried waste, and daughter ingrowth is assumed, the risk could approach 1.0. This type of analysis and discussion should be included in the risk assessment.	
5.	N/A	The failure to address the temporal nature of the contamination in the risk assessment could present a problem in supporting future-use scenarios. Many of the containers buried in the disposal areas may still be intact as in is the case of the TCE drums that were excavated from WMU 2, which had been in the ground for 25 years. As these "waste packages" begin to deteriorate, the contaminant concentrations could significantly increase over the years, which is not reflected in the current soil and groundwater contaminant concentrations. At a minimum, the uncertainty section must discuss these issues.	Agree. The uncertainty section will be expanded to discuss these issues.

Comment Number	Section/ Page	Comment	Response
6.	N/A	The dermal route is not included in the future groundwater use by residents scenario because of a reference to a 1985 paper which claims that the dermal route is insignificant compared to the ingestion and inhalation route. There also is no correction for absorbed dose versus administered dose in the dermal route due to "a lack of available data." The first argument is in conflict with the studies included in the recent EPA guidance document on dermal absorption listed as reference EPA 1992b in the RI Addendum. The studies by Jo et al., Brown and Hattis, Hall, and Shehata all show that the dermal route for volatiles is comparable to both the ingestion and inhalation routes. The second argument, concerning the lack of bioavailability data, may be true for organics but not for inorganics as bioavailability factors can be found in ATSDR documents, Health Assessment documents, or other literature sources. For some metals, use of the bioavailability factor will increase its contribution to the dermal risk by 10 to 20 times.	Disagree. The dermal pathway was specifically excluded from the RIA following a series of meetings with the EPA at the start of the project. Language regarding the significance of the dermal exposure pathway and the lack of bioavailability data will be revised accordingly.
7.	N/A	The manner in which the data were collected and evaluated appears to be questionable. For example, only two surface soil samples were taken at WMU 2/3 for semivolatiles, metals and pesticides/PCBs; and only one sample for radioactive compounds. Total metal concentrations in water are actually lower in a number of cases than corresponding dissolved samples. Vinyl chloride appears in only one well at a very high concentration in apparent conflict with the distribution and concentration of its parent compound TCE and other corresponding degradation products. No additional field work was done to support this RI Addendum from what was presented in the Phase II RI.	Disagree. The data limitations were recognized and agreed to prior to report preparation. Added sentence and Table 1-1 in Section 1.1.1 to discuss objectives of the investigation.

Comment Number	Section/ Page	Comment	Response
8.	N/A	There was no correction for multiple chemicals when the Remediation Goal options were calculated. Risk Assessment Guidance for Superfund (RAGS) Part B Preliminary Remediation Goal calculations are for single chemicals. For carcinogens, the recommendation is to use a target risk of 10^{-6} with the expectation that the total number of carcinogens will not add up to more than 10^{-4}. For noncancer risk, the Quick Reference Fact Sheet on Part B from OSWER, dated April 1990, explains the intent of accounting for multiple chemicals: Noncancer risk is expressed in terms of the hazard quotient. A value of 1 is used in these equations where the intake equals the reference dose. However, if multiple chemicals are encountered it would be prudent to divide the concentration generated by the total number of noncarcinogenic chemicals of concern to obtain the initial PRGs until more information is available from the risk assessor regarding the identity of the most significant toxic effects. For example, if there are five chemicals with noncancer effects in a medium, divide the PRG calculated from the equation for each chemical by five.	Disagree. None of the non-cancer effects for chemicals of concern are the same, and are, therefore, not considered additive. Furthermore, considering that the non-cancer risk from groundwater is contributed primarily by manganese, and considering the relative concentrations observed at this site, it is not necessary to consider the additive effects of the relatively insignificant risk contributions posed by other chemicals in this group. As for cancer risks, it is true that the additive effects of each chemical were not considered, but again, it makes little difference in the actual outcome. In view of the risk contribution by U-235 in soil (98 percent of the risk), n-nitroso-di-n-propylamine in the RGA (99 percent of the risk), and Beryllium in the UCRS (99 percent of the risk), the risk contribution of the other chemicals of concern are insignificant. Recalculation of these numbers would not significantly improve the risk information available to decision makers. According to the guidance quoted under general comment number 10, the listing of risk levels indicated in this table is correct.
9.	N/A	Throughout this report hazard quotient and hazard index are often used incorrectly. A hazard quotient is the ratio of a single substance exposure level over a specified time period to a reference dose for that substance derived from a similar exposure period. A hazard index is the sum of more than one hazard quotient for multiple substances and/or multiple exposure pathways. Also, throughout this document risk estimates, hazard indices and hazard quotients should be presented as one significant figure.	Agree. The indicated errors will be corrected, and the number of significant digits expressing non-cancer risk will be reduced to one.

Comment Number	Section/ Page	Comment	Response
10.	N/A	The risk assessment should include a section which outlines the remedial goal options (RGOs) for the contaminants and media of concern, in a manner consistent with the following discussion. This section should include both ARARs and health based cleanup goals. This section should contain a table with media cleanup levels for each chemical that contributes to a pathway that exceeds a 10^{-4} risk (or whatever risk level is chosen as the remediation "trigger" by the risk manager) or HI of 1 or greater for each scenario evaluated in the baseline risk assessment. Chemicals contributing risk to these pathways need not be included if their individual carcinogenic risk contribution is less than 10^{-6} or their noncarcinogenic HQ is less than 0.1. The table should include the 10^{-4}, 10^{-5}, and 10^{-6} risk levels for each chemical, media and scenario (land use) and the HQ 0.1, 1 and 10 levels as well as any ARAR values (state and federal). The values should be developed by rearranging the site-specific average-dose equation used in the risk assessment to solve for the concentration term; RAGS Part B is not appropriate at this stage in the risk assessment process. The purpose is to provide the RPM with the maximum risk-related media level options on which to develop remediation aspects of the Feasibility Study and Proposed Plan.	Disagree/Agree. Considering the fact that these comments are requesting the completion of a residential scenario, it is inconsistent to also request that the RGOs be based on the industrial scenario, which is less conservative than the residential scenario. Some of the chemicals listed in Table 2-15 through 2-21 are not necessary since they did not contribute individual risks of greater than 0.1 (non-cancer) or $1x10^{-6}$ (cancer) in any single pathway. These chemicals will be removed.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
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Comment Number	Section/ Page	Comment	Response
U.S. EPA–Specific Comments			
1.	Inside Cover Sheet	The title needs to be corrected so that it states "Burial Grounds" instead of "PCB Sites."	Agree. Title will be changed.
2.	Section 1.2 Page 1-5	The statement that the "Addendum provides an evaluation of the existing data by defining WMU-specific conceptual models that provide the basis for source-specific evaluation of baseline risk consistent with the NCP" is a bit misleading since WMU 2 and 3 were treated as a single unit. Furthermore, the sources were not truly characterized, but only the peripheral soil contamination and groundwater leachate emanating from the source.	Agree. Sentence will be changed.

Comment Number	Section/ Page	Comment	Response
3.	Section 1.2.2 Page 1-5	The following statement pertaining to the "Observational Approach" suggests that the CERCLA process of characterization of hazardous substances within the source and the associated surface and subsurface soils can be short circuited: "The Observational Approach, which is based on the streamlining principles of the NCP of CERCLA, is a method used to effectively manage uncertainties so that response actions can be taken in a timely manner. The Observational Approach, unlike traditional methods, emphasizes data sufficiency, while proceeding expeditiously with site remediation."	Comment noted.
		It should be made clear that methods of streamlining characterization of hazardous substance releases <u>do not necessitate a reduction of data quantity</u>. Rather, effective use of scoping and the DQO process will enable design of a flexible data collection effort, which will ensure an appropriate mix of data quality/quantity for all data users needs. Often, such an effort may entail a greater quantity data set of various data quality levels and greater flexibility in S&A activities to permit fewer rounds of data collection efforts, thereby streamlining the process.	Comment noted.
4.	Section 1.4 Page 1-13	This section is too generic to the entire Paducah investigation. There should be a tie-in to these specific WMUs in this WAG.	Agree. Will add a sentence which specifically addresses which offsite contaminants could have come from WAG 22.
5.	Table 1-2 Page 1-14	The Table indicates that no contaminants were detected in the offsite soils. This is difficult to believe, particularly with metals such as lead that have very high partitioning coefficients and would require high soil concentrations before any lead was detected in the groundwater.	Phase II data that shows no pattern of soil contamination associated with the PGDP was found in offsite soil. Specifically, lead has a high background concentration in soil in the Paducah area. Other preliminary unpublished studies at PGDP have confirmed the high background lead concentrations.

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Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
6.	Section 2.1.1 Page 2-1	Concern over disturbing the source material in SWMU 2 has been highlighted. How was it that the 1984 excavation of a portion of SWMU 2 could have been safely conducted.	DOE policy is not to sample or disturb this waste to avoid health and safety impacts to workers and the environment.
7.	Figure 2-5 Page 2-13	Inhalation of volatiles and dermal contact is left out of the exposure pathway for groundwater.	Agree. This figure will be corrected as requested.
8.	Section 2.2.2.1 Page 2-14	The statement in the second full paragraph, "It is anticipated that both contaminated soils and contaminated buried material will be remediated, since the primary objective will be to prevent further releases and direct exposure" is in conflict with the first sentence of the fourth paragraph which states, "Identified containment technologies could include multilayer capping of WMU 2 (WMU 3 presently has a multilayer cap) and associated surface water run-on/runoff controls, along with sediment control barriers for both WMUs 2 and 3." The cap may inhibit, but will not prevent the release of contaminants to the groundwater, especially if the buried source-material is within or below the phreatic surface.	Agree. A cap does not prevent release of contaminants. Statement in second paragraph will be revised accordingly.
9.	Section 2.2.2.1 Page 2-14	On the bottom of the page the statement is made that excavation was not considered as an alternative because potential releases during excavation and handling of pyrophoric wastes could result in higher risks to human health and the environment than are currently associated with the low levels of contamination in the groundwater. <u>This statement needs to be supported by analyses that demonstrate that the risks are unacceptable</u>. A more definitive argument must be demonstrated to support the lack of any attempt to characterize SWMU 2 in this RI. Also, these risks must be included in the assessment of baseline risk.	Disagree. This issue was addressed in a qualitative manner. A quantative hazards analysis for excavation and handling pyrophoric materials could be conducted, but is outside of the original scope of work for this report.

Comment Number	Section/ Page	Comment	Response
10.	Section 2.2.2.1 Page 2-15	The last sentence in the first paragraph on the page states that "air or groundwater monitoring on a plant-wide basis could detect changes over time or unforeseen releases that may initiate contingent collection systems." This concept should be an integral part of any action that leaves hazardous substances in place which does not permit unlimited use and unrestricted exposure to the area. However, the monitoring must be on a WMU, rather than a plant-wide basis. Otherwise, the same problems of source attribution that cannot currently be resolved with the existing data will continue to plague site characterization activities, making the design and placement of contingent collection systems difficult.	Agree. Monitoring of remediation alternatives will be addressed in the feasibility study. Sentence added to make this statement.
11.	Section 2.3.2 Page 2-17	The first sentence on the page states that "results from the double-ring infiltrometer tests conducted on surface soils at WMU 2 confirm that a 6-in. cap may exist at this WMU." The apparent doubt of the existence of the cap does not put the site characterization in a favorable light. The cap was supposed to be placed on the unit in 1982, yet infiltrometer test results have to be used to determine if this is the case. This raises a concern in the adequacy of the characterization in that such heavy reliance was placed on the disposal records dating back to 1951 for what was placed in the WMU. Furthermore, the results from these tests are very similar to those performed on WMU 7 and 30, which are not capped. Therefore, it is unclear how infiltrometer results from WMU 2 confirm that a cap exists.	Agree. The wording will be revised to include this information. WMU2 was capped in 1982. The cap was installed by Asphalt Paving Inc. and consisted of a 6-inch thick clay cap with a permeability of 1×10^{-7} cm/s and a 18-in. thick vegetative cover. This cap is in addition to the 4 feet of dirt that was placed on top of the wastes at the time of placement. See EPA General Comment No. 7 Response concerning data sufficiency.

Comment Number	**Section/ Page**	**Comment**	**Response**
12.	Figure 2-6 Page 2-19	This figure should indicate the limits of the WMUs and the average water table height relative to the wastes. Furthermore, why are different wells used for the cross-section in Figure 2-6 than are presented in Figure 2-7, for water-table information? The RI must definitively describe the relationship of the source-material and the phreatic surface, and any temporal variations in this contact.	Agree. Will modify Figure 2-6 to use a more standard plane of points. Refer to KDEP Comment 14, 15, and 16, Response. Different wells are used in Figures 2-5 and 2-7 because Figure 2-6 is not intended to present stratigraphy and Figure 2-7 presents water level fluctuations.
13.	Section 2.3.3 Page 2-20	The second sentence of the fourth full paragraph that states "because the zone of interconnection of sand lenses is limited in area, flow is not expected to occur over large distances," is incorrect. A more accurate statement would be that "... flow within the sand units will not occur over large distances."	Agree. Will reword sentence.
14.	Section 2.4.1.3 Page 2-23	It is unclear why N-nitrosodiphenylamine was eliminated from further evaluation as it is not a common contaminant to be found in blanks.	Disagree. As stated in the last sentence of this paragraph, *uncommon* laboratory contaminants are considered false positives if the maximum environmental concentration found was less than five times the maximum blank. This procedure follows the Data Useability Guidance as quoted, as well as RAGS (1989).

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
15.	Section 2.4.1.5 Potential Contaminants of Concern. Page 2-26	The criteria in the first bullet should be changed since the approach presented is not consistent with EPA Region IV guidance. The 10^{-4} and 1.0 criteria should be changed to 10^{-6} and 0.1. The criteria for no EPA assigned reference dose or slope factor should be removed from the third bullet. These chemicals should remain as CPCs and should be addressed qualitatively in the risk assessment. It should be noted that EPA has issued provisional toxicity values for TCE. It should be noted for risk assessment purposes, chemicals should be included in the chemicals of potential concern (COPC) list if the maximum onsite concentration exceeds twice the average background or reference.	Agree/Disagree. The criteria presented in the first bullet will be changed accordingly. The last bullet will be deleted in its entirety and no longer used as a criterion. The background specification is noted.
16.	Section 2.4.2 Page 2-26	The last sentence references Figure 2-8 for groundwater rather than Figure 2-9.	Disagree. The reference is for shallow soil analytical results (Figure 2-8) and deep soil analytical results (Figure 2-9).
17.	Table 2-4 Page 2-27	An additional column should be added that identifies which of the "bullets" described in Section 2.4.1.5 apply to each given constituent.	Disagree. Additional column not necessary since table revised to indicate that all the chemicals listed were eliminated by using only one criterion based on concentration-toxicity screen.

Comment Number	Section/ Page	Comment	Response
18.	Table 2-5 Potential Contaminants of Concern Found in Soils and Unfiltered Groundwater at WMUs 2 and 3. Page 2-29 - 2-31	RAGS (EPA 1989) states in Section 5.9.3, "Evaluate Frequency of Detection," that chemicals can be eliminated from the quantitative risk assessment if they are infrequently detected such as less than 5 percent in any medium. A number of chemicals could be eliminated from the list of potential COC if this screening approach was used, including thallium, 1,2-DCE, and all of the SVOCs. This document should include an initial data summary table similar to this table, however, the following criteria should apply. The table should include all contaminants detected in at least one CLP sample, contaminants that are present at concentrations significantly higher than in blank samples, inorganics which are detected at concentrations significantly above background samples (the criteria for determining significance should generally be that maximum level onsite media samples are two or more times the average background concentration), TICs that may be associated with site activities or that have been identified by SAS. The data summary table should contain the frequency of detection, range of detects, average concentration and background concentration. The non-detects should not be incorporated into the average concentrations. The document should also include a table summarizing the chemicals of potential concern in all media sampled in the format of RAGS Exhibit 5-7. It should be noted that chemicals of potential concern are those chemicals that are carried through the risk assessment process. It is unclear why all the SVOCs except 2-nitroaniline are listed as NA (not analyzed) and 2-nitroaniline is listed as ND (not detected).	Disagree. This comment represents a major departure from the agreements reached with EPA (Elmer Aiken) during the March 9, 1993, meeting covering the draft WMU 1 RI Addendum review document. Our understanding was that EPA preferred a risk-based contaminant screening rather than a frequency of detection screening since some contaminants could be highly toxic, but infrequently detected. Revising the risk assessment to provide the data requested in this comment in the form requested will require a major rework of the risk assessment, including additional database inquiries, new table generation, and reformatting the document. In addition, if the contaminants of concern are altered by using a different screening method (frequency of detection versus risk screening), all risks will have to be recalculated. Much of the information requested in the comment is contained in Tables 2-4 and 2-5. While not specifically in the format requested, the information is available.
19.	Table 2-5 Page 2-30	What is the MDA for Np-237 and Pu-239 in soil and groundwater?	MDA refers to minimum detectable activity.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
20.	Figure 2-8 Page 2-32	Units for radionuclide contamination in soil, and the data reported in brackets are not defined.	Agree. Table and footnotes will be revised.
21.	Section 2.4.2.1 Page 2-34	In section 2.4.1, PCBs were eliminated as a chemical of concern. Why are they included in the discussion of the surface migration pathway in section 2.4.2.1?	Agree. PCBs will be removed from the discussion.
22.	Section 2.4.2.1 Page 2-34	The surface radiological walkover survey appears to be limited to the ditch to the south of WMU 2 and 3. For the purpose of estimating worker exposures, the walkover survey should have also included the trenches. On the bottom of the page, significantly elevated readings are defined as those that exceed 3 to 10 times background. This is not a very useful method for determining the presence of contaminated soil. Typical background levels of terrestrial radiation are about 6 uR/hr. Three times terrestrial background would be 18 uR/hr, which would represent a significant level of uranium contamination. For example, the external dose rate 1 meter above a smooth infinite slab of soil uniformly contaminated with U-238 and its short lived daughters (Th-234 and Pa-234m) is about 0.01 uR/hr per pCi/g. Accordingly, the U-238 contamination in soil would have to be about 1600 pCi/g to cause 16 uR/hr. If all daughters are present, the exposure rate is about 2.4 uR/hr per pCi/g. In this case, the level of U-238 plus daughter contamination required to cause 16 uR/hr is about 7 pCi/g. It is clear that the use of external gamma survey measurements (whether at 3 times or 10 times background) is not an appropriate method for detecting the presence of uranium contamination if its long lived daughters are not present. A more appropriate method would be to grid the site and take soil samples at each grid point.	Disagree. The walkover survey was intended to define the extent of contamination present in the ditch, which leads to the outfall and, therefore, to offsite contamination. Results from this survey were used to support soil sampling data in describing this. The purpose of estimating worker exposures was not the original intention. This was indicated in the section headed "Interpretation of Surface Migration Pathway," as well as in the reading results, which are given in units of counts per minute. An additional walkover survey was performed to supplement the information given in this report. This survey is included in Appendix D.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS Draft Remedial Investigation Addendum Waste Area Grouping 22, Burial Grounds Paducah Gaseous Diffusion Plant, Paducah Kentucky			
Comment Number	**Section/ Page**	**Comment**	**Response**
23.	Page 2-34 Last 2 ¶s	What criteria, DOE or otherwise, was used to establish a "significantly elevated" radiation reading of about "10 times background?" We assume natural background in this area is approximately 5-10 microR/hr.	The data presented in Figure 2-10 and Table 2-6 are intended to provide information on the nature and extent of radiological contamination. It was never intended to support risk assessment. The criteria of 3 and 10 x background were arrived at arbitrarily as a means to explain the contamination/radiation elevations without providing "too many numbers." The words "significantly elevated" are in quotes to avoid interpretation as official distinction/designation.
24.	Table 2-6 Page 2-37	This table should present the background readings at the site so that they could be compared to the observed readings. Also, a correlation between the CPM readings and pCi/g of individual radionuclides responsible for the elevated readings should be established. With some reasonable assumptions about radionuclide content and detector efficiencies, counts per minute could be converted to exposure and dose rates. This would allow direct result comparisons to many radiological ARARs. This comparison would be very useful in determining whether soils require remediation.	Agree/Disagree. For the purposes of this table, typical background readings will be entered, but the conversion from CPM to pCi/g is not possible without knowing the relative concentrations for each radionuclide. Also, it is not necessary to conduct a detailed modelling scheme which would be fraught with uncertainty for this particular purpose. As previously stated in comment 22, the gamma survey has been requested in units of μRem/hr, which are directly applicable to human health.
25.	Table 2-9 Pages 2-41 - 2-43	There are several cases where the total metal concentration is less than the dissolved metal (barium, chromium, lead, and manganese). This contradiction should be explained in the text and included in the discussion of uncertainty.	Agree. Text will be added.
26.	Table 2-10 Page 2-44	It appears that monitor well MW-58 has significantly elevated levels of U-238. However, adjacent wells MW-57 and MW-154 have no reported contamination. Explain.	Needs clarification. Could not find any results for MW-57. MW-154 did have some U-238 contamination.

Comment Number	Section/ Page	Comment	Response
27.	Page 2-46 Figure 2-11	This figure showing trends of TCE and Tc-99 in a particular well is very informative/helpful in seeing the contamination over time.	Agree.
28.	Page 2-47 Paragraph 1	Clarify the determination that contamination found in MW-169 and MW-171 are not related to SMUs 2 and 3; as groundwater flow was previously described as flowing north towards these wells.	Because no corresponding groundwater contamination for these compounds were in MW-169, it was considered unlikely that subsurface soils were contaminated from a source located at WMUs 2 and 3. This statement was added to the text.
29.	Page 2-47 Last ¶	The high values for the uranium isotopes were all rejected due to low chemical yields? There are no flags shown here. Was there any resampling done? If not, why not? If these values were not plugged into the risk assessment, were similar values? What pathways were the leachate results used for?	Leachate results are not used in the risk assessment. The wording in this paragraph will be revised to clarify why the data were rejected. The Summers model was used for WMU 2 to show the impact of the leaching of Uranium. WMU 3 has a RCRA Cap and leachate is handled under the post closure monitoring.
30.	Section 2.4.2.2 Page 2-47	On the bottom of this page, leachate concentrations with high levels of radionuclide concentrations were observed but rejected due to low yields. These data could be useful in modeling the concentrations and transport of radionuclides in leachate.	See reponse to state comment 53.
31.	Section 2.4.2.2 Page 2-48	For subsurface soil contamination, the most probable conditions for lateral extent of contamination is stated as 50 ft. around the perimeter of the two SWMUs. This description of the nature and extent of contamination in the subsurface soil must be supported with data. Were probable conditions defined for the extent of surficial soil contamination?	Data limitations were recognized and agreed to prior to preparation of this report. Probable conditions for extent of surficial soil contamination are defined in Section 2.4.2.1.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
32.	Section 2.5.1 Page 2-49	In the second paragraph, the areas for WMU 2 and 3 are given in linear feet. The appropriate units are square feet.	Agree. Units will be corrected.
		The statement in the second paragraph that "This cover significantly impedes erosion and transport of contaminants such as PCBs and dioxin/furans, which tend to adhere to particulate matter," suggests that PCBs are present in the soil at these WMUs. If this is the case, they have not been mentioned previously. Furthermore, the sentence that follows the PCB reference that "grass also increases the time it takes for surface water to reach the drainage ditches, which, in turn, increases the amount of water used in seepage and groundwater recharge," is unintelligible.	The presence of PCBs in soil is mentioned on page 2-34, paragraph 3. The last sentence discussing increasing the seepage and groundwater recharge will be deleted.
		The discussion pertaining to infiltration in the last paragraph needs to be clarified. The rationale for using .7 in/yr, apparently is an estimate that only 10 percent of the normally available recharge will infiltrate through the cap. Generally, if infiltration measurements are available (which they are) they are used to make this kind of determination.	Agree. Infiltration rate will be calculated.
		The calculated volume of water available for runoff (2.8×10^4) is incorrect. This volume would correspond to 1.4 in/yr. It should actually be 16 - .7 - 15.3 in/yr or 3×10^5 gallons.	Agree. Runoff and infiltration volumes were recalculated to reflect site specific data.
		If infiltration through the RCRA cap is negligible as the text "again, infiltration is assumed to be negligible at WMU 3 because of its RCRA cap" indicates, then <u>where is the leachate coming from in the leachate collection sump</u>?	Agree. Some infiltration will get through a cap; however, this amount is very small compared to the total possible infiltration in other areas.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
33.	Section 2.5.2 Page 2-50	Hydraulic "conductivity," referenced in the first paragraph, should be changed to hydraulic "gradient."	Agree. Text will be revised.
		The third paragraph is not clear and needs to be rewritten. The infiltration rate cannot be greater than the saturated hydraulic conductivity of the soils, and it is unclear what is meant by "...the conductivity of the soils is greater than the average infiltration of precipitation over time."	Agree. Paragraph will be rewritten.
		The conclusion in the fourth paragraph that the groundwater travel time in the RGA to the nearest offsite location would be 43.6 years is in direct contrast to velocity information for the RGA presented on Page 1-8 that states "probable flow rates in the RGA are estimated to range between 200 to 400 ft. per year toward the Ohio River." This translates to a travel time of 4 to 8 years. This discrepancy appears to be a result of extrapolating data collected at a relatively small scale (that is, WMUs) over the entire flow path.	Agree. Actual travel time is likely somewhere between these extremes. Will reword to indicate range of possibilities.
		The fifth paragraph is also misleading and needs to be rewritten. The first sentence suggests that an f_{oc} of .001 or less will lead to sorption, whereas, as organic carbon contents decrease, sorption becomes less of a transport factor. Furthermore, the statement that "TCE in a dense non-aqueous phase liquid (DNAPL) state would have minimal retardation" is simply not true. The mechanisms for retardation are different, but DNAPL will be more retarded than the dissolved phase, otherwise TCE, as a DNAPL, would comprise the leading edge of the plume, which is not the case.	Agree. Text will be rewritten to state that "f_{oc} of 0.001 or more". Agree. Text will be rewritten to discuss mechanisms other than retardation (that is, viscosity and density) that control the rate of movement of the DNAPL mass.
		The second and third sentences in the sixth paragraph are not *(Continued on next page...)*	

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
33. (Cont'd.)		clear. The horizontal gradients have absolutely nothing to do with the rate that TCE will migrate relative to groundwater. The objective of calculating the retardation coefficient was to show that groundwater probably moves in the range of 1.8 times faster than TCE, regardless of hydraulic conductivities, effective porosities and gradients. The second sentence needs to be clarified in that 1,2-DCE moves faster than TCE and not the groundwater.	Paragraph modified to clearly describe the relationship between potential rates of movement of TCE and DCE with respect to water.
34.	Table 2-11 Page 2-51	The information in this table should be expanded for all COCs, not just TCE and DCE. The retardation equation needs to have parentheses added to ensure that the one (1) is added after the multiplication and division.	Disgree. Added VOC and SVOC Contaminants of Concern table. PCBs and Inorganics: these are not listed since listing properties for these chemicals would not add to the document. Parenthesis added to equation. Comment noted.
35.	Section 2.5.3.4 Page 2-52	Oxygen is also a critical parameter in determining the fate and transport of metals.	Comment noted.

Comment Number	Section/ Page	Comment	Response
36.	Section 2.6 Human Health and Ecological Risk Assessment. Page 2-53	The calculation of interval estimates of risk in the screening risk assessment as the basis for the remedial decision is not consistent with the NCP requirement that remedial decisions are to be based on the reasonable maximum exposure scenario (RME). It is unclear from this document if the upper-bound or lower-bound risk estimate is representative of the RME. This section states that these estimates will be used to evaluate whether further investigation of the units is appropriate or to justify interim measures, although Section 2.8.2 indicates that sufficient information is supplied to support the assessment of risks and evaluation of alternatives for final remedial action at these sources. Also, it is not clear from this document that this is a screening risk assessment and a not baseline risk assessment. There are many statements that would imply that this document is a baseline risk assessment. For example, this section states that the approach to the evaluation was developed and executed in accordance with the RAGS, which details the procedures for a baseline risk assessment.	The risk assessment used the screening approach (upper and lower bound analyses) developed by ORNL Risk Analysis Section. The language in this section will be revised to limit confusion. The upper bound term will be replaced with "reasonable maximum" and the lower bound term will be replaced with "most likely". Reference to conducting a baseline risk assessment was specifically avoided.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
37.	Section 2.6.1.1 Page 2-54	The third paragraph states that only radionuclides found in the upper 6 feet of soil, and in groundwater, were evaluated in the risk assessment. This is appropriate for the present use scenarios but not for future use scenarios where radionuclides and other hazardous chemicals in the trenches may leach to receptor locations. For future scenarios, modeling is needed. In the last paragraph, it is stated that a quantitative assessment of the risks from the contents of the trenches cannot be made due to the presence of the cap. However, an estimate of the inventory of the trenches is provided in Table 2-1 that can be used to assess risks using models. It should be noted that for risk assessment purposes EPA Region IV Office of Health Assessment considers the top 1 foot of soil as surface soil available for direct contact.	Agree. Modelled data will be included in the final version of the RIA. (As long as the RPM approves.) See response to general comment number 3. It is noted that EPA Region IV would have preferred using the top 1-foot of soil. We included data down to six feet for lack of options—the only soil data we had for this area was for the 0- to 6-foot interval.
38.	Section 2.6.1.1 Page 2-55	Regarding the last paragraph, one would not expect the concentrations of solvents in groundwater to be dependent upon measured soil concentrations since the buried waste, not the contaminated soil, is the source of solvents in the groundwater.	Agree. Will revise text.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
39.	Section 2.6.1.2 Page 2-55	Include an evaluation of a future onsite residential scenario. EPA granted the extension of time for development of the RI Addenda based on requirement (See letter of 5/13/93). Analysis of the future industrial scenario should consider the following approach to direct contact. Two exposure scenarios should be developed. The first which the workers are exposed to surface soil (0-1 ft bls), and the second which the workers are exposed to the surface and subsurface soil (0-6 ft bls) during construction and excavation. Additionally, the exposure duration may be changed to develop additional scenarios. Clearly describe why groundwater is being evaluated in this source unit risk assessment when it will be evaluated in the area wide baseline risk assessment.	The onsite residential scenario will address soil exposures qualitatively and will quantitatively address groundwater exposures. A worker scenario for direct contact with the "principal threat" will also be included as a qualitative scenario. The purpose for evaluating groundwater in this risk assessment is to account for potential risks that can be attributed to the source units themselves. It is not intended to replace the groundwater OU in any way, but to supplement the risk assessment information available regarding the SWMUs 2 and 3, specifically.

Comment Number	Section/ Page	Comment	Response
40.	Section 2.6.1.2 Onsite Worker/ Intruders Exposure to Onsite Contaminated Soil. Page 2-57	The statement that subsurface soils (1-6 ft bls) are being considered as surface soil available for direct contact because only two surface soil (0-1 ft bls) samples were collected indicates inadequate site characterization for a defensible risk assessment (screening or baseline). The scenario for worker intrusion directly upon the waste should be quantitatively evaluated. Based upon the description of the buried waste given in sections 2.1.1 and 2.1.2, a reasonable upper bound estimation of waste mass ingested and inhaled and direct exposures can be made for workers' intrusion into the waste, assuming institutional control is lost. There is an incomplete sentence in the first paragraph that states "however, because only two surface soil samples (zero to 1 ft bls) were taken at WMUs 2 and 3." Since taking only two surface samples is an oversight and may invalidate the calculation of risk from direct contact to surface soil, this sentence should be completed. Reference to the possible consequences of too few surface soil samples should be explained thoroughly in the uncertainty section. The notation "1 ft bls" used in the first full paragraph needs to be defined. A sentence in the last paragraph states that "uranium, metals, TCE, and Tc-99 were reported in the subsurface soils within the unit and in the UCRS adjacent to the units and to a lesser extent in the RGA, but not in the groundwater downgradient of the units" contradicts the second full paragraph on page 2-11, which states that "numerous monitoring wells have been *(Continued on next page...)*	Disagree. The limited data that were available for the risk assessment were considered adequate by agency representatives in meetings prior to the writing of this document, for the limited purposes it is to serve. We have elected to describe the data limitations as an uncertainty, not a shortfall, under the circumstances. There are not enough data to do a quantitative evaluation of worker intrusion directly into the waste. As previously stated, a qualitative evaluation will be performed instead. Incomplete sentence should be combined with last sentence. The sentence described as "incomplete" will be revised, and "1 ft bls" will be defined. The sentence in the last paragraph will be revised.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
40. (Cont'd.)		installed in the vicinity of WMU 3. Historical data (1983 through 1988) from the wells indicate total organic halogen and alpha and beta contamination in both up- and downgradient wells (reported concentrations are generally higher in the samples from the downgradient wells.)	
41.	Table 2-12 Page 2-58	The exclusion of future use of groundwater onsite, because there are no supply wells currently onsite, is not justifiable. The rationale that the future use be excluded because there are no wells currently onsite does not appear to rule out supply wells being installed at some point in the future. Furthermore, if this is not a possibility, it assumes that DOE will maintain indefinite institutional controls. Does the future resident exposure to contaminated crops include crop contamination due to irrigation with contaminated groundwater? If not, it should be included. Replace "No" with "Yes" for the "Future" column and "Future Resident - Onsite" and "Future Crop" rows.	Disagree. Contradiction between this and comment number 39 makes it difficult to discern what the EPA is requesting. Our interpretation is that groundwater modelling for soluble species of uranium, especially, should be considered in the RIA. An effort is being made to this end, and we intend to include this information in the final version of the RIA. Disagree. The future residential exposure to be included in the final version of the RIA will not include a crop watering scenario using groundwater from the site. Potential threats to residential receptors from the "principal threat" are far greater than the potential risks from contaminant uptake in plants. Evaluation of this pathway would not be useful or practical considering its relative significance to onsite explosive hazards and gamma exposure. The first correction will be made, to evaluate future ingestion of groundwater to workers from onsite groundwater (and inhalation of VOCs). The second correction, to include crop ingestion in future residents, will not be made for reasons described above. The data are not available even if we thought it would provide valuable information.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
42.	Section 2.6.1.2 Page 59	At the top of the page, the statement is made that since onsite sources of drinking water are currently from the Ohio River, onsite groundwater use is not postulated. However, since offsite groundwater is used, it is feasible that onsite groundwater may be used in the future.	Agree. The paragraph will be amended as suggested describing potential for onsite groundwater use by a residential receptor.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
43.	Section 2.6.1.2. Page 2-58 and 2-60	At the bottom of the page, RMEs were calculated in a different manner in the Risk Assessment previously submitted to EPA. What is the rationale for the current method presented for determining RMEs?	The old version of the RA used the normal distribution to calculate RMEs. The version in question uses the lognormal distribution to calculate RMEs. Both methods followed EPA Region IV guidance at the time they were written.
		The reasonable maximum exposure (RME) approach should be utilized in the development of scenarios. Statements that the upper-bound exposure assumptions are considered excessive and that the lower-bound exposure assumptions are more realistic are inappropriate. If two estimates of risk are desired the RME should be presented in the text and an estimate of the central tendency could be presented in an appendix and discussed in the uncertainties section.	Agree. Language regarding an upper bound estimate as "excessive" will be revised.
		Two surface soil samples are inadequate for a defensible risk assessment and further sampling should be conducted rather than the proposed method of inclusion of all samples in the upper 6 feet of soil. Inclusion of all samples in the upper 6 feet of soil potentially dilutes concentrations present at the surface. The equation presented should be labeled as the 95 percent upper confidence limit (UCL) and not as the RME. RME is a whole concept in which the 95 percent UCL value for the concentration term is part of the concept. For Superfund exposure assessments, intake variable values for a give pathway should be selected so that the combination of all intake variables results in an estimate of the reasonable maximum exposure for that pathway.	Agree. Although it is arguable that sufficient data are not available, the RIA used all the data that were available from Phase II sampling in the RI. More data will not become available for future use in resolving this issue. A decision was made between agency and contractor representatives to conduct the RIA with the data that were available, prior to the writing of this document. The equation label will be corrected. The uncertainty section will be revised to include the concerns addressed here.
		Also, it is stated that if the RME value (calculated from the 95 percent upper confidence limit) exceeded the maximum observed concentration, the observed maximum value was used *(Continued on next page...)*	The last sentence in this paragraph is inconsistent with guidance from the EPA, Supplemental Guidance to RAGS: Calculating the Concentration Term, U.S. EPA Office of Solid Waste and Emergency Response, Washington, D.C., May 1992.

Comment Number	Section/ Page	Comment	Response
43. (Cont'd.)		to calculate risk. For small data sets, such as the soil measurements, this approach underestimates the RME when measurement variability is large. Ignoring the true variability in the measurement falsely represents the reasonable maximum exposure. It is recommended that the RME always be the upper 95 percent confidence limit.	

Comment Number	Section/ Page	Comment	Response
44.	Section 2.6.1.2 Page 2-61	In the first paragraph, reference the recent studies that have suggested that soil ingestion may be less than 50 mg/day.	Agree. This sentence will be either deleted and the paragraph revised, or the reference will be cited, as directed.
		The second paragraph uses the EPA dust suspension factor of 4.63E9 m^3/kg, that corresponds to a dust loading of about 0.2 ug/m^3. The lowest dust loading in non-urban areas is about 10 ug/m^3 (NUREG/CR-5512). Accordingly, the EPA value is only appropriate for areas where only a very small fraction of the dust loading is from the local soil. In cases where large areas of soil are contaminated, it should be assumed that all the airborne dust is from the contaminated soil and the dust has the same concentration of contaminants as in the soil. Hence, the dust loading may be low by over a factor of 10. Typical outdoor dust loadings are 100 ug/m^3 up to 500 ug/m^3 while gardening (NUREG/CR5512).	Disagree. The area being discussed is a small area (less than 4.4 acres), and it is covered with vegetation. Furthermore, the cover material for the larger unit is a RCRA cap, which according to RCRA regulations must be clean soil, tested to assure that no contamination is present. The smaller area, SWMU 2, is also covered with a clean cap, made of clay. Dust loading is expected to be minimal since the areas are entirely covered with grass. The dust loading value used is appropriate.
		As explained in the General Comments, bioavailability factors are available in the literature for most of the inorganic contaminants.	Disagree. Lack of bioavailability factors will be addressed as an uncertainty.
		Reference to EPA Region IV guidance in paragraph four is incorrect. Chemical specific oral absorption factors should be used to convert oral RfDs and CSFs to dermal values for all chemicals with values available. If there are no chemical specific oral absorption factors available then the following default values are to be used: 80 percent for VOCs, 50 percent for SVOCs, and 20 percent for inorganics.	Disagree. The values for oral absorption used in the risk assessment were taken from 1992 EPA Region IV Guidance. These values are correct for the time of citation.
		In the last paragraph, it is stated that GI absorbance data is not available. Much data is available for the chemicals of concern, especially for the elements (see ICRP-30). It is recommended that corrections can be made using GI	Disagree. GI absorbance data will not be collected and used in the revision of the RIA.

Comment Number	Section/ Page	Comment	Response
45.	Section 2.6.1.2 Page 2-62	Explain why direct contact exposure to subsurface soils is considered unlikely. Excavations for buildings, utilities and road gradings are very likely. In addition, subsurface soil contamination should not be related to groundwater. The buried waste is the source of groundwater contamination. At the top of the page, reference is made to the SUMMERS groundwater model. Is this the model that predicts the 0.039 dilution factor? A description of the model is needed, along with a discussion of why this dilution factor is appropriate at this site. Dermal absorption should be added to the residential use of the groundwater scenario as explained in the General Comments. In the third paragraph, give reference for the national median time of residence. In the fourth paragraph, the exposure point concentrations for groundwater are confusing. The first sentence says that exposure point concentrations for each of the above routes of exposure are based on the average concentrations of contaminants detected in the groundwater wells. What routes are being addressed? The paragraph goes on to say that the wells with the highest risk due to ingestion were selected for estimation of total risk. Using different wells to get the highest risk number gives a different result than pooling well data from one aquifer together to calculate a 95 percent level concentration value to use for the future residential use scenario. The rationale behind the use of data from the wells should be explained in more detail.	Disagree. Nothing is missing from this equation. The reviewer is encouraged to consider the fact that RAGS, Part B equations have been revised since the units on the external slope factor changed. The external slope factor for radionuclides is now in units of Risk/yr per pCi/g soil (See HEAST, 1993, Table 4A). Since the unit change, three components of the original equation on page 37 of RAGS, Part B have been dropped; the 10^{-3} g/kg conversion factor, the depth of radionuclide in soil, and the soil density.

Comment Number	**Section/ Page**	**Comment**	**Response**
46.	Section 2.6.1.2 Page 2-63	As explained in the General Comments, the dermal absorption from groundwater use is important, particularly when the bioavailability factors are added for the metals, and should be included in the risk assessment. This section indicates that HEAST FY 1992 was used to obtain toxicity information that is included in Table A-2. However, Table A-2 references HEAST FY 1991. It should be noted that the current version of HEAST is FY 1993 (EPA 540R-93-058, March 1993). The text in this section should indicate that preference was given to IRIS in the compilation of the toxicity values. 1,4-Dichlorobenzene listed in paragraph 2 as a chemical that contributes to site risks is not included in Table 2-5, Potential Contaminants of Concern found in Soils and Unfiltered Groundwater at WMUs 2 and 3. It is unclear how a chemical can contribute to risks at this site and not be included in the list of potential contaminants of concern. Also, the toxicity assessment should not discuss which chemicals contribute to the risks at the site. The discussion of risk should be included in the risk characterization section. This section should include a brief paragraph for each chemical of potential concern listed in Table 2-5.	Disagree. The pathways and assumptions were defined and agreed upon in a series of meetings with EPA at the start of the project. This pathway was specifically excluded. Agree. The references to HEAST 91 and 92 will be corrected. A statement pertaining to the hierarchy of sources will be included. Agree. 1,4-Dichlorobenzene was screened out of the list of COCs based on the toxicity screen conducted in Table 2-4. Evaluaiton of 1,4 dichlorobenzene will not be performed. The text and tables will be revised.
47.	Section 2.6.1.3 Page 2-69	The top of the page states that radiological risk is estimated by multiplying the derived dose by a risk conversion factor. This is true for external exposures. However, for internal exposures, the EPA recommends using the slope factor, which relates risk to a unit intake of individual radionuclides. The radiological hazard identification summary is excellent.	Internal exposures (inhalation and ingestion) are calculated using slope factors. (See Section 2 attachments). Comment noted.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
48.	Section 2.6.1.4 Page 2-72	At the top of the page, it states that summing hazard indices for different chemicals is conservative due to different target organs and biological endpoints for different chemicals. For cancer risks for radionuclides, and other stochastic effects, summing risks is appropriate. In the fourth paragraph from the bottom, it is stated that the major contributors to the non carcinogenic risk were As, Mn and Cr. If intrusion into the waste is modeled, uranium toxicity should show HI>1.0.	Agree. Text will be clarified to include this information.
49.	Table 2-13 Page 2-73	It is not apparent why MW-154 and MW-84 were used to estimate off-site risk from groundwater. Inspection of Table 2-10 reveals several wells with much higher radionuclide concentrations. The J notation should not be used as a basis for the rejection of data when that data may still have some value. This table or an additional table should include the chemical specific risks and hazard quotients for chemicals of concern (chemicals exceeding HQ of 0.1 or risk of 10^{-6} in a pathway exceeding HI of 1 or a risk level of 10^{-4}).	Disagree. The wells chosen had the highest concentration of risk drivers among the radionuclides. Higher concentrations of some radionuclides in other wells exist, but not the critical risk drivers (U-238 in the UCRS and Tc-99 in the RGA). The information requested is available in section 2.
50.	Section 2.6.1.4 Page 2-74	The first complete paragraph represents the only impact evaluation of excavating the waste material. Since the impacts under unrestricted industrial use are very much greater than all the other scenarios, the risks from intrusion into the waste should dictate site cleanup remedies and DOE's policy of future land use. <u>This fact is completely lost because this RI Addendum pays only minimal attention to the greatest risks from the burial grounds</u>.	Agree. Potential risks from the "principal threat" will be addressed as previously indicated.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
51.	Section 2.6.1.4 Page 2-76	The first full paragraph states that all the carcinogenic risk is the result of manganese ingestion. Manganese is not a carcinogen. Do you mean Beryllium? In the third full paragraph, 1 x 10^{-5} represents the lower bound and 5 x 10^{-5} represents the upper bound, not the reverse. It also states that the upper bound radiological risks from groundwater is about 1E-5 at MW-84. Using the measured value of 778 pCi/L of Tc-99 in MW-84, we also arrive at a lifetime risk of about 10^{-5}. However, there are several problems with this assessment. Inspection of Table 2-10 reveals that there are several wells where the radionuclide concentrations could be much higher than in MW-84. Also, modeling of leachate transport, as exemplified in the General Comments, reveals that the radionuclide concentration in nearby wells could result in risks in excess of 10^{-3}. It also appears that this risk estimate does not include irrigation, and uses a 0.039 dilution factor. The irrigation pathway could contribute significantly to risks. In addition, the dilution factor needs to be justified. It is possible that the actual dilution factor could be close to 1.0 if it is assumed that the future offsite resident places a well close to the downgradient edge of the waste disposal units. It appears that the actual upper bound risk is probably at least 100 times higher than the indicated value.	Agree. These apparent typos will be corrected. Agree/Disagree. The reviewer is referred to Table 2-15 of section 2 of the RIA, where it can be observed that the total radiological risk from groundwater is highest in well MW-84, in the RGA. Other wells with greater radiological risk exist, but they are in the UCRS, which is evaluated separately. Modelling of leachate transport into groundwater will be evaluated by the use of groundwater models, with a future residential receptor directly downstream of the SWMUs 2 and 3, using a dilution factor of 1.0 as suggested.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
52.	Section 2.6.1.5 Page 2-77	In the second bullet, the term "ft bgs" is used. Define. The third bullet states that no quantification of the excavation risks is provided because no direct sampling of the waste was performed. A risk estimate for workers and the public for excavation should be made using estimated inventories, such as those provided in Table 2-1. Measurement variability should be explained in quantitative terms. Variability due to time, space, sampling and laboratory techniques can and should be explained quantitatively. The same statistical techniques used to estimate the 95 percent upper limit exposures (RME) can be used to determine the confidence limits of duplicates, replicates and co-located samples. Also, loss of volatile organics from soil samples can be greatly reduced by placing soil samples in the field into methanol and analyzing the methanol (not the soil) by purge and trap techniques in the laboratory.	Agree. "ft bgs" will be defined. Agree. While it is not possible to obtain samples of the "primary threat" itself due to the pyrophoric nature of the waste itself, it is possible to draw conclusions regarding the results of disturbing the buried waste. These concerns will be addressed in the direct contact, qualitative analysis to be included in the RIA. Disagree. A quantitative analysis of the uncertainties associated with this risk assessment is not feasible in the time allowed, nor is it worth extending the deadline for the response to comments, considering its impact on decision making for these two SWMUs. Nothing can be done to recover the soil samples taken during Phase II sampling at this point.
53.	Section 2.6.1.5 Page 2-78	There is a trend in the discussion of uncertainties to suggest that the assumptions made are conservative and will overestimate risk. When using standard factors given by EPA guidance, such as soil ingestion rate, skin area available for dermal contact, exposure duration, etc., emphasis should not be placed on whether or not they represent conservative values, but that they are recommended for use in risk characterization by EPA.	Disagree. The current description will be retained.

Comment Number	Section/ Page	Comment	Response
54.	Section 2.6.1.5 Page 2-79	The validity of the revised oral RfD for manganese is questioned. Justify why approved values are questionable.	Agree. Statement questioning validity will be moved to the uncertainty section.
		In the last paragraph, the statement is made that the linear, no threshold model is the "most" conservative model for estimating radiation risks. This statement should be changed to state that it is a conservative model. There are some models that assume that the risk per unit dose increases as the doses decrease.	Agree. Language will be revised as indicated.
55.	Section 2.7.1 Page 2-83	The last complete paragraph erroneously references Table 2-13.	Agree. Editorial comment will be addressed.
		In addition to the regulatory numbers included in Table 2-15 remedial goal options (RGOs) should be calculated by rearranging the risk equations to solve for the concentration term at the risk levels of 10^{-4}, 10^{-5}, and 10^{-6}, and hazard quotients of 0.1, 1, and 10. The last sentence of paragraph 4 should be deleted.	Disagree. The difference between ARARs and risk-based RGOs is clearly stated in the titles of tables 2-14 and 2-15. It is not appropriate to combine these tables since the information provided is voluminous and has an obvious differentiation. The last sentence of paragraph 4 will be deleted, as suggested.
56.	Table 2-15 Page 2-84	Add a column that shows the site specific SWMU-specific concentrations for each constituent.	Disagree. Time does not allow inclusion, although information is presented elsewhere in the document.

Comment Number	Section/ Page	Comment	Response
57.	Table 2-22 Page 2-94	Several concerns exist about the accuracy of Table 2-22. I could find no reference in the text for how the distribution coefficients (Kds) were arrived at for inorganic compounds and radionuclides. In comparing the inorganic Kds shown in <u>The Soil Chemistry of Hazardous Materials</u> by James Dragun, the values depicted in the table are within the range of Dragun's values but are not the most conservative. If these are site specific Kds my concerns are lessened, but if these are default values from a publication, defense of their use must be presented.	Agree. The derivation of the K_ds will be addressed specifically in the revised version of the RIA. The K_ds selected were not intended to be the most conservative, but the most realistic. Site-specific information is not used. A reference for the Kds shown in Table 2-22 has been added. A paragraph has been added to text to justify Kds used.
		Specific corrections for Table 2-22 are the MCL for 1,2-dichloroethene is 7 ug/l and 1,2-dichlorobenzene is 600 ug/l. The soil concentration for protection ground water for 1~2-dichlorobenzene changes to 53 mg/kg. The octanol/carbon partition coefficient (Koc) for pentachlorophenol is 53,000 (see Table A-1 in <u>Basics of Pump-and-Treat Ground-Water Remediation Technology</u>, EPA600/8-90/003). Subsequently the change in Kd is 106 and the soil concentration protective of ground water is 1.0 mg/kg. The MCL for antimony is 6.0 ug/l and for beryllium is 4 ug/l. The correction of the MCL necessitates correction of the soil concentration protective of ground water, however until the Kd controversy for inorganics and radionuclides is resolved this correction will need to be postponed.	A Koc of 63,100 μl/gm was used for pentadalorophenol bacause tht is what was in EPA's Subsurface Contamination Reference Guide (October 1990). The MCL for 1,2-dichlorobenzene has been changed to 600 μg/l. The MCL for 1,2-dichloroethene is correct as shown in the table (70 μg/l).

Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
58.	Section 2.7.2 Page 2-86	The reference to the Summers Model in second full paragraph should be to Appendix "C," rather than "B." It is inappropriate to use RAGS Part B to calculate RGOs. RGOs should be calculated by rearranging the risk equations using site-specific exposure values to solve for the concentration term at the risk levels of 10^{-4}, 10^{-5}, and 10^{-6}, and hazard quotients of 0.1, 1, and 10. A set of RGOs should be developed for each scenario presented in the risk assessment.	Agree. Will revise. Disagree. This question was addressed in general comment number 8.
59.	Section 2.7.2 Page 2-93	At the top of the page, the 0.039 dilution factor is part of the equation used to determine the concentration of radionuclides in soil associated with the target risk goal for groundwater. Inspection of Appendix C, which briefly describes the Summer's model used to derive the dilution factor, indicates that the model assumes that the leachate is mixed in the volumetric flow of the groundwater. This approach tends to significantly underestimate risk if it is feasible for the leachate to reach receptors prior to extensive mixing in the aquifer. For future use scenarios, when the receptor is postulated to be located close to the source, the dilution factor should be minimal. This issue needs to be discussed and the 0.039 dilution factor justified.	Agree. The uranium modelling in groundwater will be used for an assessment of the risks to potential future residents, using a zero dilution factor, as if the resident is directly downgradient of the waste pits SWMU 2 and 3.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
60.	Section 2.8 Page 2-93	The conclusion that "risk estimates for direct contact to soil under industrial exposure scenarios do not exceed 1 x 10^{-4} carcinogenic risk levels nor 1.0 HI for either chemical or radiological contaminants" should not be made due to the limitations of only taking two surface soil samples (only one radiological sample). Also, using samples up to six feet below the surface represent a different scenario and should not be used to make conclusions about direct exposure to surface soil. This statement should be eliminated or caveated to explain the limitations in the sampling data.	Agree. The sentence will be caveated to explain the limitations in the sampling data.
		Add a new Section 2.8.3 to show and describe the SWMU - specific conceptual release model after completion of the risk characterization. A version of Figure 2-5 should be updated and highlighted for those pathways in which the risk characterization exceeds 10^{-6} or an ARAR concentration has been exceeded. A separate figure for each receptor scenario should be illustrated to improve clarity of the figure and allow room for listing of COCs that apply to each pathway. An identification of COCs in each contaminated medium applicable to a particular receptor scenario should be listed on an inset table on the figure. The figures should highlight those release mechanisms, primary and secondary contaminated media, and migration exposure paths which, based upon the RI, are either currently or are expected to pose a risk (including an exceeding concentration-based ARAR) to the given receptor.	Disagree. Because of time availability to respond to comments, this proposed new section and figure will not be incorporated into the revised RA. The information requested is available in its current form.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
61.	Section 2.8.1 Contaminants of Concern Page 2-93	The elimination of several SVOCs in groundwater and dioxin in soil because of high uncertainties in their detection or biased sample population is not in accordance with risk assessment guidance.	Agree. RGOs are not calculated for several SVOCs and dioxin because these chemicals do not contribute to cancer risks or non-cancer hazards.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
62.	Table 2-22 Page 2-94	Why was a f_{α} value of .002 used to calculate distribution coefficients when a value of .001 had been previously used for the same approximation on page 2-50? A target risk level of 10^{-5} is used. The point of departure risk goal is specified as 10^{-6}. Why is a target risk of 10^{-5} used to calculate the RG0s?	It is not clear why the two different values for organic carbon content of soil are used. Perhaps the measured value was 0.0015, and two different modellers rounded in opposite directions. One value (0.002) is used for calculating K_ds, and the other is used for calculating the retardation factor. This will be reviwed and a consistent number will be used. Table 2-22 was change to reflect an F_{α} of 0.001. A target risk level of 1 x 10^{-5} is used because this is the number that the EPA instructed us to use. Specifically, this was under the direction of Elmer Aiken.
63.	Page 2-92 Table 2-21	Typo. Last column should be 10E-$\underline{4}$.	Agree. Typo will be corrected.
64.	Page 2-94	The organic carbon fraction used to calculate K_d in Table 2-22 is different from the one used to calculate retardation factors on Page 2-51.	See comment #62.
65.	Table 2-23 Page 2-95	The transformation products of trichloroethene (TCE) should be included as contaminants of concern, to be addressed during RD/RA activities, even if they fall out of the risk assessment. Substantial concentrations of TCE currently exist and the potential for formation of daughter and granddaughter compounds exits.	Disagree. There is no guidance to support the inclusion of degradation products in the list of COCs unless they contribute significant risk as determined in the risk assessment.

Comment Number	Section/ Page	Comment	Response
3366.	Section 2.8.2 Data Sufficiency. Page 2-96	The EPA disagrees with the statement in paragraph one that "sufficient information is supplied from the site investigation and PGDP waste management record to support the assessment of risks and evaluation of alternatives for a final remedial action at these sources." Paragraph two states that uncertainties associated with the nature and extent of contamination exist at WMUs 2 and 3. The uncertainties due to the limited RI data regarding the nature and extent of residual soil contamination in the subsurface and surficial soil horizons around the perimeter of the landfills do not permit a complete risk assessment for this portion of the conceptual model of the release. However, due to the nature of the sources (for example, RCRA closed landfill and concentrated/reactive source material), an evaluation of alternatives for a final remedial action may proceed for the source-material.	Disagree. See comment response #40.
		Add a bullet describing the limited soil data around the perimeter of the landfills (surface and subsurface) and describe the uncertainties regarding the lateral extent and continuity of contaminants of concern within these media.	Agree. A bullet to this effect will be added.
67.	Attachment 2-1, Cancer Risk Estimates for Direct Contact to Soil	This table does not present the equation for excess lifetime cancer risk.	Disagree. The equations for intake are outlined in the tables for each pathway, at the top of the box below the results. All parameters are defined as well. Risk is not specifically shown, but the only change requested is to divide the intake by the reference dose, or to multiply the slope factor by the intake, for non-cancer and cancer risk, respectively. We feel that this step is obvious and need not be specified. Guidance does not require a specific form of the equation to be included in the risk calculation tables.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
68.	Attachment 2-2, Chronic Hazard Index Estimates for Direct Contact to Soil	This table does not present the equation for chronic hazard.	Disagree. The equations for intake are outlined in the tables for each pathway, at the top of the box below the results. All parameters are defined as well. Risk is not specifically shown, but the only change requested is to divide the intake by the reference dose, or to multiply the slope factor by the intake, for non-cancer and cancer risk, respectively. We feel that this step is obvious and need not be specified. Guidance does not require a specific form of the equation to be included in the risk calculation tables.
69.	Attachment 2-3	Given the units for all the parameters in the <u>external radiation risk equation</u>, there seems to be missing parameters or wrong units. Review this equation.	Disagree. Nothing is missing from this equation. The reviewer is encouraged to consider the fact that RAGS, Part B equations have been revised since the units on the external slope factor changed. The external slope factor for radionuclides is now in units of Risk/yr per pCi/g soil (See HEAST, 1993, Table 4A). Since the unit change, three components of the original equation on page 37 of RAGS, Part B have been dropped; the 10^{-3} g/kg conversion factor, the depth of radionuclide in soil, and the soil density.
70.	Attachment 2-4, Cancer Risk for Direct Contact to Soil	This table does not present the equation for excess lifetime cancer risk.	Disagree. The equations for intake are outlined in the tables for each pathway, at the top of the box below the results. All parameters are defined as well. Risk is not specifically shown, but the only change requested is to divide the intake by the reference dose, or to multiply the slope factor by the intake, for non-cancer and cancer risk, respectively. We feel that this step is obvious and need not be specified. Guidance does not require a specific form of the equation to be included in the risk calculation tables.

Comment Number	Section/ Page	Comment	Response
71.	Attachment 2-5, Chronic Hazard Index Estimates for Direct Contact to Soil	This table does not present the equation for hazard quotient.	Disagree. The equations for intake are outlined in the tables for each pathway, at the top of the box below the results. All parameters are defined as well. Risk is not specifically shown, but the only change requested is to divide the intake by the reference dose, or to multiply the slope factor by the intake, for non-cancer and cancer risk, respectively. We feel that this step is obvious and need not be specified. Guidance does not require a specific form of the equation to be included in the risk calculation tables.
73.	Attachments 2-3 and 2-6	The concentration of radionuclides in soil is based on measured levels of contamination in the soil adjacent to the trenches. The worker risks associated with inadvertent exhumation of the waste in the trenches should be addressed. In the same tables, a particle emission factor of 4.63E9 m^3/kg is used. This is a very low value applicable to small, undisturbed areas of contamination. For large areas of contamination and areas where worker activity may be going on, the emission factor could be larger by at least a factor of 10 to 100.	Disagree. Data do not exist to make this evaluation possible. Furthermore, the incorporation of a scenario of this kind does not significantly add to the information currently available to make remediation decisions. Disagree. The area in question is less than 4.4 acres and the surface of these units is completely vegetated with grasses. The PEF is appropriate for this area. Excavation of the buried waste is not planned and is specifically being excluded from any future activities at this site.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
74.	Attachment 2-7, Cancer Risk Estimates for Domestic Use of Groundwater	This table should not indicate that the risk from inhalation of volatile compounds during domestic use for groundwater is 0E+00. If no volatiles were detected in the groundwater the risk is not applicable. This table does not present the equation for excess lifetime cancer risk.	Agree. The reference to a risk result of 0E+00 will be corrected to NA, if appropriate. If volatile compounds have been detected in these wells, they will be included in this table. Language in the groundwater risk results section of 2.6.1.4 will be added to this effect. Disagree. The equations for intake are outlined in the tables for each pathway, at the top of the box below the results. All parameters are defined as well. Risk is not specifically shown, but the only change requested is to divide the intake by the reference dose, or to multiply the slope factor by the intake, for noncancer and cancer risk, respectively. We feel that this step is obvious and need not be specified. Guidance does not require a specific form of the equation to be included in the risk calculation tables.
75.	Attachment 2-8, Cancer Risk Estimates for Domestic Use of Groundwater	This table should not indicate that the risk from inhalation of volatile compounds during domestic use for groundwater is 0E+00. If no volatiles were detected in the groundwater the risk is not applicable. This table does not present the equation for exce9s lifetime cancer risk.	Agree. The reference to a risk result of 0E+00 will be corrected to NA, if appropriate. If volatile compounds have been detected in these wells, they will be included in this table. Language in the groundwater risk results section of 2.6.1.4 will be added to this effect. Disagree. The equations for intake are outlined in the tables for each pathway, at the top of the box below the results. All parameters are defined as well. Risk is not specifically shown, but the only change requested is to divide the intake by the reference dose, or to multiply the slope factor by the intake, for noncancer and cancer risk, respectively. We feel that this step is obvious and need not be specified. Guidance does not require a specific form of the equation to be included in the risk calculation tables.

Comment Number	Section/ Page	Comment	Response
76.	Attachment 2-9, Hazard Index Estimates for Domestic Use of Groundwater	This table should not indicate that the hazard quotient from inhalation of volatile compounds during domestic use for groundwater is 0.00. If no volatiles were detected in the groundwater the hazard quotient is not applicable. This table does not present the equation for hazard quotient.	Agree. The reference to a risk result of 0E+00 will be corrected to NA, if appropriate. If volatile compounds have been detected in these wells, they will be included in this table. Language in the groundwater risk results section of 2.6.1.4 will be added to this effect. Disagree. The equations for intake are outlined in the tables for each pathway, at the top of the box below the results. All parameters are defined as well. Risk is not specifically shown, but the only change requested is to divide the intake by the reference dose, or to multiply the slope factor by the intake, for noncancer and cancer risk, respectively. We feel that this step is obvious and need not be specified. Guidance does not require a specific form of the equation to be included in the risk calculation tables.
77.	Attachment 2-10, Hazard Index Estimates for Domestic Use of Groundwater	This table should not indicate that the hazard quotient from inhalation of volatile compounds during domestic use for groundwater is 0.00. If no volatiles were detected in the groundwater the hazard quotient is not applicable. This table does not present the equation for hazard quotient.	Agree. The reference to a risk result of 0E+00 will be corrected to NA, if appropriate. If volatile compounds have been detected in these wells, they will be included in this table. Language in the groundwater risk results section of 2.6.1.4 will be added to this effect. Disagree. The equations for intake are outlined in the tables for each pathway, at the top of the box below the results. All parameters are defined as well. Risk is not specifically shown, but the only change requested is to divide the intake by the reference dose, or to multiply the slope factor by the intake, for noncancer and cancer risk, respectively. We feel that this step is obvious and need not be specified. Guidance does not require a specific form of the equation to be included in the risk calculation tables.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
78.	Attachment 2-11	The risks from groundwater ingestion are based on observed levels of contamination in wells. For future use scenarios, the concentration of radionuclides in wells should be based on leachate transport and dilution models. Such calculations will reveal that the risks are at least a factor of 100 times higher.	Agree. Modelling will be used to discuss the future residential groundwater risks, as indicated.
79.	Attachment 2-13, Summary of Cancer Risk Estimates by Well	Excess lifetime cancer risk estimates should not be presented as 0E+00.	Agree. An appropriate term will be inserted for the wells that list the cancer or non-cancer risk as 0E+00.
80.	Attachment 2-14, Summary of Hazard Indices by Well	Hazard quotients should not be presented as 0.000.	Agree. An appropriate term will be inserted for the wells that list the cancer or non-cancer risk as 0E+00.
Kentucky DEP—General Comments			
1.	N/A	The submittal of the RI Addendum should have been an opportunity for DOE to present the available data, to formulate conclusions and to determine if the data collected was sufficient to proceed with the next phase of activities. This report did little to meet these ends. The text rambles with vague statements of contaminate concentration ranges and distribution. Although some monitoring well specific and sample specific data are given, they are often not presented in a readily reviewable format.	Comment noted.
2.	N/A	The report relies entirely on previous documents for supporting data. Although the report need not be a stand alone document, data referenced from other reports should include the document name, the volume number, section number and page number.	References that cite specific data will be adequately described to allow source location.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
3.	N/A	Basic reporting format necessitates that tables provide a convenient summary of data, including where and when the data originated and what the data is expressing. Notes, comments and symbols should be defined on each table. In addition to the general summary tables, tables presenting well specific and interval specific analysis should be provided. For each separable area, in this case SWMUs 2 and 3, and 7 and 30, detailed summary tables should be prepared. If data is reference in the text or used for any purpose it should be summarized on a table, the source and supporting data should be readily available in the document being reviewed or clearly referenced (see comment 2).	Addressed under specific comments. Disagree. We believe data is sufficient as presented.
4.	N/A	Some figures are poorly prepared and reproduced and do little to illustrate the extent of contamination or the physical layout of the WMUs in question. Figure should be prepared to show all relevant data points. If a feature is referenced in the text it should be shown on a figure. The figures should be prepared at a scale which provides adequate detail. Figures should not be limited to 8.5 x 11 in. or 11 x 17 in. for the convenience of the preparers. It may be necessary and appropriate to prepare a figure on 24 x 36 in. paper.	Monitoring wells referenced in text have been shown on Figures.
5.	N/A	SWMUs 7 and 30 need further characterization to determine 1) potential continuities in the UCRS flow system, 2) on and off-site contaminant source, and 3) the potential for consolidation and containment of the presently identified contaminant sources.	Agree. Additional sampling has been proposed for WMUs 7 and 30.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
6.	N/A	The Remedial Investigation Addendum (RIA) for WAG 22 does not provide sufficient data on the source to do a baseline risk assessment. More data needs to be collected in regard to onsite sources and their impact to onsite and offsite contamination. Without a better understanding of sources, with regard to waste form, leachability, site specific Kd chemistry, etc., a proper remedial plan cannot be developed and a no action risk assessment cannot be properly performed. The addendum lacks the data to conduct a risk evaluation for restricted and unrestricted workers. Walkovers with a micro R survey must be conducted to determine potential doses at WAG 22. The direct readings will support or refute the risk calculations that have been estimated in the RIA for WAG 22.	Disagree that more data are needed to assess risk. Sources will be dealt with qualitatively. DOE will not do source sampling. A walkover survey was performed and is included in RIA. Additional monitoring will be performed during the Feasibility Study.
7.	N/A	Capping at these Solid Waste Management Units (SWMUs) will not be effective without addressing lateral infiltration. Lateral infiltration has become more of a problem at SWMUs 2 and 3 since they were capped. Capping has created a potential difference and is causing water to be drawn into the trenches. Until something is done to prevent or retard lateral infiltration, water will continue to enter the trenches. Leaching and transporting of contaminants into the groundwater and surrounding soil is a major concern at WAG 22.	Verbal agreement on preferred alternative has been obtained. Agreed alternative is RCRA Cap. Groundwater at the site is being modeled and lateral flow will be addressed in specific comments.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
8.	N/A	Uranium is being solubilized at PGDP. The Quarterly Inspection Report, for the C-404 Hazardous Waste Landfill, has reported soluble uranium levels found in the sumps. Water Tank RA-04 had 16,174 picocuries/liter (pCi/L) U-238 on June 29, 1993. Monitoring Well (MW) 58 was pulled and grouted because mobile species of uranium were entering the well. Valuable information, with regard to uranium and its potential to contaminate the regional gravel aquifer, could have been gained from a detailed study of this area and MW-58. Uranium is being solubilized at PGDP, but is not moving as rapidly as technetium-99 (Tc-99) and Trichlorethylene (TCE).	Comment noted.
9.	N/A	SWMUs 2 and 3 are significantly different from SWMUs 7 and 30 in terms of waste components, the method of disposal, and location. The nature of the contaminant sources at the two groups of WMUs warrants that they should be treated as separate WAGs (that is, the rubble piles at SWMUs 7 and 30 will be handled differently from the pyrophoric uranium at SWMU 2).	Comment noted.
10.	N/A	The quantity of waste uranium, the existence of pyrophoric uranium, and the existence of unknown quantities of TCE and Tc99 at SWMUs 2 and 3 warrant the immediate implementation of corrective measures study to 1) limit the threat of uranium fires, 2) limit the threat of migration of uranium, and 3) limit the migration other contaminants at the site. Corrective measures could include the placement of caps on SWMU 2 and 3 to limit any infiltration until further data can be gathered to address lateral flow and contaminant migration at the site.	A paragraph will be added to discuss the potential explosion or fire threat from pyrophoric uranium.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
Kentucky DEP–Specific Comments			
1.	Section 1.2.2; Page 1-6; Paragraph 1	Sufficient validated data is not available for WAG 22 to identify probable conditions and support development of base and contingency actions without further field investigation. Most of the radionuclide data for groundwater in Table 2-10 has uncertainties in the reported concentrations. Valid data must be used to conduct a baseline risk assessment for WAG 22.	Disagree. Data were validated before being used in the report, as stated on pages 2-22 (Section 2.4.1.1) and 2-54 (Section 2.6.1.1) of the RIA. Radionuclide data are reported with error terms, which are standard for activity analysis. We do not plan to collect additional data.
2.	Section 1.4.2; Page 1-15; Paragraph 2	If radiological contamination in lakes, marshes, and ponds to the north of the site is not readily attributable to the PGDP, what is the source of the contamination? Are surface and groundwater pathways with their interactions from the plant to the Ohio River not sufficiently characterized? Do the streams, lakes, and ponds to the south of the plant show similar non-plant related contamination? Comment on these issues.	WMUs 2 and 3 are not suspected of contributing to surface water contamination; groundwater contribution to the Ohio River will be covered in the Groundwater Operable Unit.
3.	Section 1.4.1; Page 1-15; Paragraph 4	There is no corresponding explanation of "MMES 1993" within the Works Cited Section. Add this information to the text.	Should be MMES 1992a.
4.	Section 2.2.1; Page 2-12; Paragraph 1	A further description of the multilayer cap should be provided.	The multi-layer cap description will be provided. It will include 2 feet of compacted clay, 36-mil Hypalon, 1-foot granular fill, geotextile, and 2-feet of vegetative cover.
5.	Section 2.2.1; Page 2-8; Paragraph 3	There are insufficient water level data to determine whether the water table occurs above the base of the burial pits of SWMU 2. MWs 48, 49, 50, 51, and 57 should be monitored to characterize the water table at SWMU 2. If these wells have been decommissioned, they should be replaced with nested wells.	The elevation of the base of the burial pits in SWMU 2 are unknown, but is believed to vary from 7 to 17 feet deep. This depth corresponds to an elevation of approximately 355 to 365 feet above mean sea level (msl). Based on past monitoring of UCRS wells, the water levels are approximately 350 to 365 feet above msl. The deeper UCRS wells have lower water levels. Monitoring wells MW-48, -49, -50, -51, and -57 have been abandoned due to poor construction. An RCRA CAP and monitoring wells are planned for the Feasibility Study.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
6.	Section 2.1.2; Page 2-8; Paragraph 4	The location of the vitrified clay pipe and former weir at the southwest corner of the SWMUs should be shown on a figure. Provide a larger scale map that will best depict SWMUs 2 and 3.	Agree. Figure will be revised to show weir and pipe.
7.	Section 2.2.2.2; Page 2-15; Paragraph 6	Referenced well MW-78 is not located on Figure 2-3. The figure should be prepared so that all referenced wells, borings and sampling points are shown.	Agree. Figure will be revised to show well location.
8.	Section 2.2.2.2; Page 2-16; Paragraph 2	The location of surface water and sediment sampling points should be provided.	Sampling locations for the WMU 3 underdrain and leachate samples are shown on Figure 2-3.
9.	Section 2.3.1; Page 2-16; Figure 2-3	The figure does not clearly show the drainage patterns and ditches referenced in the text. The figure should clearly show all referenced features including outfall 015.	Agree. Figures 2-1 and 2-3 were revised and ditches were identified to show surface drainage direction
10.	Section 2.3.2; Page 2-17; Paragraph 1	Confirmation that a cap may exist is similar to stating that a cap may not exist. If the data are not sufficient to draw a conclusion, then additional data may be required to formulate one. In the interim, it is appropriate to consider and carry both possibilities throughout the text. Revise the text accordingly.	WMU 2 was capped in 1982 with a 6-inch thick clay cap with a permeability of 1×10^{-7} cm/s and an 18-in. thick vegetative cover. The wording will be revised to include this information.
11.	Section 2.3.3; Page 2-17; Paragraph 5	Why is the number of wells used during the assessment an approximate number? Which four wells were abandoned? Where is the pumping well? Provide this information on the appropriate figure or in the text.	The number of wells used during the assessment is not approximate. The six wells that were abandoned were MW-48, -49, -50, -51, -57, and -58. This information will be included in the text.
12.	Section 2.3.3; Page 2-17; Paragraph 6	Provide a complete summary of the slug test and pumping test data in the vicinity of the SWMUs.	A summary of hydraulic conductivity data can be found in Appendix D of the "*Report of the Paducah Gaseous Diffusion Plant Groundwater Investigation Phase III*" (KY/E-150).

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
13.	Section 2.3.3; Page 2-17; Paragraph 5	Provide the most recent quarterly result with all other quarterly results from a recent calendar year of SWMU specific groundwater elevation data on tables and on potentiometric surface maps for both the UCRS and RGA.	Annual groundwater reports for C-404, which contain hydraulic gradient maps and calculations for the RGA, have been submitted. It is not appropriate to show hydraulic gradient maps for the UCRS. A map only shows the lateral component of hydraulic gradient, not the vertical gradient. A reference was added to C-404 gradient maps.
14.	Section 2.3.3; Page 2-19; Figure 2-6	The cross section does not correlate with the boring logs referenced. Also, no cross section line is provided on any of the figures provided in the Addendum. Make the appropriate corrections or additions.	Agree. Will modify Figure 2-6.
15.	Section 2.3.3; Page 2-19; Figure 2-6	The utility of constructing a two-dimensional cross section from the pattern of points is not clear. A fence diagram would seem more appropriate. If a cross section is used, a more standard plane of points should be used.	Will revise to use a more standard plane of points.

Comment Number	Section/ Page	Comment	Response
16.	Section 2.1.1; Page 2-1; paragraph 2	The limits to fill material do not seem appropriate given the following statement: Section 2.1.1, Page 2-1, Paragraph 2, which indicates that WMU 2 "consisted of a series of pits excavated to a depth of 7 to 17 feet." Considering an approximate surface elevation of 370 feet above mean sea level (ASL) as derived from Figure 2-3, this would indicate a bottom of waste boundary of between 363 to 352 feet ASL. The current limits of the bottom of fill as presented on Figure 2-6 appears to indicate an elevation of 375 feet ASL. The figure should be amended to reflect actual or strongly suspected conditions. This matter is extremely important given its relationship to the likelihood that buried waste is apparently in direct contact with the water table.	Agree. Projected maximum and minimum wasted elevations were added to Figure 2-6.
17.	Section 2.3.3; Page 2-20; Paragraph 1	The UCRS is not an aquitard. Revise the text.	The UCRS is comprised of two hydrogeologic units (HU): HU2 consists of the discontinuous sand and gravel units and HU3 consists of a continuous clay. Together the two HUs govern the rate and direction of shallow groundwater movement and provide recharge to the RGA. The RGA behaves as a confined to semi-confined aquifer. The UCRS, primarily HU3, is the confining layer above the RGA. Text revised to make statement above.
18.	Section 2.3.3; Page 2-20; Paragraph 2	Why was the aquifer data from well 170 used to characterize the subsurface near SWMUs 2 and 3? Was there no other aquifer data closer to the SWMU? Comment on this issue.	The aquifer data from well 170 were intended as an exception rather than a characterization of the aquifer data.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
19.	Section 2.3.3; Page 2-20; Paragraph 3	Explain why wells 170-172 were to be installed downgradient of the SWMUs (p. 2-17, para. 5), but were installed in an upgradient location (p. 2-20, para. 4)?	Agree. Revised page 2-17, paragraph 5, to clarify. Added paragraph to page 2-20 after paragraph 4 to expand discussion of gradients in UCRS.
20.	Section 2.3.3; Page 2-20; Paragraph 3	Provide SWMU specific hydraulic gradient maps and calculations. The maps should indicate 1"=100' or similar units that show flow patterns through the SWMUs.	Annual groundwater reports for C-404, which contain hydraulic gradient maps and calculations for the RGA have been submitted. It is not appropriate to show hydraulic gradient maps for the UCRS. A map only shows the lateral component of hydraulic gradient, not the vertical gradient. A specific reference was added to the text.
21.	Section 2.3.3; Page 2-20; Paragraph 6	Has anisotropy been identified in the RGA in the vicinity of the C-404? Is there any indication that groundwater flow in the RGA at SWMUs 2 and 3 has an east-west orientation? Please provide the data that these statements are based on or reference the document which contains the information.	The reference for this statement is the "*Results of the Site Investigation, Phase II*", Volume 2, page 4-60.
22.	Section 2.4.1.3; Page 2-24; Table 2-3	Provide WAG specific supporting documentation on the elimination of organic compounds from being COCs.	Not all organic compounds have been eliminated from being considered COCs. Table 2-3 lists those organic compounds detected in environmental samples, but determined to be laboratory contaminants and subsequently eliminated as COCs. This determination is based on procedures found in Section 5.5 of RAGS, Volume I (1989).
23.	Section 2.4.1.4; Page 2-25; Paragraph 1	If the presence of phthalate compounds in soil and sediment samples is considered to be indicative of laboratory contamination, then it would seem to reduce the credibility of the laboratory data and consequently suggest further investigation to confirm or deny the presence of constituents. Comment on this issue.	Disagree. Phthalates were deleted from the list of COPCs for the reasons quoted in the referenced paragraph. Since there are no known sources of phthalates in the waste at this site, it is prudent to exclude it at this point. It may be better explained by itself rather than as laboratory contamination, or it could have been evaluated in Table 2-4, where it would have been eliminated based on the fact that maximum concentration found (450 ug/kg for di-N butyl phthalate, vs. a residential soil reference concentration of 32,000 mg/kg). For clarification, this chemical will be moved to Table 2-4.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
24.	Section 2.4.1.4; Page 2-25; Paragraph 4	The fact that these constituents are able to be utilized at certain concentrations by humans is no reason for eliminating them from further evaluation. The purpose should be to define the total extent of contamination regardless of the apparent human effects. Address this concern in the text.	Disagree. Section 5.9.4 of the RAGS (1989) discusses this issue in detail. We do not find that the RIA is out of compliance with EPA guidance on this issue.
25.	Section 2.4.1.4; Page 2-26; Paragraph 1 (first full paragraph)	Has the extent of the contaminants contained in Table 2-4 been defined? While the need for remediation of the contamination is unclear at this time and subsequent risk assessments may allow for no action concerning these constituents, a full evaluation of the need for such activity should only be made after defining the full extent of the constituent contamination.	See EPA Comment 40.
		There are no groundwater results evident on Figure 2-9. Additionally, the groundwater data provided on Figure 2-8 is not easily interpretable. It should be clearly noted on this figure (not on a table many sections removed from the figure) from which wells the data are derived.	Agree. Reference for groundwater results will be changed to Figure 2-8. A note will be added to the figure referencing the tables with the well specific information (Tables 2-8, -9, -10).
26.	Section 2.4.1.5; Page 2-28; Table 2-4	Provide supporting data for the elimination of Hg, Zn and Se as COCs.	These chemicals are eliminated as a result of the toxicity screen used as per RAGS (1989) guidance, section 5.9.5. The reason for elimination is stated under the first bullet of section 2.4.1.5, and in the title of table 2-4.
27.	Section 2.4.1.5; Page 2-31; Table 2-5	Prepare this and other tables to avoid conflicting units of measurements.	Agree. The table will be revised as suggested.

Comment Number	Section/ Page	Comment	Response
28.	Section 2.4.2; Page 2-32; Figure 2-8	What are the groundwater units on the table within the figure? DMNA and PCP are not defined on table 2-5 or on the figure. Regarding soil results from H008, 0.9 of what? What do the brackets indicate on the tables? The table should indicate that only select soil results (0 to 6 feet) are presented. Make the necessary additions or corrections.	Agree. The table will be corrected/clarified.
29.	Section 2.4.2; Page 2-33; Figure 2-9	H-169, MW-171 and -172 are not shown on a site map. MW-171 and 172 are not at SWMU 2 and 3 as the title states. MW-154 is not on table 3B-1. Boring log 170 cannot be found as well as logs for MW-48, -74 and -95. Address these comments by providing the appropriate information.	MW-169, -171, and -172 were added to Figure 2-1. Boring log for MW-170 is the same as for MW-169. Soil lithologies for MW-74 and MW-95 are included in Table 3 B-2 of the Phase II SI. Boring logs for MW-48 and MW-74 are included in Appendix D. MW-154 was drilled to replace MW-58. See MW-58 log for lithology information. H-169 will be changed to MW-169.
30.	Section 2.4.2; Page 2-34; Paragraph 2	Where was the location of the sample collected from the drainage northwest of SWMU 3?	Location is shown on Figure 2-8.
31.	Section 2.4.2.1; Page 2-34; Paragraph 6	Detection of ANY constituent above a determined background level is considered contamination. Levels above the background may be used to trigger different action, but the lesser levels are still to be considered contamination. Revise the text accordingly.	Agree. Wording will be modified to clarify this agreement.
32.	Section 2.4.2.1; Page 2-34; Paragraph 1	Provide a detailed summary table of all referenced data in this and all other sections.	Agree to better reference data.
33.	Section 2.4.2.1; Page 2-34; Paragraph 3	Explain the significance for detecting PCB in MW-169. What is the source?	PCBs are present in the surficial soils up to 600 feet away from WMU2. The source is unknown. This section was deleted since PCBs were eliminated as a COC in Table 2-4.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
34.	Section 2.4.2.1; Page 2-35; Figure 2-10	Provide a north arrow and a scale on the figure.	Agree. North arrow will be added to Figure 2-10.
35.	Section 2.4.2.1; Page 2-34; Paragraph 1	Why is WMU 3 not considered a source of surface contamination when the first sentence of the next paragraph indicates that semivolatile compounds were detected in a surface water sample from a drain in the northwest area of WMU 3? Comment on this issue.	Added statement to justify elimination of these compounds.
36.	Section 2.4; Page 2-34, Paragraph 5	If the high U-235 and U-238 concentrations in MW-58 came from the surface or shallow subsurface in the vicinity of the well, a walkover gamma survey should have been conducted to isolate the source. Comment on this issue.	A walkover survey was added to document and is included in Appendix D.
37.	Section 2.4	The present monitoring scheme does not address the following concerns at SWMUs 2 and 3: (1) the lateral migration of groundwater to and from the SWMUs, (2) the contaminants which are moving onsite via the lateral migration of ground water and the potential sources of these contaminants, (3) the contaminants which are moving offsite via lateral migration of ground water, and (4) the sources of contamination within the SWMUs. Address these issues.	Refer to U.S. EPA General comment No. 3 response.
38.	Section 2.4.2.1; Page 2-34; Paragraph 6	Identify the purpose/rational for using a "three times" background criteria for indicating surface radiological contamination.	See EPA specific comment No. 23 response.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
39.	Section 2.4.2.1; Page 2-36; Paragraph 5	Are data from field investigations the basis for the estimate of the depth of radiological contamination in the ditch along SWMUs 2 and 3? Have any field investigations been conducted to determine if radiological contamination has moved vertically and/or laterally from the ditches into soils and unconsolidated materials surrounding the ditch? Comment on these issues.	No, data from field investigations are not the basis for the estimate of the depth of radiological contamination in the ditch; samples were not taken because of the cap. Vertical or lateral movement from the ditches into the soils will be addressed in the Surface Water Integrator Unit.
40.	Section 2.4.2.1; Page 2-36; Paragraph 5	"The existing clay cap" as stated in the previous section has not been confirmed. It is not appropriate to convert the possible existence of a feature into a confirmed conclusion in other sections of the report. Revise the text accordingly.	Agree. Text will be clarified throughout the report to delete "may" or other qualifications and, thus, consistently refer to the presence of a cap.
41.	Section 2.4.2.1; Page 2-36; Paragraph 5	The extent of radiological contamination should be presented graphically. There are no maps within this document that allow the evaluation of the quality of surface water or sediment from the SWMU to outfall 015. The lateral extent of the 6 foot depth of radiological contamination is not presented. The omission of the evaluation of the surface of the SWMU due to the assumed clay cap is not justified. Collecting surface soil samples will not adversely affect the effectiveness of such a minimally designed cover, if it exists, to the extent that it could not be immediately repaired.	The quality of surface water at Outfall 015 will be addressed in Surface Water Operable Unit. The purpose of the RI was to address sources of offsite groundwater contamination; surface soil data were not collected because the information was not considered necessary for this purpose, not because of reluctance to disturb the cap. Additional information collection will be addressed in the Feasibility Study of WMUs 2 and 3.
42.	Section 2.4.2.2; Page 2-36; Paragraph 6	How are the units contributing to groundwater contamination offsite and not downgradient? Clarify the apparent discrepancy.	The paragraph was revised to remove the discrepancy.
43.	Section 2.4.2.2; Page 2-36; Paragraph 6	Does water level data at SWMU 3 indicate that the water level substantially decreased after the assumed installation of the multi-layer cap? The text should include historical groundwater data illustrating the effect of the assumed cap.	The multi-layer cap is not assumed. A cursory review of water level data did not show a decrease in water levels. Inserted sentence that makes this statement.

Comment Number	Section/ Page	Comment	Response
44.	Section 2.4.2.2; Page 2-39; Paragraph 1	What is the probable source for the PAHs in MW-169 and 170? Describe in the text.	The source for PAHs has not been identified. Sentence added to text to make this statement.
45.	Section 2.4.2.2; Page 2-39; Paragraph 3	Substantiated proof as to what degree the lateral flow within the UCRS is prohibited due to lenses/zones of less permeable strata should be provided.	A discussion of the gradients in the UCRS is included in Section 2.3.3.
46.	Section 2.4.2.2; Page 2-39; Paragraph 5	What significance are shallow wells MW-170, 171 and 172 upgradient of the SWMU to the assessment of these SWMUs? Comment on this issue. Does the configuration of the RGA Tc-99 plume at the C-404 suggest that the groundwater flow direction in the RGA in the vicinity of the C-404 has an east-west orientation (pp. 47-49, RCRA Part B Permit, June, 1992)? Incorporate comments to these issues into the text.	MW-170, -171, and -172 are not significant to the assessment except that they indicate the lateral extent of contamination from WMUs 2 and 3 does not extend that far from the unit. Text modified to include this response.
47.	Section 2.4.2.2; Page 2-40; Table 2-8	What pesticides are listed on the table? Make the appropriate additions or changes to the table.	Pesticides will be deleted from the table title.
48.	Section 2.4.2.2; Pages 2-40 - 2-45; Tables 2-9 and 2-10	The footnotes "a" and "b" need to be defined in the tables. Clarify the table.	Footnote a: Proposed MCLs. The regulatory limit for uranium is for total uranium activity. Footnote b: The proposed MCL for Tc-99 is 3,790 pCi/l.
49.	Section 2.4.2.2; Pages 2-41-43; Table 2-9	Are the numbers listed at top, well ID Numbers? Clarify the table.	Yes, the table header numbers are well ID numbers. Table will be revised to clarify this.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
50.	Section 2.4.2.2; Pages 44 & 45; Table 2-10	Most of the data listed in this table have uncertainties in reported concentrations. Data should be properly validated, and more samples need to be collected and analyzed to confirm results. One example is MW-49, which has a gross beta concentration of 10, 765 pCi/L, and only 292 pCi/L is reported to be Tc-99. If these results are correct, then what other beta emitters are present in MW-49? The quality analysis/quality control (QA/QC) for data validation of radionuclides in the RIA for WAG 22 is not adequate.	Refer to Kentucky DEP Specific Comment 1, concerning data validation. A footnote was added to Table 2-10 to note unreliability of data. A discussion in the uncertainty section of the Risk Assessment was added to cover this unreliable data.
51.	Section 2.4.2.2; Page 2-47; Paragraph 7	If the clay liner exists and is preventing infiltration, explain the origination of the leachate.	The source of this leachate is either from infiltration through the cap or lateral flow through the wastes.
52.	Section 2.4.2.2; Page 2-47; Last Paragraph	The leachate sample from SWMU 3 contained high concentrations of U-234, U235, and U238. Why was this not resampled? Describe the approach used in evaluating the results of this analysis.	Leachate is sampled every time the sump is drained. Additional data are not reported because leachate from the sump is expected to be high in U-234, U-235, and U-238.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
53.	Section 2.4.2.2; Page 2-47; Last paragraph	If there are problems with validating leachate sample data because of low chemical yields, then the leachate sample should be reanalyzed or another leachate sample taken to obtain valid results. It is critical to know the uranium concentration in WMUs 2 and 3 to be able to conduct a baseline risk assessment for WAG 22.	Agree. This paragraph will be amended to address the issue of data rejection more clearly. Low radiochemical yields refers to the spike recovery data not being within control limits. The lab that did the original analysis for this leachate sample should have rerun the sample after obtaining valid spike recovery results. Since they didn't, subsequent analyses of the leachate from DOE's quarterly reports to the Kentucky Department of Environmental Protection will be used to verify these concentrations. The concentrations listed in the first sample of the April 1994 report are 638, 251, and 24575 pCi/l for U-234, U-235, and U-238, respectively. The Tc-99 concentration listed in the first sample was listed in the quarterly report at 158±28 pCi/l. The concentrations listed in the second sample of the June 1994 report are 1680, 383, and 34509 pCi/l for U-234, U-235, and U-238, respectively. The Tc-99 concentration was listed in the quarterly report at 55±23 pCi/l. Source: C-404 Hazardous Waste Landfill Quarterly Inspection Report, Department of Energy, First Quarter, Calendar Year 1994.
54.	Section 2.4.2.2; Page 2-47; Single sentence paragraph	The statement supports not eliminating Se as a COC. Explain in more detail why Se was eliminated.	Disagree. Risk assessment guidance and the risk managers working on the project when this document was written, support the elimination of chemicals using the concentration-toxicity screening approach.
55.	Section 2.4.2.2; Page 2-47; Paragraph 1	Explain the reference and use of wells MW-169 and 171 in the previous sections relative to the last sentence in this paragraph.	Subsurface soil contamination has not migrated to these wells from WMU 2 and WMU 3.
56.	Section 2.4.2.2; Page 2-48; Paragraph 4	However detailed the disposal records may be, they have already been shown to be inaccurate (page 2-8). Comment on the reliability and perceived accuracy of the records.	The uncertainty associated with this issue will be noted in the uncertainty analysis.

Comment Number	Section/ Page	Comment	Response
57.	Section 2.4.2.2; Page 2-48; Last paragraph	Why is the conclusion regarding TCE in the subsurface radiological section? Separate conclusions in their appropriate sections.	This is an editorial correction that will be made in the final report.
58.	Section 2.4.2.2; Page 2-48; Paragraph 1	The statement that "contamination was not found in the RGA in the other wells around the two units or in the well north of the two units" is not clear. Table 2-3 shows that MW-50, 84, 86, 89, and 169 contain TCE concentrations of 2, 21, 98, 7 and 110 ug/1, respectively. Additionally, Table 2-10 demonstrates consistent contamination of the RGA screened monitoring wells.	The cited sentence will be deleted. Please clarify the references. Table 2-3 does not contain references to specific monitoring wells or to TCE.
59.	Section 2.4.2.2; Page 2-48; Paragraph 5	On what basis was the 50 foot extent of contamination established? Present the reasoning that was used to reach this conclusion.	Removed paragraph with discussion of 50 ft. extent.
60.	Section 2.5.1; Page 2-49; Paragraph 4	Provide a clear contour map indicating surface water flow to support the narrative.	Agree. Existing figures will be revised to show drainage pattern.
61.	Section 2.5.1; Page 2-49; Paragraph 4	If a 6 inch clay cap does exist, it will not significantly impede contaminant movement.	Vegetative cover impedes erosion and transport of contamination which adheres to soil particles.
62.	Section 2.5.1; Page 2-49; Last paragraph	How was 0.7 determined? Provide supporting data used to reach this conclusion.	Unknown. The calculated values based on actual site data will be used to estimate infiltrate.
63.	Section 2.5.2; Page 2-50; Paragraph 2	Explain the different hydraulic conductivities values, gradients, and flow velocities on 2-50 and 2-20. Revise or comment appropriately.	Revised page 2-50 to agree with 2-20.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
64.	Section 2.5.2; Page 2-50; Paragraph 2	How can the UCRS be 15 feet thick while still containing a 30 foot thick clay layer? The definition of an aquifer is defined in regulations [401 KAR 30:010, Section 1 (14)] and is not based on permeability, lack of connections, and lack of horizontal connections across a certain area. Comment on these issues.	The description of the thicknesses of the UCRS are in error. The attached Figure 3-13 cross-section from the Phase II Site Investigation Report will be referenced in the discussion and the text will be modified.
65.	Section 2.5.2; Page 2-50; Paragraph 2	Is the 30 foot clay barrier site specific to the SWMUs in question? Provide data to support this conclusion.	Refer to Comment 64 response.
66.	Section 2.5.2; Page 2-50; Paragraph 4	What is a "location" as referenced here and throughout the text?	Location is generally describing any point outside the PGDP property boundary. Text modified to clarify.
67.	Section 2.5.2; Page 2-50; Paragraph 7	Provide the TOC, CEC and FOC data.	Agree. Attached table presents data.
68.	Section 2.5.2; Page 2-51; Table 2-11	In Table 2-11, what PAH data are referenced on the table? Clarify the table and delete unnecessary information.	The reference to PAH will be deleted from the table.
69.	Section 2.5.3; Page 2-52; Paragraph 3	Where is the "probable source" information referenced in Section 2.5.3. Add appropriate information to the text.	The words "including probable source" will be deleted from the sentence.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
70.	Section 2.5.3.5; Page 2-53; Paragraph 3	Soluble uranium has been found in the shallow groundwater system (results from MW-58). Uranium is moving slowly because of its K_d value. Soluble uranium has been found in the sumps and monitoring wells surrounding WMUs 2 and 3 (See Table 2-10). Please provide data to confirm the statement that uranium is not migrating because of the insoluble nature of uranium oxide (UO_2). Uranium is being solubilized at PGDP.	Agree. Text will be revised to reflect the migration of solubilized uranium at PGDP in WMUs 2 and 3.
71.	Section 2.6.1.2; Page 2-56; Paragraph 1	Due to privatization of the gaseous diffusion process, what controls will the federal government institute to ensure the public that the land won't be sold by the private corporation to make money in the future? Institutional controls will be required for at least 10,000 years at WAG 22.	Disagree. While it may be agreed that institutional controls will be required for at least 10,000 years at WAG 22, it is not true that the gaseous diffusion process has been privatized to the extent that the land is privately owned. The DOE owns the land that the site is on, and has made every indication to maintain the industrial use policy of the land.
72.	Section 2.6.1; Page 2-58; Table 2-12	The statement that the surface water migration pathway has been excluded appears to conflict with statements made on Page 2-57, Paragraph 5. It is presumed that the fact contaminants have been discovered in sediments offsite will require further evaluation of this pathway in the investigation of the surface water integrator OU. Address this issue.	Will be covered in the Surface Water Operable Unit. A statement will be added to Table 2-12 describing that the surface water migration pathway will be further evaluated in the surface water on investigation.
73.	Section 2.6.1.2; Page 2-60; Paragraph 2	While it is agreed that a more realistic exposure scenario would be a reduction in the standard default value of 250 days for eight hours, supporting documentation should be provided for making the assumption that 25 days are adequate or realistic.	In the Phase II report, the number of days spent working outdoors by the worker was given as 25 days per year. Consistency with the Phase II report was one of the standards under which the RIA was written. This value was negotiated between MMES, DOE, and agency representatives several years ago.

Comment Number	**Section/ Page**	**Comment**	**Response**
74.	Section 2.6.1; Page 2-62; Paragraph 4	Justification for the use of average concentrations of contaminants in groundwater rather than maximum concentrations for evaluating risk should be provided.	Disagree. Apparent confusion with the wording in this paragraph will be addressed and the text revised. An average of all the rounds was calculated for each constituent in each well. Total risks were calculated for each well, and the well with the highest risk (in each of three separate risk categories) was chosen for the risk evaluation. This methodology was used per EPA direction, June 1992.
75.	Section 2.6.1.2; Page 2-67; Paragraph 1	Supporting documentation or explanation should be provided for each TEF used.	Disagree. The TEFs are standard risk assessment language referring to the EPA 1989b reference quoted here. It is unnecessary to repeat the reference for each one. If there were more than one reference for the TEFs, it would be given for each one.
76.	Section 2.6.1.4; Page 2-73; Table 2-13	Why are MW-154 (RGA) and MW-84 (UCRS) used to estimate offsite radiological groundwater contamination risks when there are wells with much higher concentrations of radiological constituents such as MW-88 (UCRS) and MW-58 (RGA)? Do the concentrations in MW's 154 and 84 reflect the full extent of the potential radiological risk which has been measured at SWMUs 2 and 3?	Disagree. Risk from radiological contaminants is not driven by concentration alone. The corresponding risk estimates for each radionuclide determine which ones will actually *drive* the risk estimate. Wells MW-154 and MW-84 were selected because they had the highest concentrations of *risk drivers*. No, these wells do not tell the full extent of contamination; they describe the nature of contamination. Monitoring Well 58 was not used because this well was abandoned. The well casing was cracked near the surface which may have allowed surface water infiltration.
77.	Section 2.7.1; Page 2-85; Table 2-15	The current Maximum Contamination Level (MCL) for Tc-99 is 900 pCi/L. The proposed MCL for Tc-99 is 3,790 pCi/L, but it has not been approved as of this date. Neither of these values are "as low as reasonably achievable" as required by DOE Orders and 10 CFR 834.	Agree to change MCL to 900.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
78.	Section 2.8.2; Page 2-96; -First bullet	Water is getting into WMUs 2 and 3 via lateral infiltration. There are still too many unknowns about where sources exist and what is going on at WMUs 2 and 3. Leachate samples need to be collected and valid radionuclide data need to be documented before a baseline risk assessment can be conducted for WAG 22.	Comment noted. Leachate samples are collected whenever the sump is emptied. Analytical data from sample collected is reported to KDED.
79.	Section 2.8; Page 2-93	The stated purpose of this document was to discuss the extent of contamination (Section 1, p. 1-1) and meet the requirements of an RFI Report (Section 1.2, p. 1-5). The conclusions provided in this section do not meet these stated goals. A preliminary review of the risk assessment values in Attachment 2 reveals several exposure paths. And contaminants yielding a significant risk (cancer > 1x10EE-6) or HI >1 should be evaluated during the feasibility study.	Please clarify what is being requested.
80.	Section 2.8.1; Page 2-96; Paragraph 1	While surface water may not be impacted by a "continuing" release, data support the probability of past releases. Past releases demand as much consideration for remediation as continuing releases. No consideration has been given to potential releases to the air. Address these issues.	Surface water releases will be handled under the Surface Water Operable Unit. Air releases are covered on pages 2-61 and 2-62.
81.	Section 2.8.2; Page 2-96; Paragraph 4	The first sentence of this paragraph indicates that the nature and extent of contamination within the soils and groundwater at WMUs 2 and 3 <u>are sufficient</u> to identify probable conditions and reasonable deviations. Whereas, the following paragraph begins by indicating that because <u>uncertainties</u> associated with the nature and extent of contamination exist at SWMUs 2 and 3, appropriate contingent action should be identified in the FS to manage the uncertainties. Please provide an explanation to this apparent contradiction.	The words: "associated with the nature and extent of contamination" will be deleted from the paragraph five.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
Kentucky DEP Radiation Control Branch – General Comments			
RCB1.	N/A	The Remedial Investigation Addendum (RIA) for WAG 22 does not provide sufficient data on the source to do a baseline risk assessment. Sufficient validated data needs to be collected to characterize on-site sources and assess their impact on on-site and off-site contamination. Without a better understanding of sources, with regard to waste form, leachability, site specific K_d, chemistry, etc., a proper remedial plan cannot be developed and a no action risk assessment cannot be properly performed. The Radiation Control Branch (RCB) has always stressed that a realistic no-action risk assessment must be conducted to determine future actions. The addendum lacks the data to conduct the necessary risk evaluation for restricted and unrestricted workers. Walkovers, with proper survey equipment, must be conducted to determine external dose and areas of contamination at WAG 22. Direct radiation readings will provide support for the risk calculations that have been estimated for WAG 22.	See KDEP General Comment No. 6 Response.
RCB2.	N/A	Capping at these Waste Management Units (WMUs) will not be effective without addressing lateral infiltration. Lateral infiltration has become more of a problem at WMUs 2 & 3 since they were capped. Capping has created a potential difference and is causing water to be drawn into the trenches. Until something is done to minimize lateral infiltration, water will continue to enter the trenches and leaching with subsequent transport of contaminants into the groundwater and surrounding soil will occur at WAG 22.	See KDEP Comment No. 7 Response

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
RCB3.	N/A	Uranium is being solubalized at PGDP. The Quarterly Inspection Report, for the C-404 Hazardous Waste Landfill, has documented soluble uranium levels found in the sumps. Water Tank RA-04 had 16,174 picocuries/liter (pCi/L) U-238 on June 29, 1993. Monitoring Well (MW) 58 was pulled and grouted because mobile species of uranium were entering the well. Valuable information, with regard to uranium and its potential to contaminate the regional gravel aquifer, could have been gained from a detailed study of this area and MW-58. Uranium is being solubalized at PGDP but it is not migrating as rapidly as technetium-99 (Tc-99) and Trichloroethylene (TCE) because of the difference in K_d's. (See attached paper; Sheppard, 1990.)	See KDEP Comment No. 8
		Kentucky DEP Radiation Control Branch – Specific Comments	
RCB4.	Section 1.2.2; Page 1-6; Paragraph 1	The data collected for WAG 22 is not sufficient to characterize the sources of groundwater contamination or to serve as the basis for determining "the most probable site conditions and reasonable deviations."	Commend noted.
RCB5.	Section 1.2.2; Page 1-6; Paragraph 1	Sufficient validated data is not available for WAG 22 to identify probable conditions and support development of base and contingency actions without further field investigation. Most of the radionuclide data for groundwater in Table 2-10 has uncertainties in the reported concentrations. Valid data must be used to conduct a baseline risk assessment for WAG 22 in order to determine the magnitude of risk reduction provided by the various remedial actions.	See KDEP Comment No. 1 Response

Comment Number	Section/ Page	Comment	Response
RCB6.	Section 1.3.2; Page 1-8; Paragraph 2	The characterization of ground water flow in the RI indicates lateral ground water flow may be a significant factor in the UCRS at WAG 22. Previous descriptions of ground water flow in the UCRS indicate ground water flow in the UCRS is primarily vertical, while lateral flow is insignificant. What data supports this reverse conclusion? We agree that some lateral migration is occurring. Please expand the discussion of lateral flow in the UCRS and include potentiometric surface maps for the individual SWMU's in WAG 22.	Agree. Reworded paragraph to say primary flow path is vertically and not laterally. Expanded discussion of groundwater hydraulics in the UCRS. See KYDEP specific comment number 20 for response to potentiometric surface maps.
RCB7.	Section 1.4.2; Page 1-15; Paragraph 2	What is the source of radiological contamination in lakes, marshes, and ponds to the north of PGDP if the contamination is not readily attributable to the PGDP? Are streams, lakes, and ponds to the south of the PGDP contaminated? Are the surface and ground water pathways (and their interactions) from PGDP to the Ohio River sufficiently characterized to rule out the PGDP as the source of contamination?	See KDEP Comment No. 2 Response.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
RCB8.	Section 2.1.1; Page 2-4 to 2-7; Table 2-1	The volume of Uranium and Uranium waste in SWMU 2 poses a serious potential environmental and health threat. What happens when the disposal drums disintegrate? What is the potential for ground water contamination from SWMU 2 (See next paragraph)? What is the potential threat of explosion or fire from the pyrophoric Uranium buried at SWMU 2?	A paragraph will be added to discuss qualitatively the potential explosion threat or fire from pyrophoric uranium.
		A RESRAD 4.3 radiological model indicates that U-238 and decay products could migrate and cause a substantial health threat given the present conditions at SWMU 2. The model reflected the following parameters: 1) the minimum known activity U-238 buried at SWMU 2 as outlined in Table 2.1, 2) Burial depths at the site as described in Section 2.0, 3) Physical and ground water flow parameters for the unsaturated zone, UCRS, and RGA, as outlined in the RI, the Phase II Site Investigation, and the Phase III Ground Water Investigation, 4) use of only the drinking water ingestion pathway and ingestion of 2 L/day of ground water immediately down gradient from SWMU 2, and 5) the assumption that U-238 and decay product sources were readily mobilized. The entry of U-238 and decay products into the ground water system was not evident for over 100 years. During a period from 100 to 1000 years dose rates rose from 0 to 11000 mrem/yr., while dose rates at the end of the 10,000 year modeling period were still above drinking water standards. It should be emphasized that the breaching and leaching of waste is very conservative in this model analysis. Other analyses will be conducted to assess a spectrum of breaching and leaching conditions.	Summers model was performed by SAIC as part of the F.S. for WMU 2. This model is discussed in Section 2.5.3 and is included in Appendix D.

Comment Number	**Section/ Page**	**Comment**	**Response**
3RCB9.	Section 2.4.2.2; Pages 2-44 & 45; Table 2-10	Most of the data listed in this table has uncertainties in reported concentrations associated with it. Data needs to be properly validated and more samples need to be collected and analyzed to confirm results. One example is MW-49, which has a gross beta concentration of 10,765 pCi/L and only 292 pCi/L is reported to be Tc-99. If these results are correct, then what other beta emitters are present in MW-49? The Quality Assurance/Quality Control (QA/QC) for data validation of radionuclides in the RIA for WAG 22 does not appear to be adequate. The Radiation Control Branch would suggest splitting of samples at WMU's 2 and 3 to ensure accuracy and precision of analyses. The RCB has split samples with DOE in the past and this has provided validation.	Refer to KDEP Specific Comment No. 1 Response.
RCB10.	Section 2.4.2.2; Page 2-47; Last Paragraph	If there are problems with validating leachate sample data because of low chemical yields, then the leachate sample should be reanalyzed or another leachate sample taken to obtain valid results. It is critical to know the uranium concentration in WMUs 2 and 3 to be able to conduct a baseline risk assessment for WAG 22. Larger sample volumes should be obtained, if at all possible, and samples should be split with the RCB.	Refer to KDEP Specific Comment No. 1 Response.
RCB11.	Section 2.5.3.5; Page 2-53; Paragraph 3	Soluble uranium has been found in the shallow ground water system (results from MW-58). Uranium is moving slowly because of its K_d value. Soluble uranium has been found in the sumps and monitoring wells surrounding WMUs 2 and 3 (See Table 2-10). Please produce data to confirm the statement that uranium is not migrating because of the insoluble nature of uranium compounds. Uranium is being solubilized at PGDP.	Refer to KDEP Specific Comment No. 70 Response.

RESPONSE TO KY DEP AND U.S. EPA COMMENTS
Draft Remedial Investigation Addendum
Waste Area Grouping 22, Burial Grounds
Paducah Gaseous Diffusion Plant, Paducah Kentucky

Comment Number	Section/ Page	Comment	Response
RCB12.	Section 2.6.1.2; Page 2-56; Paragraph 1	Due to privatization of the gaseous diffusion process, what controls will USEC or a private company, (if PGDP is privatized) institute to ensure the public that the land won't be sold to make money in the future? According to our initial estimates, institutional controls will be required for at least 10,000 years at WAG 22.	Refer to KDEP Specific Comment No. 71 Response.
RCB13.	Section 2.6.1.4; Page 2-73; Table 2-13	Why are MW-154 (RGA) and MW-84 (UCRS) used to estimate off-site radiological ground water contamination risks when there are wells with much higher concentrations of radiological constituents such as MW-88 (UCRS) and MW-58 (RGA)? Do the concentrations in MW's 154 and 84 reflect the full extent of the potential radiological risk which has been measured at WMU's 2 and 3? Please explain the rationale for using these other wells.	Refer to KDEP Specific Comment No. 76 Response.
RCB14.	Section 2.7.1; Page 2-85; Table 2-15	The current Maximum Contamination Level (MCL) for Tc-99 is 900 pCi/L. The proposed MCL for Tc-99 is 3,790 pCi/L, but this has not been promulgated as of this date. Neither of these values are "as low as reasonably achievable" as required by DOE Orders and 10 CFR 834. How does DOE plan to implement CFR 834 at PGDP?	Refer to KDEP Specific Comment No. 77 Response.
RCB15.	Section 2.8.2; Page 2-96; First bullet	Water is entering WMUs 2 and 3 via lateral infiltration. There are still too many unknowns regarding the location of sources and the breaching, leaching, and transport of waste at WMUs 2 and 3. Leachate samples need to be collected and valid radionuclide data needs to be documented before a baseline risk assessment can be conducted for WAG 22. A plan for proper sampling and analysis needs to be agreed upon by DOE, MMESI, and RCB.	Refer to KDEP Specific Comment No. 78 Response.

Section 1
Introduction

Section 1
Introduction

The United States Department of Energy (DOE) owns the Paducah Gaseous Diffusion Plant (PGDP) near Paducah, Kentucky, and Martin Marietta Energy Systems, Inc. (MMES) manages the plant under contract to DOE. In August 1988, volatile organic compounds (VOCs) and radionuclide contaminants were found in private wells north of the plant. In the fall of 1988, the United States Environmental Protection Agency (EPA) and DOE entered into an Administrative Order by Consent (Consent Order) under Sections 104 and 106 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to address the situation.

The contaminants detected in the groundwater offsite that led to the Consent Order are technetium-99 (Tc-99), a radionuclide, and trichloroethene (TCE), an organic solvent.

The burial grounds have been identified as probable sources of offsite contamination in surface water and groundwater. The burial grounds are an operable unit (OU) designated as Waste Area Grouping (WAG) 22 and include the following waste management units (WMUs):

- WMU 2: C-749 Uranium Burial Ground
- WMU 3: C-404 Low-Level Radioactive Waste Burial Ground
- WMU 7: C-747-A Burial Ground
- WMU 30: C-747-A Burn Area

contamination and risks associated with WMUs 2 and 3. These WMUs are discussed together because they are contiguous to one another and contamination currently cannot be differentiated between the units. WMUs 7 and 30 are also contiguous, and will be addressed in a separate document to be issued after additional information is gathered on the nature and extent of the contaminants contained in these units.

1.1 Background

The PGDP is a uranium-enrichment facility consisting of a diffusion cascade and extensive support facilities. Construction at the plant began in 1951 and, by 1952, the plant was operating. The PGDP is owned and operated by DOE and is currently managed by MMES.

The plant is located in northwestern Kentucky on a reservation of about 1,350 acres in western McCracken County, about 10 miles west of Paducah, Kentucky, and about 3 miles south of the Ohio River (Figure 1-1). Approximately 740 acres of the reservation are within a fenced security area. A raw-water treatment plant, a residential landfill, an

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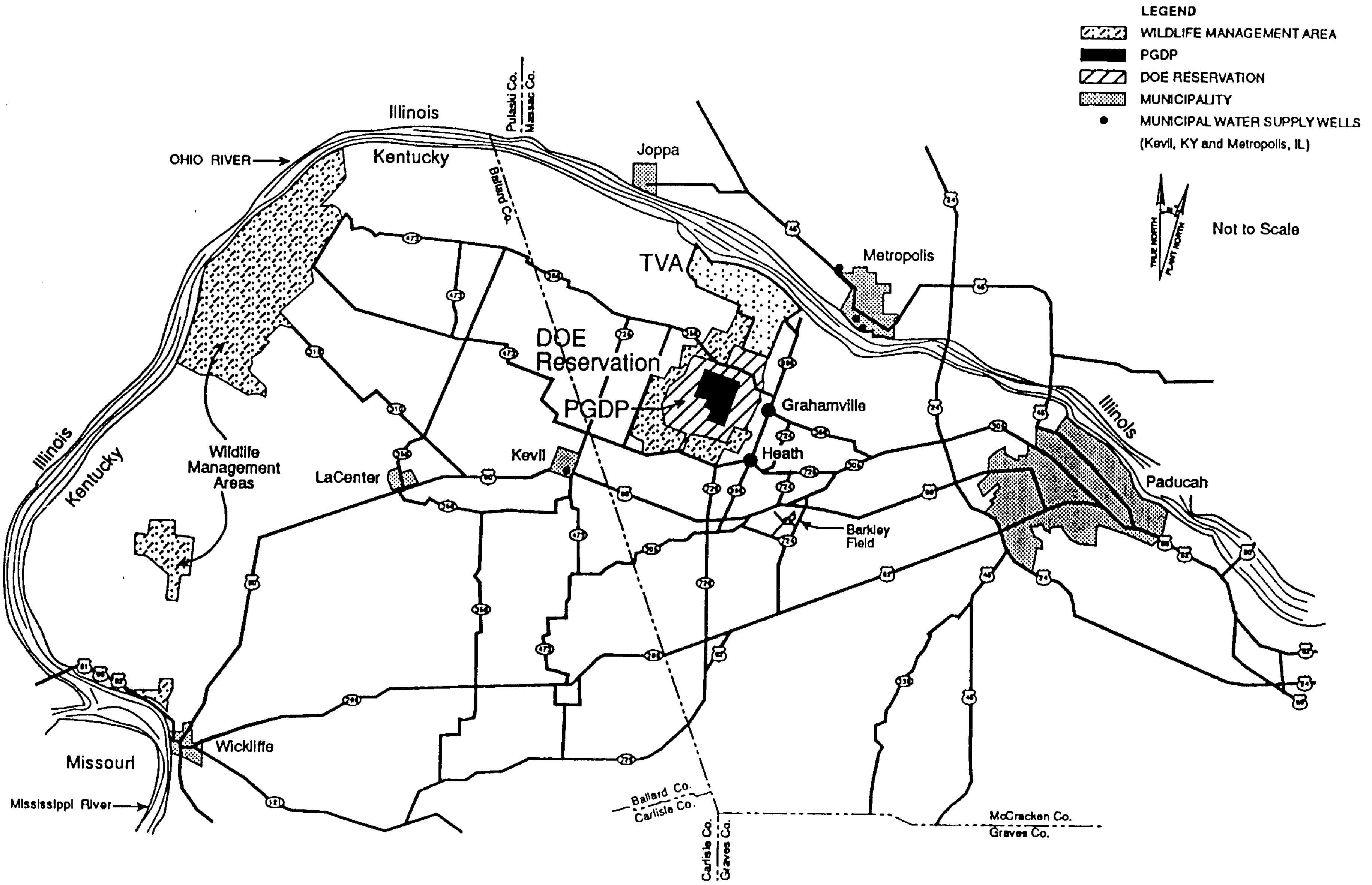

Source: [illegible]in Marietta Energy Systems (1973)

Figure 1-1
VICINITY MAP
PADUCAH GASEOUS DIF[illegible]ON PLANT
PADUCAH, [illegible]

inert landfill, and two industrial treatment lagoons are operating areas outside the security area.

In addition, a former sanitary landfill and several concrete rubble piles are inactive units outside the security fence. An uninhabited buffer zone surrounds the fenced area.

Beyond the DOE-owned buffer zone is a wildlife management area of 2,100 acres deeded or leased to the Commonwealth of Kentucky. During World War II, the Kentucky Ordnance Works, a trinitrotoluene (TNT) production facility, operated in an area southwest of the plant on what is now part of the West Kentucky Wildlife Management Area (WKWMA).

The PGDP performs the first step in the uranium-enrichment process. The product from the PGDP must be further enriched before being used as nuclear fuel. The plant provides an enriched feed stream to the gaseous diffusion plant in Portsmouth, Ohio. It also provided a similar feed stream to the Oak Ridge Gaseous Diffusion Plant in Oak Ridge, Tennessee, before that plant ceased production.

The PGDP enriches the uranium-235 (U-235) radionuclide in a physical separation process. The separation is based on the faster rate at which U-235 diffuses through a membrane barrier, in comparison to the heavier uranium-238 (U-238). Extensive support facilities are required for maintaining the diffusion process. Some of the major support facilities include a steam plant, four major electrical switchyards, four sets of cooling towers, a building for chemical cleaning and decontamination, a water treatment plant, maintenance facilities, laboratory facilities, and two active landfills. Several inactive facilities are also located on the plant site.

Hazardous, nonhazardous, and radioactive wastes have been generated and disposed of as a result of PGDP operations. In August 1988, contamination was found in an offsite drinking water well north of the PGDP. The contamination included Tc-99, which is a man-made radionuclide created as a byproduct of the fission of uranium. Tc-99 was initially introduced to the PGDP in 1953 as a contaminant in feed material during a program in which spent nuclear reactor fuel was fed into the cascade. Further sampling showed that a commonly used solvent, TCE, was also present in offsite wells. At DOE's expense, a community water line was extended as an alternative water supply to residences with contaminated wells. DOE is also paying for the water.

To establish a schedule for investigating and remediating the offsite groundwater contamination, EPA and DOE entered into a Consent Order under CERCLA, Sections 104 and 106. The effective date of the Consent Order is November 23, 1988. The intent of the Consent Order is outlined in four major objectives:

- To determine the nature and extent of the threat to human health and welfare and to the environment from the offsite contamination of groundwater and surface water

- To ensure that the environmental effects of the releases and threatened release are thoroughly investigated, and that appropriate actions are taken to protect the public health and welfare and the environment

- To establish a schedule and a work plan for developing, implementing, and monitoring necessary response actions at the site

- To promote cooperation (exchange of information among, and participation of, DOE, EPA, and the Commonwealth of Kentucky) in achieving the first three objectives

The Consent Order defined the work to be performed by DOE and MMES in response to the discovery of groundwater and surface-water contamination, and established the schedule for completing certain elements of the work. The Draft PGDP Site Management Plan (MMES, 1992) identified the burial grounds as onsite sources of contamination to be addressed further in accordance with the Consent Order.

1.1.1 Previous Investigations

Since the PGDP began operating, environmental data have been collected at and around the plant as part of a continuing environmental surveillance program, or as part of the environmental programs established by DOE/MMES.

A site investigation of the PGDP and surrounding area was conducted to collect and evaluate data that could supplement existing data to provide the basis for determining the nature and extent of offsite contamination.

Phase I of the site investigation was conducted in 1989 and 1990 to identify the chemicals of concern, identify WMUs possibly contributing to offsite contamination, describe the physical characteristics of the site, and give a preliminary description of the nature and extent of contamination and risk associated with the offsite contamination. The Phase I report was finalized in March 1991 and was approved as final by EPA in June 1991.

Phase II of the site investigation was conducted in 1990 and 1991 to further assess the nature, extent, and risk of offsite contamination identified in Phase I; to characterize WMUs possibly contributing to offsite contamination; to identify contaminant migration pathways contributing to offsite contamination; to collect data to support an alternatives evaluation; and to identify areas to be remediated. Phase II became final in April 1992. The consent order and work plan objectives, and the corresponding Phase I and Phase II investigation activities are shown in Table 1-1. Sections of the SI investigation applicable to WAG 22 are highlighted.

Other investigations have been conducted in the vicinity of the burial grounds by PGDP. These include routine groundwater monitoring of adjacent wells, routine

Table 1-1
Compliance of Site Investigation Activities with Consent Order Requirements
PGDP Phase II Site Investigation

Consent Order and Work Plan Objectives	Phase I Site Investigation Activities	Phase II Site Investigation Activities
Determine fully the nature and extent of the threat to human health and the environment caused by the offsite contamination of the groundwater from the PGDP. (Consent Order)	1. Installation of 25 wells 2. Groundwater sampling 333 well samples 3. Groundwater Users Survey 4. Well Evaluation of 15 existing wells 5. Offsite Receptor Assessment	1. Installation of 51 wells 2. Groundwater sampling 204 well samples 3. Public Health and Ecological Assessment
Ensure the environmental effects associated with the releases and threatened releases are thoroughly investigated. (Consent Order)	1. Drilling of 7 shallow soil borings in drainage ditches 2. Sampling of offsite surface soil at 17 locations for air dispersion 3. Radiological survey of 27 rubble piles 4. Surface water sampling at 45 locations in creeks, lakes, ponds, and wetlands 5. Sediment sampling at 20 locations in creeks, ponds, and wetlands 6. Sampling of soil in creek banks at 20 locations 7. Sampling of soil in outfall ditches in 12 locations 8. Sampling of biota including 12 deer samples and 23 fish samples 9. Sampling of plants and opportunistic animals	1. Surface water sampling at 17 outfall and 35 creek locations 2. Sediment sampling at 17 outfalls and 37 creek and floodplain locations 3. Radiation dose assessment at nearly 150 creek bank locations
Ensure appropriate action is taken as necessary to protect the public health, welfare, and the environment. (Consent Order)	1. Ensuring posting of Little Bayou Creek and the North-South Diversion Ditch 2. Ensuring public water supply to any affected resident 3. Groundwater sampling of residential wells on a weekly or monthly basis	1. Ensuring posting of Little Bayou Creek and the North-South Diversion Ditch 2. Ensuring public water supply to any affected resident 3. Groundwater sampling of residential wells on a weekly or monthly basis

Table 1-1
Compliance of Site Investigation Activities with Consent Order Requirements
PGDP Phase II Site Investigation

Consent Order and Work Plan Objectives	Phase I Site Investigation Activities	Phase II Site Investigation Activities
Determine the extent of surface water and groundwater contamination, both onsite and offsite. (Consent Order, Section V)	Onsite Surface Water: 1. Sampling of soils in drainage ditches and outfall ditches 2. Conducting storm sewer evaluation 3. Conducting radiation walkover surveys of drainage ditches Onsite Groundwater: 1. Sampling of 15 existing onsite wells Offsite Surface Water: 1. Sampling of surface water and sediments in creeks, lakes, ponds, and wetlands 2. Conducting radiation walkover surveys of creeks 3. Sampling of fish and macroinvertebrates in creeks and ponds Offsite Groundwater: 1. Installing 35 wells 2. Groundwater sampling of the 35 new wells, 13 TVA wells, and 34 residential wells	Onsite Surface Water: 1. Sampling of surface water in 4 WMUs 2. Sampling of soils in drainage ditches Onsite Groundwater: 1. Installation of 39 wells onsite at 18 waste areas 2. Sampling of the 39 new wells and 15 existing onsite wells Offsite Surface Water: 1. Sampling of surface water and sediments in outfalls, creeks, and floodplains 2. Collection of reference surface water, sediment, and soil samples Offsite Groundwater: 1. Installation of 12 additional wells offsite at 9 locations 2. Sampling of the 12 new wells, 35 Phase I wells, 10 TVA wells, and 17 residential wells

Table 1-1
Compliance of Site Investigation Activities
with Consent Order Requirements
PGDP Phase II Site Investigation

Consent Order and Work Plan Objectives	Phase I Site Investigation Activities	Phase II Site Investigation Activities
Address the identification of potential sources, pathways, and receptors. (Consent Order, Section V)	1. Drilling of 39 shallow soil borings and 12 deep soil borings at onsite WMUs 2. Conducting aquifer slug tests in 25 wells 3. Measuring water levels in wells, including continuous measurement over a 2-week period 4. Sampling of offsite surface soils at 17 locations for air dispersion 5. Conducting soil gas survey at 41 locations onsite 6. Conducting groundwater and surface water users survey 7. Sampling of environmental media (groundwater, surface water, sediment), including residential wells 8. Sampling of fish, deer, plants, and other biota	1. Conducting surface geophysical surveys at 4 WMUs 2. Conducting surface radiation walkover surveys at 5 WMUs and 2 onsite ditches 3. Drilling of 50 deep and shallow borings at 33 WMUs 4. Collecting 81 surface soil samples from 33 WMUs 5. Conducting aquifer slug tests in 35 wells and 1 aquifer pumping test 6. Measuring water levels in up to 130 wells for 1 year 7. Conducting double-ring infiltrometer testing at 5 WMUs 8. Excavating test pits at 2 WMUs 9. Sampling of environmental media (groundwater, surface water, sediment), including residential wells
Identify the number of residents using groundwater wells potentially impacted by the groundwater plume. (Consent Order, Section V)	1. Conducting a groundwater users survey of all wells within a 4-mile radius of the plant	
Identify the number of drinking water intakes within 15 miles downstream of the PGDP. (Consent Order, Section V)	1. Conducting a surface water users survey of all intakes within 15 miles downstream of the plant	

Table 1-1
Compliance of Site Investigation Activities with Consent Order Requirements
PGDP Phase II Site Investigation

Consent Order and Work Plan Objectives	Phase I Site Investigation Activities	Phase II Site Investigation Activities
Determine the lateral and vertical extent of the contamination in surface water and groundwater. (Phase I Work Plan)	Lateral extent in surface water: 1. Sampling of soils in drainage ditches and outfall ditches 2. Conducting storm sewer evaluation 3. Conducting radiation walkover surveys of drainage ditches 4. Sampling of surface water and sediments in creeks, lakes, ponds, and wetlands 5. Conducting radiation walkover surveys of creeks 6. Sampling of fish and macroinvertebrates in creeks and ponds Vertical extent in surface water: Not applicable Lateral extent in groundwater: 1. Installing 35 wells at 13 locations north, south, east, and west of the plant 2. Groundwater sampling of the 35 new wells, 15 existing onsite wells, 13 TVA wells, and 34 residential wells Vertical extent in groundwater: 1. Installing and sampling wells in 4 separate aquifer zones (shallow groundwater system, upper Regional Gravel Aquifer, lower Regional Gravel Aquifer, and deep groundwater system)	
Evaluate releases from selected onsite sources of TCE and Tc most likely to be contaminating groundwater and surface water. (Phase I Work Plan)	1. Drilling of shallow soil borings and deep soil borings at 9 different WMUs likely contributing to TCE or Tc contamination	
Evaluate those onsite sources of PCB contamination that may be contaminating surface water. (Phase I Work Plan)	1. Drilling of shallow soil borings at 12 WMUs likely contributing to PCB contamination	

Table 1-1
Compliance of Site Investigation Activities
with Consent Order Requirements
PGDP Phase II Site Investigation

Consent Order and Work Plan Objectives	Phase I Site Investigation Activities	Phase II Site Investigation Activities
Identify and characterize onsite sources of contamination found in Phase I, including additional chemicals of concern. (Phase II Work Plan)	1. Analyzing all environmental media (groundwater, surface water, sediments, soils, biota) for full TAL/TCL and a suite of radionuclides	1. Conducting surface geophysical surveys at 4 WMUs 2. Conducting surface radiation walkover surveys at 5 WMUs and 2 onsite ditches 3. Drilling of 50 deep and shallow borings at 33 WMUs 4. Collecting 81 surface soil samples from 33 WMUs 5. Sampling of surface water in 4 WMUs 6. Sampling of soils in drainage ditches 7. Installation of 39 wells onsite at 18 waste areas 8. Sampling of the 39 new wells and 15 existing onsite wells 9. Analyzing all environmental media (groundwater, surface water, sediments, soils) for full TAL/TCL and a suite of radionuclides
Fully characterize the nature and extent of any offsite contamination (not necessarily just the surface water or groundwater contamination known to be present). (Phase II Work Plan)		Offsite Surface Water: 1. Sampling of surface water and sediments in outfalls, creeks, and floodplains 2. Collection of reference surface water, sediment, and soil samples Offsite Groundwater: 1. Installation of 12 additional wells offsite at 9 locations 2. Sampling of the 12 new wells, 35 Phase I wells, 10 TVA wells, and 17 residential wells 3. Collection of reference groundwater samples
Determine the appropriate alternatives for remediation of offsite contamination. (Phase II Work Plan)		Alternatives evaluation

surface water monitoring of outfall ditches downstream of the burial grounds, a groundwater investigation of plantwide hydrogeology, a study of the Northwest Plume, and a Biological Monitoring Program (BMP) of plantwide impacts in downstream creeks.

1.2 Purpose

The purpose of this RI addendum is to provide additional supporting documentation specific to the burial grounds to augment the Phase II site characterization and risk assessment documentation, and to satisfy the requirements for an RI/Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Report for WAG 22. The addendum provides an evaluation of the existing data by defining conceptual models that provide the basis for baseline risk consistent with the National Contingency Plan (NCP). These evaluations will be used by PGDP to evaluate, select, and implement final remedies for the source areas.

1.2.1 Approach

Through PGDP's working meetings with the EPA, onsite source areas and media at PGDP have been grouped into potential OUs to more effectively manage the development, review, and approval of the supporting documentation needed to select appropriate actions consistent with the NCP and PGDP's RCRA permit. The potential OUs are defined in the Proposed Site Management Plan for PGDP.

The role of each OU at PGDP can be described in terms of two basic designations: source units and integrator units. Source units are defined as WMUs or Areas of Concern (AOCs) that release contaminants into the environment. These include burial grounds, landfills, spill sites, or any other areas that are classified as originating sources of site contamination. Integrator units are defined as "collectors" of contaminants migrating from source units. Integrator units at PGDP include groundwater, surface water, and the plant storm sewer/ outfall ditches.

The source units that are suspected of contributing to offsite contamination are being addressed by PGDP under the CERCLA Consent Order. PGDP has assigned these source units a high priority for evaluation. These WMUs have already been investigated under the CERCLA Consent Order.

1.2.2 The Observational Approach

During remediation of hazardous waste sites such as PGDP, numerous uncertainties regarding site conditions, technology performance, and regulatory conditions will exist throughout the process. The Observational Approach, which is based on the streamlining principles of the NCP of CERCLA, is a method used to effectively manage uncertainties so that response actions can be taken in a timely manner. The

Observational Approach, unlike traditional methods, emphasizes data sufficiency, while proceeding expeditiously with site remediation. The traditional approach typically emphasizes data completeness, assuming that uncertainties must be minimal before proceeding with the next phase of the process. This can result in excessive data collection and study during the RI/feasibility study (FS), which can delay site remediation.

The Observational Approach is not a substitute for developing an understanding of the fate and movement of contaminants at a site. Rather, it recognizes that complete site characterization and the development of infallible fate and transport models are not realistic or necessary. Contingency planning is conducted to manage the uncertainties.

The following elements collectively serve as the primary basis for effectively applying the Observational Approach to site remediation projects:

- Identification of the most probable site conditions and reasonable deviations
- Development of base actions using most probable site conditions
- Development of contingency actions based on reasonable deviations
- Identification of key indicators for monitoring during remediation to determine when to implement contingency actions

The Observational Approach stresses a dual conceptual design that incorporates both a base action and contingent actions. As efforts progress, the base action is initiated; however, if a reasonable deviation results due to changes in site conditions or technology performance, the contingent action is promptly implemented, thus minimizing delays.

The Observational Approach was applied to the Phase II study to develop this RI addendum. The document reflects site-specific applications of the approach to manage uncertainties by identifying the probable site conditions and recognizing uncertainty in the form of reasonable deviations. Use of the Observational Approach at the end of an investigation is less effective than early implementation. However, sufficient data is available for WAG 22 to use the Observational Approach to identify probable conditions and to support development of base and contingency actions without further field investigation. Additional monitoring will be included in the Feasibility Study to supplement the data collected for the RIA.

1.2.3 Report Organization

The remainder of Section 1 describes the regional environmental setting containing the PGDP. The regional environmental setting includes surface water hydrology, groundwater hydrology, ecology, meteorology, and demography and land use. Section 1 also contains a summary of the nature and extent of offsite contamination near the PGDP. Nature and extent of contamination is discussed in more detail in Section 2.

Section 2 describes WMU-specific information for WMUs 2 and 3, including description and operating history; previous investigations; physical characteristics (surface water hydrology, stratigraphy, hydrogeology); nature and extent of contamination; contaminant fate and transport; human health and ecological risk assessment; and remediation goal options (RGOs).

Attachments are provided at the end of Section 2 that present the risk estimate calculations specific to those WMUs.

Appendix A describes the general risk assessment methods used for this report. Appendix B describes the background risk assessment, and Appendix C describes the soil to groundwater leaching model and Appendix D includes selected boring logs, a walkover gamma survey for WMU 2 and Groundwater Modeling of WMU 2 uranium.

1.3 PGDP Environmental Setting

The PGDP is located in an area characterized by low relief. Elevations in the adjacent part of McCracken County vary from about 300 ft above mean seal level (msl) along the Ohio River north of the plant, to over 450 ft msl south of the plant. The topography in the area slopes at a rate of approximately 27 ft per mile toward the Ohio River. The plant property is relatively flat, with elevations varying from about 350 to 380 ft msl.

1.3.1 Regional Surface Water Hydrology

The regional land surface is incised by streams that flow northward toward the Ohio River. Locally, the PGDP is situated on a drainage divide; surface flow is to the east and northeast toward Little Bayou Creek, and to the west and northwest toward Big Bayou Creek. Big Bayou Creek is a perennial stream; its drainage basin extends from approximately 2.5 miles south of the PGDP to the Ohio River. The creek flows toward the river along a 9-mile course that passes along the western boundary of the plant. Little Bayou Creek originates in the WKWMA and flows north toward the Ohio River along a 6.5-mile course that includes parts of the eastern boundary of the plant. The 11,910-acre drainage basin of Big Bayou Creek is about twice that of Little Bayou Creek (about 6,000 acres).

During periods of dry weather, when aquifer recharge from precipitation is at its lowest, the majority of the flow in both Big and Little Bayou Creeks is water discharged from the PGDP through the PGDP Kentucky Pollutant Discharge Elimination System (KPDES) outfalls. The effluents from the PGDP operations constitute about 85 percent of the normal flow in Big Bayou Creek and almost 100 percent of the normal flow in Little Bayou Creek; higher percentages would be expected in the dry parts of the year.

Data from Little Bayou Creek indicate that the creek flow is relatively constant (no gains or losses) until a point near the northern boundary of the PGDP. Downstream from this point, Little Bayou Creek begins to gain water from the groundwater system. The data from Big Bayou Creek indicates that the creek loses water to the groundwater system in its upper reaches. However, below a point near the northwest corner of the PGDP, Big Bayou Creek gains water from the groundwater system.

1.3.2 Regional Groundwater Hydrology

The conceptual model of the regional hydrogeology groups the stratigraphic units into three hydrologic formations: (1) Upper Continental Recharge System (UCRS) (formerly referred to as the shallow groundwater system), which refers to the sands and gravels found at different elevations throughout the predominantly clayey silt of the Upper Continental Deposits; (2) Regional Gravel Aquifer (RGA), which occurs in the Lower Continental Deposits; and (3) McNairy Flow System, consisting of the Coastal Plain Deposits (including the combined Porters Creek Clay, McNairy Formation, and Eocene Sands, where present).

The UCRS is contained in the units above the RGA. Lenses of sand and clay in the UCRS direct rainwater percolating through the system. Where these lenses occur, interconnections between lenses allow vertical migration of shallow groundwater to the confining layer immediately above the RGA. Seepage through the confining layer or the absence of this layer in some areas allows migration of shallow groundwater and associated contaminants to the RGA. The primary flow pathway is believed to be vertical and not lateral. This vertical flow is driven by the vertical gradients which are much greater than the horizontal gradients. Lateral groundwater flow in the UCRS is toward areas where downward flow to the RGA can occur more easily. Downward seepage rates are estimated to be about 4 to 7 in. per year (2.5 to 4.5 gal per year per square foot of surface area). Hydraulic conductivity values in the UCRS have a wide range and are estimated to be less than 40 ft per year (4×10^{-5} cm/s); however, lenses may not be connected laterally.

The RGA, contained within the sands and gravels of the Lower Continental Deposits, is the major water supply aquifer for this area. This aquifer is not homogeneous. Preferential pathways for more rapid groundwater movement apparently occur along alignments of former river channels, which are oriented generally east-west beneath the plant. Aquifer tests indicate that conditions in these channels have resulted in a transmissivity parallel to the former river channels that is about 1.4 times greater than those perpendicular to the channels. Probable flow rates in the RGA are estimated to range between 200 to 400 ft per year (2×10^{-4} to 4×10^{-4} cm/s) toward the Ohio River.

The McNairy Flow System is within the Coastal Plain Deposits and represents the lowest vertical extent of interest for this report. The McNairy Flow System is not typically used as a water supply in the Paducah area because of its high clay fraction. Hydraulic conductivities within the McNairy Flow System range from 10 to 100 ft per year (10^{-5} to 10^{-4} cm/s).

1.3.3 Regional Stratigraphy

The PGDP site is underlain by the Coastal Plain Deposits, which are predominantly clay deposits in the area. Overlapping scour channels from the Tennessee River (Olive, 1966) eroded the top of the Coastal Plain Deposits to form a major erosional feature near the southern part of the site, referred to as the Porters Creek Clay terrace. The Lower Continental Deposits were deposited in the old scour channels and were subsequently overlain by (in ascending order) sand and clay of the Upper Continental Deposits, loess, alluvium, and fill.

The site is located on the Mississippi Embayment within the Coastal Plain Physiographic Province. Table 1-2 shows the regional stratigraphy. The Mississippi Embayment is a north-south trending trough filled with sediments from the middle portion of the North American Continent. The Coastal Plain Deposits consist of the Tuscaloosa Formation as a basal gravel, the McNairy Formation (with the undifferentiated Clayton Formation), and the Porters Creek Clay (Davis et al., 1973; Olive, 1966). Eocene sands occur in the region south of the plant (Dreier et al., 1990). Continental Deposits at the site lie above the Coastal Plain Deposits on an erosional unconformity formed by the overlapping scour channels. The Continental Deposits have been divided into a lower unit, consisting primarily of gravel or sandy gravel, and an upper unit, composed mostly of clay and sand (Olive, 1966; Finch, 1967a; Finch, 1967b). Wind-blown material from northern glaciers (loess) overlies the Continental Deposits. The uppermost deposits consist of recent alluvial floodplain material.

The major terrace in the Porters Creek Clay through the southern part of the site is an important hydrogeologic feature because it marks the southern extent of the Lower Continental Deposits. Since the Lower Continental Deposits contain the RGA, this terrace also marks the southern boundary of the major aquifer in the area. This feature is referred to in this report as the Porters Creek Clay terrace.

1.3.4 Regional Ecology

The terrestrial component of the regional ecosystem includes the plants and animals that use the upland habitats for food, reproduction, and protection. The terrestrial community is described by the dominant vegetation types that characterize the area. The communities range from an oak and hickory forest in areas that have been undisturbed, to managed fencerows and agricultural lands in the more developed areas.

Table 1-2
Regional Stratigraphy Near the PGDP

Page 1 of 2

System[a]	Series	Formation	Thickness (ft)		Lithology	Topography and Geologic Setting
Quaternary	Pleistocene and Recent	Alluvium	0-40		Brown or grey sandy and silty clay or clayey silt with streaks of sand. Some brown sand with streaks of clay and silt.	Recent floodplain deposits in the valleys of the Ohio River and its larger tributaries.
	Pleistocene	Loess	0-43		Brown or yellowish-brown to tan to grey unstratified silty clay.	Wind-laid deposits covering all upland areas and sloping sides of streams.
	Pleistocene	Continental Deposits	3-121		Clay Facies (Upper Continental Deposits) Orange to yellowish brown to brown clayey silt, some fine sand and gravel. Often micaceous.	Underlying loess or alluvium throughout the area. A thick silt deposit blankets the lower levels of the Plio-Pleistocene gravel.
Tertiary	Pliocene (?)				Gravel Facies (Lower Continental Deposits) Reddish-brown silty and sandy chert gravel and beds of grey sandy gravel, silt, and clay.	Terrace deposits lying on an irregular surface cut at different levels into sediments of Eocene, Paleocene, and Cretaceous ages. The pre-Pliocene surface consists of channels and terraces cut by an intricate drainage system at an altitude of about 280 feet above sea level.
	Eocene, Undifferentiated	Eocene Sands	0-200+	0-300+	Red, brown, or white fine- to coarse-grained sand. Beds of white to dark-grey clay are distributed at random.	Becomes thin and difficult to differentiate from the lower Eocene unit north of Childress Road. Generally not present north of U.S. Highway 60. Underlies Plio-Pleistocene gravel and younger deposits where present. Exposed in creek beds and railroad cuts in the southern half of the Heath Quadrangle.
			0-100+		White to grey sandy clay, clay conglomerate and boulders, scattered clay lenses and lenses of coarse red sand. Black to dark-grey lignitic clay, silt, or fine-grained sand. A bed of coarse sand at the base of the Eocene sequence is apparently discontinuous.	Underlies the main body of Eocene sediments in the southern part of the Heath Quadrangle. May be exposed in creeks north of U.S. Highway 60.
	Paleocene	Porters Creek Clay	0-200		Dark grey, slightly to very micaceous clay. Fine-grained clayey sand, commonly glauconitic in the upper part. Glauconitic sand and clay at the base.	Underlies the entire Heath Quadrangle except north of Grahamville. Pinches out north of the steep slope of the erosional Plio-Pleistocene surface and thickens quickly southward.

Table 1-2
Regional Stratigraphy Near the PGDP

Page 2 of 2

System[a]	Series	Formation	Thickness (ft)	Lithology	Topography and Geologic Setting
Cretaceous		Clayton and McNairy Formations	200-300	Greyish-white to dark grey micaceous clay, often silty, interbedded with light grey to yellowish-brown very fine- to medium-grained sand. The upper part is mostly clay; the lower part is predominantly micaceous fine sand.	Underlies the Plio-Pleistocene gravel north of Grahamville and the Porters Creek Clay south of Grahamville.
		Tuscaloosa Formation	?	White, well-rounded or broken chert gravel with clay.	May occur in pockets in the eroded surface of the Paleozoic rocks.
Mississippian		Mississippian Carbonates	500+	Dark grey limestone and interbedded chert, some shale.	Underlies the entire area at approximately sea level.

[a] Presented in descending order.

Sources: Hansen, 1966, and Lambert, 1966

The aquatic communities within the study area include two perennial streams (Little Bayou Creek and Big Bayou Creek), the North-South Diversion Ditch (a PGDP discharge), and other smaller drainage areas. In the area of Big Bayou Creek's confluence with Little Bayou Creek, there is a marsh. In addition, about 13 ponds that are used for fishing are located primarily in the WKWMA, but are not connected to runoff drainages or streams from the PGDP. There are two lakes, Crawford Lake and Metropolis Lake, north of the plant. During spring floods, the Ohio River connects several of these lower-lying water bodies, and the biota and sediment that they contain are flushed and exchanged with the river. These lakes are not connected to the Big and Little Bayou Creeks watersheds.

The majority of wetlands within the region are forested bottomland wetlands associated with the Ohio River floodplain. Within the WKWMA, approximately 4,000 acres have been identified as having hydric soil capable of supporting wetlands. Approximately 400 of these acres consist of tupelo swamp (considered unusual by state and federal land managers), 600 acres are in bottomland hardwood, and the balance of wetlands in the area is in agricultural use or is in some stage of regrowth as scrub-shrub wetland.

1.3.5 Regional Meteorology

The region has a humid-continental climate, characterized by extremes of both temperature and precipitation. The 20-year average monthly precipitation is 4.19 in., varying from an average of 2.99 in. in January to an average of 5.16 in. in April. From March through July and during November and December, the weather is somewhat wetter than average. From August through October and during January and February, it is somewhat drier than average. Less than 2 percent of the annual precipitation is snow.

The 20-year average monthly temperature is 57.1°F, varying from 29.9°F in January to 79.0°F in July.

Estimated actual and potential evapotranspiration rates are equal in all months except June, July, August, and September. For these four months, estimated actual evapotranspiration is a function of the available soil moisture and is less than potential evapotranspiration. Maximum potential and maximum estimated actual evapotranspiration rates occur in July. The potential evapotranspiration monthly average is approximately 2.73 in., and the estimated actual evapotranspiration monthly average is approximately 2.45 in.

From June through October, precipitation either dissipates through evapotranspiration or replenishes the depleted soil moisture. During this time, water from precipitation is generally not available for infiltration, groundwater recharge either does not occur or is very limited, and little of the precipitation that falls within the stream drainage basins runs off and is available for stream flow. From November through May, evapotranspiration is less, and water is available for infiltration or runoff (AFIRO).

Most groundwater recharge and stream flooding occurs during this part of the year. The average annual amount of precipitation AFIRO in the PGDP area is estimated to be 21.04 in.

Information on wind direction and speed was obtained from Barkley Field Airport, Paducah, Kentucky. The average prevailing wind has a speed of 9.8 miles per hour (mph) and blows from directions varying from south to southwest. Generally, stronger winds are observed when the winds are from the southwest or northwest.

1.3.6 Demography and Land Use

The PGDP, which is a major western Kentucky industry, employs about 1,700 people from 18 counties in Kentucky, Illinois, Tennessee, and Missouri. The WKWMA and some lightly populated farmlands are in the immediate vicinity of the PGDP. The WKWMA serves as an active recreational area for the western Kentucky region, and more than 10,000 people use the area annually.

Homes are sparsely located along rural roads in the vicinity of the site. The nearest residential cluster (18 homes) is located 1.5 miles southwest of the plant. The closest communities, both unincorporated, are Grahamville and Heath, 1 to 2 miles east of the plant. The largest cities within the 50-mile radius are Paducah, Kentucky, located about 10 miles east of the plant, and Cape Girardeau, Missouri, located about 40 miles west of the plant. The total population within the 50-mile radius is about 500,000, and approximately 50,000 people live within 10 miles of the PGDP (MMES, 1987). Two large industries are located within a 5-mile radius of the PGDP. Essex Group, Inc., employs 178 people, and the Tennessee Valley Authority (TVA) Shawnee Power Plant has 545 employees.

The area within a 5-mile radius of the PGDP is predominantly agricultural and open land, totaling approximately 75 percent of the area. Forested areas account for another 15 percent. Urban and industrial areas constitute approximately 4 percent. Surface-water bodies cover approximately 5 percent of the area. Gravel pits account for less than 0.5 percent.

1.4 Nature and Extent of Offsite Contamination

Contamination has been identified in offsite groundwater and surface water. Contaminants have been identified as those compounds or elements within a given sampled medium that are detected at higher concentrations than reference values. Reference values represent the maximum concentration measured in samples of each respective medium from sampling stations believed to be unaffected by plant activities.

Table 1-3 lists the contaminants detected off the site in the environmental media sampled as part of the site investigation. The most widespread and commonly detected

Table 1-3
Contaminants Found Offsite in Assessed Media
PGDP

Contaminants[a]	Assessed Media						
	Groundwater	**Surface Water**	**Sediment**	**Fish**	**Deer**	**Plants**	**Soil**
PCBs			X	X[b]	X[c]		
Dioxins, Furans			X				
Pesticides		X					
Phenol	X						
Polycyclic Aromatic Hydrocarbons (PAHs)			X				
TCE	X	X	X				
Benzene, Toluene, Ethylbenzene, Xylenes (BTEX)	X	X	X				
Other VOCs	X	X	X				
Arsenic	X			X	X	X	
Beryllium	X			X	X		
Lead	X			X	X	X	
Nickel	X	X		X	X	X	
Zinc	X	X	X	X			
Other Metals		X	X	X	X	X	
Tc-99	X	X	X	X	X	X	
Uranium	X	X	X	[d]	X		
Other Radionuclides	X	X	X	[d]	X		

[a] A constituent is listed as a contaminant if it has been found in concentrations greater than reference values.
[b] PCBs in fish were detected as a part of the BMP.
[c] Oak Ridge National Laboratory (ORNL) detected PCBs in one deer liver tissue.
[d] Not analyzed.

Note: Table summarizes data obtained during both Phase I and Phase II of the site investigation.

contaminants were TCE and Tc-99 in the groundwater, and PCBs and uranium in the surface water and sediments. Of the contaminants listed in Table 1-3, TCE and Tc-99 are the contaminants that may have originated from WMUs 2 and 3. The following media-specific discussions indicate the importance of these findings.

Chemical data for liquid samples, such as samples of groundwater or surface water, are typically reported by the laboratory as the number of micrograms of the analyte per liter of liquid (μg/L). Chemical data for solid samples, such as samples of soil or sediment, are typically reported as the number of micrograms of the analyte per kilogram of solid (μg/kg). Both 1 μg/L and 1 μg/kg are equivalent to one part per billion (ppb). Frequently, a concentration of an organic constituent is reported as, for example, "$<5\mu$g/L." This indicates that the constituent was not detected at or above the detection limit for that constituent (in this case, 5 μg/L) by the laboratory.

Radiological data for liquid samples are typically reported in number of picoCuries of activity per liter of liquid (pCi/L). For solid samples, data are typically reported in picoCuries per gram (pCi/g) to indicate the level of radioactivity in the sample. Radioactivity is determined by how fast the unstable material decays, or disintegrates. One pCi is equal to 2.22 disintegrations per minute (dpm). A direct equivalence between radioactivity and chemical concentration is a linear relationship that can be calculated only on a radionuclide-specific basis. For example, in water 1 pCi/L of Tc-99 is roughly equal to 5.9×10^{-5} μg/L. In solids, 1 pCi/g of Tc-99 is roughly equal to 0.059 μg/kg.

1.4.1 Groundwater

Offsite groundwater contamination consists primarily of TCE and Tc-99 contamination within the RGA, although offsite contamination within the UCRS north of the plant has also occurred. Contaminants (primarily constituents of petroleum products and Tc-99) were also found in trace amounts in the deep groundwater system. Table 1-3 lists the contaminants that were detected in the groundwater off the site.

EPA has established a maximum contaminant level (MCL) in the Safe Drinking Water Act (SDWA) for TCE of 5 μg/L. An MCL for Tc-99 of 900 pCi/L has been derived based on 4-mrem/year exposure. Currently, proposed MCLs for Tc-99 would increase the derived standard to 3,790 pCi/L based on revised dose assessment assumptions (EPA, 1991c).

TCE contamination is present offsite in the RGA in concentrations exceeding the MCL. A TCE plume appears to originate at the northwest corner of the PGDP and extends northward toward the Ohio River for approximately 3 miles (MMES, 1992a). Within this plume, a zone of higher TCE concentration ($>1{,}000\mu$g/L) is present near the suspected point of origin. TCE contamination is also present in the RGA within a smaller northeasterly trending plume that extends northeast from PGDP to approximately Metropolis Lake Road.

Within the northwest plume, Tc-99 contamination within the RGA seems to follow the same general trend as the TCE contamination. A zone of Tc-99 contamination with concentrations exceeding the current MCL (900 pCi/L) appears to coincide with the zone of high TCE concentrations.

1.4.2 Surface Water and Sediment

Chemical and radiological contamination associated with the PGDP was detected in Little Bayou Creek and the North-South Diversion Ditch in both surface water and sediment (see Table 1-3). The contamination consists primarily of uranium and PCBs. Radiological contamination, primarily uranium, was detected in sediments from Big Bayou Creek.

The low levels of chemical and radiological contamination found off the site in ponds, lakes, and marshes could not be readily attributed to the PGDP. A direct pathway, for migration from the plant to those ponds where trace contamination was found, is not present. The marsh at the confluence of Big and Little Bayou Creeks is in direct communication with the creeks and with the Ohio River during flood stage.

1.4.3 Biota

Low levels of contaminants were detected in fish from both streams and ponds (see Table 1-3). PCB concentrations above the Food and Drug Administration's (FDA's) action level of 2 parts per million (ppm) were not found in any of the more than 30 fish collected as part of the site investigation, although the PGDP's BMP has reported such levels.

Analyses of radionuclides in edible parts of deer by both the Oak Ridge National Laboratory (ORNL) and subcontracted laboratories detected low levels of radionuclides (Tc-99 and uranium) in one deer sample. The concentrations detected showed high uncertainty terms and did not exceed reference (background) levels for soils. One deer liver tissue sample contained a detectable concentration of PCBs. Inorganic contaminants, primarily arsenic, were detected, but at levels below FDA action levels for meat to be used for human consumption.

The only crops found with radionuclides above reference values were some composite samples from whole (root, stem, and pod ground together) soybean plants.

1.4.4 Soil

No pattern of soil contamination associated with the PGDP, including air dispersion, was found in offsite soil.

Section 2
WMUs 2 and 3

Section 2

WMU 2: C-749 Uranium Burial Ground and WMU 3: C-404 Low-Level Radioactive Waste Burial Ground

2.1 WMU Description and Operating History

2.1.1 WMU 2: C-749 Uranium Burial Ground

WMU 2, the C-749 Uranium Burial Ground, is located on the western edge of the C-404 Low-Level Radioactive Waste Burial Ground (WMU 3) in the western area of the PGDP site, north of Virginia Avenue (Figure 2-1). The WMU 2 burial ground, used primarily for uranium and uranium-contaminated waste, may have been in operation as early as 1951 and received waste until 1977.

The burial ground covers an area of roughly 32,000 ft^2 (about 160 ft by 200 ft) segregated into sections 20 ft^2 (Figure 2-2). The site consisted of a series of pits excavated to a depth of 7 to 17 ft. Wastes were covered with 2 to 4 ft of soil as they were disposed of. The trenches occasionally filled with water during disposal activities. Fires reportedly occurred occasionally at the C-749 Uranium Burial Ground from oxidation of pyrophoric uranium, but no subsidence was observed that resulted from the fires. The burial ground was covered with a 6-in. clay cap in 1982.

The majority of the waste received at WMU 2 consisted of pyrophoric (that is, spontaneously combustible) forms of uranium metal, such as machine shop turnings, shavings, and sawdust. An inventory of the wastes disposed at WMU 2 is listed in Table 2-1. Pyrophoric uranium metal was usually placed in 20-, 30-, or 55-gal drums and submerged in petroleum-based or synthetic oils to prevent rapid oxidation of the turnings. Other forms of uranium, including oxides of uranium (solid and dissolved in aqueous solutions), uranyl fluoride solutions, uranium-zirconium alloy, slag, and UF_4, were buried in smaller quantities. Records indicate that fifteen 30-gal drums of contaminated TCE were also buried in WMU 2 in October 1959. Estimates are that 270 tons of uranium, 59,000 gal of oils, and 450 gal of TCE were disposed of in the C-749 Uranium Burial Ground. While there is no documentation of Tc-99 disposal at this unit, Tc-99's presence is suspected because of its association with uranium at the plant.

In August 1984, Area 9 (Figure 2-2), where the drums of TCE were reportedly disposed of, was excavated because of concern about the integrity of the drums used to bury TCE after 25 years underground (Thompson, 1984). Only four 30-gal drums (instead of the 15 expected) were recovered. Three of the drums were in such poor condition that the contents could not be determined; the fourth drum had no top, but was otherwise in good condition. Mud and sludge in this drum contained approximately 4.5 percent TCE and 20 percent uranium. Soil samples in the area showed <0.1percent TCE.

DOES NOT CONTAIN
OFFICIAL USE ONLY INFORMATION
WFCage
Name/Org: SST-PGDP
Date: 1/6/11

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ORO3

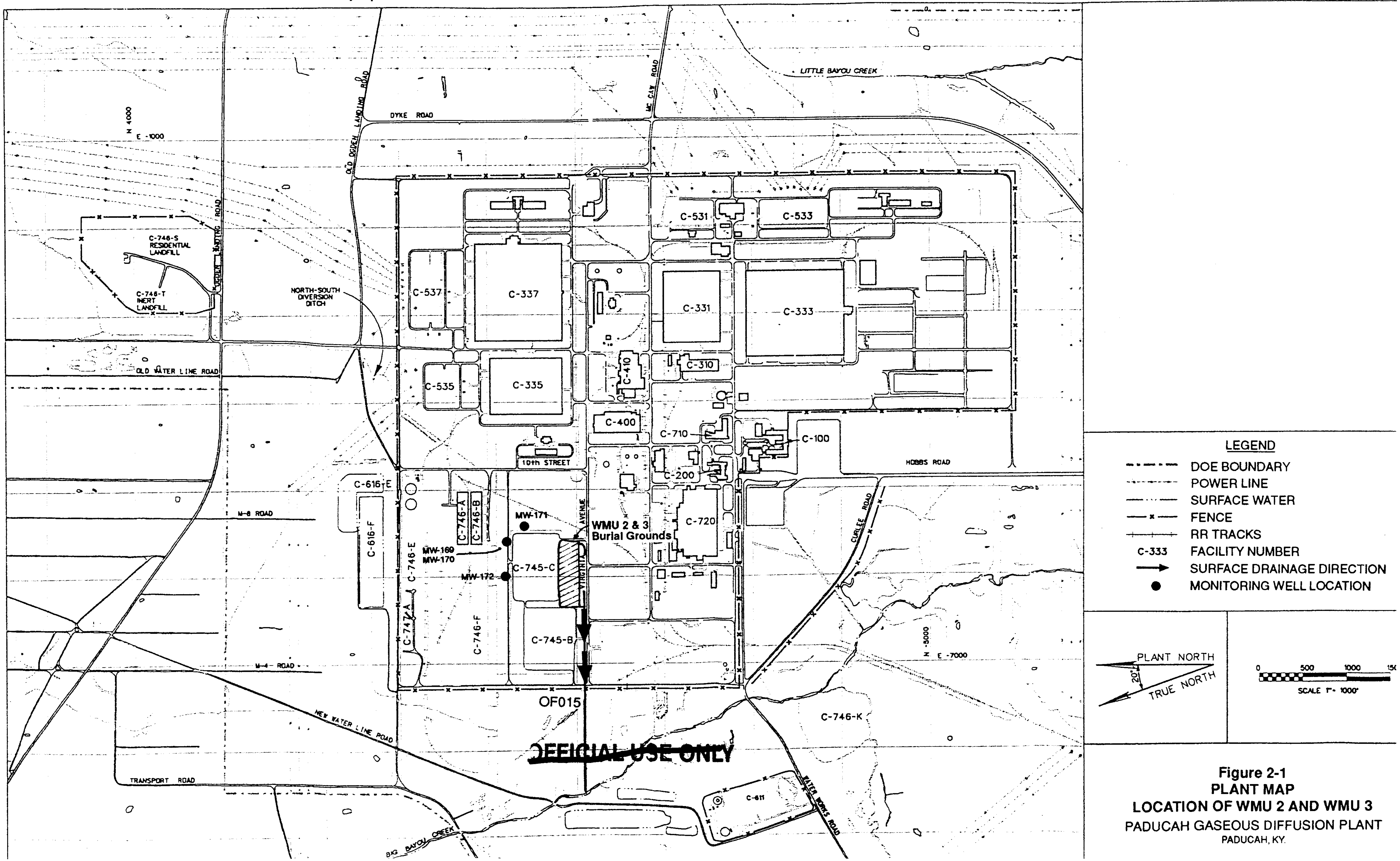

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Figure 2-1
PLANT MAP
LOCATION OF WMU 2 AND WMU 3
PADUCAH GASEOUS DIFFUSION PLANT
PADUCAH, KY.

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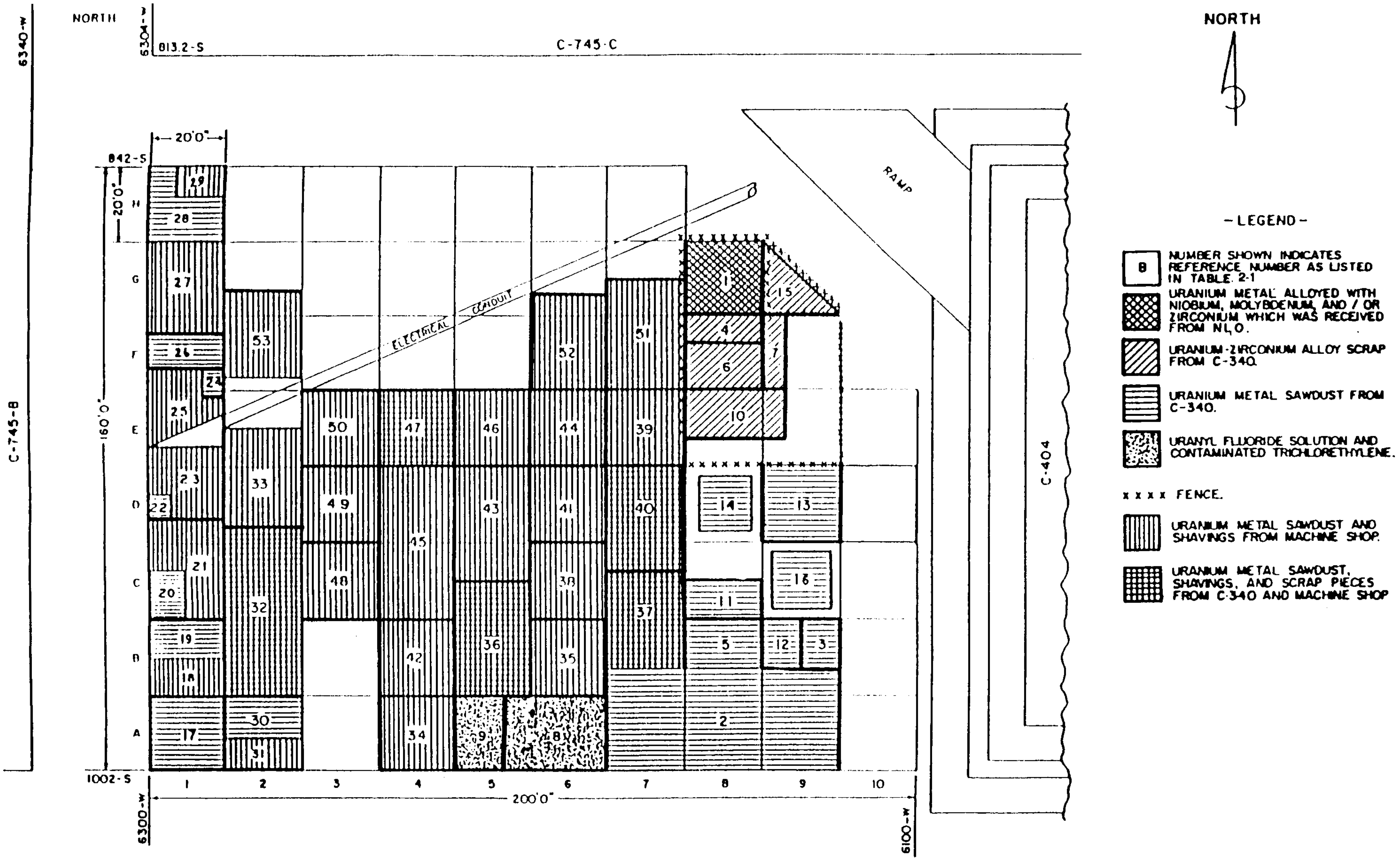
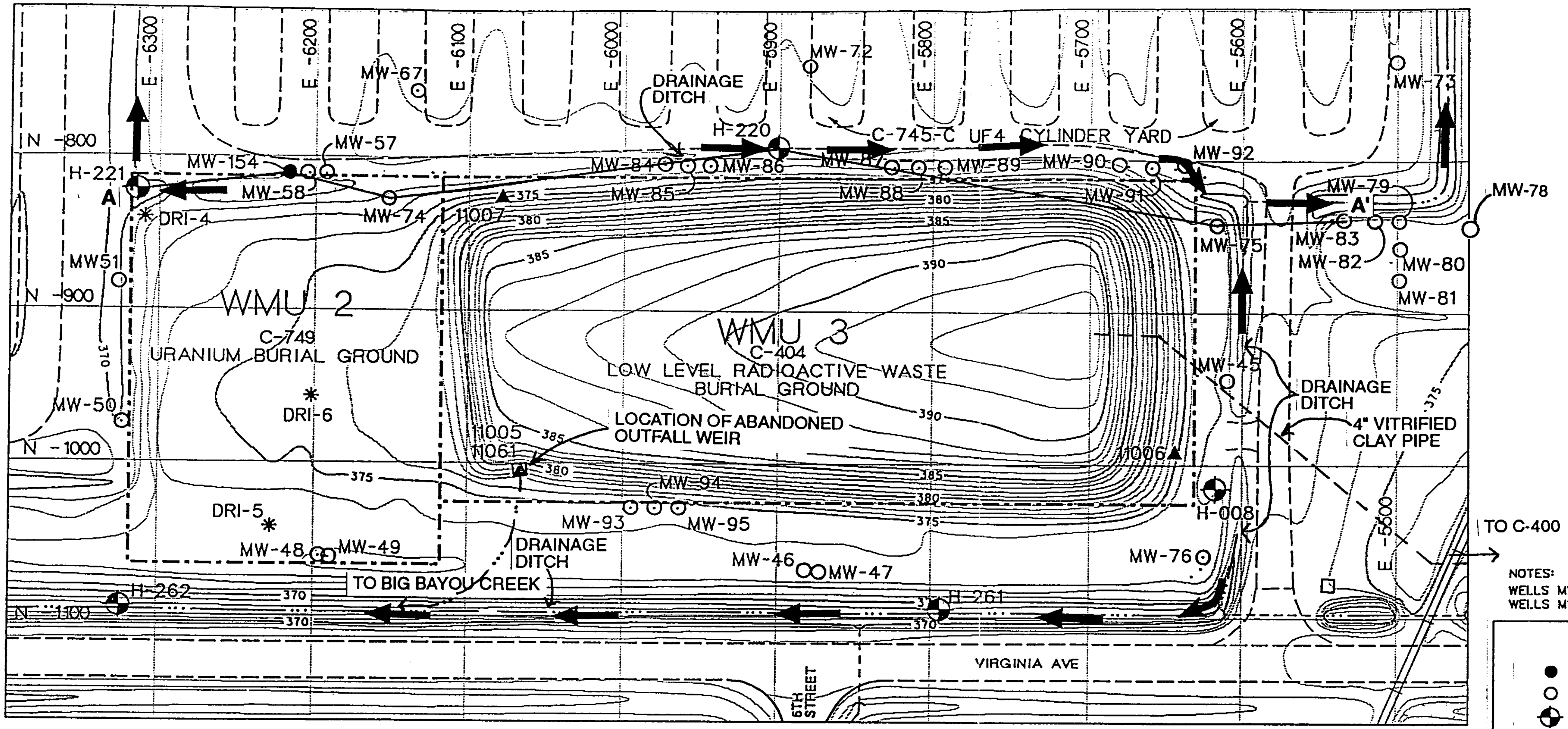


Figure 2-2
SITE PLAN OF BURIAL AREAS AT WMU 2
PADUCAH GASEOUS DIFFUSION PLANT
PADUCAH, KY.

Source: Union Carbide (undated)



NOTES:
WELLS MW-49, 74, 85, 88, 91, 94, 154, 170, 171, 172, IN SGS
WELLS MW-48, 50, 67, 84, 86, 87, 89, 90, 92, 93, 95, 169 IN RGA

LEGEND

●	MONITORING WELL
○	EXISTING PGDP MONITORING WELL
⊕	SOIL BORING
▲	WATER SAMPLE
*	DOUBLE-RING INFILTROMETER TEST
-·-·-	WMU BOUNDARY
→	SURFACE DRAINAGE DIRECTION

NOTE:

MONITORING WELLS MW-169, MW-170, MW-171, AND MW-172 ARE LOCATED APPROXIMATELY 600 FEET NORTH OF THE WMUs

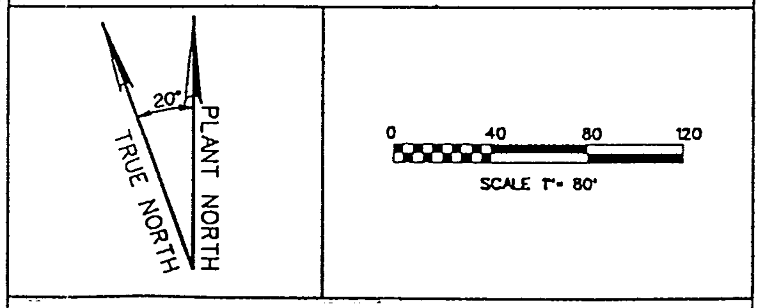


Figure 2-3
PHYSICAL FEATURES OF WMU 2: C-749 URANIUM BURIAL GROUND AND WMU 3: C-404 LOW-LEVEL RADIOACTIVE WASTE BURIAL GROUND
PADUCAH GASEOUS DIFFUSION PLANT
PADUCAH, KY.

Table 2-1
Inventory of Uranium-Bearing Scrap in WMU 2

Page 1 of 4

Pit No.	Date Buried	Type of Material	Number of Containers				Net Weight or Volume	Uranium (g)	Wt. % U-235[a]	Remarks
			20-gal Drums	30-gal Drums	55-gal Drums	Miscellaneous				
1	12-16-57	U–Metal Alloy	--	4	--	Twelve 8-gal pails	4,686 lb	2,125,386[c]	0.1400[d]	Nb_7Mo-Zr alloy received from RLO
2	5-6-59	Uranium Sawdust	18	57	19		94,401 lb[e]	38,537,414[f]	0.1519	From routine C-340 operations
3	6-16-59	Uranium Sawdust	--	1	--		800 lb[e]	326,585[f]	0.1617	From routine C-340 operations
4	8-14-59	U–Metal Alloy	--	--	--	One 1-gal pail	10 lb	4,445[g]	0.2200[h]	Zirconium-bearing scrap from C-340
5	8-26-59	Uranium Sawdust	--	1	--		800 lb[e]	326,585[f]	0.1675	From routine C-340 operations
5	8-31-59	Uranium Sawdust	--	1	--		800 lb[e]	326,585[f]	0.1675	From routine C-340 operations
6	9-24-59	Slag	--	--	--	Buried loose	2,100 lb	28,576	0.2200[h]	Zirconium-bearing scrap from C-340
7	9-30-59	Saw Chips	--	--	--	Buried loose	25 lb	10,206	0.2200[h]	Zirconium-bearing scrap from C-340
8	10-1-59	Uranyl Fluoride Solution	--	35	--		6,048 L	68,377	0.408	Contaminated waste solution
9	10-1-59	Contaminated Trichloroethylene	--	15	--		5,843 lb	54,272	0.348	Contaminated waste solution
10	10-19-59	U–Metal Alloy	--	--	--	Buried loose	300 lb	122,469	0.2200[h]	Zirconium-bearing scrap from C-340
10	10-19-59	Crucible Burnout	--	--	--	Buried loose	100 lb	36,287	0.2200[h]	Zirconium-bearing scrap from C-340
10	10-19-59	Saw Chips	--	--	--	Buried loose	50 lb	20,412	0.2200[h]	Zirconium-bearing scrap from C-340
11	11-16-59	Uranium Sawdust	--	5	--		4,000 lb[e]	1,632,924[f]	0.1733	From routine C-340 operations
11	11-16-59	Reject "U" Scrap	--	--	--	Buried loose	3,550 lb	1,449,220	0.1733	From routine C-340 operations
12	5-27-60	Uranium Sawdust	4	--	--		2,400 lb[e]	979,754[f]	0.2483	From routine C-340 operations
13	12-16-60	Uranium Sawdust	12	--	--		9,600 lb[e]	5,919,018[f]	0.1700	From routine C-340 operations
13	12-16-60	Saw Chips	--	--	--	One small box	200 lb	81,646	0.1700	From routine C-340 operations
14	4-25-62	Uranium Sawdust	5	2	--		4,600 lb[e]	1,877,863[f]	0.1800	From routine C-340 operations
15	7-24-62	Sandblast Grit	--	--	--	One 1-gal pail	5 lb	Insignificant	--	Buried for safety reasons only
15	7-24-62	Zr Alloy Scrap	1	--	1		700 lb	Insignificant	--	Buried for safety reasons only

Table 2-1
Inventory of Uranium-Bearing Scrap in WMU 2

Pit No.	Date Buried	Type of Material	Number of Containers				Net Weight or Volume	Uranium (g)	Wt. % U-235[a]	Remarks
			20-gal Drums	30-gal Drums	55-gal Drums	Miscellaneous				
16	5-9-63	Uranium Sawdust	5	1	--		3,800 lb[e]	1,378,914[f]	0.1800[i]	From routine C-340 operations
17	11-13-63	Uranium Sawdust	13	--	--		7,800 lb[e]	3,184,202[f]	0.2200[i]	From routine C-340 operations
18	2-3-64	Uranium Sawdust and Shavings	18	39	7		4,683 lb	2,124,297[j]	0.2335	From machining operations
19	2-3-64	Uranium Sawdust	15	16	--		25,400 lb[e]	10,369,067[f]	0.2200[i]	From routine C-340 operations
20	4-15-64	Uranium Sawdust	--	24	2		22,200 lb[e]	9,062,728[f]	0.2200[i]	From routine C-340 operations
21	4-15-64	Uranium Sawdust and Shavings	--	88	--		1,342 lb	608,717[j]	0.2271	From machining operations
22	7-2-64	Uranium Sawdust	--	6	--		6,000 lb[e]	2,449,386[f]	0.2200[i]	From routine C-340 operations
23	7-2-64	Uranium Sawdust and Shavings	--	30	5		5,436 lb	2,219,416[j]	0.3102	From machining operations
24	10-21-64	Uranium Sawdust	--	3	--		3,000 lb[e]	1,224,693[f]	0.2200[i]	From routine C-340 operations
25	10-21-64	Uranium Sawdust and Shavings	--	25	--		4,774 lb	2,165,439[j]	0.2196	From machining operations
26	1-28-65	Uranium Sawdust	--	6	--		6,000 lb[e]	2,449,386[f]	0.220[i]	From routine C-340 operations
27	1-28-65	Uranium Sawdust and Shavings	--	25	8		1,422 lb	645,005[j]	0.2288	From machining operations
28	4-30-65	Uranium Sawdust	--	23	--		23,000 lb[e]	9,389,313[f]	0.2200[i]	From routine C-340 operations
29	4-30-65	Uranium Sawdust and Shavings	--	5	--		1,706 lb	773,825[j]	0.2308	From machining operations
30	10-21-65	Uranium Sawdust	--	36	--		36,000 lb	13,063,392[f]	0.2200[i]	From routine C-340 operations
31	10-21-65	Uranium Sawdust and Shavings	--	15	5		2,917 lb	1,322,940[j]	0.2200	From machining operations
32	7-20-66	Uranium Sawdust, Shavings, and Scrap Pieces	--	78	13	Seven 5-gal pails	100,251 lb	45,472,851[j]	0.1776	From routine C-340 and machining operations
33	11-28-66	Uranium Sawdust and Shavings	--	41	2		21,364 lb	9,690,703[j]	0.2205	From machining operations
34	3-28-67	Uranium Turnings and Shavings	64	5	--		5,355 lb	2,428,931[j]	0.1845	From machining operations
35	6-14-67	Uranium Turnings and Shavings	103	--	--		4,699 lb	2,131,542[j]	0.2063	From machining operations

Table 2-1
Inventory of Uranium-Bearing Scrap in WMU 2

Pit No.	Date Buried	Type of Material	Number of Containers				Net Weight or Volume	Uranium (g)	Wt. % U-235[a]	Remarks
			20-gal Drums	30-gal Drums	55-gal Drums	Miscellaneous				
36	7-26-67	Uranium Turnings and Shavings	145	--	--		10,455 lb	4,742,294[j]	0.2001	From machining operations
36	7-26-67	U_3O_8	--	--	20		20,000 lb	7,257,440[j]	0.1870[i]	From routine C-340 operations
37	8-25-67	Uranium Turnings and Shavings	35	--	--		4,316 lb	1,957,543[j]	0.2102	From machining operations
37	8-25-67	U_3O_8	--	6	10		13,600 lb	4,935,059[j]	0.1622[i]	From routine C-340 operations
38	11-21-67	Uranium Turnings and Shavings	45	--	--		2,309 lb	1,047,394[j]	0.2115	From machining operations
39	3-26-68	Uranium Turnings and Shavings	71	--	--		5,034 lb	2,283,564[j]	0.1775	From machining operations
40	5-1-68	Uranium Turnings, Sawdust, and U_3O_8	55	--	9		4,357 lb	1,976,130[j]	0.1540	From routine C-340 and machining operations
41	7-8-68	Uranium Turnings and Shavings	31	--	--		679 lb	307,987[j]	0.2201	From machining operations
42	9-10-68	Uranium Turnings and Shavings	55	--	--		3,115 lb	1,412,924[j]	0.1710	From machining operations
43	11-15-68	Uranium Turnings and Shavings	83	--	--		16,279 lb	7,384,065[j]	0.1654	From machining operations
44	3-5-69	Uranium Turnings and Shavings	82	--	--		726 lb	329,499[j]	0.2100	From machining operations
45	7-17-69	Uranium Turnings and Shavings	118	8	--		2,784 lb	1,262,602[j]	0.2070	From machining operations
45	7-17-69	U_3O_8	--	--	2		2,000 lb	725,744[l]	0.2000[i]	From routine C-340 operations
46	12-22-69	Uranium Turnings and Shavings	20	--	--		288 lb	130,600[j]	0.1983	From machining operations
46	12-22-69	U_3O_8	--	--	1		1,000 lb	362,872[l]	0.2000[i]	From routine C-340 operations
47	7-21-70	Reject Uranium Metal Scrap	--	--	15		12,000 lb	5,443,080	0.2000[i]	From routine C-340 operations
47	7-21-70	Uranium Turnings and Shavings	20	--	--		308 lb	139,674[j]	0.2200	From machining operations
48	3-5-71	Uranium Turnings and Shavings	93	--	--		9,283 lb	4,210,526[j]	0.1626	From machining operations
49	8-23-71	Uranium Turnings and Shavings	107	--	--		10,680 lb	4,844,368[j]	0.1626	From machining operations
50	3-16-72	Uranium Turnings and Shavings	200	--	--		19,575 lb	8,879,024[j]	0.199	From machining operations

Table 2-1
Inventory of Uranium-Bearing Scrap in WMU 2

Page 4 of 4

Pit No.	Date Buried	Type of Material	Number of Containers				Net Weight or Volume	Uranium (g)	Wt. % U-235[a]	Remarks
			20-gal Drums	30-gal Drums	55-gal Drums	Miscellaneous				
51	11-8-72	Uranium Turnings and Shavings	143	--	--		10,803 lb	4,900,000	0.201	From machining operations
52	10-19-73	Uranium Turnings and Shavings	111	--	16		7,057 lb	3,201,000	0.198	From machining operations
53	12-12-74	Uranium Turnings and Shavings	86	--	2		7,151 lb	3,243,000	0.198	From machining operations

[a] Weight percent U-235 of all material shown as originating from routine C-340 operations was derived from the average assay of uranium metal produced during the approximate period the scrap was accumulated.

[b] Location shown with a P suffix denotes only partial use of the section indicated for the specified burial.

[c] Derived from application of shipper's analyses to Paducah net weight.

[d] Received into the plant on the basis of the current metals plant assay at the time of receipt (in accordance with letter of K. C. Brooks to R. G. Jordan on September 9, 1957).

[e] Based on an average net weight of sawdust plus oil obtained from a limited number of weighed drums.

[f] Calculated on basis of the net weight (sawdust plus oil) and an estimated average analysis of 80 percent uranium.

[g] Calculated on a basis of 98 percent uranium.

[h] Estimated.

[i] Derived from the average assay of uranium metal processed during the period the sawdust was accumulated.

[j] Derived from a net balance of receipts, shipments, and inventories.

[k] Uranium sawdust from C-340 buried on top of material from machine shop in Location B-1.

[l] Calculated on basis of the net weight and an estimated average analysis of 80 percent uranium.

Source: Union Carbide, undated.

In addition to the four 30-gal drums, approximately 36 plastic-lined, 55-gal drums were excavated. About 30 of these drums had good integrity and contained uranium-contaminated sludge; 5 drums were of poor integrity and the contents could not be analyzed; and 1 plastic-lined drum contained TCE-contaminated sludge. There had been no record of 55-gal drums buried in the area that was excavated.

Several groundwater monitoring wells exist in the vicinity of this unit (Figure 2-3). Historical (1983 through 1988) analytical data for the wells closest to WMU 2 (MW-48 through MW-51, MW-57, MW-58, and MW-67) indicate some TCE and Tc-99 contamination. Because TCE and Tc-99 have been detected, the C-749 Uranium Burial Ground was identified as a potential source of offsite groundwater contamination.

2.1.2 WMU 3: C-404 Low-Level Radioactive Waste Burial Ground

The C-404 Low-Level Radioactive Waste Burial Ground (LLRWBG) is located on the eastern side of the C-749 Uranium Burial Ground (WMU 2) in the west-central area of the plant, north of Virginia Avenue (Figure 2-1). The burial ground surface area is approximately 53,200 ft^2 (140 ft by 380 ft). The burial ground was active from 1951 to 1986 and was closed with a multi-layer cap under RCRA in 1987. The C-404 LLRWBG is a likely source of Tc-99 contamination.

The C-404 LLRWBG was originally constructed as an aboveground holding pond with a tamped earth floor and 6-ft high clay dike walls (Figure 2-4). From 1952 through 1957, the holding pond served as a neutralization/sedimentation treatment facility for uranium-contaminated wastewater generated at the C-400 Cleaning Building. C-400 effluents were pumped through an underground vitrified clay pipe (WMU 26) to the eastern end of the impoundment. Water was decanted from the basin, through a weir at the southwest corner of the pond, to Big Bayou Creek. When a treatment system was installed in the C-400 Cleaning Building in 1957, use of the holding pond as a treatment facility was terminated and free liquids were removed from the impoundment.

An estimated 3,200 Ci of Tc-99 were discharged to surface water at a controlled rate from the Reactor Tails Program, primarily through effluents from the C-400 Cleaning Building (MMES, 1986). The largest discharges occurred in 1954, 1955, and 1956 when 440 Ci per year were released. Because the C-404 facility was operating as a neutralization/sedimentation treatment facility for effluents from the C-400 facility during that period, most of the Tc-99 is assumed to have been released through the C-400 facility to the C-404 facility. Because Tc-99 is mobile in an aqueous environment, some fraction of the Tc-99 probably passed through the C-404 holding pond and discharged to Big Bayou Creek.

From 1957 through 1976, the impoundment was used for bulk disposal of solid waste contaminated with uranium. Uranium-contaminated magnesium-fluoride slag from the

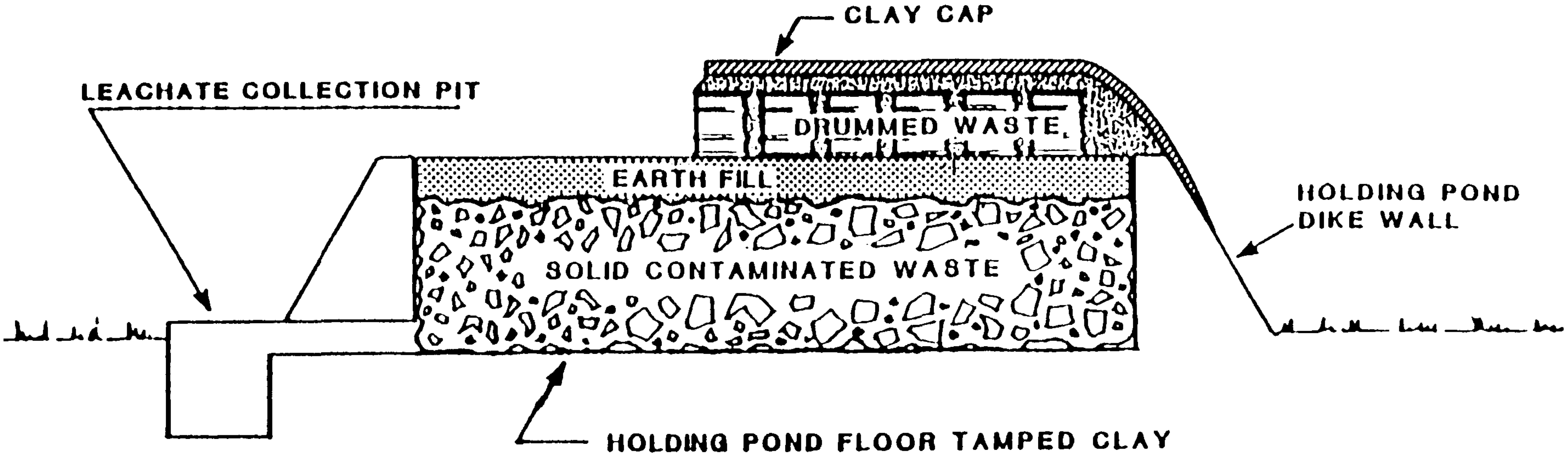


Figure 2-4
CLOSURE PLAN CROSS-SECTION OF WMU 3:
LOW-LEVEL RADIOACTIVE WASTE BURIAL GROUND
PADUCAH GASEOUS DIFFUSION PLANT
PADUCAH, KY.

Source: MMES, 1987

metal reduction plant and rejected UF_4 constituted much of the disposal volume. Magnesium fluoride traps contaminated with Tc-99 were also disposed of in the C-404 LLRWBG. The net weight of uranium committed to the area from 1957 through 1977 is approximately 3,200 tons. Until the C-404 facility was filled and covered, it collected rainwater, which was pumped and released at a controlled rate to the North-South Diversion Ditch. When the facility was filled with bulk solid waste to within 1 or 2 ft of the top of the original dikes, it was covered with compacted earth to the top of the original dikes and sloped to facilitate runoff. The exit weir was converted to an enclosed concrete basin for use as a leachate collection sump. Starting in 1977, the top of the filled-in pond area was used for burial of bulk and containerized uranium-contaminated solid waste. As wastes were placed on the upper portion of the facility, they were covered with earth. The upper tier of wastes reportedly included approximately 450 drums of Extraction Procedure (EP) toxic wastes (Cd, Se, Pb). In 1983, a partial clay cap was installed on the eastern end of the site; in 1987, the site was closed with a multilayer cap.

A groundwater monitoring plan was submitted to the Commonwealth of Kentucky with the Part B post-closure permit application for the facility. A release to groundwater was detected prior to approval of the post-closure permit application. DOE received a Notice of Violation on February 16, 1990, from the Commonwealth of Kentucky. This Notice of Violation required DOE to provide a description of the contaminant plume, a compliance monitoring plan, and a description of the actions that DOE will implement to address the release. A revised post-closure permit application was submitted to the Commonwealth of Kentucky in June 1992. It was approved on September 30, 1992, and became effective on October 30, 1992. The approved application amended the RCRA permit and contains groundwater monitoring provisions that require PGDP to initiate a detection monitoring program for the C-404 burial grounds. The information contained in the application was considered by the State as sufficient to resolve the existing notices of violation (NOV) for the unit.

Numerous monitoring wells have been installed in the vicinity of WMU 3 (Figure 2-3). Historical data (1983 through 1988) from the wells indicate total organic halogen and alpha and beta contamination in both up- and downgradient wells (reported concentrations are generally higher in the samples from the downgradient wells).

2.2 Site Investigation

2.2.1 Conceptual Site Model

The conceptual site model is a framework within which the environmental pathways of potential concern are identified and illustrated. The potential contaminants and potentially impacted media are also identified in the model. The model serves as the framework for summarizing the nature of contamination, summarizing the fate and transport of contaminants, characterizing risks, and conceptualizing general response actions.

The model includes a set of hypotheses about the contaminated media and environmental pathways that are selected on the basis of existing information. The source area is identified as the area of direct waste deposition. At WMUs 2 and 3, the source consists of low-level radioactive waste, primarily uranium and uranium-contaminated materials. At WMU3, a multi-layer cap has been constructed that consists of 2 ft of compacted clay with a permeability less than 1×10^{-7} cm/s, a 36-mil Hypalon flexible membrane lining, 1-ft of granular fill, geotextile, and 2 ft of vegetative cover. A contaminant release mechanism is defined as a process that results in migration of a contaminant from the source area into the immediate environment. Once in the environment, contaminants can be transferred between media and transported away from the WMUs.

Figure 2-5 illustrates the various media, transport pathways, and exposure pathways that could be affected by a release from the former burial grounds. This is a model of the current conditions and potential future exposure scenarios at the WMUs. In the conceptual site model, a distinction has been made between probable conditions and reasonable deviations from the probable conditions.

Organic chemical and radionuclide contamination of onsite subsurface soils is considered probable. The most probable contaminants include TCE, Tc-99, uranium, and phenols. Other contaminants are possible, primarily associated with degradation products or impurities in the waste buried at the WMUs (metals). These contaminants are considered to be reasonable deviations from the probable conditions.

In the conceptual site model, there are two probable release mechanisms for contaminants from subsurface soils: (1) Leaching—Contaminants, particularly TCE and Tc-99, can leach from the surface into the vadose zone soil or groundwater; and (2) Direct Contact—Contaminants can cause exposures through contact with waste material directly at the WMUs. Potential release mechanisms that are considered reasonable deviations to the probable conditions include volatilization and particulate suspension into the air, and erosion and surface runoff. Releases to air are considered less likely than releases to vadose zone soil, surface water, sediment, or groundwaters because the units are capped and grass covered.

Through infiltration or groundwater movement, the contaminants in the primary contaminated media could migrate. It is probable that contaminant migration would continue to contaminate more of the same media. Reasonable deviations to these probable migration pathways include air movement, runoff of contaminants from surface soils to surface water or sediment, infiltration of contaminants from the surface water or sediments to soil and groundwater, or groundwater discharge to surface water. Particle suspension and air movement of contaminants is considered unlikely due to the grass covers and caps over the units, and has been shown to be insignificant in air dispersion studies at the plant (CH2M HILL, 1992). Runoff of contaminated surface

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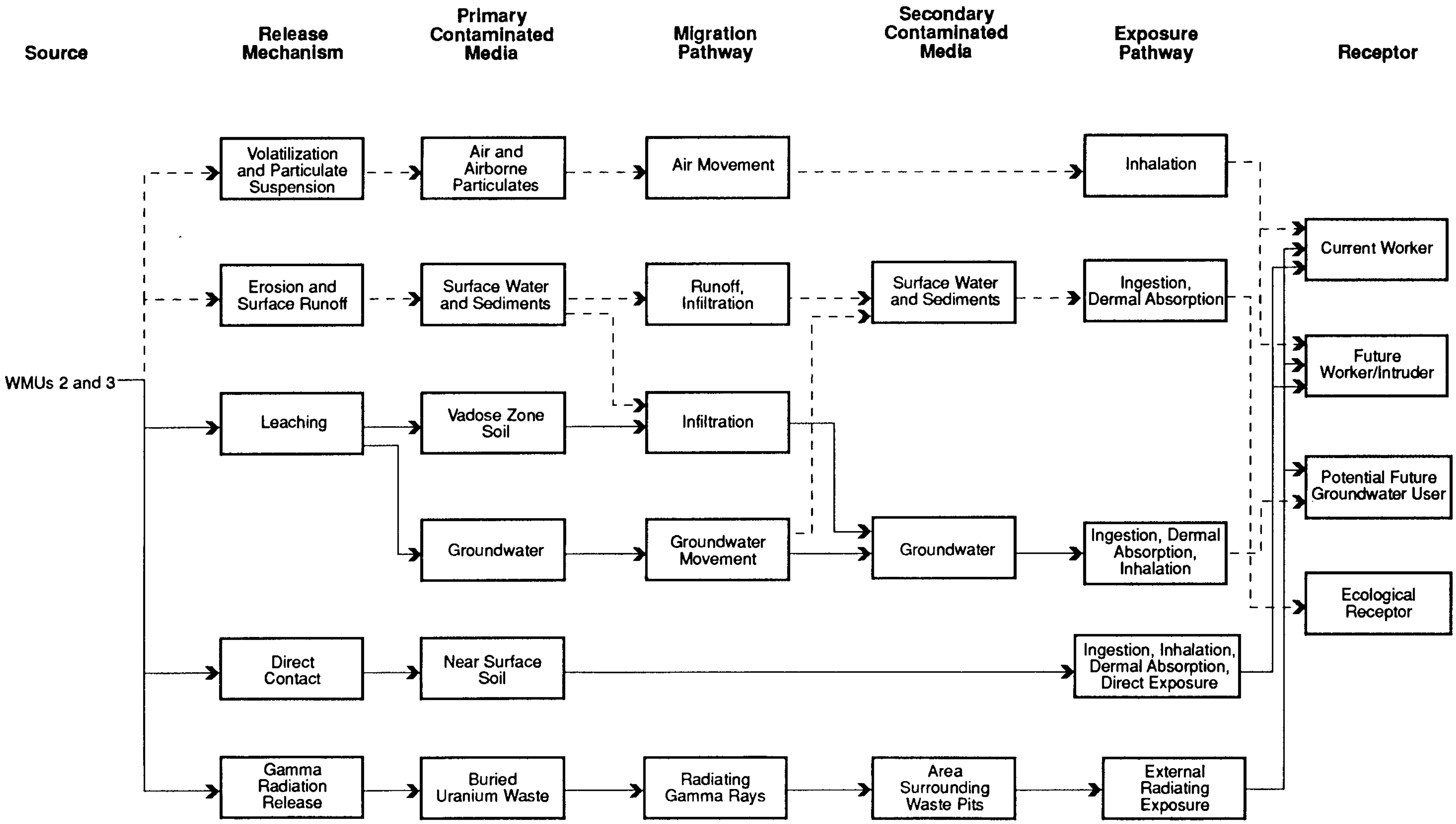


Probable contaminants: TCE, Uranium, Phenols, Tc-99
Potential contaminants: Heavy Metals

——— Probable pathway
- - - - Potential pathway

Figure 2-5
CONCEPTUAL SITE MODEL
WMUs 2 AND 3
PADUCAH GASEOUS DIFFUSION PLANT
PADUCAH, KY.

water or sediment is also unlikely due to the various caps and grass covers over the units. Discharge of contaminated groundwater to surface water is possible, but has not been shown to be significant downgradient of PGDP (CH2M HILL, 1992).

The potential current exposure to these probable and potential contaminated media is limited because the units are covered. Direct contact (ingestion, inhalation, dermal absorption, external gamma radiation) exposure to onsite soil may occur. Potential future exposure may be through ingestion of groundwater; inhalation of volatiles in groundwater as a result of domestic groundwater use; ingestion, dermal adsorption, and inhalation of contaminants in soil; by direct contact exposures through excavation into wastes; and by ingestion of surface water contaminated by surface erosion.

2.2.2 Sampling Rationale

2.2.2.1 Potential Remedial Action Technologies

Potential technologies for remediating contaminated soil and buried materials at WMUs 2 and 3 are discussed so that data to support the alternatives evaluation can be identified. The uncertainties concerning site conditions and technology performance are also discussed so that data collected during the Phase I and Phase II site investigations can be assessed.

Contaminated soils and contaminated buried material would need to be addressed in any remedial action to prevent further releases and direct exposure. Remediation of groundwater contamination is to be addressed separately by PGDP under a groundwater integrator operable unit on a plantwide basis. Remediation of downstream surface water or sediment contamination is also to be addressed separately by PGDP under a surface water integrator operable unit on a plantwide basis.

Potential response actions and technologies for remediating contamination at the uranium and low-level radioactive waste burial grounds were developed during the Phase II Alternatives Evaluation [Science Applications International Corporation (SAIC), 1992]. The following discussion is not intended as a substitute for the more detailed process of technology screening during the FS.

Identified containment technologies could include multilayer capping of WMU 2 (WMU 3 presently has a multilayer cap) and associated surface water runon/runoff controls, along with sediment control barriers for both WMUs 2 and 3. Capping technologies could isolate contaminated surface soils from human contact to mitigate direct exposure, and could reduce contaminant mobility by controlling potential erosion to surface water runoff and by reducing infiltration through contaminated soils and buried waste to groundwater by use of infiltration barrier technologies such as multilayer caps.

Capping would not be effective in containing contamination that has previously reached the saturated zone. Therefore, the caps would be used in conjunction with groundwater remediation technologies.

Excavation was not considered as an alternative for WMUs 2 and 3 because potential releases during excavation and handling of pyrophoric wastes could result in higher risks to human health and the environment than are currently associated with the low levels of contamination in the groundwater at this site. Additionally, excavation would destroy the existing cap/covers.

Surface-water and sediment monitoring could be implemented downgradient of WMUs 2 and 3 in the drainage ditch adjacent to the unit. Monthly KPDES permit monitoring of Outfall 015 could be continued as required under the current permit. Monitoring would be used to identify deviations as they occur, in addition to evaluating the effectiveness of the selected remedial action. Site surveys could detect subsidence of a cap, which may initiate a contingent action. Air or groundwater monitoring on a plantwide basis could detect changes over time or unforeseen releases that may initiate contingent collection systems. Monitoring of remediation alternatives will be addressed in the feasibility study.

Identified technologies for active institutional controls include maintenance of existing controls, such as site security and deed restrictions and maintaining cap integrity. Technologies for passive controls could include fences and markers, primarily to prevent human access to contamination. Current access and use restrictions include the fence around the perimeter of PGDP, radiological area posting around the units, and plant security. These measures would be maintained as part of normal plant operations.

2.2.2.2 Rationale for Field Investigation Activities

The uranium and low-level radioactive waste burial grounds were investigated during the Phase I and Phase II Site Investigation conducted in response to the Consent Order (CH2M HILL, 1991 and 1992).

Site investigation activities were conducted to assess potential releases from the two burial grounds via the probable groundwater migration pathway, because the units are both covered. The groundwater migration pathway was investigated by drilling of deep soil borings around the perimeter of the area, by installing monitoring wells within the UCRS and the upper RGA, and by sampling these and previously existing wells. In addition, double-ring infiltrometer tests were conducted to evaluate the rate of percolation of precipitation that generates leachate at WMU 2, and a water sample from the leachate sump next to WMU 3 was analyzed. The surface migration pathway, a reasonable deviation, was investigated by taking borings in the ditch south of the units to check for past releases and by analyzing rainfall percolation discharging from the underdrains above the cap at WMU 3.

Sampling locations are shown on Figure 2-3. Three deep soil borings (H008, H220, and H221) and two shallow soil borings (H261 and H262) were drilled near these units. Boring H008 was drilled during Phase I east of WMU 3 at the location of a former ramp that had been constructed of Tc-99-contaminated magnesium fluoride traps. Borings H220 and H221 were drilled during Phase II north of each unit to evaluate possible subsurface migration of TCE, Tc-99, and uranium within the Upper Continental Deposits. The shallow soil borings were made in the ditch south of the units to evaluate possible surface migration of uranium toward Outfall 015.

Adjacent monitoring wells include 33 wells installed previously by PGDP (MW-45 through -51, MW-57 through -58, MW-67, MW-72 through -76, and MW-78 through -95) that surround the area, and five new wells installed during Phase II (MW-154, -169, -170, -171, and -172). MW-154 was installed as a replacement well for MW-58, which was abandoned because near-surface contamination was migrating down the well casing. MW-170 through -172 are located within the UCRS approximately 600 ft north and east of the units, to evaluate the extent of possible lateral migration of TCE and Tc-99. MW-169 was also installed in the RGA north and east of the units in the apparent downgradient direction.

Other Phase II investigation activities included the collection of water samples from two cap underdrain discharge points and the leachate collection sump at WMU 3, as well as three infiltrometer tests (DRI 4-6) at WMU 2 (Figure 2-3). The cap discharge samples were taken to evaluate whether radiological elements are seeping out of the drains (above the multilayer cap), and the leachate sample was taken to identify the potential contaminants present within WMU 3. The infiltrometer tests will be used during the evaluation of alternatives to estimate the amount of precipitation that percolates through WMU 2 wastes.

2.3 Physical Characteristics of the WMUs 2 and 3 Site

2.3.1 Surface Water Hydrology

The Uranium Burial Ground (WMU 2) and LLRWBG (WMU 3) sites combined are approximately 5 acres in size. WMU 2 is slightly mounded, with surface elevations ranging between 370 and 377 ft msl. WMU 3 has greater relief above the surrounding grade, with surface elevations ranging between 372 and 392 ft msl (Figure 2-3). Ditches surrounding the WMUs on the north, south, and east are approximately 2 to 6 ft deep. These ditches discharge through KPDES Outfall 015 to Big Bayou Creek (see Figures 2-1 and 2-3).

The surface of the WMUs and the surrounding ditches are grass-covered, except for areas of gravel pads placed during previous investigations for drill rig access. Surface water runoff is radially to the perimeter ditches that drain west toward KPDES Outfall 015. Discharge through Outfall 015 include surface runoff from the west central plant area. Flow through the outfall is therefore erratic, in response to rainfall events.

2.3.2 Stratigraphy

Surficial deposits within the area surrounding WMUs 2 and 3 consist of 16 to 20 ft of lean clay. The surficial deposits are included in the Henry Silt Loam soil series and consist of silt loam and silty clay loam. These soils are poorly drained, with water standing at the surface during wet periods. A low-permeability layer (fragipan) is typically present at depths ranging from 1 to 4 ft below land surface (bls) and is 1 to 2 ft thick. Because the fragipan restricts vertical drainage, water typically perches on this layer during the winter and spring, causing a seasonally high zone of saturation near the surface. Excavation beneath the burial mounds has probably disturbed the fragipan layer, resulting in higher vertical flow potential of water and leachate.

Results from the double-ring infiltrometer tests conducted on surface soils at WMU 2 confirm that a 6-in. clay cap exists at this WMU. The unit was capped in 1982 with a 6 in. clay cap with a permeability of 1×10^{-7} cm/s and an 18-in. thick vegetative cover. Three surface locations (Figure 2-3) within WMU 2 were tested to evaluate the infiltration rates and assess the effectiveness of the cap. Incremental infiltration rates were calculated by dividing the difference in head drop over the elapsed time, assuming a constant head throughout the test. Average long-term infiltration rates measured in the inner ring of the testing device were 2×10^{-6}, 3×10^{-6}, and 5×10^{-6} cm/s, respectively, for the three test locations (DRI-4, DRI-5, and DRI-6) at WMU 2. Three surface soil samples were also collected one at each infiltrometer test locations at WMU 2. These samples were tested for geotechnical parameters for use in evaluating the existing cap. Test results are presented in Table 2-2.

The Upper Continental Deposits underlying these surface soils were encountered at an elevation of 351 to 358 ft, at a depth of approximately 13 to 20 ft. The unit ranges in thickness from 42 to 62 ft near WMUs 2 and 3. The typical soil type is sandy clay with interlayers of sand at various depths.

The Lower Continental Deposits are approximately 20 to 30 ft thick with the top elevation at 310 to 315 ft near WMUs 2 and 3. The lithology is predominantly well-rounded chert gravel with sand. Based on previous PGDP subsurface investigations, the gravel is underlain by the McNairy Formation at elevations of 270 to 280 ft.

The stratigraphy is shown on Figure 2-6 and summarized in the Lithologic Database presented in Appendix 3B of the Phase II Report (CH2M HILL, 1993). Detailed soil boring logs may be found in Appendices 2B-3 through 2B-6 and 2B-11 of the Phase I Report and Appendices 2B-9 and 2B-10 of the Phase II Report.

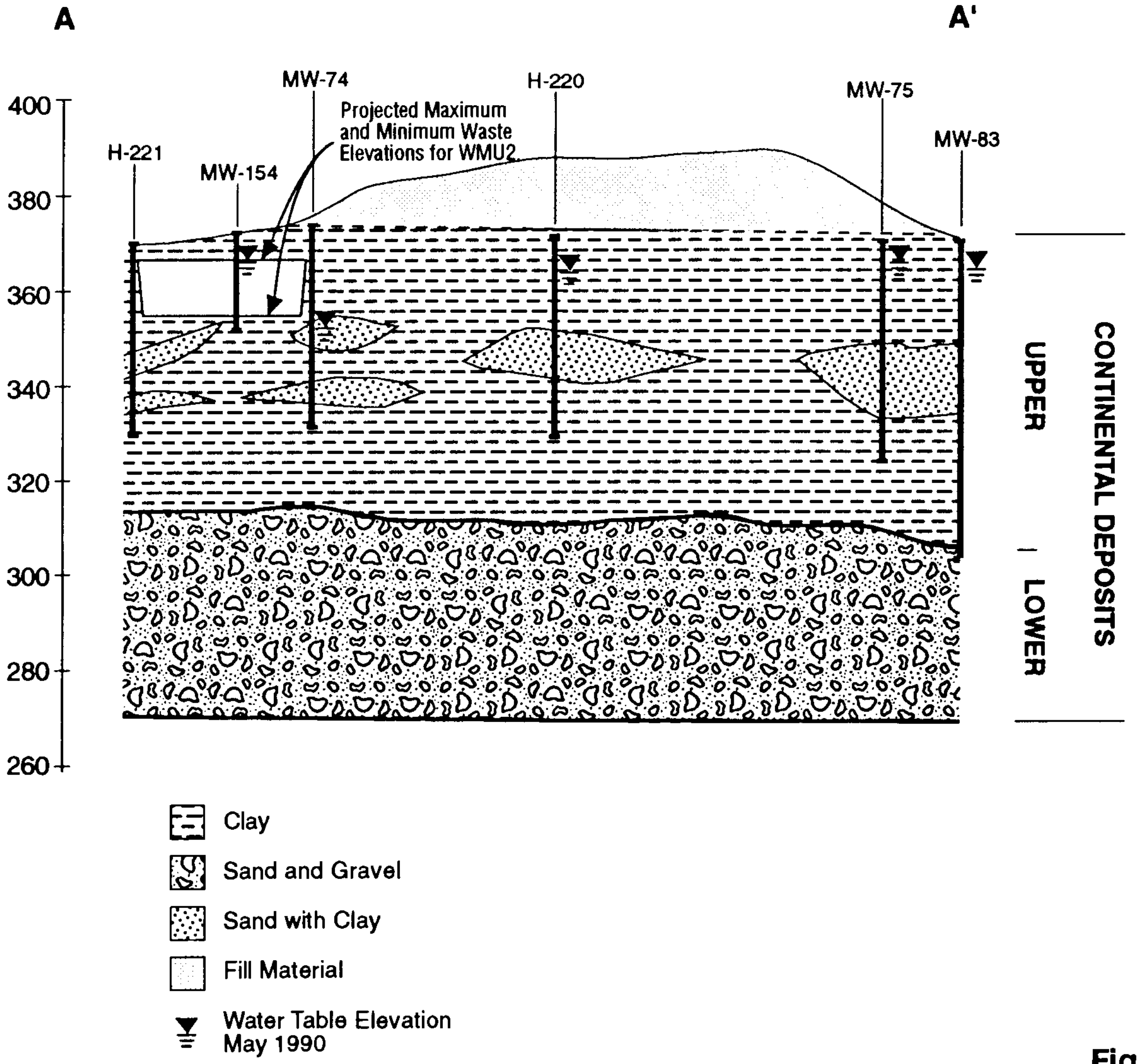
Table 2-2
Summary of Geotechnical Testing Data
WMUs 2 and 3

Boring No.	Sample Depth (ft)	Natural Moisture Content (%)	Atterberg Limits (%)			pH in Water	Grain Size Analysis		
			L.L.	P.L.	P.I.		Finer No. 200 (%)	Finer No. 40 (%)	Finer No. 4 (%)
DRI-4	0-0.5	19.6	35	19	16	4.2	93.1	95	100
DRI-5	0-0.5	26.5	46	17	29	4.4	91.6	97	100
DRI-6	0-0.5	24.7	36	19	17	5.4	92.4	95	100

Notes:

L.L. = Liquid Limit.
P.L. = Plastic Limit.
P.I. = Plastic Index (L.L.-P.L.).

Source: Law Engineering, July 24, 1991.



NOTE: Lower Continental Deposits profile estimated from MW-48, MW-95, and H-008.

Figure 2-6
STRATIGRAPHIC CROSS-SECTION OF WMUs 2 AND 3
PADUCAH GASEOUS DIFFUSION PLANT
PADUCAH, KY.

2.3.3 Hydrogeology

A total of 33 historical PGDP wells, 1 historical pumping well, and 8 abandoned wells (MW-46, -47, -48, -49, -50, -51, -57, and -58) are located in the area of WMUs 2 and 3 (Figure 2-3). Four wells, 3 UCRS wells (MW-170, -171, -172) and 1 RGA well (MW-169) were installed approximately 600 ft from the WMU during the Phase II investigation to assess contaminant migration from the burial grounds. RGA well MW-169 is in a downgradient location. Logs for wells MW-48 and M-74 are presented in Appendix D.

Hydrogeologic data from these Phase II wells include water level measurements and aquifer slug test results (MW-169 and MW-170). Hydrogeologic data from the historical wells include water level measurements (MWs-73, -74, -75, -77, -82, -83, -85, -88, -90, -91, -92, -93, -94, and -95); aquifer slug test results (MWs-46, -51, -79, -80, and -81); and aquifer pumping test results (MW-79) (MMES, 1992a[Apx. D]).

Water level data are available from October 1990 through September 1991 and are summarized in Technical Memorandum (TM) No. 1 in Appendix 3A of the Phase II Report. Water levels in the UCRS range from approximate elevation 355 to 365 ft at a depth of approximately 10 to 20 ft. Water levels in the RGA range from about elevation 326 to 332 ft at an average depth of 45 ft. Monthly groundwater elevations for six of the historical PGDP wells at WMUs 2 and 3 are shown on Figure 2-7. In this area, both the RGA and the UCRS respond to seasonal precipitation events with very little lag time. The head difference between the units is approximately 30 to 35 ft.

The UCRS is comprised of two hydrogeologic units (HU): HU2 consists of discontinuous sand and gravel and HU3 consists of a continuous clay. Together the two HUs govern the rate and direction of shallow groundwater movement and recharge to the RGA. The RGA behaves as a confined to semi-confined aquifer. The UCRS, primarily HU3, is the confining layer above the RGA.

Aquifer slug tests were completed in MWs-46, -51, -79, -80, -81, -169, and -170 near the WMUs. The values of hydraulic conductivity for the well (MW-170) completed in the UCRS averaged at 4.0×10^{-6} cm/s. This value, on the average, is a magnitude lower than other UCRS hydraulic conductivity values for PGDP and indicates that conditions around MW-170 are exceptional rather than typical. Based on the Phase II investigation report, a hydraulic conductivity of 3.6×10^{-5} cm/s would be more typical for the UCRS at PGDP. Slug test data results for wells in the RGA showed an average hydraulic conductivity value of 2.8×10^{-3} cm/s, which is typical for that groundwater system at PGDP. Aquifer pumping test data (Huntsman, 1990, and Phase II) results from the RGA showed an average hydraulic conductivity value of 3.4×10^{-2} cm/s. Based on the above mentioned data, the average hydraulic conductivity value for the RGA at WMUs 2 and 3 is approximately 1.0×10^{-2} cm/s.

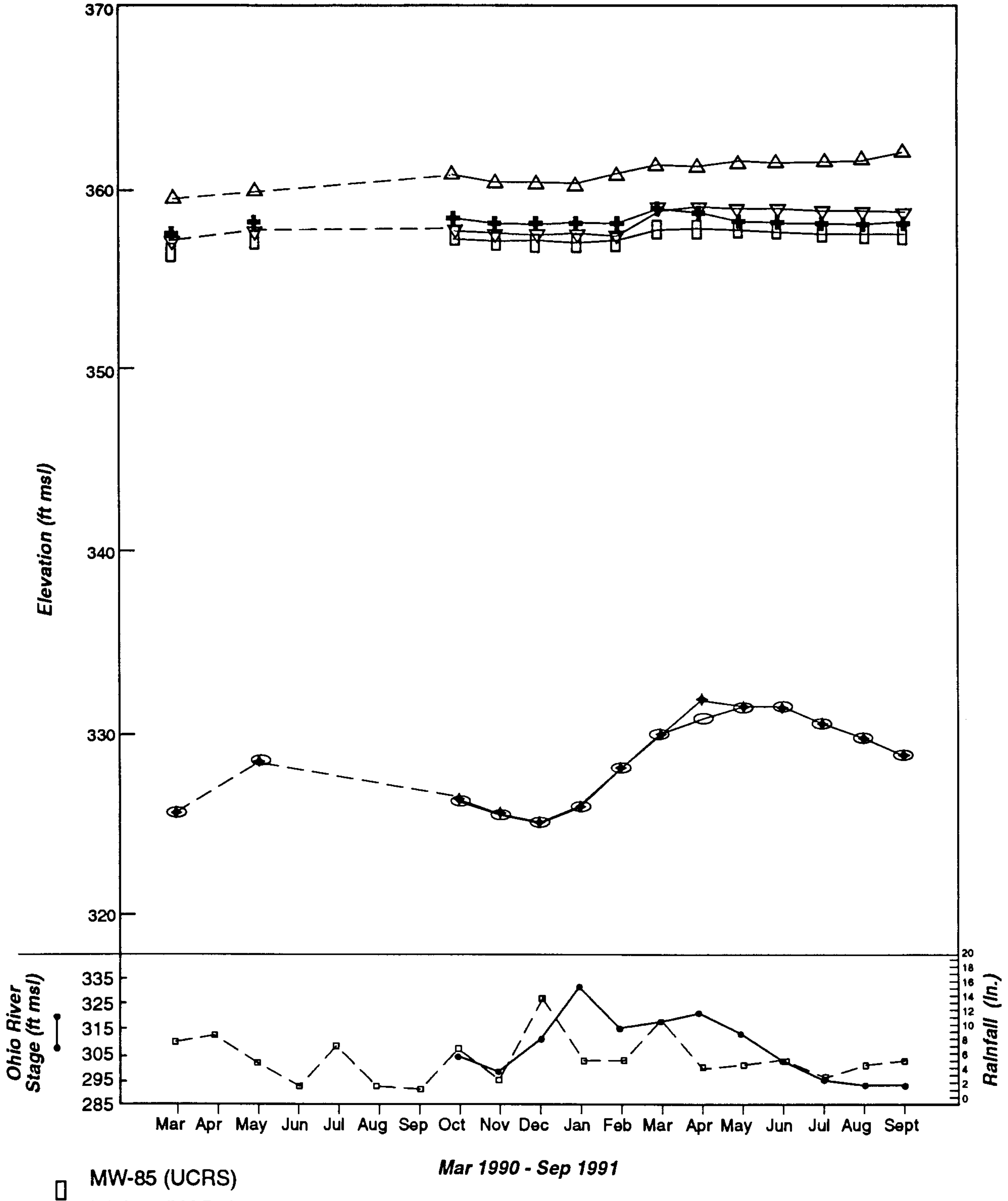


Figure 2-7

SEASONAL GROUNDWATER ELEVATIONS CENTRAL PLANT NEAR WMUs 2 AND 3

PADUCAH GASEOUS DIFFUSION PLANT

PADUCAH, KY.

Note: C404 Facility at approximate elevation 370 ft msl (EDGe, 1988)

The information on groundwater hydraulic head gradients (Phase II Report) and hydraulic conductivities was used to estimate velocities of groundwater flow in each hydrogeologic system. Specific hydraulic gradient maps and calculations for the RGA are contained in the "C-404 hazardous Waste Landfill Quarterly Inspection Report" (MMES, October 1993).

Within the UCRS, the horizontal gradient in the area of WMUs 2 and 3 is approximately 0.0002 ft/ft towards the south-southeast. The unit is separated into layers of interlayered sand and clay, with an unknown degree of interconnection between the sandy materials.

Assuming an effective porosity of 0.2 and permeability of 3.6×10^{-5} cm/s, the calculated flow velocity within the UCRS at WMUs 2 and 3 was estimated to be approximately 3.6×10^{-8} cm/s. Because the sand lenses are apparently not interconnected, flow within these sand units will not occur over large distances. Due to the variability in the types and interconnections of different soil lenses, the velocity of groundwater movement in the UCRS is expected to vary greatly. It is anticipated that the hydraulic gradient, and corresponding flow velocity, also vary over time.

The current conceptual model of the groundwater hydraulics within the UCRS shows groundwater flow primarily downward. This downward flow is via interconnected sand lenses within the UCRS and is driven by the vertical gradients which are much greater than the horizontal gradients. The effective lateral extent of horizontal gradients is difficult to define due to the lenticular nature of these sand deposits.

The horizontal gradient in the RGA is approximately 0.00027 ft/ft towards the north. Assuming an effective porosity of 0.2, the calculated flow velocity within the RGA at WMUs 2 and 3 was estimated to be approximately 3.8×10^{-5} cm/s. Due to the low hydraulic gradient, actual flow directions may be governed by other factors such as localized changes in material types and anisotropy (CH2M Hill, 1992). Because WMUs 2 and 3 are located over an ancestral river channel deposits that underlie the PGDP, flow may follow a preferred east-west orientation.

2.4 Nature and Extent of Contamination

This section discusses the chemicals detected in soil and groundwater, summarizes the development of a set of chemical data on which the quantitative calculation of risk is based, and assesses the extent of chemical contamination at WMUs 2 and 3.

2.4.1 Evaluation of Chemicals Detected

The data presented in the Phase II Report describe the results of analyses on samples from WMUs 2 and 3 and provide a basis for decisions about chemicals of concern and associated risks. Summary statistics for detected chemicals are presented in tables in this section and have been organized by medium. The tables include the detection frequency and range of chemical concentrations. The concentration ranges are based on detected values and do not include duplicate or rejected values.

Reference sample results are also included in the tables. "Reference samples" are those that are representative of naturally occurring conditions or conditions resulting from other, non-plant-related activities (such as fallout). Samples were analyzed for Target Analyte List (TAL) and Target Compound List (TCL) chemicals and selected radionuclides. Because of the small reference sample data set, the resulting metal and radionuclide reference levels are probably conservatively low and may not represent naturally higher levels. Reference values for total (unfiltered) metals and radionuclides are presented for groundwater.

Data gathered as part of the PGDP program have been analyzed by several laboratories. Some potentially anomalous data reported during the site investigations may include elevated concentrations in blanks, inconsistent field duplicate analyses, and varying results from multiple sampling events at the same location.

The data were evaluated using procedures described in U.S EPA risk assessment guidance (Section 5.1 through 5.9, RAGS, 1989) in order to develop a set of chemical data and information for use in the quantitative risk assessment. The data evaluation procedures involved review of validated data to eliminate data that:

- did not meet QC guidelines
- may represent laboratory contamination
- are considered essential nutrients
- were present at concentrations equal to or less than background (i.e. reference)
- are unlikely to contribute significantly to risks as determined by a concentration-toxicty screen.

Data evaluation results are described in the following subsections.

2.4.1.1 Use of Qualified and Coded Data

Both chemical and radiological data were evaluated by assessing the following data quality indicators: precision, accuracy, representativeness, completeness, and comparability (PARCC).

Chemical data included in this assessment were validated using the guidance documents *Laboratory Data Validation Functional Guidelines for Evaluating Organics Analysis* (EPA, 1988c) and *Laboratory Data Validation Functional Guidelines for Evaluation Inorganics Analysis* (EPA, 1988d). Radiological data were validated in accordance with similar procedures.

Many of the qualifiers for inorganic and organic chemical data, including the most common "J" qualifier, indicate uncertainty in the reported concentration of the chemical, but not in the assigned identity. These data were included in the evaluation. Data qualified with an "R" flag indicate uncertainty in the identity or presence of the chemical. Data that were rejected during validation (identified by an "R" qualifier) were not used in the evaluation.

Positive radiological results are included in the evaluation without regard to the error term associated with individual data points.

Both the dissolved and total metal concentrations were evaluated for the groundwater pathway. For risk calculations, the total concentrations were used to estimate the risk from ingestion of water from a given well system.

2.4.1.2 Tentatively Identified Compounds

Compounds that are not on the TCL may be detected during analysis of organic constituents by gas chromatography/mass spectrometry (GC/MS). The mass spectra of a particular unknown constituent may be compared with a library of known spectra resulting in "tentative identification." Tentatively identified compounds (TICs) are reported for each medium in Appendix D of Volume 6 of the Phase II Report (CH2M HILL, 1992). These TICs are not specifically addressed in this assessment for the following reasons:

- Considerable uncertainty exists for both identification and concentration of these constituents.
- These have not been identified as constituents used by the plant.
- TICs are generally present in samples that have elevated concentrations of chemicals of concern, which are included in this evaluation. Risks at these locations are dominated by the chemicals of concern, which are identified as confirmed constituents.

2.4.1.3 Analysis of Blanks

The following approach to evaluating and refining environmental data was developed from the *Guidance for Data Useability in Risk Assessment* (EPA, 1992a) and *Risk Assessment Guidance for Superfund, Volume I—Section 5.5* (EPA, 1989. The approach involves a comparison of detections in blanks to detections in environmental samples, using the maximum value reported in both sets of samples. Positive detections in environmental samples were considered false positives and eliminated from the set of sample results if the maximum environmental sample value was less than 5 times the maximum blank value for chemicals that are not common laboratory contaminants, or less than 10 times the maximum blank value for common laboratory contaminants (EPA, 1989). Data for blank samples and a detailed evaluation of blank results are included in the Phase II Site Investigation Report.

Using this approach, several constituents were eliminated from further evaluation. These include: methylene chloride, acetone, 2-butanone, N-nitrosodiphenylamine, and carbon disulfide (see Table 2-3).

2.4.1.4 Essential Human Nutrients

Also excluded from this evaluation are calcium, iron, magnesium, potassium, and sodium, which are essential human nutrients, are naturally occurring, and may be toxic only at very high doses. However, these parameters may be considered when the ions are indicators of plant activities, have concentrations noticeably higher than elsewhere on the site, or assist in developing conclusions about the nature and extent or fate and transport of hazardous constituents. At WMUs 2 and 3, these constituents were not detected at concentrations of concern for toxic effects.

2.4.1.5 Potential Chemicals of Concern

To further focus the list of chemicals of concern at WMUs 2 and 3, chemicals and radionuclides were eliminated from consideration if they met one or more of the following criteria:

- The chemical contributed less than 1 percent of the estimated total cancer risk or noncancer hazard as a result of ingestion of either soil or groundwater at the WMUs, and the risk estimated for an individual chemical in either medium did not exceed 1×10^{-6} (cancer) or hazard quotient (HQ) of 0.1 (noncancer). This concentration-toxicity approach to refining the set of chemicals of concern is consistent with EPA (RAGS, 1989) guidance for conducting a concentration-toxicity screen.
- The onsite chemical concentration was less than or equal to the background concentration (that is, maximum onsite concentration is less than two times the average background concentration).

The chemicals that were eliminated based on meeting one of the above criteria are presented in Table 2-4.

Table 2-3
Contaminants Found in Soils or Unfiltered Groundwater at WMUs 2 and 3 That Were Eliminated as Chemicals of Concern on the Basis of Classification as an Essential Human Nutrient or Laboratory Contaminant

Analyte	Groundwater					Soils				
	Reference		WMUs 2 and 3			Reference		WMUs 2 and 3		
	Detected Maximum (μg/L)	Frequency (Det./Tot.)	Detected Minimum (μg/L)	Detected Maximum (μg/L)	Frequency (Det./Tot.)	Detected Maximum (μg/kg)	Frequency (Det./Tot.)	Detected Minimum (μg/kg)	Detected Maximum (μg/kg)	Frequency (Det./Tot.)
Essential Human Nutrients										
Calcium	38,700	6/6	8,230	97,300	32/32	2,370,000	5/5	147,000	2,360,000	43/43
Iron	16,400	6/6	87.8	449,000	31/32	22,400,000	5/5	4,960,000	52,100,000	43/43
Magnesium	15,200	6/6	3,530	40,800	32/32	2,460,000	5/5	54,000	3,000,000	43/43
Potassium	8,510	4/6	331	9,340	21/32	889,000	5/5	52,800	1,360,000	38/43
Sodium	97,600	6/6	6,370	275,000	32/32	82,800	5/5	37,200	521,000	18/43
Laboratory Contaminants										
2-Butanone	ND	0/7	7	7	1/36	NA		6	9	2/31
Acetone	ND	0/7	7	7	1/62	NA		26	51	17/43
Carbon Disulfide	6	1/7	3	8	3/62	NA		1	1	6/43
Methylene Chloride	22	2/7	ND	ND	0/62	NA		34	210	20/43
N-Nitrosodiphenylamine	2	2/7	ND	ND	0/4	NA		47	63	3/42

Notes:

NA = Not Analyzed.
ND = Not Detected.
Duplicate sample values not included.

Table 2-4
Potential Contaminants Found in Soils and Unfiltered Groundwater at WMUs 2 and 3 That Were Eliminated as Chemicals of Concern Based on Concentration-Toxicity Screening[A]

	Groundwater					Soils				
	Reference		WMUs 2 and 3			Reference		WMUs 2 and 3		
Analyte	Detected Maximum (μg/L)	Frequency (Det./Tot.)	Detected Minimum (μg/L)	Detected Maximum (μg/L)	Frequency (Det./Tot.)	Detected Maximum (μg/kg)	Frequency (Det./Tot.)	Detected Minimum (μg/kg)	Detected Maximum (μg/kg)	Frequency (Det./Tot.)
VOCs										
Bromoform	ND	0/7	1	1	1/62	NA		ND	ND	0/43
Chloromethane	ND	0/7	180	180	1/62	NA		ND	ND	0/43
Dichloro-defluoromethane	ND	0/7	2	2	3/12	NA		ND	ND	0/43
Toluene	ND	0/7	2	3	2/62	NA		ND	ND	0/43
SVOCs										
Bis(2-Ethylhexyl)-Phthalate	3	2/7	2	25	7/48	NA		38	440	20/42
Di-N-Butyl Phthalate	ND	0/7	1	1	1/48	NA		87	450	8/42
Di_N-Octyl Phthalate	ND	0/7	3	3	2/48	NA		ND	ND	0/42
Diethyl Phthalate	ND	0/7	5	6	2/48	NA		ND	ND	0/42
1,2,4-Trichlorobenzene	ND	0/7	34	34	1/48	NA		ND	ND	0/42
1,4-Dichlorobenzene	ND	0/7	33	33	1/48	NA		ND	ND	0/42
Acenapthene	ND	0/7	38	38	1/48	NA		62	62	1/42
Benzoic Acid	ND	0/7	4	4	1/46	NA		260	260	1/42
Di-N-Butyl Phthalate	ND	0/7	3	3	3/48	NA	—	ND	ND	0/42
Phenol	ND	0/7	23	23	1/45	NA		77	77	1/42
Pyrene	ND	0/7	43	43	1/48	NA		ND	ND	0/42

Table 2-4
Potential Contaminants Found in Soils and Unfiltered Groundwater at WMUs 2 and 3 That Were Eliminated as Chemicals of Concern Based on Concentration-Toxicity Screening[A]

Page 2 of 2

Analyte	Groundwater					Soils				
	Reference		WMUs 2 and 3			Reference		WMUs 2 and 3		
	Detected Maximum (μg/L)	Frequency (Det./Tot.)	Detected Minimum (μg/L)	Detected Maximum (μg/L)	Frequency (Det./Tot.)	Detected Maximum (μg/kg)	Frequency (Det./Tot.)	Detected Minimum (μg/kg)	Detected Maximum (μg/kg)	Frequency (Det./Tot.)
Pesticides/PCBs										
Aroclor-1248	ND	0/7	ND	ND	0/18	ND	0/5	100	210	2/36
Aroclor-1260	ND	0/7	ND	ND	0/18	ND	0/5	39	130	2/36
Inorganics										
Cyanide	ND	0/6	3.0	13.2	3/38	ND	0/5	850	900	40/43
Mercury	ND	0/6	0.22	0.22	1/44	ND	0/5	150	150	1/43
Selenium	2.8	3/6	0.4	9.5	9/43	450	3/5	280	480	5/42
Zinc	116	1/6	3.6	604	32/44	54,400	5/5	2,800	76,100	43/43

Notes:

Reason for elimination as chemical of concern (COC):
A. Contributed less than 1 percent of total cancer risk or noncancer hazard as determined by concentration-toxicity screening.

MDA = Minimum Detectable Activity.
NA = Not Analyzed.
ND = Not Detected.
Duplicate sample values not included.
Value in brackets indicates that error was greater than one-half the value.

2.4.1.6 Chemicals of Concern for Use in the Risk Assessment

The remaining chemicals are identified as the chemicals of concern for use in the quantitative risk assessment and are summarized by medium in Table 2-5.

Some chemicals associated with blank contamination were not eliminated as chemicals of concern because there is evidence or reason to believe that the chemical may be present. An important chemical in this regard is TCE which was reported in approximately 5 percent of the field blank samples at concentrations near the detection limit. This level of TCE detection in blanks indicates that TCE at low concentrations in onsite samples should be interpreted with caution.

The accuracy of the reported values for octachloro-dibenzo-p-dioxin (OCDD) in soil is also questionable. OCDD is frequently encountered at low levels in laboratories because it is difficult to remove from glassware. However, it is also commonly reported along with other high molecular weight organic constituents. Because OCDD may be associated with PCB site contaminants, it is retained as a chemical of concern.

2.4.2 Interpretation of Contamination Pathways at WMUs 2 and 3

TCE has been detected within the UCRS at levels up to 270 μg/L. Tc-99 (up to 2,175 pCi/L) is present in the UCRS adjacent to the unit and, to a limited extent, in the RGA at lower concentrations. Uranium was found in MW-58 (now abandoned) and in its replacement well (MW-154) within the UCRS at levels up to 27 pCi/L (U-238 at MW-154). Tc-99 (up to 58 pCi/g) and total uranium (up to 89 pCi/g) have been detected in surface soils and in the ditch southwest of the units to a depth of approximately 6 ft.

Site investigation activities were conducted to assess potential releases from the two burial grounds primarily via the groundwater migration pathway, because the units are both covered. The groundwater migration pathway was investigated by drilling of deep soil borings, by installing monitoring wells, and by sampling these and previously existing wells. In addition, double-ring infiltrometer tests were conducted to evaluate the rate of percolation of precipitation that generates leachate at WMU 2, and a water sample from the leachate sump next to WMU 3 was analyzed. The surface migration pathway was investigated by taking borings in the ditch south of the units to check for past releases, by taking borings one each north and east of the units to evaluate possible surface migration, by taking shallow borings and conducting a surface radiation walkover survey in the ditch south of the units, and by analyzing rainfall percolation discharging from the underdrains above the cap at WMU 3.

The analytical results from the shallow and deep soil samples are shown in Figures 2-8 and 2-9, respectively.

Table 2-5
Potential Chemicals of Concern Found in Soils and Unfiltered Groundwater at WMUs 2 and 3

Page 1 of 3

Analyte	Groundwater					Soils				
	Reference		WMUs 2 and 3			Reference		WMUs 2 and 3		
	Detected Maximum (μg/L)	Frequency (Det./Tot.)	Detected Minimum (μg/L)	Detected Maximum (μg/L)	Frequency (Det./Tot.)	Detected Maximum (μg/kg)	Frequency (Det./Tot.)	Detected Minimum (μg/kg)	Detected Maximum (μg/kg)	Frequency (Det./Tot.)
VOCs										
1,2-DCE (total)	ND	0/7	1	2	3/62	NA		ND	ND	0/43
TCE	0.2	2/7	1	270	19/61	NA		0.8	0.8	1/43
SVOCs										
1,2-Dichlorobenzene	ND	0/7	ND	ND	0/48	NA		40	42	2/42
2-Chlorophenol	ND	0/7	73	73	1/45	NA		92	92	1/42
2-Nitroaniline	ND	0/7	65	65	1/48	NA		ND	ND	0/42
2,4-Dinitrotoluene	ND	0/7	28	28	1/48	NA		ND	ND	0/42
4-Chloro-3-Methylphenol	ND	0/7	67	67	1/45	NA		65	100	2/42
N-Nitroso-di-N-propylamine	ND	0/7	35	35	1/48	NA		ND	ND	0/42
Pentachlorophenol (PCP)	ND	0/7	67	67	1/45	NA		100	200	2/42
Pesticides/PCBs										
Total Octachlorodibenzo-p-Dioxin	NA		ND	ND	0/15	NA		1.3	3.3	2/2
Total Tetrachlorodibenzo-p-Dioxin	NA		ND	ND	0/18	NA		0.1	0.1	1/2
Inorganics										
Aluminum	8,880	6/6	57.8	137,000	28/32	15,700,000	5/5	964,000	13,500,000	43/43
Antimony	ND	0/6	ND	ND	0/32	390	1/5	5,100	20,900	3/34
Arsenic	ND	0/6	1.0	11.2	16/42	11,800	5/5	460	18,700	40/43
Barium	210	6/6	23.3	1,200	44/44	157,000	5/5	7,800	308,000	43/43

Table 2-5
Potential Chemicals of Concern Found in Soils and Unfiltered Groundwater at WMUs 2 and 3

Analyte	Groundwater					Soils				
	Reference		WMUs 2 and 3			Reference		WMUs 2 and 3		
	Detected Maximum (μg/L)	Frequency (Det./Tot.)	Detected Minimum (μg/L)	Detected Maximum (μg/L)	Frequency (Det./Tot.)	Detected Maximum (μg/kg)	Frequency (Det./Tot.)	Detected Minimum (μg/kg)	Detected Maximum (μg/kg)	Frequency (Det./Tot.)
Beryllium	ND	0/6	0.65	20.8	7/38	17,300	5/5	210	1,200	36/43
Cadmium	ND	0/6	4.0	5.1	2/38	2,400	5/5	350	5,600	21/43
Chromium	31.3	2/6	3.2	279	32/44	17,200	5/5	1,600	58,800	41/43
Cobalt	8.2	3/6	4	191	14/44	14,100	5/5	1,700	32,300	39/43
Copper	11.7	4/6	4.6	207	26/44	15,800	5/5	2,300	31,900	40/43
Lead	4.1	3/6	1.5	113	27/44	30,900	5/5	1,200	36,100	43/43
Manganese	335	6/6	4.9	3,920	32/32	2,700,000	5/5	20,600	1,510,000	43/43
Nickel	10.4	1/6	5.9	239	21/44	21,000	5/5	1,400	29,000	42/43
Silver	ND	0/6	10.4	46.9	5/38	1,900	2/5	850	7,600	17/43
Thallium	ND	0/6	0.8	0.9	2/44	440	2/5	170	210	2/43
Vanadium	4.7	4/6	1.3	805	24/44	37,300	5/5	2,300	43,300	43/43

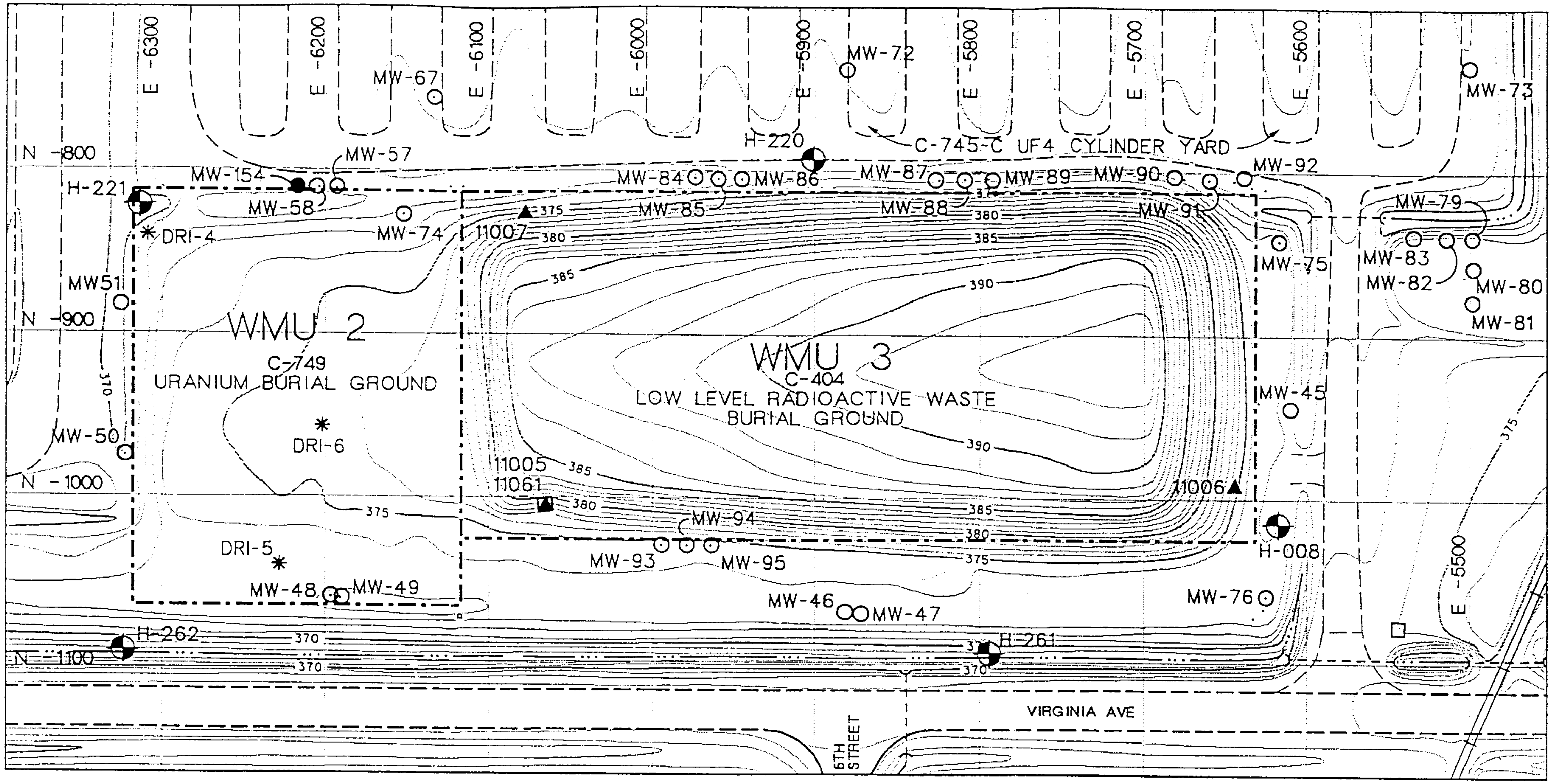
Table 2-5
Potential Chemicals of Concern Found in Soils and Unfiltered Groundwater at WMUs 2 and 3

Page 3 of 3

Analyte	Groundwater					Soils				
	Reference		WMUs 2 and 3			Reference		WMUs 2 and 3		
	Detected Maximum ($\mu g/L$)	Frequency (Det./Tot.)	Detected Minimum ($\mu g/L$)	Detected Maximum ($\mu g/L$)	Frequency (Det./Tot.)	Detected Maximum ($\mu g/kg$)	Frequency (Det./Tot.)	Detected Minimum ($\mu g/kg$)	Detected Maximum ($\mu g/kg$)	Frequency (Det./Tot.)
Radionuclides	pCi/L	pCi/L	pCi/L	pCi/L	pCi/L	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g
Np-237 (pCi/L or pCi/g)	ND	0/5	ND	ND	0/39	MDA	7/33	0.041	0.32	2/7
Pu-239 (pCi/L or pCi/g)	ND	0/5	0.18	0.90	3/35	MDA	1/33	0.014	7.9	2/4
Tc-99 (pCi/L or pCi/g)	ND	0/5	2.9	2,175	29/47	MDA	25/33	0.9	58	3/7
Th-230 (pCi/L or pCi/g)	1.3J	2/5	0.22	11.6	5/39	1.85J	7/33	0.34	14	7/7
U-234 (pCi/L or pCi/g)	0.31	2/5	0.14	10	24/39	1.24	20/33	0.21	18	6/6
U-235 (pCi/L or pCi/g)	ND	0/5	0.063	1.0	3/29	MDA	0/33	0.006	1.7	6/6
U-238 (pCi/L or pCi/g)	0.87	2/5	0.15	27	23/39	1.22	18/33	0.24	69	6/6

Notes:

MDA = Minimum Detectable Activity.
NA = Not Analyzed.
ND = Not Detected.
Duplicate sample values not included.
Value in brackets indicates that error was greater than one-half the value.



GROUNDWATER ANALYSES				
PARAMETER	UCRS MAXIMUM		RGA MAXIMUM	
	Total	Dissolved	Total	Dissolved
TCE	270		110	
1,2 DCE	1		2	
NDNA			35	
PCP			67	
Total:				
ARSENIC	11.2J	8.7	10.9	4.8
BARIUM	1200	217	305	210
BERYLLIUM	20.8		2.3J	0.5
CHROMIUM	279	33.3	51.6J	18.7
COBALT	191	14.2	20.3	16.5
COPPER	207		47.4	
LEAD	113J	17.8J	78.9	36J
NICKLE	239	35.3	62	52.6
SILVER	46.9		10.4	
VANADIUM	805	68.3	41.7	22.2
Tc-99	2175	1200	778	390
Th-230	11.6J	[1]	[0.68]	
U-234	10J	11J	[1.6]	[0.22]
U-235	1	[0.04]	[0.02]	[0.22]
U-238	27	31J	2J	1.7J
Pu-239	[0.9]	[0.12]J	[.28]	[.28]

NDNA - N-Nitrosodi-N-Propylamine
PCP - Pentachlorophenol

NOTES:
WELLS MW-49, 74, 85, 88, 91, 94, 154, 170, 171, 172, IN SGS
WELLS MW-48, 50, 67, 84, 86, 87, 89, 90, 92, 93, 95, 169 IN RGA

SOIL ANALYSES			
STATION NUMBER	DEPTH (ft)	RESULTS	
H008	0-8		0.9
H220	0-5	CHROMIUM COPPER	19,000J 28,400J
H221	0-5	DIOXINS/FURANS SILVER Tc-99 U-234 U-235 U-238	3.3 6,300 6J 7.6J 0.65J 61J
H261	0-1	ZINC	76,100J
	2-4	CHROMIUM Tc-99	17,600J [0.88]J
	4-6	—	

SOIL ANALYSES (con't)			
STATION NUMBER	DEPTH (ft)	RESULTS	
H262	0-1	PCP ARSENIC COPPER SILVER ZINC Tc-99 Th-230 U-234 U-235 U-238 Np-237 Pu-239	100J 15,200J 27,100 3,300J 60,100J 58 14 18 1.7 69 0.32 7.9
	2-4	U-234 U-238	2 3.9
	4-6	U-234 U-238 Pu-239	2.2 4.6 0.17

NOTES:

ONLY SELECTED SOILS RESULTS (0-6 FEET) ARE SHOWN. MONITORING WELLS MW-169, MW-170, MW-171, AND MW-172 ARE LOCATED APPROXIMATELY 600 FEET NORTH OF THE WMU'S.

SOIL CHEMICAL DATA REPORTED IN µg/kg.
RADIOLOGICAL DATA REPORTED IN pCi/L.

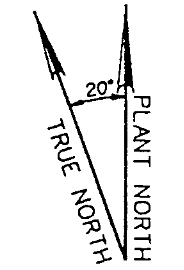
ONLY VALUES FOR DETECTED ANALYTES OF INTEREST ARE PRESENTED. SEE VOLUME 4 OF PHASE II REPORT FOR COMPLETE DATA SET.

[ ] INDICATE THAT ERROR WAS GREATER THAN ONE-HALF THE VALUE.
J INDICATES ESTIMATED VALUE.

DETAILED GROUNDWATER SAMPLING RESULTS ARE LISTED AS FOLLOWS:
TABLE 2-8: MAXIMUM DETECTED CONCENTRATIONS (µg/L) FOR VOCS, AND SVOCS
TABLE 2-9: MAXIMUM CONCENTRATIONS OF INORGANICS (µg/L)
TABLE 2-10: MAXIMUM DETECTED ACTIVITY LEVELS (pCi/L) OF RADIONUCLIDES

LEGEND

●	MONITORING WELL
○	EXISTING PGDP MONITORING WELL
⊕	SOIL BORING
▲	WATER SAMPLE
✱	DOUBLE-RING INFILTROMETER TEST
—·—··	WMU BOUNDARY



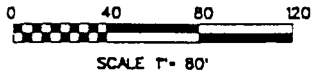


Figure 2-8
SAMPLING RESULTS AT WMU 2: C-749 URANIUM BURIAL GROUND AND WMU 3: C-404 LOW-LEVEL RADIOACTIVE WASTE BURIAL GROUND
PADUCAH GASEOUS DIFFUSION PLANT
PADUCAH, KY.

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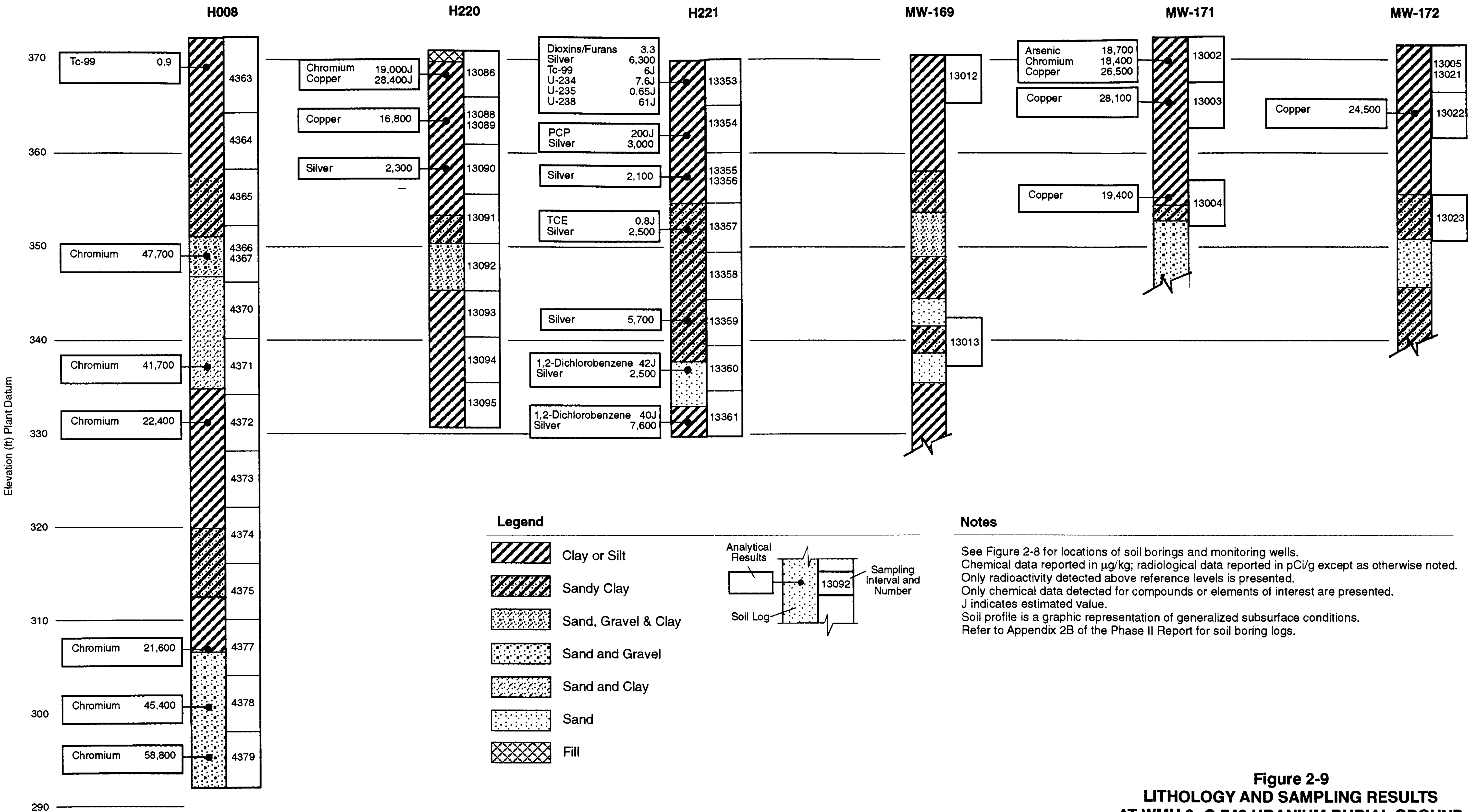

Notes

See Figure 2-8 for locations of soil borings and monitoring wells.
Chemical data reported in µg/kg; radiological data reported in pCi/g except as otherwise noted.
Only radioactivity detected above reference levels is presented.
Only chemical data detected for compounds or elements of interest are presented.
J indicates estimated value.
Soil profile is a graphic representation of generalized subsurface conditions.
Refer to Appendix 2B of the Phase II Report for soil boring logs.

Figure 2-9
LITHOLOGY AND SAMPLING RESULTS AT WMU 2: C-749 URANIUM BURIAL GROUND AND WMU 3: C-404 LOW-LEVEL RADIOACTIVE WASTE BURIAL GROUND

PADUCAH GASEOUS DIFFUSION PLANT
PADUCAH, KY.

2.4.2.1 Interpretation of Surface Migration Pathway

The C-749 Uranium Burial Ground (WMU 2) is considered a possible source of offsite contamination in surface water or sediment. Radionuclides, particularly uranium, were detected in the ditch leading to Outfall 015; however, the unit itself is covered with a low-permeability cap. The observed contamination may be a result of historical discharges. The C-404 Low-Level Radioactive Waste Burial Ground (WMU 3) is not considered a source of surface contamination.

2.4.2.1.1Surface Organic Contamination. Semivolatile organic compounds (SVOCs) were detected in the water sample from the cap underdrain in the northwest area of WMU 3. Polycyclic aromatic hydrocarbons (PAHs) were detected at less than 6J μg/L, and total phenols at less than 6J μg/L. These concentrations are well below MCLs or health advisory levels for these compounds. The water quality within the cap underdrainage appears unrelated to other surface or subsurface contamination at these units.

2.4.2.1.2 Surface Metal Contamination. Copper and zinc were detected in the near-surface soil samples from H220 and H262 slightly above reference levels (Figures 2-8 and 2-9). Chromium was detected in the near surface soil samples from H220 and H261 slightly above reference levels. Silver was detected above reference in surface soils at H221 and H262. Arsenic (15,200J μg/kg) and mercury (150 μg/kg) were also detected in the surface sample from H262.

2.4.2.1.3 Surface Radiological Contamination. A surface radiological walkover survey was conducted within the ditch south of WMUs 2 and 3 and for WMU 2 to identify surface radiological contamination. Cone-shielded gamma readings and Geiger-Mueller (GM) (shielded/unshielded) measurements were obtained along the length of the ditch beginning at the east end of C-404 (WMU 3) and extending to the west perimeter fence, as shown in Figure 2-10. The walkover survey for WMU 2 is included in Appendix D.

Surface radiological contamination was defined as readings or measurements greater than a three times background value. This criterion for determining surface radiological contamination accounts for natural background variation. "Localized" surface radiological contamination is usually associated with a "significantly elevated" reading or measurement. In order to identify localized surface radiological contamination, a significantly elevated reading was defined as a ten times background value, for both gamma (SPA-3) readings and GM measurements.

In the ditch south of WMUs 2 and 3 cone-shielded gamma (SPA-3) measurements were taken at 25-ft intervals. Locations of elevated gamma readings are given in Table 2-6. Localized areas of contamination were observed along the ditch banks, but the center (bottom) of the ditch exhibited readings that were consistently elevated. The GM measurements were obtained at 50-ft intervals, alternating between the banks and

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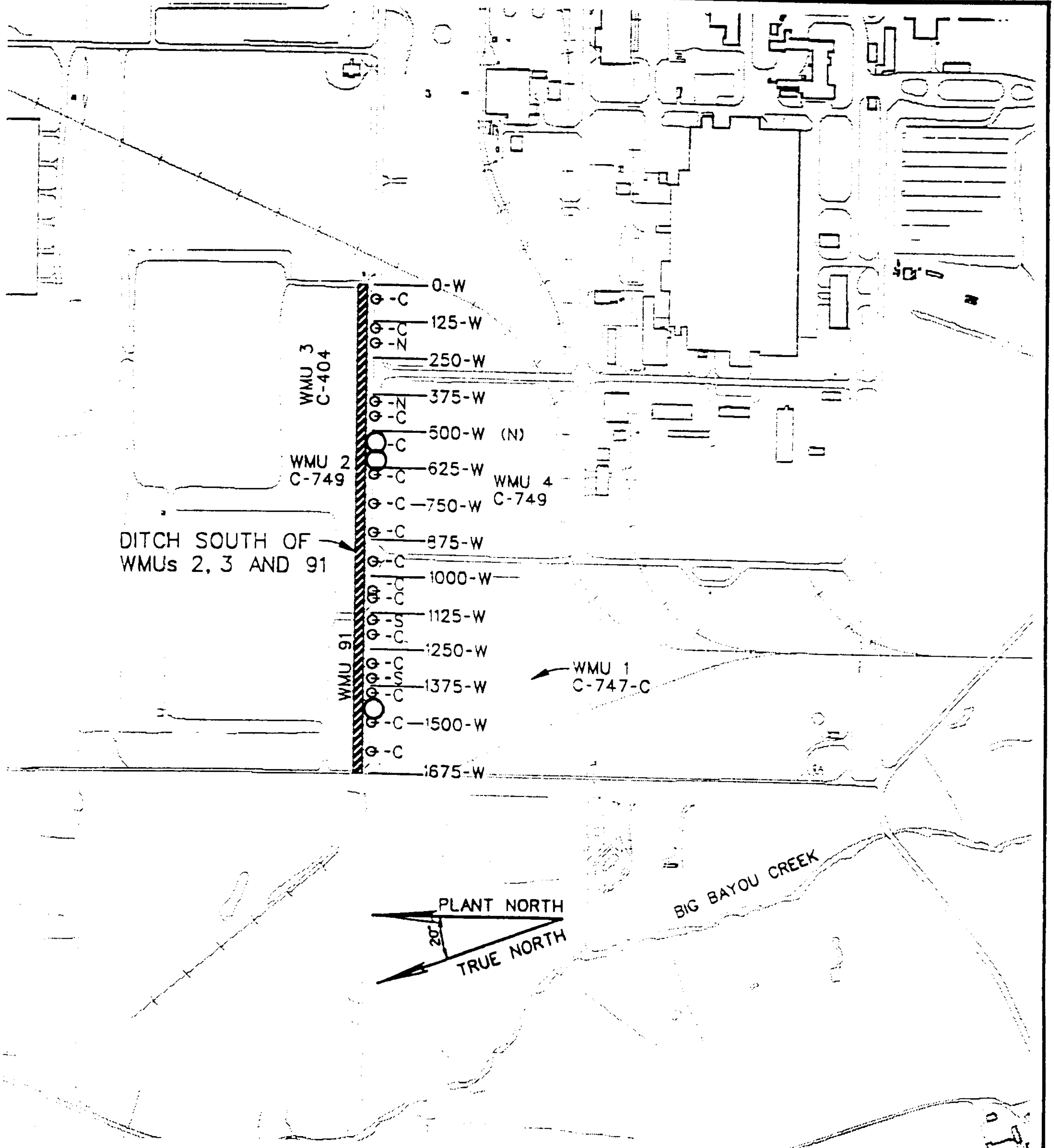

Legend

▨	Location of Surveyed Ditches
o	HP-210 Elevated Readings >3 x Background
O	Significantly Elevated >10 x Background
N	North Bank
C	Ditch Center
S	South Bank

Figure 2-10
RADIATION WALKOVER SURVEY OF DITCH SOUTH OF WMU 2: C-749 URANIUM BURIAL GROUND AND WMU 3: C-404 LOW-LEVEL RADIOACTIVE WASTE BURIAL GROUND

PADUCAH GASEOUS DIFFUSION PLANT
PADUCAH, KY.

Table 2-6
Elevated Gamma Measurements Along the Ditch South of WMUs 2 and 3

Location	Side	Gamma (cpm)	Location	Side	Gamma (cpm)
175-W	Center	30K	975-W	Center	48K
200-W	North	32K	1075-W	Center	57K
400-W	North	44K	1025-N	Center	56K
425-W	Center	48K	1150-W	South	52K
475-W	Center	52K	1175-W	Center	54K
500-W	North	32K	1225-W	Center	54K
525-W	Center	104K	1275-W	Center	85K
575-W	Center	104K	1325-W	Center	84K
625-W	Center	30K	1375-W	Center	92K
675-W	Center	32K	1425-W	Center	112K
725-W	Center	35K	1475-W	Center	64K
825-W	Center	41K	1525-W	Center	78K
875-W	Center	48K	1575-W	Center	48K
925-W	Center	56K			

* Typical background measurements range from 10 to 15 cpm.

the center of the ditch. Elevated readings were also obtained and were located predominantly at the center (bottom) of the ditch, as shown in Table 2-7.

The results of the gamma and beta/gamma walkover survey for the ditch south of WMUs 2 and 3 are shown in Figure 2-10. Based on the measurements, it appears that both beta and gamma emitters are present, particularly in the ditch center. The contamination appears to be distributed throughout the length of the ditch.

The walkover gammer survey conducted for WMU 2 indicates that the gamma dose is highest at the north side of WMU2 which receives gamma radiation "shine" from the cylinder yard. The drop in gamma readings from 240 μRem/hour to about 100 μRem/hour, indicates that the "shine" from the cylinder yard may be contributing over half of the gamma dose at the area surrounding WMU 2.

Surface radiological contamination was also found in soil samples, primarily at H221 northwest of WMU 2, and in H262, taken in the ditch southwest of WMU 2. At the surface of H221, uranium was detected at levels of 7.6J ± 0.3 pCi/g (U-234), 0.65J ± 0.8 pCi/g (U-235), and 61J ± 1 pCi/g (U-238), and Tc-99 was found at 6J ± 0.1 pCi/g. In H262, uranium was detected at 18 ± 1 pCi/g (U-234), 1.7J ± 0.1 pCi/g (U-235), and 69J ± 1 pCi/g (U-238). Tc-99 was detected at 58J ± 2 pCi/g, Th-230 at 14J ± 1 pCi/g, and transuranics at 7.9J ± 0.2 pCi/g (Pu-239) and 0.32 ± 0.05 pCi/g (Np-237). The values generally declined with depth, as shown in Figure 2-9.

The extent of radiological contamination probably extends from H221 in the swale west of WMU 2, and from H262 in the ditch south of WMU 2, to Outfall 015. Depleted uranium (at concentrations up to 90 pCi/g) and associated Tc-99, Th-230, and Pu-239 were found near the unit. Tc-99 was also found at boring H078 in the ditch further downstream near the plant boundary. The total length of contaminated ditch onsite is approximately 1,000 ft. The depth of radiological contamination is most likely up to 6 ft near the unit, and less than 1 ft downstream. The extent of radiological contamination over the ground surface within WMUs 2 and 3 was not investigated because of the existing clay cap.

2.4.2.2 Interpretation of Groundwater Migration Pathway

The burial grounds are a possible source of contamination in offsite groundwater. Although groundwater contamination has not been directly attributed to originate from WMU 2 and 3, uranium, Tc-99, and TCE were detected in the UCRS adjacent to the units. Tc-99 has been detected in wells near the unit completed in the RGA; however, only trace levels of TCE have been detected in the same wells. These contaminants have currently not been detected in the groundwater downgradient of the units. Since the two WMUs are contiguous, the exact source of each contaminant has not been confirmed.

Table 2-7
Elevated GM Measurements Along the Ditch South of WMUs 2 and 3

Location	Side	Beta/Gamma Unshielded (cpm)	Beta/Gamma Shielded (cpm)	Location	Side	Beta/Gamma Unshielded (cpm)	Beta/Gamma Shielded (cpm)
50-W	Center	186	74	1050-W	Center	330	88
150-W	Center	174	50	1075-W	Center	196	94
200-W	North	106	84	1150-W	South	326	278
400-W	North	556	106	1200-W	Center	234	164
450-W	Center	160	88	1300-W	Center	176	60
550-W	Center	216	80	1350-W	South	144	64
650-W	Center	562	98	1400-W	Center	420	188
750-W	Center	230	88	1500-W	Center	554	118
850-W	Center	214	114	1600-W	Center	166	104
950-W	Center	320	110				

*Typical background measurements from 10 to 15 cpm.

The conceptual site model was depicted in Figure 2-5 and includes transport via percolation of precipitation through buried wastes and contaminated subsurface soils, leaching of contaminants to vadose zone soil and groundwater, and subsequent groundwater flow. Percolation occurs primarily through the existing caps; infiltration rates at WMU 2 were measured at less than 10^{-5} cm/sec, and infiltration at WMU 3 is expected to be negligible because of the presence of the multi-layer cap. However, insufficient historical data is available to make a comparison between pre- and post-cap water levels (i.e., no pre-cap data). Computer modelling indicates water levels would drop after installing the cap (McConnell, 1992).

Lateral flow within the UCRS is limited because of the lack of horizontal connection between permeable soil zones. No contamination in the UCRS was found northeast of the units. Vertical separation of the UCRS from the RGA in this area is generally good; the vertical difference in water levels between the two groundwater systems is about 30 to 35 ft. Flow within the RGA is generally northward; however, because the gradients are so flat, contaminant movement may trend northwesterly or northeasterly in response to anisotropy within the ancestral river channel beneath the plant.

Analytical results of subsurface soil sampling from deep soil borings are shown in Figure 2-9. Analytical results of groundwater sampling are summarized in Tables 2-8, 2-9, and 2-10, and shown in Figure 2-8. Table 2-9 presents the maximum detected concentrations of inorganics in groundwater for both total and dissolved samples. The maximums for some of the total and dissolved analyses are for different sampling events which is why some of the total data have a lower concentration than the dissolved data. The data for each respective sampling round showed the typical pattern of dissolved data having lower concentrations than total data.

2.4.2.2.1 Subsurface Organic Contamination. TCE contamination is found primarily in the UCRS immediately adjacent to the burial grounds. TCE was detected in 10 of 22 wells that were sampled in the area. Three wells within the UCRS (MW-88, -91, and -94) have shown levels of TCE above 5 μg/L in more than one sampling event. The maximum level reported was 270 μg/L in MW-88. Temporal trends of PGDP monitoring of MW-88 over time is shown in Figure 2-11. The TCE trend diagram indicates an increasing concentration during the sampling period. TCE was not detected in the shallow wells (MW-170, -171, and -172) north of the units. This indicates that the lateral extent of contamination from WMU 2 and 3 has not extended to these locations. Wells within the RGA at this unit did not consistently exhibit TCE levels above 5 μg/L, however, a maximum concentration of 98 μg/L was detected in MW-86. This result is considered uncertain since subsequent samples at this well did not confirm high levels of TCE.

The TCE degradation product 1,2-dichloroethene (DCE) was detected in wells MW-49 and -50 at concentrations of less than 2 μg/L. Some VOCs were also detected in the leachate sump at WMU 3. TCE was detected at 30 μg/L, and 1,2-DCE was detected at 37 μg/L.

Table 2-8
Maximum Detected Concentrations (μg/L) for VOCs and SVOCs in Groundwater

Analyte	Ref.	Reg. Limit	Well 49	50	84	85	86	88	89	90
VOCs										
1,2-DCE	ND	70	1	2						
TCE	0.2	5	5	2	71		98	270	7	2
SVOCs										
2-Chlorophenol	ND									
2-Nitroaniline	ND		65							
2,4-Dinitrotoluene	ND									
4-Chloro-3-methylphenol	ND									
N-Nitrosodi-n-propylamine	ND									
Pentachlorophenol	ND									

Analyte	91	92	93	94	169
VOCs					
1,2-DCE					
TCE	14			49	110
SVOCs					
2-Chlorophenol			73		
2-Nitroaniline					
2,4-Dinitrotoluene			28		
4-Chloro-3-methylphenol			67		
N-Nitrosodi-n-propylamine			35		
Pentachlorophenol			67		

Table 2-9
Maximum Detected Concentrations of Inorganics ($\mu g/L$) in Groundwater

Page 1 of 3

Analyte	Fraction	Ref.	Reg. Limit	MW-48	MW-49	MW-50	MW-67	MW-74	MW-84	MW-85	MW-86
Aluminum	Dissolved	195		23.8	54.5	2,010J	585J	20,800	389J	224J	42.1J
	Total	8,880		202	53,400J	3,650	960	137,000J	57.8	398	176
Antimony	Dissolved	27.4	5								
	Total	ND	5								
Arsenic	Dissolved	ND	50		3.8J	4.8		3.4			
	Total	ND	50		8.9J	6.8					
Barium	Dissolved	195	1,000	85.9J	148	75.2	81.7	143	73.8	91.4	210
	Total	210	1,000	96.5J	486J	82.8	82.8	1,200	57.4	62.3	177
Beryllium	Dissolved	ND	1			0.5					
	Total	ND	1		10.6	2.3J		20.8			
Cadmium	Dissolved	ND	5		6.8	3.3					
	Total	ND	5			4.0		5.1J			
Chromium	Dissolved	2.1	50		15.8	17.3	12.4	33.3	9.5	9.3	8.6
	Total	31.3	50	5.5	45.1	60.3	16	279	9.7	9.8	7.9
Cobalt	Dissolved	4.7				16.5					
	Total	8.2		4	90.2	20.3		191			
Lead	Dissolved	ND	15	28J	17.8J	36J		17.8J	2.8J		1.3J
	Total	4.1	15	18.9	113J	78.9		68.2	1.5J		
Manganese	Dissolved	264		538	900J	858	24.1	268	62	17.9	652
	Total	335		821	2,520J	911	30.2J	2,910	21.9J	4.9J	655J
Nickel	Dissolved	5.4	100		8.6	43	52.6				
	Total	10.4	100		126	59.3	62	239			
Silver	Dissolved	ND	50								
	Total	ND	50		22.4			46.9			
Thallium	Dissolved	ND	1			1.6					
	Total	ND	1								
Vanadium	Dissolved	1.3				22.2		68.3			
	Total	4.7	8.5	8.5	45.2	41.7		805			

Table 2-9
Maximum Detected Concentrations of Inorganics ($\mu g/L$) in Groundwater

Page 2 of 3

Analyte	Fraction	MW-87	MW-88	MW-89	MW-90	MW-91	MW-92	MW-93	MW-94	MW-95	MW-154
Aluminum	Dissolved	38	1,540J	453J	63.1	578	2120		735	526	
	Total	356J	2,130	1,930	829	2,450	2920		1,620	3,050	4,210J
Antimony	Dissolved										
	Total										
Arsenic	Dissolved		8.7				3.6		3.9		
	Total		11.2J	3.9J		1	3.7		3.9	4.6	
Barium	Dissolved	81.4	164	168	39.4	64.4	170	81.5	125	99.8	
	Total	84.7	167	305	51.8	126	197	73.8	128	147	77.4
Beryllium	Dissolved										
	Total						2				
Cadmium	Dissolved		4.6J	1.1							
	Total										
Chromium	Dissolved	8.3	9.3	7.3	8.1	6.1	18.7		14.9		
	Total	3.2	6.1	13.1	11.4	84.2	19.9		25.8	13.3	14.2J
Cobalt	Dissolved			4.4							
	Total			8.6		8.8					
Lead	Dissolved			0.6			8				6.2J
	Total		3.3J	8.7J		11.7	10.7		7.4	11.2	7.2
Manganese	Dissolved	225	13.8	3490	2.4		790	27.5	12.2	201	39.8J
	Total	242	106	3920	145	24.6	869	15.9	56.7	533	177J
Nickel	Dissolved								35.3		
	Total	6.3		14.6		34			38.6		5.9J
Silver	Dissolved										
	Total										
Thallium	Dissolved						10.4J				
	Total	0.8		0.9							
Vanadium	Dissolved		3.3	2.5			14.8				9.6
	Total	1.3	10.6	8.5		52.3	15.9		6.2	18.8	4.4J

Table 2-9
Maximum Detected Concentrations of Inorganics ($\mu g/L$) in Groundwater

Page 3 of 3

Analyte	Fraction	MW-169	MW-170	MW-171	MW-172
Aluminum	Dissolved			97.5	
	Total	8,400J	3,960J	34,800	5,210
Antimony	Dissolved		22.7		
	Total				
Arsenic	Dissolved				
	Total			8.6	
Barium	Dissolved	131	217	50.2	51.1
	Total	302	239	237	87.9
Beryllium	Dissolved				
	Total			2.2	0.65
Cadmium	Dissolved				
	Total				
Chromium	Dissolved				
	Total	61.6J	42.8J	35.8	94.3
Cobalt	Dissolved		14.2		
	Total	14.3	15.9	22.6	6.2
Lead	Dissolved	3.8J	4.6J		
	Total	9.7J	8.4J	23.2J	6.7
Manganese	Dissolved	160J	1,250J	276	77.5
	Total	1970J	1,250J	1,060	169
Nickel	Dissolved	8.4			5.8
	Total	51.6	24.4	22.5	38.2
Silver	Dissolved				
	Total			16.5J	
Thallium	Dissolved				
	Total				
Vanadium	Dissolved				
	Total	14J	12.2J	71.3	20

Table 2-10
Maximum Detected Activity Levels (pCi/L) of Radionuclides in Groundwater

Page 1 of 2

	Fraction	Alpha	Beta	Tc-99	Np-237	U-234	Th-230	Pu-239	U-235	U-238
Reference	Dissolved	ND	12	ND	ND	0.53	ND	ND	ND	0.87
	Total	2.9	47	ND	ND	0.53	1.3	ND	ND	0.87
Reg. Limit	Dissolved	15	50^a	900^b	7.19^a	30^a	82.7^a	64.9^a	30^a	30^a
	Total	15	50^a	900^b	7.19^a	30^a	82.7^a	64.9^a	30^a	30^a
MW-48	Dissolved			[2.2]J						
MW-48	Total		[10]J							[1.3]J
MW-49	Dissolved		17J	9.3J		[0.51]J				
MW-49	Total	1,724J	10,765J^a	292J^a		10J			[0.38]J	21J
MW-50	Total	[3]	38J	20		[1.6]	[0.68]			
MW-58	Dissolved	1,200	5,100^a	370^a		360	2.6		63	2,700
MW-58	Total	4,893	36,126J^a	747J^a		1,860J			63	3,333
MW-67	Dissolved							[0.28]		
MW-67	Total							[0.28]J		
MW-74	Dissolved	5.8	160	180J						
MW-74	Total	76	1,087J^a	240J^a		4.9J	11.6J			11.4J
MW-84	Dissolved	19	460	390						[0.21]
MW-84	Total	21	988	778		[0.14]				[0.23]
MW-85	Dissolved	13J	440	340		2J				4.2J
MW-85	Total	19	444J	330J		2.7		[0.9]		6.3
MW-86	Dissolved	[1.6J]	10							1.7J
MW-86	Total	5	20J			[0.57]				2J
MW-87	Dissolved									
MW-87	Total		6.5J			[0.22]J				
MW-88	Dissolved	37	1,300	1,200			[1]			[0.12]J
MW-88	Total	44	1,878	2,175		2.7J	3			5
MW-89	Dissolved		[3.8]J					[0.25J]	[0.4]	
MW-89	Total		14J				[0.39]J			
MW-90	Dissolved		9.3							
MW-90	Total		7	[3.8]						
MW-91	Dissolved		14							
MW-91	Total	6.7J	150J	24		6.2	[0.22]		[1]	[1.2]

Table 2-10
Maximum Detected Activity Levels (pCi/L) of Radionuclides in Groundwater

Page 2 of 2

	Fraction	Alpha	Beta	Tc-99	Np-237	U-234	Th-230	Pu-239	U-235	U-238
MW-92	Dissolved	[0.98]	5.6							
MW-92	Total	5.1	19	3		[0.26]J				
MW-93	Dissolved									
MW-93	Total		[5]							
MW-94	Dissolved	21J	530J	670						[0.21]
MW-94	Total	21	850	890J		1.9				2.3
MW-95	Dissolved									
MW-95	Total	[2]	6.3	[3.1]						
MW-154	Dissolved	39J	970J	850		11J				31J
MW-154	Total	48J	960J	1,000J		3.6		[0.18]J		27
MW-169	Dissolved	[0.6]	7	[2.6]J	[0.04]J	[0.22]		[0.17]J	[0.02]	[0.09]
MW-169	Total	5.5J	30							
MW-170	Dissolved	[2.1]	36	8.5J	[0.08]J	[0.25]		[0.12]J	[0.04]	[0.27]
MW-170	Total	8.9J	46J			[0.44]J				
MW-171	Dissolved	[2.3]J	6.5J	4.4J						
MW-171	Total	13J	66J	2.9J		0.58J				0.65J
MW-172	Dissolved	[0.77]J	5.4							[0.11]J
MW-172	Total	11J	70J			[0.49]J				[0.33]J

[a] The discrepancy between total beta and Tc-99 for these samples may indicate unreliabile data.
[b] The proposed MCL for Tc-99 is 3,790 pCi/L and the current MCL is 900 pCI/L.

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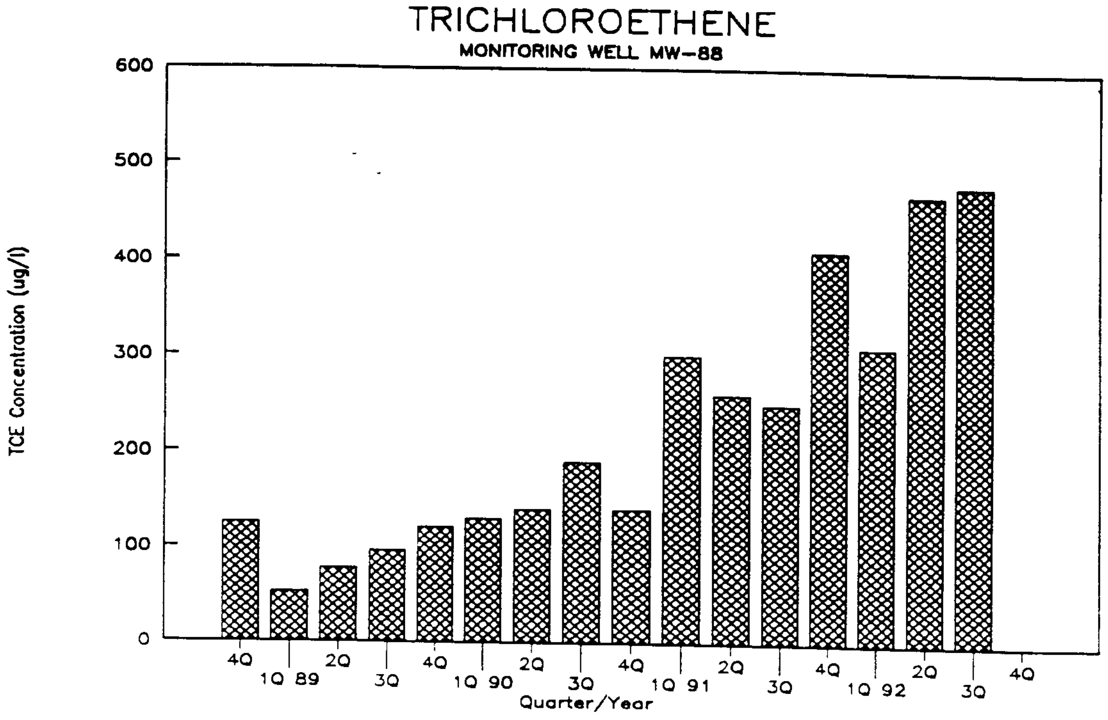

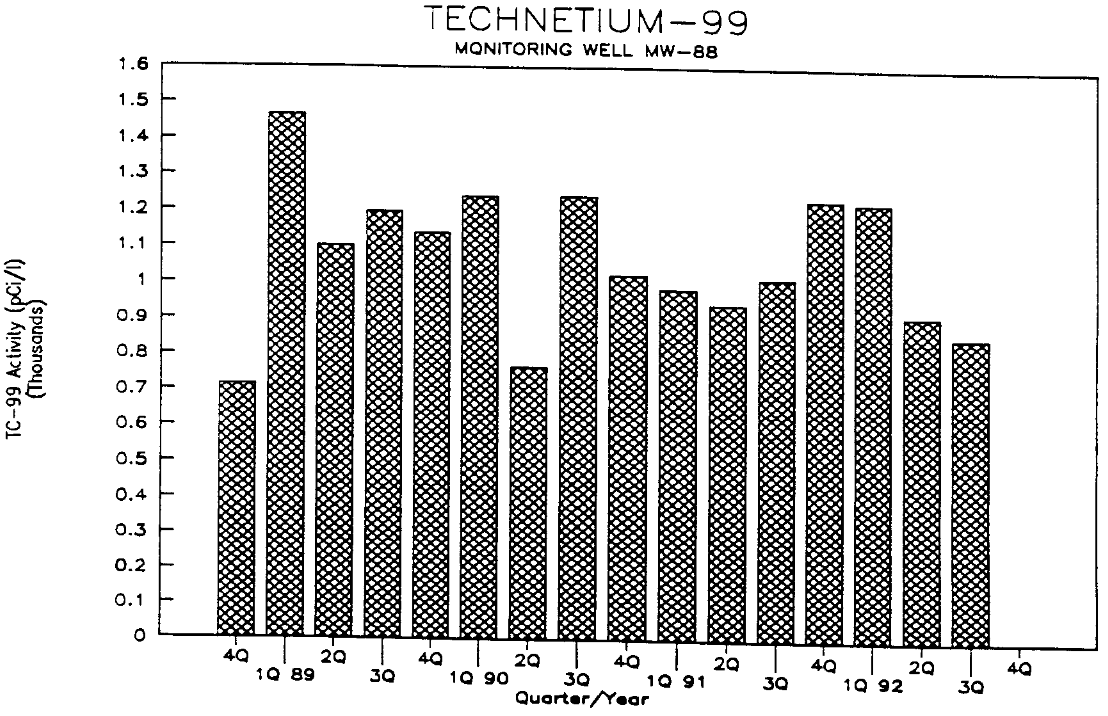

Figure 2-11
TRENDS OF TCE AND Tc-99 IN MW-88
PADUCAH GASEOUS DIFFUSION PLANT
PADUCAH, KY.

Source: Martin Marietta Quarterly Monitoring Program

Concentrations of SVOCs detected during Phase II in groundwater were near the detection limits; the compounds were not detected in more than one groundwater sampling event. One sample from RGA well MW-93 detected 2-chlorophenol (73 µg/L), 2,4-dinitrotoluene (28 µg/L), 4-chloro-3-methylphenol (67 µg/L), N-nitrosodipropylamine (35 µg/L), and pentachlorophenol (67 µg/L).

Several organic compounds were detected in subsurface soils from boring H221, north of WMU 2. TCE was detected at 0.8 µg/kg at a depth of 15 to 20 ft, but not at any other depth. Pentachlorophenol (200J µg/kg) was detected from 5 to 10 ft, and 1,2-dichlorobenzene (up to 42J µg/kg) was detected from 30 to 40 ft. Pentachlorophenol (100J µg/kg) was also detected in the surface soil sample from boring H262, in the ditch downstream of WMU 2. In soil samples from MW-171, at a depth of 15 to 20 ft, PAHs were detected at 62 µg/kg, 2-chlorophenol at 92J µg/kg, and 4-chloro-3-methylphenol at 100 µg/kg. 4-chloro-3-methylphenol was also found in soil samples from MW-169 at a depth of 30 to 35 ft at 65 µg/kg. Because MW-169 and MW-171 are located approximately 600 ft north of the units, this contamination is not considered related to WMUs 2 and 3. Because no corresponding groundwater contamination for these compounds was detected in MW-169, it was considered unlikely that surface soils were contaminated from a source located at WMUs 2 and 3. The source of this contamination has not been identified.

Neither PCBs nor associated dioxins/furans were detected in the groundwater samples from MW-84 through -95. Aroclor 1248 was detected at a concentration of 1.1 µg/L in the leachate sample from WMU 3.

2.4.2.2.2 Subsurface Metal Contamination. Inorganic elements were detected in the leachate sample from WMU 3 at levels above reference surface-water or groundwater quality values. Beryllium (5 µg/L), cobalt (210 µg/L), nickel (320 µg/L), and silver (388 µg/L) were detected in total (unfiltered) metals analyses. These metals were also detected from the wells within the UCRS nearest the leachate sump (MW-49 and -74). Beryllium (up to 20.8 µg/L), chromium (up to 279 µg/L), lead (up to 113J µg/L), and nickel (up to 239 µg/L) were detected in those wells in the total metals fraction at levels above MCLs for drinking water. Arsenic (11.2J µg/L), barium (1,200 µg/L), cobalt (191 µg/L), copper (207 µg/L), silver (46.9 µg/L), and vanadium (805 µg/L) were also above reference values in these wells. Metals were not found in a consistent pattern above reference values in the dissolved (filtered) fraction and (therefore may not be available to migrate.) The exception may be dissolved lead, which was detected at levels up to 28J µg/L above MCLs in wells MW-48, -49, -50, and -74 in both the UCRS and the RGA. out

Some of these same metals were detected at levels higher than reference in subsurface soil samples from borings around the units. Chromium levels were higher than reference in H008 throughout the depth of the boring (76 ft) at levels of 13,400 to 58,800 µg/kg. Silver levels were higher than reference in H221 throughout the depth of the boring (40 ft) at levels of 1,500J to 7,600 μg/kg. Silver was also above reference in H220 at a depth of 10 to 15 ft.

Although cadmium, magnesium, lead, and selenium were reportedly disposed of in WMU 3, consistent patterns of these metals were not found in soils in the area.

2.4.2.2.3 Subsurface Radiological Contamination. Radiological analyses of soil samples indicate no contamination in subsurface soils above gross alpha or gross beta screening levels in the deep soil borings (H008, H220, H221).

In the leachate sample from WMU 3, uranium concentrations were much higher than those detected in soil or groundwater. The leachate is either from infiltration through the cap or lateral flow through the wastes, and is sampled every time the sump is emptied. U-234 was reported at 2,500 ± 100 pCi/L, U-235 at 290 ± 30 pCi/L, and U-238 at 30,000 ± 1,000 pCi/L; however, the quantified results were rejected during data validation because of low radiochemical yields in reference samples (that is, the spike recovery data were not within control limits). Tc-99 was reported at 150J ± 10 pCi/l. Transuranics were not detected in the leachate sample.

Groundwater analyses show radiological contamination in the UCRS. In all seven of the UCRS wells adjacent to the units, Tc-99 was detected at levels up to 2,175 ± 53 pCi/L (total fraction) and 1,200 ± 100 pCi/L (dissolved fraction) with the highest levels found at MW-88. Temporal trends of PGDP monitoring of MW-88 for TCE and Tc-99 contamination over time are shown in Figure 2-11. Thorium was detected in MW-74 and -88 in the UCRS at levels up to 11.6J pCi/L (total fraction only). Uranium was detected at varying levels within the UCRS wells; maximum values for total fraction analysis were: 10J ± 1 pCi/L (for U-234), 1 ± 0.7 pCi/L (for U-235), and 27 ± 2 pCi/L (for U-238). The values were recorded in most cases from wells around WMU 2 and MW-49, -74, and -154 (which replaced well MW-58). Sampling of MW-58 during Phase I of the site investigation indicated activities up to 747J ± 34 pCi/L of Tc-99, 1,860J ± 160 pCi/L of U-234, and 3,333 ± 56 pCi/L of U-238 in samples that were taken prior to the well abandonment. Sampling of MW-154 by PGDP between October 1990 and June 1991 indicated levels of Tc-99 up to 856J pCi/L and uranium up to 49 μg/L (34 pCi/L at natural assay), which are similar to the sampling results of the site investigation.

Uranium in the dissolved fraction had maximum values near the total values, although slightly above, indicating agreement in the general order of magnitude. Pu-239 was detected sporadically at values up to [0.9 ± 0.7] pCi/L; however, these results are uncertain because the error factor is nearly as large as the value. In these wells, Tc-99 was detected at levels near the minimum detectable activity.

In the RGA, radiological contamination was less than in the UCRS. Tc-99 was detected in 5 of the 12 wells; however, only one well had values that exceeded the PGDP action level of 25 pCi/L for providing water to offsite residents. In MW-84, located on the north side of WMU 3, Tc-99 was reported up to 778 ± 21 pCi/L (total fraction) and up to 390 ± 10 pCi/L (dissolved fraction). Uranium in the RGA was slightly above reference values; the maximum U-234 value was 2.5J ± 0.7 pCi/L, and the maximum U-238 value was 3.3J ± 0.8 pCi/L (total fraction) in a duplicate sample from MW-67.

Buried waste materials and contamination within the subsurface soils in the vadose zone beneath these units may serve as a source of continuing release to groundwater. The extent of buried waste within the burial grounds is well defined. PGDP records show detailed quantities and specific locations of buried materials within the limits of the WMUs. These limits are also clearly defined by surface topography, especially for WMU 3.

Tc-99 contamination in the RGA is limited in extent. Maximum values have been reported in wells (MW-84 and MW-86) at the northwest perimeter of WMU 3, although similar levels are not apparent in the overlying UCRS at that location. The unit that is the source of Tc-99 is not fully known.

2.5 Contaminant Fate and Transport

The purpose of this section is to assess the transport potential of the detected contaminants and to evaluate their potential fate. Water is the most important transport mechanism present. Windblown distribution of contaminants at WMUs 2 and 3 are thought to be minimal, either as gases or particulate matter, because of the current grass cover over the unit and on the basis of offsite surface soil sampling. Onsite ingestion of contaminants by biota is also thought to be minimal, and therefore not discussed because of the lack of biota within the PGDP security fence. The water transport pathways have been identified as reasonable deviations through surface water runoff and erosion for particulate matter and through groundwater seepage for liquid and dissolved contaminants.

2.5.1 Surface Transport

Physical transport of contaminants on the surface can be defined by the amount of water available for runoff, the types of surface soils present, the topography of the site, and the ability of the contaminant to travel with the surface water.

The topography of WMU 2 is relatively flat, while WMU 3 is slightly mounded. A drainage ditch borders the two units on the south. This ditch eventually drains into Outfall 015, which leaves the site approximately 1,250 ft west of WMUs 2 and 3 enroute to Big Bayou Creek. The area of WMU 2 is roughly 32,000 ft^2 and the area of WMU 3 is around 53,200 ft^2. WMU 3 has a multilayer RCRA cap, so infiltration of surface water is considered negligible. WMU 2 was covered with a 6-in. clay cap in 1982 and is now grass covered, along with the ditch that leads to Outfall 015. This cover significantly impedes erosion and may limit the transport of possible contaminants, such as PCBs and dioxin/furans, which tend to adhere to particulate matter.

Precipitation at PGDP averages about 50.3 in. per year. Davis (1973) has estimated about 21 in. is available for runoff or infiltration into the ground, with the remainder being evaporated or used by vegetation. Of these 21 in. of precipitation (primarily rainfall), about two-thirds (14 to 16 in.) apparently leave the site as surface runoff, with the other 5 to 7 in. infiltrating and recharging the groundwater system. Although WMU 2 is primarily flat, it is covered by a 6-in. clay cap. Based on the average permeability of the clay cap (3×10^{-6} cm/sec) and the average slope for WMU 2 (1 percent), approximately 4 inches per year are estimated to infiltrate through the cap to the groundwater system. Given the area of the unit, this translates to about 8×10^4 gallons of infiltrate and about 6×10^4 gallons of runoff for the year. Again, while some infiltration will occur, it is assumed to be negligible at WMU 3 because of its RCRA cap.

2.5.2 Subsurface Transport

The soil properties in the subsurface that affect the potential for the migration of liquid or dissolved contaminants are permeability (discussed above), no cation exchange capacity (CEC), mineral content, and organic carbon content of the soil.

The horizontal hydraulic conductivity of the UCRS soils above the RGA is low on average (3.6×10^{-5} cm/s), with a flow velocity of 1.7×10^{-6} cm/sec, and an average thickness of about 50 ft. The vertical gradient (-0.5) is much larger than the horizontal gradient (0.008) indicating predominantly vertical flow. Computer modeling of the vertical conductivity yielded 0.2×10^{-7} cm/s (McConnell, 1992). The UCRS soils consist primarily of clay with interspersed sand lenses. Refer to Figure 3-13 of the Phase II Site Investigation (CH2M HILL, 1993) for a detailed cross-section. Because of the poor permeability and the lack of pathways between sand lenses, the UCRS soils are not considered an aquifer and are not thought to provide a horizontal pathway for contaminants.

UCRS soils are not believed to provide a significant vertical pathway for seepage from the surface to the RGA. This statement is based on the low hydraulic conductivity of the UCRS soils and the observation from soil boring logs that these soils do not contain laterally extensive permeable beds.

The hydraulic conductivity of the soils of the RGA has been approximated to be 2.8×10^{-3} cm/s. The flow direction is generally to the north or northwest with a gradient approximately 0.00027. The unit is about 45 ft thick in this area and has an assumed porosity of 0.2. The calculated flow velocity from these values is 3.8×10^{-5} cm/s. Although the horizontal gradient is low, this aquifer is the primary groundwater pathway for contaminant transport offsite. The closest distance to the site boundary in the direction of groundwater flow (northwest) is about 1,700 ft. This calculates to a travel time of approximately 43.6 years from the WMUs to an offsite location through the RGA. Velocity information for the RGA presented in Section 1.3.2 indicates that probably flow rates in the RGA range between 200 to 400 ft per year toward the Ohio River, or a travel time of 4 to 8 years. Actual travel time is likely somewhere between the extremes presented here.

With a fraction of organic carbon (f_{oc}) of 0.001 or more, sorption of organic compounds to the soils will likely occur and must be considered in determining the contaminant-specific distribution coefficient (K_d). A f_{oc} of 0.001 will be used to estimate K_d factors. Therefore, organic compounds such as TCE and other VOCs may have a slight tendency to bind up with the soils.

The retardation of dissolved contaminants in groundwater is often estimated using a value for the soil/water distribution coefficient K_d for the contaminant based on the fraction of organic carbon in the porous media through which the contaminated groundwater is migrating. Migration of a mass of dense non-aqueous phase liquid (DNAPL) like TCE and DCE is controlled by many other processes besides adsorption, including density, viscosity, the variability in the hydraulic conductivity of the porous media, and the configuration of any low-permeability layer that the DNAPL mass may be moving over. Therefore, retardation of the DNAPL mass cannot be estimated simply by using a retardation coefficient based primarily on the K_d.

Based on the estimates in Table 2-11, groundwater migration of TCE occurs with a retardation coefficient of about 1.8 and DCE occurs with a retardation coefficient of 1.3. In the permeable RGA with the absence of high horizontal gradients, TCE will migrate at a slower rate than the groundwater. The other chlorinated hydrocarbons (1,2-DCE) are more soluble than TCE and tend to migrate slightly faster than TCE.

CEC and total organic carbon (TOC) were measured in samples from four boreholes near the top, middle, and bottom of each boring (Table 5-1, CH2M HILL, 1993). These analyses showed a low range of CEC rate of 1.4 to 13 meq/100 g, with an organic carbon ratio (f_{oc}) of less than 1 part per thousand near the surface, and decreasing with depth. The CEC rate indicates that the soils do not generally have a high capacity to adsorb metals or radionuclides. Therefore, metals, including the radioactive isotopes of metals, probably will not be bound onto soil particles.

The pH measured in groundwater at the unit was about 6.5, which is typical for the PGDP area. In general, there was no tendency to either preferentially mobilize or precipitate metals.

2.5.3 Fate of Probable Contaminants

This section highlights the factors contributing to the fate of contaminants at WMUs 2 and 3, including groundwater migration, degradation potential, persistence in surface water, and bioconcentration. Table 2-11 shows the properties of selected VOC and

Table 2-11
Chemical Properties of Selected Organic Contaminants

Chemical Name	Vapor Pressure (mm Hg)	Water Solubility (mg/L)	Henry's Law Constant (atm-m^3/mol)	K_{oc} (mL/g)	LOG K_{ow}	Fish BCF (L/kg)	Estimated Retardation
Chlorinated Ethanes and Ethenes							
TCE	69	1,100	0.0103	127	2.42	10.6	1.8
1,2-DCE	201	3,500	0.00758	49	1.86	1.91	1.3
1,2-DCE (total)	201	3,500	0.00758	49	1.86	1.91	1.3
1,2-Dichlorobenzene(1)	1	100	0.00193	1700	3.6	56	11.0
1,4-Dichlorobenzene(1)	1.18	79	0.0028	1700	3.6	56	11.0
2,4-Dinitrotoluene	0.00051	240	5.09E-06	45	2	3.8	1.3
Pentachlorophenol (PCP) (1)	1.10E-04	14	2.75E-06	53000	5	770	313

Notes:

BCF – Bioconcentration factor values from the 1980 Ambient Water Quality Criteria Documents.
Retardation: $1 + [K_{oc} \times f_{oc} \times BD/P]$
where: BD – bulk density is 1.77
P – porosity is 0.3
and f_{oc} (fraction of organic carbon) is 0.001
K_{oc} – Organic carbon partition coefficient. Data from Arthur D. Little, 1989.
K_{ow} – Octanol water coefficient.

SVOC contaminants. The most commonly found contaminants are addressed in this section.

2.5.3.1 TCE and Other VOCs

Anaerobic biodegradation of TCE takes place at the WMU to produce 1,2-DCE; however, 1,2-DCE may have been used as a solvent.

Because of the high Henry's constant for TCE, it would not be expected to persist in the near surface environment, including surface water. The high volatile potential also translates into a low bioconcentration potential for TCE.

2.5.3.2 Phenolic Compounds

Phenolic compounds are soluble, mobile, and readily biodegraded. Highly chlorinated phenolic compounds, such as pentachlorophenol (detected at 67 μg/L in groundwater during one sampling event), are more resistant to biodegradation. These compounds typically do not bioaccumulate and are not very volatile.

2.5.3.3 Dioxins and Furans

Dioxins and furans can be formed from PCBs under high-temperature conditions. These compounds have a low solubility and are not readily available for groundwater contamination. Although they have been detected in the surface and near-surface soils, they have not been detected in surface waters or groundwaters. The remaining dioxins/furans probably are in the surface or near-surface environment and will remain there.

2.5.3.4 Inorganics (Metals)

The fate and transport of metals is affected by pH, oxygen, the presence of dissolved organic compounds, and other ions that are present in the environment. Removal of trace metals from water can occur through several mechanisms, including precipitation, irreversible sorption, adsorption, and cation exchange.

Concentrations of metals at this site are generally higher in unfiltered (versus filtered) samples, suggesting that metals may be associated with particulates. Metals were not found in a consistent pattern above reference values in the filtered fraction and, therefore, may not be available to migrate.

2.5.3.5 Radionuclides

The most common radionuclide found in groundwater was Tc-99. Tc-99 exhibits little or no retardation with regard to the other major contaminant, TCE. Therefore, Tc-99 probably will migrate with the groundwater of the RGA and only be attenuated by natural radioactive decay.

Uranium isotopes (U-234 and U-238) were also detected in the soil and groundwater samples. Soluble uranium has been found in the shallow groundwater system (MW-58), and in the sumps and monitoring wells surrounding WMUs 2 and 3 (Table 2-10). It is possible that uranium is being solubilized at PGDP and slowly migrating (due to a high K_d value) through groundwater.

2.5.3.6 Uranium in Groundwater, Future Modeling

Future conditions may lead to the solubilization and mobility of much of the uranium now buried at SWMU 2. In the event that the groundwater is contaminated with this uranium source, there could be significant impacts to dowgradient users in the future. The Summers model has been used by SAIC to derive a future concentration for uranium in both the UCRS and the RGA in the worst-case event that all of the buried uranium waste (270 tons) becomes mobile and a portion is transported into the groundwater. Parameters used in this model are given in Table D-1 of Appendix D.[1]

Uranium concentrations in groundwater are predicted by the Summers model in mass units of μg/L. For the UCRS and the RGA the Uranium Mass Concentration was determined to be 6117 μg/L, and 100 μg/L, respectively (see Table D-1 in Appendix D). The concentration of each isotope un units of pCI/l are obtained by multiplying the total concentration by the isotopic ratio for each isotope, times the specific activity for that isotope. This calculation is shown in Table D-2 of Appendix D. The isotopic abundance for each isotope was based on the waste inventory ratios as reported in Table 2-1. The average ratio for depleted uranium-235 was 0.002 (0.2%), and uranium-238 is the balance of that, at 0.998 (99.8%). The isotopic ratio of uranium-234 was assumed to be in its natural state, at 0.00006 (0.006%).

2.6 Human Health and Ecological Risk Assessment

This human health and ecological risk assessment for WMUs 2 and 3 evaluates the concentrations of contaminants in soil and groundwater, the corresponding level of exposure, and the degree of toxicity of a contaminant into estimates of risks used to evaluate the appropriate actions to address contamination at the source area and contaminants migrating from the site.

The approach to the evaluation was developed and executed in accordance with the following guidance from EPA:

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[1] Differences between parameters used by SAIC and those used in the Summers model for calculating soil concentrations exist; the hydraulic conductivity and soil-water distribution coefficients are different, based on the technical opinions of the authors.

- *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part A. Interim Final.* December 1989a.
- *Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors.* March 1991a.

The risk assessment presents the following major components:

- Data Evaluation
- Exposure Assessment
- Toxicity Assessment
- Risk Characterization

The exposure parameters used in the human health risk assessment were developed on the basis of input from ORNL. Also, standard default assumptions were used where appropriate, for consistency in evaluation of WMUs at PGDP. Reasonable maximum and most likely risk estimate for each exposure pathway at WMUs 2 and 3 were made. The reasonable maximum risk estimates are based on assumptions such that the risk estimate would not likely underestimate the potential maximum risks for individuals who might come into contact with contaminated media at a site or with contaminants migrating from a site. The most likely risk estimates are based on assumptions such that the risk estimate would not likely overestimate the maximum risks for individuals who might come into contact with contaminated media at the site or with contaminants migrating from the site. These estimates will be used to evaluate whether further investigation of the units is appropriate or to justify interim measures.

The ecological risk assessment includes a qualitative evaluation of potential ecological disturbances that have occurred, are occurring, or that may potentially occur because of the presence of contamination at WMUs 2 and 3, or because of contaminant migration from these units. An ecological risk assessment at the PGDP facility will be performed for groundwater and surfacewater integrator OUs.

2.6.1 Human Health Risk Assessment

2.6.1.1 Data Evaluation

An initial list of chemicals of concern at WMUs 2 and 3 is presented in Table 2-5 and discussed in Section 2.4; the list consists of chemicals and radionuclides in soil and groundwater. However, only constituents available for potential receptor contact (i.e., detected in the upper 6 ft of soil and in groundwater from the well associated with the highest risk estimate) were evaluated in the risk assessment. Other constituents on the initial list of chemicals of concern are addressed in Section 2.7, Remediation Goal Options. Data for the risk assessment were validated, and no rejected data were used in this assessment.

The soil samples are considered representative of the soil conditions at the perimeter of the C-749 Uranium Burial Ground and C-404 Low-Level Radioactive Waste Burial Ground and provide sufficient data for a quantitative assessment of the Reasonable Maximum Exposure (RME) concentration for soils around the units. A reasonable deviation is that higher concentrations of contaminants are present in small, localized areas below ground surface (bgs) that may not have been detected in this analysis.

No data have been collected for the waste materials or soils within the burial pits because of the potential health and safety threat to investigation workers. In addition, WMU 2 has a 6-in. clay cap over the wastes, and WMU 3 has a multilayer RCRA cap over the waste. A quantitative assessment of risks cannot be made for the waste pits themselves.

Results of sampling of downgradient groundwater in MW-58 and -154 at WMU 2 and MW-93 and -94 at WMU 3 confirm the presence of contaminants in the UCRS and RGA and are used to support evaluation of potential releases from these units. Recognizing the uncertainty in the spatial distribution of contaminants in groundwater, these data are used to screen potential risks to groundwater from releases of contaminants from WMUs 2 and 3. A more detailed evaluation of groundwater conditions will be performed with evaluation of the onsite groundwater integrator OU. That analysis will consider in greater detail the spatial distribution of contaminants in these groundwater units and the sources of contamination from multiple waste areas.

Available data verify releases from WMUs 2 and 3 to soils and groundwater and support the source characterization. Solvents are generally not persistent in unsaturated soils; risk estimates are based on the measured levels of contaminants in these monitoring wells rather than on a modeled concentration.

2.6.1.2 Exposure Assessment

This section identifies the ways in which humans may come into contact with the contaminants from WMUs 2 and 3. Previous sections of this report presented an overview of the PGDP site with regard to location and land use, climate, vegetation, surface hydrology, and groundwater hydrology. This section will focus on those conditions specific for WMUs 2 and 3.

2.6.1.2.1 Characterization of the Exposure Setting

2.6.1.2.1.1 Current Onsite Land Use. WMUs 2 and 3 are onsite waste areas located inside of the secured fenced area of PGDP. The perimeter fence is patrolled, and public access would not be expected to occur. The combined contaminated area is approximately 85,200 ft^2. As previously stated, WMU 2 has a 6-in. clay cap, and WMU 3 has a multilayer RCRA cap. Although periodic maintenance activities occur at the site, routine daily activities do not. No domestic use groundwater withdrawal wells have been identified at PGDP; potable water is obtained from the Ohio River.

2.6.1.2.1.2 Potential Future Onsite Land Use. Risk assessment requires evaluation of alternative future uses. *Risk Assessment Guidance for Superfund (RAGS)* (EPA, 1989a) directs that alternative future land use should be based on available information and professional judgment considering master plans, Bureau of the Census projections, and established land-use trends in the general area and in the area immediately surrounding the site. A consistent policy for future land use assumptions for waste management areas is currently being developed and will be submitted to EPA for review. Based on current policy, WMUs 2 and 3 are within the onsite secure area where the future use is considered to be industrial.

Industrial land use is appropriate for areas within the PGDP security fence because the PGDP is an operating industrial facility owned by the federal government. It is reasonable that the federal government will maintain control of the waste management facilities within the PGDP and that such government control will prevent residential use of this site. This future land use designation is consistent with current DOE Oak Ridge Operations policy.

Alternative industrial uses in the area of WMUs 2 and 3 could increase the frequency of the exposures at this site. In addition, industrial development in this area may increase exposure to shallow subsurface contaminants (to 6 ft).

The onsite residential scenario is evaluated for a time in the future when the DOE and the federal government cannot be assumed to exist with 100% certainty. In the event that current policy and land use restrictions no longer apply, it would be possible that residents would build houses onsite, and use groundwater for drinking purposes.

Groundwater in the RGA is considered a potential source of potable water. This groundwater is not expected to be used as a potable water supply under the future industrial use; however, contaminants from this area may contribute to offsite groundwater contamination. The UCRS is not considered a potential source of potable water, but may represent conservative concentrations for continuing releases to the RGA.

Therefore, future onsite and offsite residential use of groundwater is addressed in this risk assessment by considering both the RGA and UCRS at the edge of the WMU as potential sources of potable water. Additional risk characterization will be conducted for the groundwater integrator OU. That characterization will assess residential use of onsite groundwater by considering leaching of contaminants from soil to groundwater. That evaluation will not be WMU-specific, but will address the PGDP as a whole.

2.6.1.2.1.3 Potentially Exposed Population. This assessment evaluates potential risks for onsite workers and less frequently exposed workers or intruders as well as future onsite and offsite residents. The following receptor populations were considered for the land use at WMUs 2 and 3:

Land Use	Current Receptors	Future Receptors
Industrial	Worker/intruder	Offsite resident Onsite worker Worker/intruder
Residential		Onsite Resident

The future onsite worker in the industrial setting is considered a person working in the WMU areas who is not covered under the Occupational Safety and Health Administration (OSHA) Guidelines for working in the plant. The worker/intruder in the industrial setting is considered a person who inadvertently or infrequently may enter the WMUs 2 and 3 area. The onsite and offsite residents are considered future users of groundwater (beneath the WMUs and the onsite resident would be potentially exposed to soil.

2.6.1.2.2 Analysis of Exposure Pathways

Exposure may occur when contaminants migrate from the source areas to an exposure point or when a receptor comes into direct contact with waste or contaminated media at the site. Exposure pathways are illustrated in the conceptual model shown in Figure 2-5. Pathways are summarized in Table 2-12 for current and future land-use scenarios.

2.6.1.2.2.1Onsite Worker/IntrudersExposure to Onsite ContaminatedSoil. Onsite workers and worker/intruders may be exposed to onsite contamination in surface soils by ingestion, dermal absorption, inhalation of dust, and/or external radiation exposures. These direct contact exposures typically occur from contact with the upper few inches of soil. However, because only two surface soil samples (zero to 1 foot below land surface) were taken at WMUs 2 and 3, concentrations of constituents in the upper 6 ft of soil are considered for potential receptor contact.

Because the burial grounds are within the secured area, worker/intruders are not expected to encounter chronic exposure to soil contaminants at WMUs 2 and 3 under current exposure assumptions. The area may become more accessible in the future industrial exposure setting. See Direct Intrusion Pathway below.

Alternative future industrial uses may increase the frequency of onsite worker exposure and as a result of disruption of soils may bring constituents in the deeper soil zones to the surface. However, the deeper soils may contain the more mobile contaminants, like TCE, that are unlikely to present long-term chronic exposures at the surface.

Table 2-12
Exposure Pathway Analysis for WMUs 2 and 3

Potentially Exposed Populations	Exposure Route, Medium, and Exposure Point	Pathway Selected for Evaluation? Current	Pathway Selected for Evaluation? Future	Reason for Selection or Exclusion
Onsite Workers/Intruders	Ingestion, dermal absorption, inhalation, and external radiation exposure from chemicals in soil	Yes	Yes	Contaminants present in surface soil, workers present in the onsite secure area. Intruder is unlikely, but evaluated based on limited worker exposure assumptions.
	Direct intrusion into waste pit.	No	Yes	Current plans and DOE policy prohibit workers from directly intruding on the waste pits themselves. Future scenario of direct intrusion to be evaluated qualitatively.
	Ingestion of contaminants and inhalation of VOCs from use of groundwater onsite.	No	No	No Supply wells currently located onsite. Ohio River to remain water source in order to meet industrial requirements.
Future Residents	Ingestion, dermal absorption, inhalation, and external radiation exposure from chemicals in soil, as well as direct waste intrusion. • Onsite • Offsite	No No	Yes No	Current land use is industrial. Future residents will be evaluated qualitatively for gamma exposure, soil exposure pathways, and direct waste intrusion. Soil contamination limited to onsite.
	Offsite surface water recreational exposure to contaminants migrating from WMUs 2 and 3	No	No	Surface migration pathway evaluation suggests contaminants are not migrating to surface water as a probable condition. However, this pathway will be further evaluated in the surface water operable unit (OU) investigation.
	Ingestion of groundwater contaminants and inhalation of VOCs from use of groundwater onsite • Onsite • Offsite	No No	Yes Yes	Future onsite residents are evaluated under a reasonable maximum exposure scenario. The burial grounds are potential sources of offsite groundwater contamination. Estimation of chemical concentrations in offsite groundwater will not be determined by fate and transport modeling but will default to concentrations in onsite groundwater. That is to say, the risks from future use of offsite groundwater is estimated to be, at worst, equal to future use of onsite groundwater.
	Ingestion of biota, crops	No	No	No transport offsite, future residential exposure by this route is insignificant relative to other routes.

2.6.1.2.2.2 Direct Intrusion into Waste Pit. In the event that the existing clay cap on SWMU 2 is not fortified and that future long-term weathering erodes the cap, it may be possible for the waste now buried to become more easily accessed. Future onsite workers, intruders, and residents may dig into the waste unit itself (for whatever reason). A qualitative analysis of the direct intrusion will be made, regarding the pyrophoricity of uranium metal shavings and other potential hazards associated with SWMU 2. SWMU 3 is not considered to be as potentially accessible in the future, considering the constructed and maintained RCRA cap.

2.6.1.2.2.3 External Radiation (Gamma) from Buried Uranium Waste. Onsite workers and future residents may be exposed to gamma radiation coming from the buried uranium waste. An onsite gamma survey conducted in July 1994 by MMES health physicists indicates that the gamma dose is highest at the north side of WMU 2, which receives gamma radiation "shine" from the cylinder yards. The drop in gamma readings from about 240 μRem/hour to about 100 μRem/hour, suggests that the "shine" from the cylinder yard may be contributing over half of the gamma dose at the area surrounding WMU 2. In the absence of conclusive evidence, the gamma readings taken at WMU 2 will be taken at face value and not adjusted for actual contribution from WMU 2 alone.

2.6.1.2.2.4 Migration of Contaminants to Surface Waters. Transport of contaminants from WMU 2 to surface waters is not a probable migration pathway, but has been identified as a reasonable deviation. This area is relatively level and has a clay cap over the waste, reducing potential releases with runoff. The interpretation of the surface migration pathway presented in Section 2.4 suggests that the contamination appears to coincide with the ditches surrounding the former burial grounds and leading to Outfall 015. Potential releases to offsite surface water will be evaluated as part of the surface-water integrator OU. WMU 3 is not considered a source of offsite contamination in surface water.

2.6.1.2.2.5 Migration of Contaminants to Air. Transport of contaminants to air as a result of dust generation has been identified as a reasonable deviation. WMUs 2 and 3 are vegetated or covered; however, due to the low mobility of some constituents, they may be present in soil in the future and may be released should the vegetation be disturbed. The evaluation of potential risk from inhalation of contaminants associated with dust in air by onsite workers provides a conservative mechanism to screen the potential contribution of surficial contaminants to the air integrator OU.

2.6.1.2.2.6 Migration of Contaminants to Groundwater. Both former burial grounds are likely sources of contamination of offsite groundwater. Uranium, metals, TCE, and Tc-99 were reported in subsurface soils within the unit and in the UCRS adjacent to the units and to a lesser extent in the RGA, but not in the groundwater downgradient of the units. The migration of groundwater contaminants and the resulting impacts and potential actions will be assessed during evaluation of the groundwater integrator unit. The purpose of this analysis of the "source" area is to evaluate potential future risks associated with groundwater uses.

As described in Section 2.5.3.6, future conditions may lead to solubilization and mobility of the buried uranium waste as WMU 2. The Summers model has been used to estimate uranium concentrations that potentially could be found in UCRS and RGA groundwater in the future. (Refer to Appendix D). The risks presented by this scenario are evaluated for a future onsite resident ingesting UCRS and RGA groundwater.

No wells at the PGDP withdraw water from the onsite groundwater because water is being supplied from the Ohio River for both potable and industrial use. Therefore, under industrial land-use conditions, there is no complete exposure pathway for the onsite groundwater contamination.

Groundwater wells were a primary source of water for offsite residential use in the area surrounding PGDP. In November, 1993, the Department of Energy implemented a Water Policy for the PGDP. All residences and businesses within an affected area north of the plant have been provided municipal drinking water, at DOE expense, as of May 31, 1994. These plant neighbors have agreed not to use existing groundwater wells nor to install any future wells. All existing wells are being locked and capped by DOE. A draft-final Water Policy was submitted in June, 1994, to incorporate (EPA/KDEP) regulator comments. The downgradient groundwater will be conservatively evaluated for offsite residential exposure for the following reasons:

- WMUs 2 and 3 are considered probable contributors to groundwater contamination

- The potential exists for continuing or future releases to the groundwater integrator unit from onsite wastes or contaminated soils at levels of potential current or future concern. In particular, uranium metal shavings are disposed in drums containing oil; future deterioration of the drums could result in release of the uranium and oil contents, with subsequent potential migration to groundwater.

- Onsite groundwater in the RGA is a Class III aquifer suitable for use as drinking water, and regulatory guidance seeks to require protection of groundwater to allow for its maximum beneficial use

The UCRS has a relatively low permeability, and transport of groundwater in that zone is downward. The RGA is the primary aquifer unit where sufficient yields would be present for water supply use and where contaminants would be transported offsite. Estimation of chemical concentrations in offsite groundwater will not be determined by fate and transport modeling, but will default to concentrations measured in onsite groundwater. As previously discussed, contaminant concentrations are generally higher in the UCRS. Therefore, contamination within the UCRS will be used to calculate a conservative reasonable maximum risk estimate. Contaminant contaminations within the RGA will be used to calculate a most likely risk estimate.

2.6.1.2.3 Quantification of Exposure

This subsection presents the basis for quantification of exposure for pathways identified in the previous subsection. Exposure factors and intake variables are summarized in Table A-1 in Appendix A and are based on EPA guidance (EPA, 1991c). The exposure concentrations, the intake equations, and the summaries of intake are included as an attachment to Section 2 in the form of Risk Calculation Tables.

2.6.1.2.3.1 Surface Soil. Surface soils in WMUs 2 and 3 were evaluated on the basis of direct contact exposures of workers to soils. The routes of exposure include ingestion, inhalation of dust, dermal absorption, and external radiation exposures for current and future industrial uses of the property. Intake calculations for these routes of exposure are shown in the attachment.

- Exposure Duration and Exposure Frequency for Industrial Exposures. An reasonable maximum estimate for worker exposures to contaminants in onsite surface soils assumes unrestricted continuous worker exposure at WMUs 2 and 3. These standard assumptions [Office of Solid Waste and Emergency Response (OSWER) Directive 9285.6-03; EPA, 1991a] for workers define exposure as 8 hr a day for 250 days a year at the site. These standard assumptions for the onsite worker are considered excessive for WMUs 2 and 3 under current operating conditions, but they provide a conservative estimate for industrial workers who may be frequently exposed.

  A more realistic scenario (most likely estimate) for an onsite worker would be exposure approximately 10 percent of the time (25 days a year or biweekly during the working year), such as during maintenance activities. This reduced exposure also provides a conservative estimate for potential risks to intruders into the secure area. This exposure scenario is referred to as the worker/intruder scenario.

- Exposure Concentrations for Soils. Under current land use conditions, direct contact exposures to surface soils would occur for only the upper few inches of soil. However, for future uses where the area may become disturbed during development, the upper 6 ft are considered for potential exposure. Because only two surface samples were taken at these units, exposure concentrations were calculated from results on samples within 6 ft bls.

  In determining the concentrations most representative of potential exposures at WMUs 2 and 3, the results above the detection limit were considered together with the results below the detection limits, by assuming concentrations of undetected samples equal to the detection limit. Parameters that were not detected in any sample in the data set under evaluation are not included. This approach to estimation of exposure point concentrations does not account for reductions in concentrations that would occur before future residential exposures. For example, volatile constituents will not persist in surface soils for extended exposure periods of 25 years.

The estimation of exposure point concentrations assumes a lognormal distribution of the data. The exposure point concentrations calculated for this assessment are based on the following equation for the 95 percent upper confidence limit on the arithmetic average (EPA, 1992b):

$$\mathrm{UCL}_{95} = e^{(\overline{x_{\ln}} + s_{\ln}^{2}/2 + H_{.95}\, s_{\ln}/(n-1)^{1/2})}$$

where

UCL_{95} = 95% Upper Confidence Limit on the Arithmetic Mean
e = constant (base of the natural log, equal to 2.718)

$\overline{x_{\ln}}$ = arithmetic average of the log-transformed data
$s_{\ln}$ = standard deviation of the log-transformed data
n = number of samples
$H_{.95}$ = the H-test statistic for 95 percent upper confidence limit

Where the calculated UCL_{95} value exceeded the maximum observed concentration, the observed maximum value was used to calculate risks.

- Soil Ingestion. It is assumed for this evaluation that the onsite worker or worker/intruder may ingest 50 mg of soil per daily site visit (OSWER Directive 9285.6-03; EPA, 1991a). This ingestion rate is based on activities in a typical workplace where outdoor activities are conducted. The ingestion rate of 50 mg/day is, therefore, considered conservative for both reasonable maximum and most likely estimates under industrial exposure conditions.

- Inhalation. Air samples from the WMUs 2 and 3 vicinity were not collected during the site investigation. However, dust releases from WMUs 2 and 3 are expected to be minimal since the WMUs are covered with grass. The potential release of dust to the air is based on a default value for the particulate emission factor (PEF) of 4.63×10^{9} m^{3}/kg, consistent with the EPA guidance on development of PRGs for soils under industrial settings (EPA, 1991d). The reasonable inhalation rate for the occupational setting was estimated to be 20 cubic meters (m^{3}) per 8-hr work day (OSWER Directive 9285.6-03; EPA, 1991a), and was used for both reasonable maximum and most likely estimates.

- Dermal Absorption. Absorption through the skin is a function of the type of contaminants, the concentrations of those contaminants in the soil, the mass of soil in contact with the skin, the area of skin contacted, and the duration and frequency of the contact. These factors are not generally estimated or well-correlated and understood. Instead of using these factors to define absorption, an alternative approach is to assume that a certain percentage of contaminants in the soil adhere to the skin and are absorbed. Information to support the selection of specific absorption values is limited. Default assumptions from new Interim Region IV guidance (EPA, Region IV, Feb. 11, 1992) were used that include 0.1 percent absorption for metals and 1 percent absorption for organic constituents and an adherence factor of 1 milligram per square centimeter (mg/cm^2) (EPA 1992b).

The potential for dermal absorption of radionuclides through contact with soil is of minimal significance at the PGDP. In general, dermal uptake is not an important route of uptake for most radionuclides because of low dermal-permeability constants for most radionuclides (EPA, 1989). None of the radionuclides found at PGDP present significant dermal intake potential. In addition, the duration of dermal contact with contaminated soil is relatively short. As a result, the potential for exposure to radionuclides through dermal intake is minimal compared to the other potential routes of exposure. For this reason, dermal intake was not calculated for radionuclides.

Dermal absorption is estimated for adult workers. For this assessment, the surface area in contact with soils was the 50th percentile for specific body part areas in males. Workers were estimated to have potential exposures to the head, hands, and forearms.

Oral SFs and RfDs are used in assessing risks that result from dermal absorption. No corrections were made to these toxicity values in applying them to dermally absorbed doses.

*2.6.1.2.3.2 **Subsurface Soil.*** Direct contact exposure to subsurface soils is considered unlikely because of the dangers of pyrophoric uranium waste makes excavation a very unlikely activity. However, the presence of contaminants in these soils suggests potential for continuing releases to groundwater. Contaminated subsurface soil would be a secondary source for groundwater contamination; the buried waste would be the primary source. The Summers model was used to evaluate the relationship between contaminants in soil and potential releases to the groundwater integrator unit.

*2.6.1.2.3.3 **Groundwater.*** Groundwater exposure routes include ingestion of contaminants and inhalation of VOCs during future offsite and onsite domestic use of groundwater. Intake calculations for these routes of exposure for groundwater are shown in the appendix and in the Risk Calculation Tables.

- Exposure Duration and Exposure Frequency. Conservative estimates for domestic use of groundwater assume an exposure duration of 30 years (national reasonable maximum time at one residence) and 350 days per year (EPA, 1991c). The national median time at one residence is 9 years. (EPA 1989, RAGS)

- Exposure Concentrations for Groundwater. Risk due to ingestion of groundwater was estimated for each monitoring well using average concentrations calculated from all rounds of data for the monitoring well. Those wells which had the highest risk were selected for estimation of total risk. These wells included MW-93 (RGA) for chemical carcinogenic effects; MW-89 (RGA) for noncarcinogenic effects; MW-84 (RGA) and MW-154 (UCRS) for radiological carcinogenic effects; and MW-74 (UCRS) for both chemical carcinogenic effects and noncarcinogenic effects. Total risk was calculated for the selected wells using the monitoring well's average chemical concentrations as the exposure point concentrations. Risks were estimated for each of the individual constituents detected in samples collected from these wells. In addition, cumulative risks from combined exposure routes are calculated for the individual RGA wells and UCRS wells.

Modelled concentrations for future onsite groundwater ingestion and inhalation scenarios were obtained from SAIC (see Appendix D) as preliminary estimates of undiluted uranium concentrations in groundwater at an unspecified time in the future, in the case of no remediation. Although these concentrations are not intended to be conclusive, they will provide an reasonable maximum concentration for the onsite future resident, in the absence of remediation.

- Ingestion. A per capita ingestion rate of 2 L/day was assumed, which is the rate adopted by the National Academy of Sciences (NAS) and used by EPA (OSWER Directive 9285.6-03; EPA, 1991a). Exposures in residential settings are assumed to occur over a 30-year period with a 70-kg body weight. These assumptions were used for both chemical and radiological constituents.

- Individuals may also be exposed to VOCs like TCE that have been transferred to the air from tap water in showers, baths, toilets, dishwater, washing machines, and cooking. Estimate of intake resulting from potential inhalation of volatile compounds during domestic use of groundwater was based on the method of Andelman (1990), as presented in RAGS, Volume I, Part B (EPA, 1991d), as the basis for development of risk. The equation uses a default volatilization constant (K) reasonable maximum value of 0.0005 x 1,000 L/m^3 and an estimated daily indoor inhalation rate of 15 m^3/day. The volatilization constant assumes: a water use rate of 720 L/day for a family of four; an air volume within a dwelling of 150,000 L; an air exchange rate of 0.25 m^3/hr; and a transfer rate of 50 percent (i.e., half of the concentration of each chemical present in water will be transferred into the air as a result of all types of water uses). As with ingestion, the exposure is considered to occur over a 30-year period with a 70-kg body weight.

- Dermal Absorption. Absorption of contaminants through the skin is another potential route of exposure associated with water use. Dermal absorption could occur during bathing, showering, food preparation, and washing dishes. Estimates of the amount of chemical intake that can result from dermal absorption of chemicals in water are variable. For most contaminants, dermal contact with water during bathing will generally pose less threat than direct consumption of water. The fastest penetrating contaminants, those with permeability coefficients (K_p) less than 0.1 cm/hour, may pose hazards similar to direct ingestion. Dermal absorption from domestic use of water was not quantified in this assessment.

- Exposure Point Concentrations for Gamma Radiation from Waste Pit. A gamma survey of the surface of SWMU 2 was conducted on August 10, 1994 by MMES health physicists, using a Bicron Micro-R detector which measures gamma radiation in units of μRem/hour. This survey is included in Appendix D. An average value for the whole area is not used, since the interference caused by the uranium cylinder yard on the north artificially elevates the gamma dose readings on that side. Also, since the contents of SWMU 2 are not expected to vary significantly from the north to the south side, the readings obtained from the south side will be used to determine a gamma dose rate applicable to the impoundment itself.

2.6.1.3 Toxicity Assessment

This toxicity assessment evaluates the potential for those chemicals of concern expected to contribute most to overall risk estimates. Potential adverse human health effects are based on a review of available scientific evidence. The toxicity assessment also estimates the degree of exposure to a contaminant and the possibility of adverse health effects.

Adverse or toxic effects in biological systems are not produced by a chemical agent unless that agent or its biotransformation products reach appropriate sites in the body at specific levels and for a period of time sufficient for producing an effect. The occurrence of a toxic response depends on the following factors:

- Chemical and physical properties of the toxic agent
- Exposure of an individual to the agent
- Susceptibility of an individual to the particular effect of the agent
- The type of effect it can produce
- The concentration needed to produce that effect

For radioactive substances, the toxic effect depends on how much energy is transferred to the critical cellular components [for example, deoxyribonucleic acid (DNA) or proteins] by radiation. This energy depends on the type of ionizing radiation generated by the radioactive material and the amount of time that the cells are irradiated. The toxicity of radioactive materials that are taken into the body depends on where the materials are deposited in the body and how long they remain.

The toxicity assessment has two major components: (1) dose-response evaluation and (2) hazard identification. Dose-response evaluation quantitatively examines the relationship between the level of exposure and the occurrence of adverse health effects in the exposed population. Hazard identification involves examination of the adverse human health effects that may result from exposure to the detected contaminants.

2.6.1.3.1 Chemical Hazards. Chemical contaminants are divided into two broad groups according to their effects on human health: (1) contaminants that exhibit carcinogenic effects and (2) contaminants that exhibit noncarcinogenic or systemic effects. Carcinogenic effects result in or are suspected of resulting in the production of cancer. EPA classifies a carcinogenic compound based on evidence as to its carcinogenicity and the quality of the evidence. The classes of carcinogenic compound are as follows:

- Class A: Human Carcinogen. Sufficient evidence exists to support a cause and effect relationship of cancer in humans.
- Class B: Probable Human Carcinogen. Limited evidence to support cancerous effects in humans (Class B1) or sufficient evidence to support cancerous effects in various animal species (Class B2) exists.
- Class C: Possible Human Carcinogen. No evidence to support cancerous effects in humans; however, limited evidence to support such effects in animals exists.
- Class D: Not Classified. Data to support cancerous effects in humans or animals does not exist or is of insufficient quality to render a judgment.
- Class E: No Evidence of Carcinogenicity in Humans. Both human and animal data are negative in terms of carcinogenic effects.

Systemic effects cover a variety of toxicological endpoints such as inhibition of or disruption of certain physiological or biochemical processes, and may include effects on specific organs or systems.

2.6.1.3.1.1 Chemical Dose Response Evaluation. Critical toxicity values are a quantitative expression of the dose-response relationship for a chemical. Although the toxicological properties must be understood prior to establishing a reasonable basis for a dose-response relationship, the toxicity values used in this risk assessment are based on published values. The toxicity values and classifications (RfDs, SFs, and cancer classification) summarize the current state of knowledge about the contaminants and provide a basis for the quantitative assessment.

Critical toxicity values for noncarcinogenic effects (Table A-2 in Appendix A) and for carcinogenic effects (Table A-3 in Appendix A) used to assess the risk from exposure to chemical hazards are based on values from the EPA Integrated Risk Information System (IRIS). If values are not available from IRIS, then values from Health Effects Assessment Summary Tables (HEAST), presented in the guidance provided by the Biomedical and Environmental Information Analysis Section (BEIAS) (MMES, 1992c) are used in this assessment. BEIAS guidance was prepared from the EPA Annual

Fiscal Year (FY) 1992 HEAST (EPA, 1992d) and from IRIS, updated through February 1992 (EPA, 1992c). Also, the critical effects and type of cancer along with confidence levels for these toxicity values and weight of evidence classifications for primary contaminants contributing to risks are shown in Tables A-2 and A-3.

Recently, EPA has begun developing subchronic and developmental RfDs. Subchronic RfDs are useful for characterizing potential noncarcinogenic effects associated with shorter term exposures (2 weeks to 7 years). This assessment assumes chronic lifetime exposures to the contaminants. Exposure periods are typically 25 to 30 years, and it is assumed that child exposures continue after age 6. Subchronic RfDs are not available for many constituents (TCE and PCBs) or are equal to the chronic RfD (1,2-DCE, arsenic, and beryllium), therefore subchronic RfDs are not used in this assessment. Developmental RfDs are used to evaluate the potential effects on a developing organism following a single exposure event. However, no developmental RfDs are currently available for the primary chemical constituents.

2.6.1.3.1.2 Chemical Hazard Identification. The mode of action currently associated with chemicals that exhibit carcinogenic and noncarcinogenic effects marks the division between the categories of contaminants. Even though the contaminants have been divided into categories of carcinogens or systemic toxicants, some elicit both types of effects. In addition, this assessment distinguishes between the chemical and radiological effects of contaminants, even though the final result (cancer) is the same. The potential risks for chemicals and radionuclides are not combined.

Some of the chemical contaminants that may contribute to risks at this site include pentachlorophenol; 2,4-Dinitrotoluene; N-nitroso-di-n-propylamine; OCDD; phenolic compounds; and the metals beryllium, arsenic, lead, chromium, barium, manganese, and soluble salts of uranium. Metals that have been identified are naturally occurring and, consequently, interpretation of these results must consider background effects. These chemical constituents are discussed briefly in the following paragraphs. In addition, TCE is discussed below since it is the major contaminant found offsite.

- **TCE** is a chlorinated solvent that has been used primarily as a metal degreaser. TCE is a common contaminant of air, water (including groundwater), and soils. Humans can absorb TCE by inhalation, ingestion, or dermal contact. There is currently no epidemiological evidence linking human exposure to TCE with an increased incidence of cancer, but TCE has been shown to cause cancer in mice and rats. TCE is classified as a B2 carcinogen for both oral and inhalation routes of exposure.

- **Pentachlorophenol** is an organic compound widely used in the wood preserving industry. Commercial formulations of pentachlorophenol typically contain other compounds as impurities. It is expected to be relatively mobile in the soil/groundwater system at low concentrations. Exposure may be primarily through ingestion, although inhalation and dermal absorption may also contribute to chemical intake. Exposure to pentachlorophenol can cause central nervous system (CNS) effects and local irritation to skin, mucous membranes, and respiratory tract, and liver and kidney toxicity. Absorption through skin has been shown to cause abnormal heartbeat, respiratory distress, and liver toxicity. Long-term dermal exposure to pentachlorophenol can cause chloracne, a dermatitis-like skin disease. Inhalation of pentachlorophenol over long periods may cause liver and CNS toxicity, and some reports suggest pentachlorophenol may alter human immune response. There is limited evidence that exposure to pentachlorophenol causes cancers of blood and soft tissues. EPA classifies pentachlorophenol as a B2 carcinogen.

- **N-nitroso-di-n-propylamine (dipropylnitrosalmine)** is an organic compound with industrial application. The primary exposure route for this compound is via ingestion of contaminated soil and groundwater. Data about noncarcinogenic health effects is limited. However, N-nitroso-di-n-propylamine is classified by EPA as a B2 carcinogen because of sufficient evidence of increased tumor incidence at multiple sites in animals. Sufficient evidence of cancer in humans resulting from exposure to N-nitroso-di-n-propylamine is lacking.

- **2,4-Dinitrotoluene** is an organic compound with wide industrial application. The primary route of exposure to 2,4-dinitrotoluene is via ingestion of contaminated soil and groundwater. Information concerning noncarcinogenic health effects is limited. However, 2,4-dinitrotoluene is classified as a B2 carcinogen by EPA due to sufficient evidence of cancer incidence in animals. Clear evidence of carcinogenicity in humans is lacking.

- **Dioxins** are groups of related halogenated aromatic hydrocarbons that may be associated with the presence of PCBs. The most well known of these is 2,3,7,8-tetrachlorodibenzo-p-dioxin, or TCDD. The reputation of TCDD is largely a result of its extreme potency to cause cancer in some animal species. Despite a substantial amount of human exposure information, these extreme effects have not been shown to occur in humans. Other compounds in this class [including polychlorinated dibenzofurans (PCDFs) and polychlorinated dibenzodioxins (PCDDs)] are structurally related and cause similar effects. These classes are designated by the number of chlorines attached to the ring (for example, 2,3,7,8-tetrachlordibenzo-p-dioxin has a total of four chlorines attached at the 2,3,7,and 8 positions of the rings). The CDDs and CDFs were detected only in onsite surface soils and in pond, lake, and marsh sediments at PGDP. The CDDs and CDFs detected in surface soils onsite at PGDP include hexachlorodibenzofuran (HxCDF), heptachlorodibenzo-p-dioxin (HpCDD), heptachlorodibenzofuran (HpCDF), OCDD, and octachlorodibenzofuran (OCDF).

  Currently, only limited experimental animal evidence is available for CDDs and CDFs that can be used for cancer risk assessment. Substantial evidence exists for TCDD, but exclusive use of this information would most likely lead to an overestimation of risks. The EPA has devised an interim approach that involves the use of Toxicity Equivalency Factors (TEFs) (EPA, 1989b). The TEF approach assumes a relative potency compared to TCDD (that is, TCDD = 1). Use of these factors will provide an estimate of cancer that is related to the potency of the particular CDD or CDF. The TEFs for the CDDs/CDFs detected at the PGDP are as follows:

HxCDF	:	0.1
HpCDD	:	0.01
HpCDF	:	0.01
OCDD	:	0.001
OCDF	:	0.001

- **Arsenic** is present naturally in the environment. Man-made sources of arsenic include the burning of fossil fuels, pesticide use, mining operations, ore smelters, and chemical manufacturing. Arsenic occurs in many different organic and inorganic forms, which vary widely in their toxicity to humans. In general, the inorganic forms are more toxic than the organic forms. The toxicity of a particular arsenic compound is dependent on its physical state, the dose and exposure duration, and the route of exposure. Absorption of arsenic from drinking water can be high.

  Inorganic arsenic is known to be carcinogenic in humans. Inhalation of arsenic has been linked with an elevated risk of lung cancer in chronically exposed individuals. Some studies have also reported noncarcinogenic effects such as vascular disorders, skin abnormalities, neurological changes, pulmonary damage, liver damage, hematological changes, and reproductive and chromosomal abnormalities in these individuals.

According to IRIS, even though inhalation and ingestion of arsenic potentially cause cancer in humans, arsenic has potential essential nutrient value (NAS, 1983). IRIS also notes that recent memorandum by the Administrator of the EPA recommended that a unit risk of 5×10^{-5} be adopted.

- **Barium** is present naturally in the environment. Its industrial use is primarily in various metal alloys, paints, and other products. Exposure to barium may be via ingestion and inhalation of contaminated dust particles. The toxicity of barium compounds depends on their solubility. Compounds such as barium salts are relatively soluble, and ingestion can cause paralysis, cardiovascular abnormalities, and gastroenteritis. Prolonged inhalation of barium has resulted in baritosis, a benign, reversible pneumonia-like disease, found primarily in exposed workers.

- **Beryllium** is present naturally in the environment. Exposure to beryllium is primarily through inhalation, because the metal is released by the burning of coal or fuel oil. The greatest exposure occurs in the work place, and most of what is known about the health effects of beryllium is based on studies of workers. Inhalation of beryllium dust can produce the noncancerous "beryllium disease." Inhalation of beryllium is clearly carcinogenic in animals, but the evidence for carcinogenicity in humans is inconclusive. Beryllium and its compounds are rarely or poorly absorbed from the gastrointestinal tract. Although information in humans is lacking, animal studies indicate that less than 1 percent of the amount of ingested beryllium is absorbed.

- **Chromium** is potentially present in the hexavalent or trivalent forms. Of these, the hexavalent form is more toxic and mobile. Risks associated with chromium are conservatively evaluated using the assumption that all reported chromium is in the more toxic hexavalent form. Hexavalent chromium would be expected to be reduced to the trivalent form in groundwater with high dissolved iron concentrations, such as those reported at PGDP. Trivalent chromium may be present in monitoring wells associated with particulates.

- **Manganese** is an essential element in all living organisms, serving as a cofactor in a number of enzymatic reactions. A major source of manganese is food, but it is generally also present in water supplies. The body has a regulating mechanism to control the levels of manganese, reducing systemic toxicity following oral or dermal exposure. Most of the toxic effects of manganese have been associated with inhalation exposure.

- **Lead** is present naturally in the environment. Infants and young children are the most vulnerable populations exposed to lead and are the focus of EPA's risk assessment efforts for this metal. Elevated levels of lead have been associated with increased risks of potentially adverse effects on neurological development and diverse physiological functions. Lead is also classified as a B2 carcinogen. Currently, no toxicity values are presented for lead.

- **Uranium** is present naturally in the environment. However, given the nature of industrial processes at PGDP, varying isotopic concentrations of uranium may be present onsite. Exposure to uranium salts may be primarily via ingestion of soil and groundwater. Uranium exposure may cause toxic effects other than those associated with radioactive decay, primarily as insoluble uranium salts (see radiological hazards section for effects of radioactive uranium). Acute kidney damage and kidney failure may occur as a result of ingestion and dermal exposure. Inhalation of uranium salts has caused respiratory tract irritation.

2.6.1.3.2 Radiological Hazards

2.6.1.3.2.1 Radiological Dose Response Evaluation. Radiological risks are usually expressed as an increased probability of cancer, similar to chemical carcinogenic risks. However, radiological risks have historically been expressed as the increased probability of induction of a fatal cancer, while chemical risks are usually expressed as the increased probability of cancer incidence. This assessment expresses radiological risks as increased risk of total cancer incidence, in accordance with EPA methods outlined in RAGS.

Another difference between chemical and radiological risk assessment methods lies in the use of radiation dose equivalent as the primary expression of harm from exposure to radiation. Radiation risks are often calculated by determining the dose equivalent received (in rems), and applying a factor that converts dose equivalent to risk. In chemical risk assessments, an intake of chemicals (usually expressed in mg/kg-day) is converted to risk, using an intake to risk conversion factor (SF, RfD). This assessment uses the intake to risk approach to determine radiological risks. However, effective dose equivalent values are also calculated for use in comparison to standards.

2.6.1.3.2.2 ***Radiological Hazard Identification.*** The effects of exposure to ionizing radiation fall into three general categories: (1) carcinogenic effects, (2) genetic effects, and (3) teratogenic effects. For this assessment, only the effects of exposure to low levels of ionizing radiation are evaluated. The most significant potential health effects of exposure to low levels of radiation are cancer induction in the exposed individual and possible genetic effects in the descendants of the exposed individual.

Radiation produces damage in biological systems through ionization of molecules. Damage may occur directly, as when a chromosome breaks into smaller pieces after absorption of energy from radiation. Damage may also occur indirectly through ionization of water molecules to produce highly reactive free radicals. The free radicals may react with other cellular compounds and cause damage through oxidation reactions.

The biological effects of radiation are classified as either nonstochastic or stochastic effects. Nonstochastic effects are those for which severity is related to dose. Examples of nonstochastic effects include reddening of the skin (erythema) and cataracts. Because nonstochastic effects are principally associated with high levels of radiation exposure (>10 rem), it is highly unlikely that individuals around PGDP could ever receive radiation doses that would cause nonstochastic effects. Stochastic effects are those for which the probability of occurrence increases with the cumulative dose. The stochastic effects associated with low levels of radiation exposure include cancer, genetic effects, and damage to a developing fetus. Only the stochastic effects of radiation exposure are considered in this assessment.

2.6.1.3.2.3 ***CarcinogenicEffects.*** Ionizing radiation is a demonstrated human carcinogen. Data exist that correlate high exposures of radiation to cancer induction in humans. In general, scientists agree that the probability of cancer increases with dose, but scientists continue to debate which dose-response model most accurately predicts the effects of low-level radiation exposure. Current radiation protection standards are based on the idea that each increment of radiation exposure causes a linear increase in the risk of cancer (the linear nonthreshold hypothesis).

The U.S. NAS, National Research Council, Committee on the Biological Effects of Ionizing Radiation (BEIR, 1990), recently completed a study entitled *Health Effects of Exposure to Low Levels of Ionizing Radiation* (otherwise known as BEIR V). The study included information from the continuing epidemiological studies of the Japanese survivors of the atomic bomb. The BEIR V Committee concluded that the linear nonthreshold dose-response model most accurately predicts the increased risk of most forms of cancer from exposure to low doses of radiation. The BEIR V Committee also increased the cancer risk estimates for radiation exposure from the 1980 BEIR III Report by a factor of 3 to 4, based primarily on results of studies that reevaluated the actual radiation doses received by the Japanese survivors of the atomic bomb.

EPA also recently finished evaluating the cancer risk from radiation exposure as part of the safety analysis for radionuclide standards for atmospheric releases [known as National Emission Standards for Hazardous Air Pollutants (NESHAPS)]. Although EPA's methodology differs slightly from that of the BEIR V Committee, the results of both studies are similar. Table A-4 in Appendix A includes a summary of the current factors for estimating risk used by EPA for cancer induction and cancer mortality from radiation exposure. These factors for estimating risks are in terms of the excess cancer induction and excess cancer deaths expected in a population of 1 million people, each person exposed to a radiation dose of 1 rad (risk/10^6 rad).

2.6.1.3.2.4 Genetic Effects. Radiation can cause damage to cells by changing the number, structure, or genetic content of the genes and chromosomes in the cell nucleus. These heritable radiation effects are classified as either gene mutations or chromosome aberrations. Gene mutations and chromosome aberrations may occur in either somatic (body) or germ (reproductive) cells. When the mutation or aberration occurs in a somatic cell, the damage is expressed in the exposed individual. For somatic-cell mutations, the worst consequence of the damage is cancer induction. When the mutation or aberration occurs in a germ cell, the resulting damage may be expressed in the descendants of the exposed individual.

Genetic effects have not been observed in follow-up epidemiological studies of human populations exposed to low doses of radiation. There is general scientific agreement, however, that these effects may be occurring in numbers so low that they are not detectable in the study populations. Because of the lack of conclusive human data, animal studies are used to determine risk factors for heritable effects in humans.

The results of animal studies have shown that radiation increases the spontaneous, or natural, mutation rate. No new types of mutations have been attributed to radiation exposure. Estimates based on extrapolation from these animal studies are that at least 100 rad of low-dose rate, low-linear energy transfer (LET) radiation are needed to double the spontaneous mutation rate in man. Current human dose response models, however, assume that the probability of genetic damage increases linearly with radiation dose, and there is no evidence of a "threshold" dose for initiating heritable damage to germ cells.

Table A-5 in Appendix A includes a summary of the current information on the risks of genetic effects from radiation exposure. The risk factors are stated in terms of severe hereditary defects per million liveborn babies for an average population exposure of 1 rad of low-LET radiation in a 30-year generation. In estimating risks of genetic effects, EPA uses the values of 20 severe hereditary defects per generation and 260 severe hereditary defects for all generations (1,000 years) in a birth cohort (people of the same age) that are a result of exposure of the parents to 1 rad per generation.

2.6.1.3.2.4 Teratogenic Effects. Relatively high doses of radiation exposure have been shown to produce abnormalities in animals and humans exposed in utero. The effects of radiation exposure to the fetus vary with the stage of gestation. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) has developed quantitative risk estimates for effects of prenatal irradiation (primarily mental retardation) over the different stages of pregnancy. Possible risks of fetal radiation exposure include mental retardation, development of fatal cancer after birth, malformation, and preimplantation loss (spontaneous abortion). Table A-4 in Appendix A includes a summary of the current EPA risk factors for radiation exposure to the fetus.

2.6.1.3.2.5 Summary. Cancer induction through exposure to low levels of radiation constitutes the most significant potential consequence of exposure. The risks of heritable effects from radiation exposure are much lower than cancer induction for the first few generations. Carcinogenic effects can be induced at any point during a lifetime. However, exposures must occur during a specific period during gestation for the risks of effects on the developing fetus to be significant. In most instances, the cumulative risk of cancer is much higher than the risk of fetal effects or genetic effects. For these reasons, cancer induction is used as the basis for assessing the radiation risks to offsite receptors around PGDP. Specific cancer incidence risk factors and dose conversion factors used in this assessment are presented in Table A-5 in Appendix A.

2.6.1.4 Risk Characterization

The risk characterization evaluates the potential carcinogenic, noncarcinogenic, and radiological risks for each of the defined exposure pathways, including the following:

- Ingestion, inhalation, dermal absorption, or external radiation exposures to contaminated surface soil

- Ingestion and inhalation of contaminated groundwater through domestic use

The toxicity values describing the dose-response characteristics of the contaminants were integrated with the exposure intake estimates. Together, they were used to generate estimates of excess lifetime cancer risk for chemicals or radionuclides and the likelihood of noncarcinogenic effects for each exposure pathway.

Detailed tables showing carcinogenic, noncarcinogenic, and radiological risks are presented in Attachments 2-1 through 2-12. The tables summarize the assumptions incorporated in each analysis and show the risks calculated for each contaminant.

The remainder of this section summarizes the carcinogenic, noncarcinogenic, and radiological risk values derived from the detailed tables. As noted in the discussion of the methodology for characterizing risk, the excess lifetime cancer risks represent the sum of risks for chemical carcinogens or suspected carcinogens in the evaluated media. Radiological cancer incidence risks also represent the sum of risks for radionuclides in the evaluated media. Likewise, the hazard indexes (HIs) presented as indicators of noncarcinogenic risk are the sum of the hazard quotients (HQs) for noncarcinogenic contaminants in the evaluated media. By convention, differences in the target organ, the mechanism of toxic action, or the quality of data underlying the toxicity values were not considered when summing risks. This approach tends to overstate the estimated hazard indexes. When estimating cancer risks and other stochastic effects, summing risks is appropriate.

2.6.1.4.1 Surface Soil Exposure Pathways. The receptors under industrial-use scenarios included workers at two different frequencies of exposure designated as follows:

Future Worker, Frequent Potential Exposure: 250 days/year
Current Worker, Remote Location/Intruder: 25 days/year

The second worker exposure frequency was conservative for intruders or visitors.

Routes of exposure associated with contaminants in surface soil include: ingestion, dermal absorption, inhalation, and external radiation.

Chemical risks associated with surface soil are summarized in Table 2-13. The sum of cancer risks over all three pathways for the unrestricted future worker exposure scenario is 5×10^{-6}. The sum for the worker/intruder scenario is 5×10^{-7}. The HIs for the unrestricted future worker exposure scenario and worker/intruder exposure scenarios are 0.07 and 0.007, respectively.

Arsenic is the primary contributor to chemical carcinogenic risk via both the ingestion and dermal absorption routes of exposure. For inhalation, Cr(VI) was the major contributor to the risk, although risks did not exceed 1E-8. Individual risk calculations for each detected compound in soil are provided in Attachments 2-1 and 2-4.

The major contributors to the noncarcinogenic risk, although HIs are less than 1, were arsenic and manganese for dermal absorption and ingestion pathways. Cr(VI) is a major contributor to noncarcinogenic risk for the inhalation pathway, although the HI did not exceed 0.001. Individual HI calculations for detected compounds appear in Attachments 2-2 and 2-5.

Radiological risks were evaluated for ingestion, inhalation, and direct external gamma exposure for the unrestricted worker (future industrial) scenario and the worker/intruder (current industrial) scenario. The sum of radiological risks via the three exposure routes for the future worker and current worker scenarios are 1×10^{-4} and 1×10^{-5}, respectively. Radiological risks associated with surface soil are summarized in Table 2-13.

The primary contributors to radiological risk via the ingestion and inhalation pathways were U-238 and its daughters. For the external gamma radiation exposure pathway, U-238, U-235, and their daughter products are the primary contributors to risk. Radiological risk calculations for each surface soil exposure pathway are shown in Attachments 2-3 and 2-6.

Note that subsurface soil samples were not taken within the boundaries of WMUs 2 and 3 because of the hazards associated with contacting buried drums at this unit. This is particularly significant for assessment of future radiological risks. Potential risks associated with excavation at WMUs 2 and 3 are much greater than those shown from the results of surface soils taken at this unit. Drums of uranium metal shavings are known to be present within WMUs 2 and 3. This material burns upon exposure to air and would present a significant health hazard to excavation workers (see Section 2.6.1.4.2)

It is more appropriate to express risks of excavation of material at WMUs 2 and 3 qualitatively in terms of the potential for individual worker radiation doses exceeding occupational standards, rather than risk of cancer incidence. Under an uncontrolled excavation scenario, the risk of worker radiation doses that exceed DOE occupational radiation protection standards is very high. Under a controlled excavation scenario, it is likely that radiation doses could be maintained within the DOE guidelines if the drums were excavated without exposing uranium metal to air. However, if a drum of uranium metal ignited (under a controlled or uncontrolled scenario), the risks to workers (physical and radiological) would be very high and could include worker fatalities.

Health risks to future onsite residents would be greater than the unrestricted worker due to a greater exposure frequency and a greater incidental soil ingestion rate.

Risks associated with naturally occurring inorganic constituents and radionuclides in soils were estimated using maximum detected concentrations in reference soil samples. Appendix B describes the rationale for the reference sampling and presents results of this analysis. Total cancer risk over all three pathways for the unrestricted worker scenario is 2×10^{-5}, and for the worker/intruder scenario is 2×10^{-6}. The sums of the HIs are 0.07 and 0.007, respectively. Radiological risk sums for these exposure scenarios are 3×10^{-7} and 3×10^{-8}, respectively. Tables B-2 through B-8 show the detailed calculations for background risk.

Table 2-13
Summary of Risk Calculations

Direct Contact to Soil	Most Likely Worker/Intruder (25 day/year)	Reasonable Maximum Exposure Unrestricted Worker (250 day/year)	Chemicals Contributing to Risk (Chemical Specific Contribution)
Cancer Risk Estimate			Intruder: None Unrestricted worker: Arsenic (3×10^{-6})
Ingestion	4×10^{-7}	4×10^{-6}	
Dermal Absorption	6×10^{-8}	6×10^{-7}	
Inhalation	$\underline{1 \times 10^{-9}}$	$\underline{1 \times 10^{-8}}$	
Sum of Pathways	5×10^{-7}	5×10^{-6}	
Chronic HI			Intruder: None Unrestricted worker: None
Ingestion	0.005	0.05	
Dermal Absorption	0.002	0.02	
Inhalation	$\underline{0.0002}$	$\underline{0.002}$	
Sum of Pathways	0.007	0.07	
Radiological Cancer Risk			Intruder:
Estimate	1×10^{-7}	1×10^{-6}	U-238 (1×10^{-6})
Ingestion	2×10^{-8}	2×10^{-7}	U-235 (1×10^{-5})
Inhalation	$\underline{1 \times 10^{-5}}$	$\underline{1 \times 10^{-4}}$	Unrestricted worker:
External Radiation			U-238 (1×10^{-5})
	1×10^{-5}	1×10^{-4}	U-235 (1×10^{-4})
Sum of Pathways			

Ingestion of Groundwater	Future Onsite and Offsite Resident (UCRS)	Future Onsite and Offsite Resident (RGA)	Chemicals Contributing to Risk
Cancer Risk Estimate	$\underline{\text{MW-74}}$	$\underline{\text{MW-93}}$	UCRS: Beryllium (8×10^{-4}) RGA: 2,4-dinitrotoluene (2×10^{-4}) N-nitroso-di-n-propylamine (2×10^{-3}) Pentachlorophenol (8×10^{-5}) Arsenic (7×10^{-5})
Ingestion	8×10^{-4}	2×10^{-3}	
Inhalation	$\underline{\text{---}}$	$\underline{\text{---}}$	
Sum of Pathways	8×10^{-4}	2×10^{-3}	
Chronic HI	$\underline{\text{MW-74}}$	$\underline{\text{MW 89}}$	UCRS: Nickel (.2) Barium (.2) Vanadium (2) Chromium (.8) Cadmium (.3) Silver (.4) Manganese (8) RGA: Thallium (.3) Manganese (20) Arsenic (.4)
Ingestion	12.0	20.8	
Inhalation	$\underline{\text{---}}$	$\underline{\text{---}}$	
Sum of Pathways	12.0	20.8	
Radiological Cancer Risk Estimate	$\underline{\text{MW-154}}$	$\underline{\text{MW-84}}$	UCRS: NP-237 (2×10^{-6}) Tc-99 (3×10^{-5}) U-234 (1×10^{-6}) U-238 (2×10^{-5}) RGA: Tc-99 (1×10^{-5})
	5×10^{-5}	1×10^{-5}	
Ingestion			

2.6.1.4.2 Groundwater Exposure Pathway. No onsite use of groundwater occurs currently at the facility. Releases from WMUs 2 and 3 to the Groundwater Integrator Unit were evaluated assuming potential future residential use of groundwater using currently detected concentrations. Initially, risks from ingestion of groundwater were calculated for each well associated with WMUs 2 and 3. The average concentration of each contaminant detected in each well was used in the risk calculations. The wells that showed the highest chemical and radiological risks were used as representative wells for the UCRS and the RGA. A summary of risk estimates at each well within WMUs 2 and 3 is shown in Table 2-14. Detailed chemical- and radionuclide-specific risk estimates for each well are shown in Attachments 2-13 through 2-15.

Chemical groundwater ingestion risks for the UCRS and RGA are characterized by MW-74 and MW-93, respectively. HI results from MW-74 and MW-89 were used to characterize risks for the UCRS and RGA. Radiological groundwater ingestion risks in the UCRS and RGA are characterized by MW-154 and MW-84, respectively. A summary of groundwater risks is included in Table 2-13.

Total excess lifetime chemical cancer risks for MW-93 and MW-74 are 2×10^{-3} and 8×10^{-4}, respectively. Detailed risk calculations are summarized in Attachments 2-7 and 2-8. HI values for MW-74 and MW-89 are 12.0 and 20.8, respectively. Detailed risk calculations are summarized in Attachments 2-9 and 2-10. The risk summaries suggest potential adverse effects from residential use of groundwater in the vicinity of WMUs 2 and 3.

Excess lifetime cancer risks for individual chemicals detected in MW-74 (representing the most likely estimate) are presented in Table 2-13. Approximately all of the estimated total carcinogenic risk is a result of beryllium ingestion. The greatest contributions of individual chemicals to the total noncancer risk (HI) for MW-74 (most likely estimate) are the metals manganese and chromium.

Carcinogenic risk from chemicals detected in MW-93 (representing the reasonable maximum estimate) are summarized in Table 2-13. The organic chemicals N-nitroso-di-n-propylamine and 2,4-dinitrotoluene were the largest contributors to the total carcinogenic risk. The total noncancer risk (HI) for MW-89 is summarized in Table 2-13. Manganese, arsenic, and thallium are the major contributors to the total noncancer risk.

Radiological risks associated with groundwater ingestion at WMUs 2 and 3 are summarized in Table 2-13. Radiological risks from groundwater ingestion range from 1×10^{-5} at MW-84 (representing the reasonable maximum estimate) to 5×10^{-5} at MW-154 (representing the most likely estimate). The primary contributor to risk from groundwater at MW-84 is Tc-99. The primary contributors to radiological risk at MW-154 are Tc-99 and U-238. Radiological risk calculations for groundwater are presented in Attachments 2-15 and 2-16.

Table 2-14
Summary of Well-Specific Risk Estimates for Groundwater Ingestion
WMUs 2 and 3

Station ID	Chemical Excess Lifetime Cancer Risk	Chemical Noncancer HI	Radiological Cancer Incidence Risk
RGA			
MW-048	NA	3.22	9.1E-07
MW-050	1.2E-04	3.94	9.5E-07
MW-067	NA	0.28	1.4E-06
MW-084	3.5E-06	0.18	1.3E-05
MW-086	1.5E-05	3.69	3.8E-06
MW-087	NA	1.55	2.2E-06
MW-089	6.9E-05	20.81	2.8E-07
MW-090	2.6E-07	0.86	2.6E-07
MW-092	1.3E-04	5.29	3.1E-06
MW-093	2.0E-03	0.46	4.0E-06
MW-095	5.9E-05	3.39	1.7E-06
UCRS			
MW-049	3.8E-04	8.99	1.3E-05
MW-074	8.0E-04	12.03	1.0E-05
MW-085	NA	0.09	9.3E-06
MW-088	1.8E-04	1.32	4.4E-05
MW-091	1.5E-06	0.72	3.6E-06
MW-094	6.0E-05	0.83	2.1E-05
MW-154	NA	1.12	4.7E-05
Leachate Sump Leachate Sample			
WMU 003	2.1E-04	3.95	4.6E-05

Note:

NA = Not Applicable (no detectable chemical carcinogens).

No onsite groundwater is currently being used; therefore, no current exposures to these contaminants occur in this onsite location. If this potable use were to occur in the future (for example, in 100 years), reductions in concentrations might occur by natural attenuation.

Risks associated with naturally occurring inorganic constituents and radionuclides in groundwater were estimated using maximum detected concentrations in reference groundwater samples. Appendix B describes the rationale for the reference sampling and presents the results. Chemical carcinogenic risks were not calculated because no carcinogenic constituents were detected. The HI via the ingestion pathway is 2.2, with the major contributor being manganese (individual HQ of 1.8). The radiological risk associated with ingestion of groundwater containing naturally occurring radionuclides (Th-230 and U-238) is 9×10^{-7}.

Future groundwater ingestion by an onsite resident was evaluated for a scenario where the uranium waste becomes solubilized and enters the UCRS or RGA. These estimates are considered to be for a reasonable maximum scenario using modelled data, and should be interpreted with caution (Table 2-14a). Ingestion of uranium isotopes in groundwater in the UCRS in the future could result in a cancer risk of roughly 1×10^{-3}. In the RGA, the total cancer risk could be as high as 3×10^{-5} from uranium isotopes. Cancer risks from uranium are approximately evenly distributed between U-234 and U-235. The U-238 contribution is approximately 1 percent of the total cancer risk.

Gamma Radiation Exposure Pathway. The receptors evaluated for gamma radiation exposure include the current and future worker, and the future onsite resident. Risks from gamma exposure are evaluated qualitatively, by comparing the measured dose rate to existing health-based guidelines for workers and residents.

The measured dose rate for SWMU 2 is 120 μRem/hour on top of the waste unit. This dose rate is roughly 5 percent of the acceptable dose to workers who are exposed on a full-time basis. It is roughly half of the gamma dose rate which is considered safe to the general public for protection of the most sensitive organs, the gonads and red bone marrow (ICRP Publication 26, 1977). Background gamma dose rates vary depending on the area, and we are lacking appropriate background data for this site. This dose is likely higher than background (perhaps by as much as ten times) but it is lower than safe dose limits for the most conservative scenario, the future onsite resident.

Direct Waste Intrusion Pathway. A qualitative risk assessment was performed for direct intrusion into the buried uranium wastes at WMUs 2 and 3. The buried uranium waste is pyrophoric (pyrophoric nature is especially high for the metal shavings) and will likely ignite spontaneously if exposed to air by intrusion (i.e., breaking the integrity of the waste pile cap). This fire hazard is exacerbated by the presence of sawdust and TCE wastes which would be a combustion sustaining fuel source.

Table 2-14A

Excess Lifetime Cancer Risk from Groundwater Ingestion, Future Residential Scenario

WAG 22, Paducah Gaseous Diffusion Plant

Chemical	U.S. EPA Carcinogen Classification	Cancer Slope Factor (Oral) (kg-day/mg) (Risk/pCi)	UCRS			RGA		
			Exposure Point Concentration (ug/l) (pCi/l)	Excess Lifetime Cancer Risk	Percent of Total Risk	Exposure Point Concentration (ug/l) (pCi/l)	Excess Lifetime Cancer Risk	Percent of Total Risk
Uranium-234	NA	1.60E-11	2010	6.75E-04	46.35	33	1.11E-05	46.64
Uranium-235	NA	1.60E-11	2280	7.66E-04	52.58	37	1.24E-05	52.29
Uranium-238	NA	2.80E-11	26.4	1.55E-05	1.07	0.43	2.53E-07	1.06
SUM OF RISKS				1.46E-03	100		2.38E-05	100

EXPOSURE ASSUMPTIONS		
Exposure Setting	Future Residential Scenario	**Future Residential Scenario**
Exposure Case	Reasonable Maximum (RME)	**Reasonable Maximum (RME)**
Daily Water Ingestion Rate (liters/day)	2	2
Body Weight (kilograms)	70	70
Number of Days/Week Exposed	7	7
Number of Weeks/Year Exposed	50	50
Number of Years Exposed	30	30
Averaging Time (yrs)	70	70
Percent of Water Consumed at Home	100	100
Lifetime Average Water Ingestion (l/kg body wt.-day)	0.012	0.012

Exposure Point Concentrations for the Onsite Future Resident, as described in Section 2.6.1.2.3.3

An intruder using a backhoe or similar machinery on top of the WMU waste pile would also be subject to an explosion hazard should the intrusion-generated waste fire reach the machinery gas tank. An intruder operating without gas-powered machinery would of course only be subject to the fire safety hazard. However, both methods of intrusion would likely result in health risks due to the release of uranium wastes in air during the waste pile fire.

The nature (such as size and longevity) of a pyrophoric waste pile fire is dependent in part on the degree of intrusion (i.e., degree of cap integrity destruction) which in turn affects the degree of air dispersal of the uranium wastes. Therefore intrusion into the waste pile could potentially result in increased radiological health risks for onsite and offsite receptors via direct contact, external, dermal, and inhalation exposure routes. It should be noted that a receptor that has suffered burns is at increased radiological risk because the damaged skin can no longer effectively act as a barrier to intake of certain forms of radiological contaminants.

2.6.1.5 Evaluation of Uncertainty

This section discusses the key assumptions and uncertainties that affect the level of confidence placed on the quantitative risk estimates derived for the WMUs 2 and 3 risk assessment. Because uncertainties are inherent in any risk assessment, a qualitative discussion of these uncertainties puts into perspective the risks calculated for the site.

2.6.1.5.1 Data Evaluation. Of the variables used in performing the risk assessment, the error terms related to the laboratory analyses are probably the best defined and provide less uncertainty than other factors in the assessment. Individual errors or biases in the data are possible, but the size of the database minimizes uncertainties in the overall concentration estimates.

The primary data limitations and uncertainties associated with concentration estimates and data at WMUs 2 and 3 include the following observations:

- Sampling strategies at WMUs 2 and 3 were designed to detect migration to offsite areas, not for current or future exposures to surface soil. In some samples, data may reflect "hot spots" and overestimate risks; in other samples, data may reflect contamination adjacent to the site and may underestimate risks.

- Risks from direct contact exposures to surface soils were evaluated using the results from soil samples from zero to 6 ft below ground surface. Thus, this evaluation closely approximates conditions that might occur during shallow excavations around the WMUs. However, current direct contact exposures to soils 6 in. to 1 ft bgs were not evaluated since only two samples were available at these depths.

- No direct sampling was conducted of the waste itself. No quantification was made, therefore, of the potential risk if excavation into the waste were to occur.

- There is considerable potential variability associated with VOC concentration results because of losses from the soil matrix even with good sampling technique. In addition, with typical laboratory holding times of 14 days at 4°C, a loss in concentration typically occurs (from the time of collection) of 40 to 90 percent of the original concentration, depending on the specific chemical. These uncertainties can lead to underestimates of risks associated with VOCs.

- Disposal records have been shown to be inaccurate. Therefore the low reliability of the buried waste materials inventory introduces uncertainties that may result in under or over estimates of risks.

- The discrepancy between maximum detected beta activity levels and maximum detected Tc-99 activity levels is a source of data uncertainty and may result in underestimation of radiological risks.

2.6.1.5.2 Exposure Assessment. Worker exposures to contaminated surface soils at WMUs 2 and 3 are considered conservative. However, the surface water pathway was not quantitatively evaluated in this assessment. WMUs 2 and 3 are not considered to contribute to the surface water exposure pathway. A reasonable deviation resulting from erosion of sediments in runoff from the site will be evaluated for the surface water integrator OU.

Risk estimates are based on steady state chemical concentrations in the various media. Environmental fate, transport, transfer, or biodegradation is not accounted for and may alter the measured chemical concentrations. This source of uncertainty may lead to under or overestimation of risks. Some of the waste was placed in containers for burial (such as TCE drums). The life expectancy of the containers is unknown and is another source of uncertainty in estimating exposure concentrations. The "waste packages" could lose their structural integrity and release waste, thereby increasing chemical concentrations in soil and groundwater. This source of uncertainty could potentially result in underestimates of risk.

The 250, 8-hr days per year assumption for workers is excessive for current onsite worker exposures at a single WMU. This exposure level would be appropriate for exposures in areas where continuous activities were required outside the domain of OSHA regulations. Further, it is unreasonable to assume that a worker would remain in the vicinity of a single WMU for a 25-year exposure period.

Current PGDP worker exposure to WMUs 2 and 3 is better estimated using the worker/intruder scenario, which reflects 10 percent of a worker's time spent at a single WMU. This scenario also conservatively addresses potential intruder exposures at

PGDP. The assumption of biweekly 8-hr exposure periods at a single WMU over a 25-year period overestimates risks to visitors/intruders, even if fences and security measures were eliminated.

The assumptions that adult workers ingest 50 mg of soil per day are likely conservative. In addition, the assumption that 100 percent of soil ingested per day comes from the contaminated source is conservative. Thus, both soil ingestion rates and the fraction from the contaminated source tend to overestimate risks.

The assumptions for dermal absorption are also conservative for the amount of soil adhering to skin, skin surface area available for contact, and the amount of a chemical absorbed from soil. These three factors tend to overestimate the amount of chemical absorbed from soil by the dermal route.

2.6.1.5.3 Toxicity Assessment. Uncertainty is associated with the use of the method to determine carcinogenic risks in humans. In discussing uncertainty, the EPA expressed the following:

> "It should be emphasized that the linearized multistage procedure leads to a plausible upper limit to the risk that is consistent with some proposed mechanisms of carcinogenesis. Such an estimate, however, does not necessarily give a realistic prediction of the risk. The true value of risk is unknown, and may be as low as zero. The range of risks, defined by the upper limit given by the chosen model and the lower limit which may be stated as low as zero, should be explicitly stated." (FR 51:34013, September 24, 1986).

To assess the overall potential for cancer and noncancer effects posed by multiple chemicals, cancer risks or HIs are summed. This method may be conservative because it does not account for potential differences in toxic end points.

Uncertainty in toxicity assessment can arise from the use of models or test systems that do not accurately describe the exposed population or the relevant exposure environment. This type of uncertainty can be found in the toxicity values derived from animal experiments and in assumptions made about dose-response models, which may or may not be valid.

Several of the constituents reported at the site do not have a current oral, inhalation, and/or dermal SF or RfD. Because no dermal toxicity values are available, oral toxicity values were used. No adjustments were made on the basis of absorbance, which tends to underestimate risks via dermal absorption.

Although EPA established an oral SF for PCBs, accurate information on potential dose-response relationships by inhalation are not quantified. Potential additional contributions to risk by the presence of lead were evaluated on the basis of available guidance, because EPA has not promulgated current toxicity values.

A high degree of certainty can be shown between high radiation doses and effects on humans. Much less certainty exists for the effects from low doses of radiation. The cancer risk coefficients are based on extrapolation of high-dose human data to low doses expected from environmental exposures. Although this approach is better than using animal-derived data, it still leads to uncertainty. The uncertainty is also influenced by other factors such as differences in the quality (LET) and type of radiation, total dose, dose distribution, dose rate, and radiosensitivity (including repair mechanisms, variations in age, state of health, target organ, and gender). The BEIR V Committee evaluated uncertainty in their cancer risk estimates. Although the BEIR V Committee increased the risk estimates for radiation-induced cancer, they also acknowledged that the uncertainty associated with these estimates is large enough that at low doses (comparable to background), the risk of cancer induction may be zero. Table A-4 in Appendix A presents ranges for most of the risk factors used to assess exposure risk to radiation. The magnitudes of variability in these ranges indicates the uncertainty in the risk of each radiation-induced effect.

2.6.1.5.4 Risk Characterization. Standard ground surface conversion factors were used to determine doses and risks associated with external exposures to radiation from contaminated surface soil at WMUs 2 and 3. The ground surface dose and risk factors are based on assumptions of uniform contamination over a large surface area. Use of generic surface risk factors will result in overestimates of risks from external gamma radiation at WMUs 2 and 3.

The linear non-threshold model is the model most frequently used for determining risk of radiation exposure. This model assumes that there is some increased risk for any increment of radiation exposure, there being no threshold below which effects are not seen. This is a conservative model for evaluating radiation risk. The model uses data from high-dose radiation exposures (such as from the Japanese survivors of the atomic bomb) and extrapolates risk from these high exposures to the low-level environmental or occupational dose range. There is a great deal of scientific debate about whether such high-dose and high-dose-rate data are applicable for comparison with doses at or near natural background levels. Federal agencies, however, currently use the linear non-threshold model for rulemaking.

The current EPA-recommended radiation risk factors are based on the 1980 BEIR III Report. The BEIR III recommendations were increased slightly by EPA to reflect recent information on the health effects of exposure to ionizing radiation. In early 1990, the NAS published the results of the most recent studies of the health effects of ionizing radiation—the BEIR V Report. The BEIR V Report increased the estimates of cancer risk by a factor of 3 to 5 over the BEIR III Report. The increases were based primarily on reevaluation of the doses received by the atomic bomb survivors. The risk factors used in this report are based on EPA guidance in HEAST and are greater than the risk factors shown in the BEIR III Report, but slightly less than the factors shown in the BEIR V Report. Thus, they represent an estimate of risk that falls within the range of risk estimates from the most recent data. The EPA regards these risk estimates as "reasonable" but not "conservative." Consequently, use of the

EPA risk factors should not tend to greatly overestimate the risk of low-level radiation exposure.

Although several uncertainties produce both over- and underestimated risk calculations in this assessment, factors that tend to overestimate risks outweigh those that underestimate risks. Therefore, risks calculated in this assessment are considered conservative.

Some portion of the risks estimated for WMUs 2 and 3 may be attributed to naturally occurring background concentrations of inorganics and radionuclides in soil and groundwater. For example, arsenic, beryllium, and manganese contribute to risks exceeding 1×10^{-6} and an HI of 1 in reference groundwater and soil samples. This background risk, while not subtracted from site-related risk, presents additional uncertainty in the risk characterization.

2.6.2 Ecological Risk Assessment

A Baseline Ecological Risk Assessment will be conducted for the PGDP on a sitewide basis in accordance with the assessment of the surface water integrator OU. The following is a preliminary ecological risk assessment for WMUs 2 and 3.

The purpose of this preliminary ecological risk assessment is to identify the areas of the surface water integrator OU where contaminants may migrate, to summarize the contaminant information for WMUs 2 and 3 in terms of potential ecological effects, and to assess whether the unit poses an immediate impact upon the ecosystems surrounding PGDP.

2.6.2.1 Identification of Watershed Systems

Surface runoff is the primary pathway through which contaminants migrate from WMUs 2 and 3 to the environment. The units lie fully within the watershed of Big Bayou Creek. Runoff from the units is collected in an excavated ditch that discharges through Outfall 015 to the creek, approximately 2,100 ft downstream of the units (Figure 2-1).

The area of WMUs 2 and 3 comprises less than 4.4 acres. The watershed area of Big Bayou Creek upstream of Outfall 015 comprises approximately 6,560 acres. Runoff from the units, therefore, comprises less than approximately 0.07 percent of the flow in Big Bayou Creek. In addition, process water plant discharges from PGDP comprise most of the base flow in Big Bayou Creek, averaging approximately 2.96 mgd downstream of Outfall 015.

2.6.2.2 *Identification of Biotic Communities*

The biotic communities at the PGDP represent the receiving environment for contaminants in runoff. The Phase II Public Health and Ecological Assessment Report identified the aquatic and terrestrial habitats near the PGDP and the potentially exposed populations, including threatened or endangered species (CH2M HILL, 1992).

The area of WMUs 2 and 3 is located within the facility boundaries, inside the PGDP security fence. The units are identified as having industrial land use (that is, open areas having little vegetation except mowed grass).

Plant communities within the PGDP boundary exist mostly in mowed grass fields and channelized ditches. No critical habitat occurs within the plant boundary. The WMUs are enclosed within a chain link fence, which suggests a low frequency of exposure of game and nongame species on the site. Wildlife that potentially use onsite areas include small mammals and birds. No waterfowl or fish are present in the ditch draining WMUs 2 and 3, which consists of a grassed swale onsite. No threatened and endangered species are recognized as being impacted at the site (Phase II Public Health and Ecological Assessment).

Results of PGDP's BMP indicate that the biological communities in a section of Big Bayou Creek next to and downstream from the plant outfalls are significantly different from aquatic communities upstream from the outfalls. Differences have included reduced diversity and density of benthic invertebrates near the outfalls and some reduction in periphyton biomass. Differences were not evident between fish communities near the outfalls in Big Bayou Creek and in similar habitats in stream sections unaffected by plant discharges. Bluegills (*Lepomis macrochirus*) and several other species of sunfishes dominated at most locations in Big Bayou Creek. The creek chub (*Semotilus atromaculatus*) and stoneroller (*Campostoma anomalum*) were also numerically important at some stations in Big Bayou Creek.

2.6.2.3 *Identification of Potential Chemicals and Media of Concern*

The Phase II Public Health and Ecological Assessment (CH2M HILL, 1992) identified PCBs as the major chemical of concern in Big Bayou Creek. PCBs were detected in surface soil in the ditches surrounding WMU 2 at levels less than 210 μg/kg. In addition, several metals, including aluminum, beryllium, cadmium, chromium, cobalt, copper, cyanide, lead, mercury, nickel, silver, and zinc, were identified as potential chemicals of concern in surface water or sediment of Big Bayou Creek and have been detected at WMUs 2 and 3. Uranium has been found at levels above background in Big Bayou Creek and in the ditches at WMUs 2 and 3. However, the Phase II Public Health and Ecological Assessment (CH2M HILL, 1992) estimated a total daily dose rate for fish exposed to contaminated sediments in Big Bayou Creek of less than a guide of 1 rad/day suggested by the U.S. National Council on Radiation Protection and Measurements.

In surface water, the contribution of contamination in runoff cannot be differentiated from the permitted effluent discharges from the PGDP outfalls. The area of WMUs 2 and 3 has an established grass cover that minimizes erosion. In addition, both units are capped so that migration of contaminants in surface runoff is minimal. For these reasons, the units are not considered to pose an immediate impact upon the ecosystems surrounding PGDP. Effects of contaminant runoff from WMUs 2 and 3 will be assessed further during the PGDP baseline ecological risk assessment for the surface water integrator OU.

Because of the industrial nature and small scale of the units, it is inappropriate to assess direct toxic effects on wildlife populations for this individual source unit. The establishment of a productive natural ecosystem that supports a diverse wildlife community also is not applicable to these units. The cumulative effects of small losses or contamination of terrestrial habitat will be assessed facility-wide (or watershed-wide) in the PGDP baseline ecological risk assessment for the surface water integrator OU.

2.7 Remediation Goal Options

Results of the human health and ecological risk assessment indicate that some of the media exposure pathways exceed a 1×10^{-4} excess lifetime cancer risk and/or an HI of 1. Some of the media exposure pathways also exceed applicable or relevant and appropriate requirements (ARARs). Remedial goal options (RGOs) were developed for those chemicals of concern that contributed to the cancer risk or noncarcinogenic health hazard of media exposure pathways exceeding the above criteria.

RGOs are media cleanup levels that are selected from ARARs or from calculated values that are protective of human health or ecological concerns, or soil values estimated to be protective of groundwater. Health based values are developed by combining the chemical intake equations with an acceptable risk or hazard value and solving for the concentration term.

The intent of this section is to outline RGOs for the chemicals of concern identified in Table 2-5 and media of concern as the basis for future risk management decisions. In some instances, the goals may be practical and cost-effective to attain. In other instances, these goals may be modified on the basis of results of the alternatives evaluation, where several factors in addition to potential future risks must be considered in the overall risk management strategy. RGOs present information for single pathway exposures typically associated with future uses.

2.7.1 Groundwater

Groundwater remediation strategies will be considered in greater detail in the evaluation of the Groundwater Integrator OU. Because contaminants were detected downgradient of WMUs 2 and 3 that are likely contributors to offsite contamination, conservative remediation goals for groundwater are presented here to assist in the evaluation of source controls to prevent further releases of contaminants to the Groundwater Integrator OU.

Table 2-15 lists available chemical-specific ARARs that have been promulgated under federal and state law summarized in Etnier and Houlberg (1992). These regulations may apply to remediation of contaminated groundwater that may be used as a drinking water source.

EPA has promulgated primary and secondary drinking water regulations applicable to public water systems that have at least 15 service connections or that serve an average of at least 25 people daily at least 60 days of the year. National Primary Drinking Water Standards (NPDWS) are established in 40 CFR 141 and include MCLs and Maximum Contaminant Level Goals (MCLGs). New drinking water standards promulgated for 8 synthetic organic chemicals (52 *FR* 25690, July 8, 1987) added a new category of suppliers referred to as noncommunity, nontransient systems that regularly serve at least 25 people for 6 months of the year. Table 2-15 lists SDWA MCLs, MCLGs, and State of Kentucky MCLs.

In the NCP, EPA states the preference for SDWA MCLs and non-zero MCLGs or other health-based standards, criteria, or guidance for remediation of Class I and II groundwater at CERCLA sites (55 *FR* 8732, March 8, 1990). Offsite groundwater that surrounds PGDP has been used for private drinking water and therefore may be classified as Class I or IIA groundwater. MCLs are enforceable standards that consider human health effects, available treatment technologies, and costs of treatment.

However, MCLs may be considered as relevant and appropriate in situations where groundwater or surface water may be used for drinking water. MCLGs are strictly health-based standards that disregard cost or treatment feasibility and are not legally enforceable. CERCLA §121(d)(2)(A) specifically mentions that remedial actions must require a level or standard of control that at least attains MCLGs and federal ambient water quality criteria (AWQC) where such goals or criteria are relevant and appropriate under the circumstances of the release. Although MCLGs and AWQC are nonenforceable guidelines, Congress elevated them to a higher status by specifically mentioning them in CERCLA. Promulgated MCLGs are listed in Table 2-15. EPA is planning to use the SDWA MCLs for remedial action compliance for carcinogens that have an MCLG of zero and for any non-zero MCLG for systemic toxicants (55 *FR* 8752, March 8, 1990).

Table 2-15
Chemical-Specific RGOs for Groundwater ARARs for the Protection of Human Health[a,b]

Chemical	RCRA[c] MCLs[d] (µg/L)	SDWA MCLs[d] (µg/L)	SDWA MCLGs[e,f]	Kentucky MCLs[g] (µg/L)
SVOCs				
2,4-Dinitrotoluene	--	--	--	0.11
N-Nitroso-di-N-propylamine	--	--	--	0.005
Pentachlorophenol	--	1	0	0.28
Inorganics				
Arsenic[h]	50	50	--	0.018
Barium[i]	1,000	2,000	2,000	2,000
Beryllium	--	4	4	0.0077
Cadmium[k]	10	5	5	1.1
Chromium (Total)[k]	50	100	100	100
Manganese	--	--	--	500
Nickel	--	100	100	160
Silver	50	[n]	[n]	105
Thallium	--	2	0.5	1.7
Vanadium	--	--	--	--
Radionuclides				
Tc-99 (pCi/L)	--	900	0	--
Uranium	--	20	--	--

[a] ARAR = Applicable or Relevant and Appropriate Requirements.

[b] Federal and state-promulgated regulations under RCRA and the SDWA. The most stringent regulation is highlighted as the ARAR.

[c] RCRA = Resource Conservation and Recovery Act (40 CFR 264.94).

[d] MCL = Maximum Contaminant Level. RCRA MCLs are properly termed "maximum concentration limits."

[e] MCLG = Maximum Contaminant Level Goal.

[f] Note: All proposed MCLs have been promulgated.

[g] Kentucky Public and Semipublic Drinking Water Regulations. Title 401 Kentucky Administrative Record (KAR) Chapter 5:032, Groundwater Standards.

[h] 40 *FR* 59570 (December 24, 1975).

[i] 56 *FR* 30266 (July 1, 1991). Effective January 1, 1993.

[j] 52 *FR* 25690 (July 8, 1987).

[k] The final MCL/MCLG was set for this chemical 56 *FR* 3526, January 30, 1991) and supersedes the original interim SDWA MCL. Effective July 30, 1992; interim MCLs remain in effect until that time.

Source: Etnier and Houlberg, 1991.

EPA has also developed other to-be-considered (TBC) guidance concentrations derived using RfDs and SFs that are available through IRIS (EPA, 1992c) and HEAST (EPA, 1992d). The BEIAS at ORNL has prepared summary tables of the toxicity values found in IRIS and HEAST used in this analysis (MMES, 1992). As suggested by EPA Region IV Guidance (EPA, 1994a), using these RfDs and SFs, health-based RGOs associated with a HI of 0.1, 1, and 10, and excess lifetime chemical cancer risk of 10^{-6}, 10^{-5}, and 10^{-4} were calculated. Site-specific exposure parameters as those described in the risk calculations previously presented in the exposure assessment section were used in deriving the health-based RGOs for groundwater. The RGOs for carcinogens in groundwater are summarized in Table 2-16, noncarcinogens in Table 2-17, and radionuclides are shown in Table 2-18.

2.7.2 Soil

Health-based RGOs for soil were also calculated using the RfDs and SFs. Health-based RGOs were calculated for commercial/industrial soils, using site-specific exposure parameters as those described in the exposure assessment section. The RGOs reflect ingestion of soil and inhalation of particulates. Neither inhalation of volatilized contaminants nor dermal absorption are included in this analysis. As suggested by EPA Region IV Guidance, health-based RGOs associated with an excess lifetime chemical cancer risk of 10^{-6}, 10^{-5}, and 10^{-4} (Table 2-19) and a HI of 0.1, 1, and 10 (Table 2-20), were calculated. RGOs were similarly estimated for the excess lifetime radiological cancer risk of 10^{-6}, 10^{-5}, and 10^{-4}, and are presented in Table 2-21.

Soil RGOs that are protective of groundwater may also be developed on a site-specific basis. Levels of contaminants in soil would be established that would not result in exceedances of MCLs at the WMU boundary as a result of water infiltration and transport of contaminants through the soil to groundwater. This evaluation was performed using a contaminant transport model from Summers et al. (1980). The assumptions and discussion of that model are presented in Appendix C. Initial screening was performed assuming the following:

- Steady-state release
- Well located at the downgradient edge of the waste area in the RGA
- No dispersion, sorption, or decay of chemicals of concern
- The time of arrival at the well was not a factor, the maximum concentration could not exceed the designated level of concern. Those protective concentrations were first the MCL, if available; second, the lower of the risk-based RGOs (10^{-5} risk level or target HI of 1).

Screening assumptions resulted in estimating a "dilution factor" for contaminants released in the soil to infiltrating water migrating to the well. The dilution factor used

Table 2-16
Risk-Based RGOs for Carcinogens in Groundwater
WMUs 2 and 3

Chemical	Oral SF $(mg/kg\text{-}day)^{-1}$	Inhalation Unit Risk $(\mu g/m^3)^{-1}$	Water Concentration at Target Risk Level		
			1×10^{-6} $(\mu g/L)$	1×10^{-5} $(\mu g/L)$	1×10^{-4} $(\mu g/L)$
2,4-Dinitrotoluene	0.68	--	0.13	1.25	12.50
Pentachlorophenol	0.12	--	0.71	7.1	71
Arsenic	1.5	0.0043	0.06	0.6	6
Beryllium	4.3	0.0024	0.02	0.20	1.98

Exposure Assumptions:

Body Weight (kg)	70
Ingestion Rate (L/d)	2
Indoor Inhalation Rate (m^3/d)	15
Exposure Frequency (d)	350
Exposure Duration (y)	70
Averaging Time (d)	25,500
Volatilization Factor (L/m^3)	0.5 [Default value from RAGS, Volume I, Part B (EPA, 1991d)]

Table 2-17
Risk-Based RGOs for Noncarcinogens in Groundwater: Residential Exposure
WMUs 2 and 3

Chemical	Oral RfD (mg/kg/day)	Inhalation Reference Concentration (RfC) (mg/m^3)	Water Concentration at Target Risk Level		
			THQ = 0.1 (μg/L)	THQ = 1 (μg/L)	THQ = 10 (μg/L)
2,4-Dinitrotoluene	0.002	--	7	73	730
Pentachlorophenol	0.03	--	110	1,095	10,950
Arsenic	0.0003	--	1	11	110
Barium	0.07	0.0005	256	2,555	25,550
Beryllium	0.005	--	18	183	1,825
Cadmium	0.0005	--	2	18	183
Chromium VI	0.005	0.000002	18	183	1,825
Manganese	0.005	0.0004	18	183	1,825
Nickel (Metallic)	0.02	--	73	730	7,300
Silver	0.005	--	18	183	1,825
Thallium	0.00007	--	0.26	2.6	26
Vanadium	0.007	--	26	256	2,555
Uranium (Soluble Salts)	0.003	--	11	110	1,095

Exposure Assumptions:

Body Weight (kg)	70
Ingestion Rate (L/d)	2
Indoor Inhalation Rate (m^3/d)	15
Exposure Frequency	350
Exposure Duration (y)	30
Averaging Time (d)	10,950
Volatilization Factor (L/m^3)	0.5 [Default value from RAGS, Volume I, Part B (EPA, 1991d)]

Note:

THQ = Target Hazard Quotient

Table 2-18
Risk-Based RGOs for Radionuclides in Groundwater: Residential Exposure
WMUs 2 and 3

Radionuclide	Ingestion Risk Factor (pCi)$^{-1}$	Water Concentration at Target Risk Level		
		1 × 10^{-6} (pCi/L)	1 × 10^{-5} (pCi/L)	1 × 10^{-4} (pCi/L)
Np-237 + D	2.2E-10	0.22	2.16	21.65
Tc-99	1.3E-12	36.63	366.30	3663.00
U-234	1.6E-11	2.98	29.76	297.62
U-238 + D	2.8E-11	1.70	17.01	170.07

Note:

D = Daughter isotopes included.

Exposure Assumptions:

Ingestion Rate (L/day)	2
Exposure Frequency (days)	350
Exposure Duration (years)	30

Table 2-19
Risk-Based RGOs for Carcinogenic Compounds in Soil: Industrial Exposure
WMUs 2 and 3

Chemical	Oral SF (mg/kg-day)$^{-1}$	Inhalation Unit Risk ($\mu g/m^3$)$^{-1}$	Soil Concentration at Target Risk Level		
			1 × 10^{-6} (mg/kg)	1 × 10^{-5} (mg/kg)	1 × 10^{-4} (mg/kg)
Arsenic	1.5	0.004	4	39	386

Exposure Assumptions:

Body Weight (kg)	70
Ingestion Rate of Soil (mg/d)	50
Inhalation Rate (m^3/d)	20
Exposure Frequency	250
Exposure Duration (y)	25
Averaging Time (d)	9,125
Particulate Emission Factor (m^3/kg)	4.63E+09

Table 2-20
Risk-Based RGOs for Noncarcinogenic Compounds in Soil: Industrial Exposure
WMUs 2 and 3

Chemical	**Oral RfD (mg/kg/day)**	**Inhalation Reference Concentration (RfC) (mg/m^3)**	**Soil Concentration at Target Hazard Index**		
			THQ = 0.1 (mg/kg)	**THQ = 1 (mg/kg)**	**THQ = 10 (mg/kg)**
Arsenic	0.0003	--	61	613	6,132

<u>Exposure Assumptions</u>:

Body Weight (kg)	70
Ingestion Rate of Soil (mg/d)	50
Inhalation Rate (m^3/d)	20
Exposure Frequency	250
Exposure Duration (y)	25
Averaging Time (d)	9,125
Particulate Emission Factor (m^3/kg)	4.63E+09
VF (m^3/kg)	0.5 [Default value from RAGS, Volume I, Part B (EPA, 1991d)]

Table 2-21
Risk-Based RGOs for Radionuclides in Soil: Industrial Exposure
WMUs 2 and 3

	Cancer Incidence Risk Factors[a]			**Soil Concentration at Target Risk Level**[b]		
Radionuclide[c]	**Ingestion (Risk/pCi)**	**Inhalation (Risk/pCi)**	**External (Risk/year per pCi/g)**	**1×10^{-6} (pCi/g)**	**1×10^{-5} (pCi/g)**	**1×10^{-6} (pCi/g)**
U-235 +D	1.60E-11	2.50E-08	2.40E-07	0.9	9	90
U-238 +D	2.80E-11	5.20E-08	3.60E-08	6	60	600

Note: +D indicates that daughter radionuclides are included in the risk and external dose calculations. Internal dose factors account for buildup of daughters assuming intake of pure parent radionuclide.

[a] Risk factors were taken from the January 1991 HEAST.

[b] RGOs shown above are calculated using the methods outlined in RAGS, Part B.

[c] Risks from ingrowth of decay products have been included for radionuclides shown with + D.

<u>Exposure Parameters</u>:

Ingestion Rate (g/day)	0.05
Inhalation Rate (m^3/day)	20
Exposure Time (hr/day)	8
Exposure Frequency (day/year)	250
Exposure Duration (years)	25
Particulate Emission Factor (m^3/kg)	4.63E+09
Gamma Shielding Factor	0.2
Fraction of Year Exposed to Gamma (day)	0.24

in these calculations is 0.039. Soil RGOs were derived using contaminant-specific K_d values to relate an "acceptable" leachate concentration to the soil concentration. For metals, the background concentration was added to the estimate of acceptable "adsorbed" concentration to reflect natural levels present in the area that are not likely to be readily exchangeable. Table 2-22 summarizes the results of this analysis and provides a comparison of maximum detected contaminant concentrations in soils to the RGOs for groundwater protection.

Inorganic K_d values obtained from a DECOM model were considered appropriate for this site, although the specific documentation as to the derivation of the proposed values were not reviewed. Some other resources have proposed more conservative numbers. The following were considerations in the use of the numbers used in the model specifically for the more controversial metals:

- Hexavalent chromium has been shown not to be present at the site. Therefore, the lower K_d for that oxidation state were not appropriate.

- Arsenic behavior is very complex. Although it is an anion, it behaves in many cases like phosphate and has been shown in various studies to have elevated K_d values, much higher than reported by other sources. Based on the soil and groundwater arsenic concentrations reported at PGDP, a low K_d than shown in Table 2-22 would not reflect background observations at the site.

2.8 Conclusion

WMUs 2 and 3 are probable sources of contamination in groundwater, and possible sources of radiological contamination in offsite surface water as a reasonable deviation. Risk estimates for surface soil exposures are based on surface and subsurface soil samples due to the limited number of surface soil samples. Risk estimates for direct contact to soil under industrial exposure scenarios do not exceed 1×10^{-4} carcinogenic risk levels nor 1.0 HI for either chemical or radiological contaminants. However, screening-level risk estimates for residential ingestion of groundwater exceed a 1×10^{-4} carcinogenic risk level and a 1.0 hazard index. Furthermore, future excavation into the buried materials represents a potential threat to human health due to of direct exposure to radionuclides. Therefore, the units should be addressed further during the FS to assess potential remedial actions.

2.8.1 Chemicals of Concern

Chemicals of concern at WMUs 2 and 3 are listed on Table 2-23. The chemicals of concern include chemical and radiological contaminants that contribute to risk in soil or groundwater, or that exceed RGOs. Contribution of an individual contaminant to risk is determined as exceeding a cancer risk level of 1×10^{-6} or exceeding a HQ of 0.1.

Table 2-22

RGOs for Soils to Protect Groundwater
WMUs 2 and 3

Contaminant	Soil Water Distribution Coefficent Kd (1)(7)	Organic Carbon Partition Coefficent Koc	Preliminary Groundwater Remediation Goal (ug/L)	Basis (2)	Reference Soil Conc. (Metals) (mg/kg)	Soil Concentration to Protect Groundwater (mg/kg) (3)	Max. Soil Concentration Observed (mg/kg)(4)	Avg. Soil oncentration Observed (mg/Kg)(5)
2,4-Dinitrotoluene	0.045	45	1.25	ELCR		0.001		
n-Nitroso-di-n-propylamine			0.12	ELCR				
Pentachlorophenol	63.1	63100	1	MCL		2	0.2	0.1
Arsenic	200		50	MCL	11.8	268	18.7	6.475
Barium	60		2000	MCL	157	3234	308	109.063
Beryllium	650		4	MCL	17.3	84	1.2	0.65
Cadmium	6.5		5	MCL	2.4	3	5.6	
Chromium	850		100	MCL	17.2	2197	58.8	12.786
Manganese	65		183	HI	2700	3005	1510	294.875
Nickel			100	MCL	21		29	15.288
Silver	45				1.9		7.6	3.633
Thallium	1500		2	MCL	0.44	77	0.21	
Vanadium			256	HI	37.3		43.3	19.763
			(pCi/L)		(pCi/g)	(pCi/g)	(pCi/g)	
Neptunium-237	3		2.2	ELCR		166	0.32	0.181
Technetium-99	0.15		366.3	ELCR		1409	58	32
Uranium (total)	45		14.0	MCL(6)	2.46	16154	88.7	28.502

1. Kd for organics calculated from the following:
   Kd = 0.001*Koc
2. This value is the MCL or is calculated for ingestion only from the ELCR or HI with the following assumptions:
   ELCR: (Excess Lifetime Cancer Risk)
   EXPOSURE ASSUMPTIONS:

Exposure Setting:	Residential
Target Risk Level	1.00E-05
Receptor	Adult
Daily water intake (l/day)	2
Body weight (kg)	70
Number of days/year exposed	350
Number of years exposed	30
Years in lifetime	70
Lifetime average water intake (l/kg body weight per day)	0.012

HI (Hazard Index)
EXPOSURE ASSUMPTIONS:

Exposure setting	Residential
Target Hazard Index	1
Receptor	Adult
Water intake (l/day)	2
Body weight (kg)	70
Number of years exp	30

3. Soil concentration calculated from the following:
   Organics: Cs = (PRG/Dilution Factor)*Kd
   Metals: Cs = [(PRG/Dilution Factor)*Kd]+Backround Metal Concentration
   Dilution factor 0.039
4. Maximum soil concentration detected at any depth
5. Average soil concentration calculated over a depth of 0 - 6 FT.
6. MCL of 20 ug/L converted to pCi/L specific activity
7. Kds for inorganics were taken from two risk models developed for use at radionuclide sites as developed by Radiological Assessments Corporation: DECOM, 1989 and DECHEM, 1989
   Documentation for the DECOM Model was published as referenced in the Phase II SI, Volume 2, page 12:
   RAC.DECOM: April, 1989

Table 2-23
Chemicals of Concern at WMUs 2 and 3

Soil Contaminant	RGOs Target Soil Concentration Direct Contact (mg/kg) (pCi/g)	RGOs Target Soil Concentration Groundwater Protection (mg/kg) (pCi/g)	Maximum Observed Soil Concentration at WMUs 2 and 3 (mg/kg) (pCi/g)	Reference Background Concentration (mg/kg) (pCi/g)
Arsenic	4	334	18.7	11.8
Uranium (total)	6	20,300	89	2.5

Groundwater Contaminant	RGOs Target Groundwater Concentration (µg/L) (pCi/g)	MCL (µg/L)(pCi/L)	Maximum Observed Groundwater Concentration at WMUs 2 and 3 (µg/L) (pCi/L)	Reference Background Concentration (µg/L) (pCi/L)
TCE	1.1	5	270	ND
Arsenic	0.001	50	11.2	ND
Barium	260	2,000	1,200	210
Beryllium	0.02	4	20.8	ND
Cadmium	2	5	5.1	ND
Chromium	18	100	279	31.3
Manganese	18	-	3,920	335
Nickel	73	100	239	10.4
Silver	18	-	46.9	ND
Thallium	0.26	2	0.9	ND
Vanadium	26	-	805	4.7
Tc-99	37	900	2,175	ND
Uranium (total)	1.7	30	38	1.2

Notes:

Chemicals of concern include contaminants that contribute to risk (cancer risk $> 1 \times 10^{-6}$ or HI > 0.1) in soil or groundwater.

ND = Not Detected.
MCL = Maximum Contaminant Level (SDWA).
TCE = Trichloroethene.

RGOs for each chemical of concern are also listed in Table 2-23. The RGOs include target soil concentrations for protection against direct contact and for protection against ingestion of groundwater.

The results of the RI do not indicate that WMUs 2 and 3 are a source of continuing release to surface water. The units are capped and grass-covered. Contamination found in ditches surrounding the units may be indicative of past releases. This contamination with regard to the surface migration pathway at WMUs 2 and 3 includes uranium and metals, primarily arsenic, that are present in surface soils, but do not appear to be migrating.

The results of the RI indicate that WMUs 2 and 3 are a probable source of continuing release to groundwater. Chemicals of concern with regard to the groundwater migration pathway at WMUs 2 and 3 are TCE, Tc-99, and uranium. Heavy metals, including arsenic, barium, beryllium, cadmium chromium, manganese, nickel, silver, thallium, and vanadium, are present above reference background levels in groundwater, but do not appear to be migrating in a dissolved phase.

The buried waste materials are present in specific disposal containers or areas and may be considered principal threat wastes in accordance with EPA guidance (EPA, 1991d). Wastes in WMU 2 include pyrophoric uranium, which is not readily treated.

2.8.2 Data Sufficiency

Data concerning the nature and extent of contamination within the soils and groundwater at these WMUs are sufficient to identify probable conditions and reasonable deviations. Sufficient information is supplied from the site investigation and PGDP waste management records to support the assessment of risks and evaluation of alternatives for final remedial action at these sources. Final remedial action alternatives for the waste in WMU 2 are limited because treatment technologies for pyrophoric uranium are limited. WMU 3 has been closed in accordance with its RCRA permit and is undergoing post-closure assessment. During design or implementation, further definition of the extent of contamination may be appropriate, depending on the selected remedial technology, to optimize design parameters or to determine when sufficient action has occurred.

Because uncertainties exist at WMUs 2 and 3, appropriate contingent action should be identified in the FS to manage the remaining data gaps. The following are considered site condition uncertainties:

- The units are covered with capping systems. Because estimated risks at these units primarily result from groundwater consumption, continuing release of contaminants percolating to groundwater is of concern. The effectiveness of the existing caps in reducing the generation of leachate and controlling migration of contaminants to groundwater has not been assessed. The probable condition at WMU 2 is that wastes are buried at least partially below the shallow groundwater level, and that the clay cap is not preventing release to groundwater. A reasonable deviation is that the existing clay cap is effective in limiting rainfall infiltration, but not lateral groundwater flow. The probable condition at WMU 3 is that wastes are above the water table and that the existing multilayer cap is effective in limiting infiltration. A reasonable deviation is that leachate from WMU 3 continues to be generated because of imperfections in the existing multilayer cap or because groundwater is mounded above the bottom of the wastes, as evidenced by the rising levels of TCE in MW-88 and the presence of liquids in the leachate collection sump.

- Because the units are capped, no surface soil samples were taken directly over the units. The presence of contamination above the caps is not a probable condition, but represents an uncertainty.

- Because the units are capped and because the buried materials (such as pyrophoric uranium) pose a significant threat to site investigation workers, no subsurface soil or waste samples were taken directly in the burial trenches. The presence of contamination within the burial trenches is a probable condition; the risk associated with that material represents an uncertainty. Future direct exposure via excavation into the waste is a probable threat, and future release to groundwater via deterioration of the drums containing uranium or other waste materials is possible. These future potential risks are not quantifiable. A reasonable deviation is that mobility of the uranium is sufficiently low such that migration to groundwater will not occur at levels of concern to public health.

- Because there is limited soil data around the perimeter of the landfills (both surface and subsurface soil data) there are uncertainties regarding the lateral extent and continuity of chemical contamination in soil.

Section 2
Attachments
Risk Calculation Tables

Attachment 2-1 WMU 2/3

Cancer Risk Estimates for Direct Contact to Soil
Future Industrial Exposure
Scenario: unrestricted worker (250 days/year)

Chemical	Slope Factor (mg/kg-day)-1	Soil Conc. mg/kg	Chronic Daily Intake mg/kg-day	Excess Lifetime Cancer Risk
INGESTION				
Pentachlorophenol	0.12	0.1000	1.7E-08	2.1E-09
OCDD (total)	150	0.0033	5.8E-10	8.6E-08
Aroclor-1248	7.7	0.2100	3.7E-08	2.8E-07
Aroclor-1260	7.7	0.1300	2.3E-08	1.7E-07
Arsenic	1.75	10.1700	1.8E-06	3.1E-06
Beryllium	4.3	0.7400	1.3E-07	5.6E-07
pathway sum=				4E-06
DERMAL ABSORPTION				
Pentachlorophenol	0.12	0.1000	1.1E-08	1.3E-09
OCDD (total)	150	0.0033	3.6E-10	5.4E-08
Aroclor-1248	7.7	0.2100	2.3E-08	1.8E-07
Aroclor-1260	7.7	0.1300	1.4E-08	1.1E-07
Arsenic	1.75	10.1700	1.1E-07	1.9E-07
Beryllium	4.3	0.7400	8.1E-09	3.5E-08
pathway sum=				6E-07
	Unit Risk (ug/m3)-1			
INHALATION				
OCDD (total)	0.000000033	0.0033	5.0E-14	5.8E-18
Arsenic	0.0043	10.1700	1.5E-10	2.3E-09
Beryllium	0.0024	0.7400	1.1E-11	9.4E-11
Chromium VI	0.012	19.0000	2.9E-10	1.2E-08
Nickel (soluble salt)	0.00024	25.1000	3.8E-10	3.2E-10
pathway sum=				1E-08
sum of pathways=				5E-06

Ingestion: Intake (mg/kg-d)=(conc. in soil*IngR*CF*FI*EF*ED)/(BW*AT)
Dermal Absorption: Abs dose(mg/kg-d)=(soil conc.*CF*SA*AF*ABS*EF*ED)/(BW*AT)
Inhalation: Inh dose (mg/kg-d)=(soil conc.*EF*ED*InhR*(1/PEF)/(BW*AT)
SFi=Unit Risk*(BW/InhR)*1000

exposure parameters

IngR=Ingestion rate (mgsoil/day)	50	
CF=Conversion factor (10E-6)	1E-06	
FI=Fraction ingested	1	
EF=Exposure frequency (days/year)	250	
ED=Expsoure duration (year)	25	
BW=Body weight (kg)	70	
AT=Averaging time (days)	25550	
SA=Skin surface area (cm2)	3120	
AF=Soil to skin adherence (mg/cm2)	1	
ABS=Absorption (.1%metals; 1%organics)	0.001	0.01
PEF=Particulate emission (m3/kg)	4.63E+09	
InhR=Inhalation rate (m3/day)	20	

Attachment 2-2 WMU 2/3

Chronic Hazard Index Estimates for Direct Contact to Soil

Future Industrial Exposure

Scenario: unrestricted worker (250 days/year)

Chemical	Reference Dose mg/kg-day	Soil Conc. mg/kg	Chronic Daily Intake mg/kg-day	Chronic Hazard
INGESTION				
Pentachlorophenol	0.03	0.10	4.9E-08	2E-06
Arsenic	0.0003	10.17	5.0E-06	2E-02
Barium	0.07	132.68	6.5E-05	9E-04
Beryllium	0.005	0.74	3.6E-07	7E-05
Chromium VI	0.005	19.00	9.3E-06	2E-03
Copper	0.037	24.71	1.2E-05	3E-04
Manganese	0.14	2541.05	1.2E-03	9E-03
Mercury	0.0003	0.15	7.3E-08	2E-04
Nickel (soluble salt)	0.02	25.10	1.2E-05	6E-04
Selenium	0.005	0.40	2.0E-07	4E-05
Silver	0.005	5.38	2.6E-06	5E-04
Vanadium	0.007	31.80	1.6E-05	2E-03
Zinc	0.3	67.05	3.3E-05	1E-04
Uranium (soluble salt)	0.003	83.58	4.1E-05	1E-02
pathway sum=				0.05
DERMAL ABSORPTION				
Pentachlorophenol	0.03	0.10	3.1E-08	1E-06
Arsenic	0.0003	10.17	3.1E-07	1E-03
Barium	0.07	132.68	4.1E-06	6E-05
Beryllium	0.005	0.74	2.3E-08	5E-06
Chromium VI	0.005	19.00	5.8E-07	1E-04
Copper	0.037	24.71	7.5E-07	2E-05
Manganese	0.005	2541.05	7.8E-05	2E-02
Mercury	0.0003	0.15	4.6E-09	2E-05
Nickel (soluble salt)	0.02	25.10	7.7E-07	4E-05
Selenium	0.005	0.40	1.2E-08	2E-06
Silver	0.005	5.38	1.6E-07	3E-05
Vanadium	0.007	31.80	9.7E-07	1E-04
Zinc	0.3	67.05	2.0E-06	7E-06
Uranium (soluble salt)	0.003	83.58	2.6E-06	9E-04
pathway sum=				0.02
	Reference Conc. mg/m3			
INHALATION				
Barium	0.0005	132.68	5.6E-09	4E-05
Chromium VI	0.000002	19.00	8.0E-10	1E-03
Manganese	0.0004	2541.05	1.1E-07	9E-04
Mercury	0.0003	0.15	6.3E-12	7E-08
pathway sum=				0.002
Sum of pathways=				0.07

Ingestion: Intake (mg/kg-d)=(conc. in soil*IngR*CF*FI*EF*ED)/(BW*AT)

Dermal Absorption: Abs dose(mg/kg-d)=(soil conc.*CF*SA*AF*ABS*EF*ED)/(BW*AT)

Inhalation: Inh dose (mg/kg-d)=(soil conc.*EF*ED*InhR*(1/PEF)/(BW*AT)

Inh RfD=RfC*(InhR/BW)

exposure parameters		
IngR=Ingestion rate (mgsoil/day)	50	
CF=Conversion factor (10E-6)	1E-06	
FI=Fraction ingested	1	
EF=Exposure frequency (days/year)	250	
ED=Expsoure duration (year)	25	
BW=Body weight (kg)	70	
AT=Averaging time (days)	9125	
SA=Skin surface area (cm2)	3120	
AF=Soil to skin adherence (mg/cm2)	1	
ABS=Absorption (.1%metals; 1%organics)	0.001	0.01
PEF=Particulate emission (m3/kg)	4.63E+09	
InhR=Inhalation rate (m3/day)	20	

ATTACHMENT 2-3 WMU 2/3

EXCESS LIFETIME RISK OF CANCER INCIDENCE FOR DIRECT CONTACT TO SOIL

FUTURE INDUSTRIAL EXPOSURE

SCENARIO: unrestricted worker (250 days/yr)

RADIONUCLIDE(a)	SOIL CONC. (pCi/g) (SC)	ANNUAL INTAKE (pCi)	TOTAL INTAKE (pCi)	DOSE CONVERSION FACTOR (b) (mrem/pCi) or (mrem*g/pci*hr)	COMMITTED EFFECTIVE DOSE EQUIVALENT 1 YR INTAKE (mrem/yr) (c)	TOTAL COMMITTED EFFECTIVE DOSE EQUIVALENT (mrem)	CANCER INCIDENCE RISK FACTOR (pCi)-1 (d) or (g/pci*l)	RISK OF CANCER INCIDENCE
INGESTION								
Neptunium-237+D	0.32	4.00	100.0	4.4E-03	1.8E-02	4.4E-01	2.2E-10	2.2E-08
Plutonium-239	7.90	98.75	2468.8	3.7E-04	3.6E-02	9.1E-01	2.3E-10	5.7E-07
Thorium-230	14.00	175.00	4375.0	5.5E-04	9.6E-02	2.4E+00	1.3E-11	5.7E-08
Uranium-234	18.00	225.00	5625.0	2.8E-04	6.4E-02	1.6E+00	1.6E-11	9.0E-08
Uranium-235+D	1.70	21.25	531.3	2.7E-04	5.7E-03	1.4E-01	1.6E-11	8.5E-09
Uranium-238+D	69.00	862.50	21562.5	2.6E-04	2.2E-01	5.5E+00	2.8E-11	6.0E-07
Technetium-99	58.00	725.00	18125.0	1.5E-06	1.1E-03	2.6E-02	1.3E-12	2.4E-08
Pathway sum=					4.4E-01	1.1E+01		1E-06
INHALATION								
Neptunium-237+D	0.32	3.5E-04	8.6E-03	5.4E-01	1.9E-04	4.7E-03	2.9E-08	2.5E-10
Plutonium-239	7.90	8.5E-03	2.1E-01	3.1E-01	2.6E-03	6.6E-02	3.8E-08	8.1E-09
Technetium-99	14.00	1.5E-02	3.8E-01	8.3E-06	1.3E-07	3.1E-06	8.3E-12	3.1E-12
Thorium-230	18.00	1.9E-02	4.9E-01	2.6E-01	5.1E-03	1.3E-01	2.9E-08	1.4E-08
Uranium-234	1.70	1.8E-03	4.6E-02	1.3E-01	2.4E-04	6.1E-03	2.6E-08	1.2E-09
Uranium-235+D	69.00	7.5E-02	1.9E+00	1.2E-01	9.2E-03	2.3E-01	2.5E-08	4.7E-08
Uranium-238+D	58.00	6.3E-02	1.6E+00	1.2E-01	7.4E-03	1.8E-01	5.2E-08	8.1E-08
Pathway sum=					2.5E-02	6.2E-01		2E-07
EXPOSURE TO EXTERNAL RADIATION								
Neptunium-237+D	0.32			1.0E-04	6.4E-02	1.6E+00	4.3E-07	8.2E-07
Plutonium-239	7.90			4.2E-08	6.6E-04	1.7E-02	1.7E-11	8.0E-10
Technetium-99	14.00			1.5E-08	4.2E-04	1.0E-02	6.0E-13	5.0E-11
Thorium-230	18.00			1.2E-07	4.3E-03	1.1E-01	5.4E-11	5.8E-09
Uranium-234	1.70			5.7E-08	1.9E-04	4.8E-03	3.0E-11	3.0E-10
Uranium-235+D	69.00			3.8E-05	5.2E+00	1.3E+02	2.4E-07	9.9E-05
Uranium-238+D	58.00			7.5E-06	8.7E-01	2.2E+01	3.6E-08	1.2E-05
Pathway sum=					6.2E+00	1.5E+02		1E-04
Sum of the Pathways=					6.6E+00	1.7E+02		1E-04

EXPOSURE ASSUMPTIONS

Ingestion Rate(IR) (g/day)	0.05	Ingestion Risk = SC x IR x EF x ED x RF
Exposure Frequency(EF) (days/yr)	250	Inhalation Risk = SC + IR x EF x ED x CF x 1/PEF x RF
Exposure Duration(ED) (years)	25	External Radiation Risk = SC x ED x Te x (1-SF) x RF
Particulate emission factor (m3/kg):	4.63E+09	
Worker inhalation rate (m3/day):	20	
Conversion factor (1000 g/kg):	1000	
Exposure Time (ET) (hr/day)	8	
Shielding factor (SF):	0	
Fraction of year exposed (Te):	0.24	Te = (ET x EF) / (8400 HR/YR)

NOTES:

(a) Radionuclides shown with +D include short lived daughter products in risk calculations.

(b) Ingestion and inhalation dose factors were taken from Federal Guidance Report 11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Factors for Inhalation, Submersion, and Ingestion"(EPA-520/1-88-020). Dose after intake of parent radionuclide. External Radiation dose factors were taken from NUREG/CR-5512 "Residual Radioactive Contamination from Decommissioning, Technical Basis for Translating Contamination Levels to Annual Dose".

(c) Committed effective dose equivalent expressed as committed (50 yr.) dose (mrem) due to one year of exposure (mrem/yr).

(d) Cancer risk factors taken from January 1992 HEAST tables.

Attachment 2-4 WMU 2/3
Cancer Risk Estimates for Direct Contact to Soil
Current Industrial Exposure
Scenario: worker/intruder (25 days/year)

Chemical	Slope Factor (mg/kg-day)-1	Soil Conc. mg/kg	Chronic Daily Intake mg/kg-day	Excess Lifetime Cancer Risk
INGESTION				
Pentachlorophenol	0.12	0.10	1.7E-09	2.1E-10
OCDD (total)	150	0.0033	5.8E-11	8.6E-09
Aroclor-1248	7.7	0.21	3.7E-09	2.8E-08
Aroclor-1260	7.7	0.130	2.3E-09	1.7E-08
Arsenic	1.75	10.17	1.8E-07	3.1E-07
Beryllium	4.3	0.74	1.3E-08	5.6E-08
pathway sum=				4E-07
DERMAL ABSORPTION				
Pentachlorophenol	0.12	0.10	1.1E-09	1.3E-10
OCDD (total)	150	0.0033	3.6E-11	5.4E-09
Aroclor-1248	7.7	0.21	2.3E-09	1.8E-08
Aroclor-1260	7.7	0.130	1.4E-09	1.1E-08
Arsenic	1.75	10.17	1.1E-08	1.9E-08
Beryllium	4.3	0.74	8.1E-10	3.5E-09
pathway sum=				6E-08
	Unit Risk (ug/m3)-1			
INHALATION				
OCDD (total)	0.000000033	0.0033	5.0E-15	5.8E-19
Arsenic	0.0043	10.17	1.5E-11	2.3E-10
Beryllium	0.0024	0.74	1.1E-12	9.4E-12
Chromium VI	0.012	19.00	2.9E-11	1.2E-09
Nickel (soluable salts)	0.00024	25.10	3.8E-11	3.2E-11
pathway sum=				1E-09
Sum of pathways=				5E-07

Ingestion: Intake (mg/kg-d)=(conc. in soil*IngR*CF*FI*EF*ED)/(BW*AT)
Dermal Absorption: Abs dose(mg/kg-d)=(soil conc.*CF*SA*AF*ABS*EF*ED)/(BW*AT)
Inhalation: Inh dose (mg/kg-d)=(soil conc.*EF*ED*InhR*(1/PEF)/(BW*AT)
SFi=Unit Risk*(BW/InhR)*1000

exposure parameters

IngR=Ingestion rate (mgsoil/day)	50	
CF=Conversion factor (10E-6)	1E-06	
FI=Fraction ingested	1	
EF=Exposure frequency (days/year)	25	
ED=Expsoure duration (year)	25	
BW=Body weight (kg)	70	
AT=Averaging time (days)	25550	
SA=Skin surface area (cm2)	3120	
AF=Soil to skin adherence (mg/cm2)	1	
ABS=Absorption (.1%metals; 1%organics)	0.001	0.01
PEF=Particulate emission (m3/kg)	4.63E+09	
InhR=Inhalation rate (m3/day)	20	

Attachment 2-5 WMU 2/3

Chronic Hazard Index Estimates for Direct Contact to Soil
Current Industrial Exposure
Scenario: worker/intruder (25 days/year)

Chemical	Reference Dose (mg/kg-day)	Soil Conc. (mg/kg)	Chronic Daily Intake (mg/kg-day)	Hazard Quotient
INGESTION				
Pentachlorophenol	0.03	0.10	4.9E-09	1.6E-07
Arsenic	0.0003	10.17	5.0E-07	1.7E-03
Barium	0.07	132.68	6.5E-06	9.3E-05
Beryllium	0.005	0.74	3.6E-08	7.2E-06
Chromium VI	0.005	19.00	9.3E-07	1.9E-04
Copper	0.037	24.71	1.2E-06	3.3E-05
Manganese	0.14	2541.05	1.2E-04	8.9E-04
Mercury	0.0003	0.15	7.3E-09	2.4E-05
Nickel, soluble salt	0.02	25.10	1.2E-06	6.1E-05
Selenium	0.005	0.40	2.0E-08	3.9E-06
Silver	0.003	5.38	2.6E-07	8.8E-05
Vanadium	0.007	31.80	1.6E-06	2.2E-04
Zinc	0.30	67.05	3.3E-06	1.1E-05
Uranium (soluble salts)	0.003	83.58	4.1E-06	1.4E-03
pathway sum=				0.005
DERMAL ABSORPTION				
Pentachlorophenol	0.03	0.10	3.1E-09	1.0E-07
Arsenic	0.0003	10.17	3.1E-08	1.0E-04
Barium	0.07	132.68	4.1E-07	5.8E-06
Beryllium	0.005	0.74	2.3E-09	4.5E-07
Chromium VI	0.005	19.00	5.8E-08	1.2E-05
Copper	0.037	24.71	7.5E-08	2.0E-06
Manganese	0.005	2541.05	7.8E-06	1.6E-03
Mercury	0.0003	0.15	4.6E-10	1.5E-06
Nickel, soluble salt	0.02	25.10	7.7E-08	3.8E-06
Selenium	0.005	0.40	1.2E-09	2.4E-07
Silver	0.003	5.38	1.6E-08	5.5E-06
Vanadium	0.007	31.80	9.7E-08	1.4E-05
Zinc	0.3	67.05	2.0E-07	6.8E-07
Uranium (soluble salts)	0.003	83.58	2.6E-07	8.5E-05
pathway sum=				0.002
	Reference Conc. (mg/m3)			
INHALATION				
Barium	0.0005	132.68	5.6E-10	3.9E-06
Chromium VI	0.000002	19.00	8.0E-11	1.4E-04
Manganese	0.0004	2541.05	1.1E-08	9.4E-05
Mercury	0.0003	0.15	6.3E-13	7.4E-09
pathway sum=				0.0002
Sum of pathways=				0.007

Ingestion:	Intake (mg/kg-d)=(conc. in soil*IngR*CF*FI*EF*ED)/(BW*AT)
Dermal Absorption:	Abs dose(mg/kg-d)=(soil conc.*CF*SA*AF*ABS*EF*ED)/(BW*AT)
Inhalation:	Inh dose (mg/kg-d)=(soil conc.*EF*ED*InhR*(1/PEF)/(BW*AT) Inh RfD=RfC*(InhR/BW)

exposure parameters

IngR=Ingestion rate (mgsoil/day)	50	
CF=Conversion factor (10E-6)	1E-06	
FI=Fraction ingested	1	
EF=Exposure frequency (days/year)	25	
ED=Expsoure duration (year)	25	
BW=Body weight (kg)	70	
AT=Averaging time (days)	9125	
SA=Skin surface area (cm2)	3120	
AF=Soil to skin adherence (mg/cm2)	1	
ABS=Absorption (.1%metals; 1%organics)	0.001	0.01
PEF=Particulate emission (m3/kg)	4.63E+09	
InhR=Inhalation rate (m3/day)	20	

ATTACHMENT 2-6 WMU 2/3

EXCESS LIFETIME RISK OF CANCER INCIDENCE FOR DIRECT CONTACT TO SOIL
CURRENT INDUSTRIAL EXPOSURE

SCENARIO: worker/intruder (25 days/yr)

RADIONUCLIDE(a)	SOIL CONC. (pCi/g) (SC)	ANNUAL INTAKE (pCi)	TOTAL INTAKE (pCi)	DOSE CONVERSION FACTOR (b) (mrem/pCi) or (mrem*g/pci*hr)	COMMITTED EFFECTIVE DOSE EQUIVALENT 1 YR INTAKE (mrem/yr) (c)	TOTAL COMMITTED EFFECTIVE DOSE EQUIVALENT (mrem)	CANCER INCIDENCE RISK FACTOR (pCi)-1 (d) or (g/pci*l)	RISK OF CANCER INCIDENCE
INGESTION								
Neptunium-237+D	0.36	0.45	11.3	4.4E-03	2.0E-03	5.0E-02	2.2E-10	2.5E-09
Plutonium-239	7.90	9.88	246.9	3.7E-04	3.6E-03	9.1E-02	2.3E-10	5.7E-08
Thorium-230	14.00	17.50	437.5	5.5E-04	9.6E-03	2.4E-01	1.3E-11	5.7E-09
Uranium-234	18.00	22.50	562.5	2.8E-04	6.4E-03	1.6E-01	1.6E-11	9.0E-09
Uranium-235+D	1.70	2.13	53.1	2.7E-04	5.7E-04	1.4E-02	1.6E-11	8.5E-10
Uranium-238+D	69.00	86.25	2156.3	2.6E-04	2.2E-02	5.5E-01	2.8E-11	6.0E-08
Technetium-99	58.00	72.50	1812.5	1.5E-06	1.1E-04	2.6E-03	1.3E-12	2.4E-09
Pathway sum=					4.4E-02	1.1E+00		1E-07
INHALATION								
Neptunium-237+D	0.36	3.9E-05	9.7E-04	5.4E-01	2.1E-05	5.2E-04	2.9E-08	2.8E-11
Plutonium-239	7.90	8.5E-04	2.1E-02	3.1E-01	2.6E-04	6.6E-03	3.8E-08	8.1E-10
Technetium-99	14.00	1.5E-03	3.8E-02	8.3E-06	1.3E-08	3.1E-07	8.3E-12	3.1E-13
Thorium-230	18.00	1.9E-03	4.9E-02	2.6E-01	5.1E-04	1.3E-02	2.9E-08	1.4E-09
Uranium-234	1.70	1.8E-04	4.6E-03	1.3E-01	2.4E-05	6.1E-04	2.6E-08	1.2E-10
Uranium-235+D	69.00	7.5E-03	1.9E-01	1.2E-01	9.2E-04	2.3E-02	2.5E-08	4.7E-09
Uranium-238+D	58.00	6.3E-03	1.6E-01	1.2E-01	7.4E-04	1.8E-02	5.2E-08	8.1E-09
Pathway sum=	7.90				2.5E-03	6.2E-02		2E-08
EXPOSURE TO EXTERNAL RADIATION								
Neptunium-237+D	0.36			1.0E-04	7.2E-03	1.8E-01	4.3E-07	9.2E-08
Plutonium-239	7.90			4.2E-08	6.6E-05	1.7E-03	1.7E-11	8.0E-11
Technetium-99	14.00			1.5E-08	4.2E-05	1.0E-03	6.0E-13	5.0E-12
Thorium-230	18.00			1.2E-07	4.3E-04	1.1E-02	5.4E-11	5.8E-10
Uranium-234	1.70			5.7E-08	1.9E-05	4.8E-04	3.0E-11	3.0E-11
Uranium-235+D	69.00			3.8E-05	5.2E-01	1.3E+01	2.4E-07	9.9E-06
Uranium-238+D	58.00			7.5E-06	8.7E-02	2.2E+00	3.6E-08	1.2E-06
Pathway sum=	7.90				6.2E-01	1.5E+01		1E-05
Sum of the Pathways=					6.7E-01	1.7E+01		1E-05

EXPOSURE ASSUMPTIONS

Ingestion Rate(IR) (g/day)	0.05	Ingestion Risk = SC x IR x EF x ED x RF
Exposure Frequency(EF) (days/yr)	25	Inhalation Risk = SC + IR x EF x ED x CF x 1/PEF x RF
Exposure Duration(ED) (years)	25	External Radiation Risk = SC x ED x Te x (1-SF) x RF
Particulate emission factor (m3/kg)	4.63E+09	
Worker inhalation rate (m3/day)	20	
Conversion factor (1000 g/kg)	1000	
Exposure Time (ET) (hr/day)	8	
Shielding factor (SF)	0	
Fraction of year exposed (Te)	0.02	Te = (ET x EF) / (8400 HR/YR)

NOTES:

(a) Radionuclides shown with +D include short lived daughter products in risk calculations.

(b) Ingestion and inhalation dose factors were taken from Federal Guidance Report 11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Factors for Inhalation, Submersion, and Ingestion"(EPA-520/1-88-020). Dose after intake of parent radionuclide. External Radiation dose factors were taken from NUREG/CR-5512 "Residual Radioactive Contamination from Decommissioning, Technical Basis for Translating Contamination Levels to Annual Dose".

(c) Committed effective dose equivalent expressed as committed (50 yr.) dose (mrem) due to one year of exposure (mrem/yr).

(d) Cancer risk factors taken from January 1992 HEAST tables.

Attachment 2-7 WMU 2/3

Cancer Risks Estimated for Domestic use of Groundwater

Scenario: Future Potable Use of Groundwater

MW093 (RGA)

Chemical	Oral Slope Factor (mg/kg-day)-1	Concentration MW093 ug/L	Chronic Daily Intake mg/kg-day	Excess Lifetime Cancer Risk	Total Pathway Risk
INGESTION OF GROUNDWATER					
2,4-Dinitrotoluene	0.68	18.50	2.2E-04	1.5E-04	
N-Nitroso-di-n-propylamine	7.0	22.00	2.6E-04	1.8E-03	
Pentachlorophenol	0.12	57.00	6.7E-04	8.0E-05	
Arsenic	1.75	3.35	3.9E-05	6.9E-05	
SUM					2E-03

Ingestion: Intake (mg/kg-d)=(conc. in gw*IngR*CF*EF*ED)/(BW*AT)

exposure parameters

IngR=Ingestion rate (L/day)	2
CF=Conversion Factor (mg/ug)	0.001
EF=Exposure frequency (days/year)	350
ED=Expsoure duration (year)	30
BW=Body weight (kg)	70
AT=Averaging time (days)	25550

Attachment 2-8 WMU 2/3

Cancer Risk Estimates for Domestic Use of Groundwater

Scenario: Future Potable Use of Groundwater

MW074 (UCRS)

Chemical	Oral Slope Factor (mg/kg-day)-1	Concentration MW074 ug/L	Chronic Daily Intake mg/kg-day	Excess Lifetime Cancer Risk	Total Pathway Risk
INGESTION OF GROUNDWATER					
Beryllium	4.3	15.8	1.9E-04	8.0E-04	
					8.0E-04
INHALATION OF VOLATILE COMPOUNDS DURING DOMESTIC USE OF GROUNDWATER					
					0.0E+00
Sum of Pathways=					8.0E-04

Ingestion: Intake (mg/kg-d)=(conc. in gw*IngR*CF*EF*ED)/(BW*AT)

Inhalation: Inh dose (mg/kg-d)=(conc. in gw*VF*InhR*EF*ED)/(BW*AT)

SFi=Unit Risk*(BW/InhR)*1000

exposure parameters

IngR=Ingestion rate (L/day)	2
CF=Conversion Factor (mg/ug)	0.001
EF=Exposure frequency (days/year)	350
ED=Expsoure duration (year)	30
BW=Body weight (kg)	70
AT=Averaging time (days)	25550
InhR=Indoor Inhalation Rate (m3/day)	15
VF=Volatilization Factor (L/m3)	0.5

Attachment 2-8 WMU 2/3

Cancer Risk Estimates for Domestic Use of Groundwater

Scenario: Future Potable Use of Groundwater

MW074 (UCRS)

Chemical	Oral Slope Factor (mg/kg-day)-1	Concentration MW074 ug/L	Chronic Daily Intake mg/kg-day	Excess Lifetime Cancer Risk	Total Pathway Risk
INGESTION OF GROUNDWATER					
Beryllium	4.3	15.8	1.9E-04	8.0E-04	
SUM					8.0E-04

Ingestion: Intake (mg/kg-d)=(conc. in gw*IngR*CF*EF*ED)/(BW*AT)

exposure parameters

IngR=Ingestion rate (L/day)	2
CF=Conversion Factor (mg/ug)	0.001
EF=Exposure frequency (days/year)	350
ED=Expsoure duration (year)	30
BW=Body weight (kg)	70
AT=Averaging time (days)	25550

Attachment 2-9 WMU 2/3

Hazard Index Estimates for Domestic Use of Groundwater

Scenario: Future Potable Use of Groundwater

MW074 (UCRS)

Chemical	Reference Dose (mg/kg-day)	Concentration MW074 ug/L	Chronic Daily Intake mg/kg-day	Hazard Quotient	Pathway Hazard Index
INGESTION OF GROUNDWATER					
Nickel	0.02	125.4	3.4E-03	0.172	
Barium	0.07	634	1.7E-02	0.248	
Zinc	0.3	343.3	9.4E-03	0.031	
Vanadium	0.007	410.1	1.1E-02	1.605	
Chromium	0.005	139.8	3.8E-03	0.766	
Cadmium	0.0005	4.6	1.3E-04	0.252	
Silver	0.003	42.1	1.2E-03	0.384	
Manganese	0.005	1535.3	4.2E-02	8.413	
Copper	0.037	95.9	2.6E-03	0.000	
Beryllium	0.005	15.8	4.3E-04	0.087	
Uranium (soluble salts)	0.003	10.68	2.9E-04	0.098	
					12

EQUATIONS:

Ingestion: Intake (mg/kg-d)=(conc. in gw*IngR*CF*EF*ED)/(BW*AT)

exposure parameters

IngR=Ingestion rate (L/day)	2
CF=Conversion Factor (mg/ug)	0.001
EF=Exposure frequency (days/year)	350
ED=Expsoure duration (year)	30
BW=Body weight (kg)	70
AT=Averaging time (days)	10950

Attachment 2-10 WMU 2/3

Hazard Index Estimates for Domestic Use of Groundwater

Scenario: Future Potable Use of Groundwater

MW089 (RGA)

Chemical	Reference Dose (mg/kg-day)	Concentration MW089 ug/L	Chronic Daily Intake mg/kg-day	Hazard Quotient	Pathway Hazard Index
INGESTION OF GROUNDWATER					
Nickel	0.02	14.6	4.0E-04	0.020	
Barium	0.07	253	6.9E-03	0.099	
Zinc	0.3	34.3	9.4E-04	0.003	
Vanadium	0.007	7.6	2.1E-04	0.030	
Chromium	0.005	7.8	2.1E-04	0.043	
Cyanide	0.02	3	8.2E-05	0.004	
Thallium (Carbonate)	0.00008	0.9	2.5E-05	0.308	
Manganese	0.005	3630	9.9E-02	19.890	
Copper	0.037	9	2.5E-04	0.000	
Arsenic	0.0003	3.9	1.1E-04	0.356	
					20.75
INHALATION OF VOLATILE COMPOUNDS DURING DOMESTIC USE OF GROUNDWATER					
					0.0
Sum of Pathways=					20.75

EQUATIONS:

Ingestion: Intake (mg/kg-d)=(conc. in gw*IngR*CF*EF*ED)/(BW*AT)

Inhalation: Inh dose (mg/kg-d)=(conc. in gw*VF*InhR*EF*ED)/(BW*AT)

exposure parameters

IngR=Ingestion rate (L/day)	2
CF=Conversion Factor (mg/ug)	0.001
EF=Exposure frequency (days/year)	350
ED=Expsoure duration (year)	30
BW=Body weight (kg)	70
AT=Averaging time (days)	10950
InhR=Indoor Inhalation Rate Z(m3/day)	15
VF=Volatilization Factor (L/m3)	0.5

Attachment 2-11 WMU 2/3

Risk of Cancer Incidence for Domestic Use of Groundwater

Scenario: Future Potable Use of Groundwater

MW 154 (UCRS)

RADIONUCLIDE (a)	GW CONC. (pCi/l) (b)	ANNUAL INTAKE (pCi/yr)	TOTAL INTAKE (pCi)	INGESTION DOSE CONVERSION FACTOR (c) (mrem/pCi)	COMMITTED EFFECTIVE DOSE EQUIVALENT 1 YR INTAKE (mrem/yr) (d)	TOTAL COMMITTED EFFECTIVE DOSE EQUIVALENT (mrem)	CANCER INCIDENCE RISK FACTOR FOR INGESTION (pCi)-1 (e)	RISK OF CANCER INCIDENCE
NP-237	0.32	224.0	6720.0	4.4E-03	9.9E-01	3.0E+01	2.2E-10	1.5E-06
PU-239	0.18	126.0	3780.0	3.7E-04	4.6E-02	1.4E+00	2.3E-10	8.7E-07
TC-99	1000	7.0E+05	2.1E+07	1.5E-06	1.0E+00	3.1E+01	1.3E-12	2.7E-05
U-234	3.6	2520.0	75600.0	2.8E-04	7.1E-01	2.1E+01	1.6E-11	1.2E-06
U-235 +D	0.14	98.0	2940.0	2.7E-04	2.6E-02	7.8E-01	1.6E-11	4.7E-08
U-238 +D	27	18900.0	567000.0	2.6E-04	4.8E+00	1.4E+02	2.8E-11	1.6E-05
Pathway totals=					7.6E+00	2.3E+02		5E-05

EXPOSURE ASSUMPTIONS

Exposure scenario: Ingestion of contaminated groundwater

Ingestion rate (l/day):	2	Ingestion risk = WC x IR x EF x ED x RF
Exposure frequency (days/year):	350	
Exposure duration (years):	30	

NOTES:

(a) Radionuclides shown with +D include short lived daughter products in risk calculations.

(b) Sample concentrations are actual values. Results are shown as calculated by the lab, even if they are less than the detection limit for this analysis. ND is shown if the actual value was negative.

(c) Dose factors taken from Federal Guidance Report 11, "Limiting Values Of Radionuclide Intake and Air Concentration and Dose Factors for Inhalation, Submersion, and Ingestion" (EPA-520/1-88-020). Dose factors include the contribution to dose from ingrowth of decay products after intake of parent radionuclide.

(d) Committed effective dose equivalent expressed as committed (50 yr.) dose (mrem) due to one year of exposure (mrem/yr).

(e) Cancer risk factors taken from January 1992 HEAST tables.

Attachment 2-12 **WMU 2/3**

Risk of Cancer Incidence for Domestic Use of Groundwater

Scenario: Future Potable Use of Groundwater

MW 84 (RGA)

RADIONUCLIDE (a)	GW CONC. (pCi/l) (b)	ANNUAL INTAKE (pCi/yr)	TOTAL INTAKE (pCi)	INGESTION DOSE CONVERSION FACTOR (c) (mrem/pCi)	COMMITTED EFFECTIVE DOSE EQUIVALENT 1 YR INTAKE (mrem/yr) (d)	TOTAL COMMITTED EFFECTIVE DOSE EQUIVALENT (mrem)	CANCER INCIDENCE RISK FACTOR FOR INGESTION (pCi)-1 (e)	RISK OF CANCER INCIDENCE
NP-237	ND	0.0	0.0	4.4E-03	0.0E+00	0.0E+00	2.2E-10	0.0E+00
PU-239	0.03	21.0	630.0	3.7E-04	7.7E-03	2.3E-01	2.3E-10	1.4E-07
TC-99	466	3.3E+05	9.8E+06	1.5E-06	4.8E-01	1.4E+01	1.3E-12	1.3E-05
U-234	0.14	98.0	2940.0	2.8E-04	2.8E-02	8.3E-01	1.6E-11	4.7E-08
U-235 +D	0.01	7.0	210.0	2.7E-04	1.9E-03	5.6E-02	1.6E-11	3.4E-09
U-238 +D	0.23	161.0	4830.0	2.6E-04	4.1E-02	1.2E+00	2.8E-11	1.4E-07
TOTALS					5.5E-01	1.7E+01		1E-05

EXPOSURE ASSUMPTIONS

Exposure scenario: Ingestion of contaminated groundwater

Ingestion risk = WC x IR x EF x ED x RF

Ingestion rate (l/day):	2
Exposure frequency (days/year):	350
Exposure duration (years):	30

NOTES:

(a) Radionuclides shown with +D include short lived daughter products in risk calculations.

(b) Sample concentrations are actual values. Results are shown as calculated by the lab, even if they are less than the detection level limit for that analysis. ND is shown if the actual value was negative.

(c) Dose factors taken from Federal Guidance Report 11, "Limiting Values Of Radionuclide Intake and Air Concentration and Dose Factors for Inhalation, Submersion, and Ingestion" (EPA-520/1-88-020). Dose factors include the contribution to dose from ingrowth of decay products after intake of parent radionuclide.

(d) Committed effective dose equivalent expressed as committed (50 yr.) dose (mrem) due to one year of exposure (mrem/yr).

(e) Cancer risk factors taken from January 1992 HEAST tables.

Attachment 2-13 WMU 2/3

Summary of Cancer Risk Estimates by Well
for Groundwater Ingestion
Scenario: Future Potable Use of Groundwater

Station ID	Chemical Name	Oral Slope Factor (mg/kg-day)-1	Average Conc. ug/L	Chronic Daily Intake mg/kg-day	Excess Lifetime Cancer Risk
REGIONAL GRAVEL AQUIFER					
MW048		SUBTOTAL			NCD
MW050	BERYLLIUM	4.3	2.30	2.7E-05	1.2E-04
MW050	TRICHLOROETHENE	0.011	2.00	2.3E-05	2.6E-07
MW050		SUBTOTAL			1E-04
MW067		SUBTOTAL			NCD
MW084	TRICHLOROETHENE	0.011	27.00	3.2E-04	3.5E-06
MW084		SUBTOTAL			3E-06
MW086	CHLOROMETHANE	0.013	66.67	7.8E-04	1.0E-05
MW086	TRICHLOROETHENE	0.011	36.00	4.2E-04	4.6E-06
MW086		SUBTOTAL			1E-05
MW087		SUBTOTAL			NCD
MW089	TRICHLOROETHENE	0.011	5.50	6.5E-05	7.1E-07
MW089	ARSENIC	1.5	3.90	4.6E-05	6.9E-05
MW089		SUBTOTAL			7E-05
MW090	TRICHLOROETHENE	0.011	2.00	2.3E-05	2.6E-07
MW090		SUBTOTAL			3E-07
MW092	ARSENIC	1.5	2.85	3.3E-05	5.0E-05
MW092	BERYLLIUM	4.3	1.50	1.8E-05	7.6E-05
MW092		SUBTOTAL			1E-04
MW093	2,4-DINITROTOLUENE	0.68	18.50	2.2E-04	1.5E-04
MW093	N-NITROSO-DI-N-PROPYLAMINE	7	22.00	2.6E-04	1.8E-03
MW093	PENTACHLOROPHENOL	0.12	57.00	6.7E-04	8.0E-05
MW093		SUBTOTAL			2E-03
MW095	ARSENIC	1.5	3.35	3.9E-05	5.9E-05
MW095		SUBTOTAL			6E-05
UPPER CONTINENTAL RECHARGE SYSTEM					
MW049	TRICHLOROETHENE	0.011	5.00	5.9E-05	6.5E-07
MW049	ARSENIC	1.5	6.40	7.5E-05	1.1E-04
MW049	BERYLLIUM	4.3	5.20	6.1E-05	2.6E-04
MW049		SUBTOTAL			4E-04
MW074	BERYLLIUM	4.3	15.80	1.9E-04	8.0E-04
MW074		SUBTOTAL			8E-04
MW085		SUBTOTAL			NCD

Attachment 2-13 WMU 2/3

Summary of Cancer Risk Estimates by Well
for Groundwater Ingestion
Scenario: Future Potable Use of Groundwater

Station ID	Chemical Name	Oral Slope Factor (mg/kg-day)-1	Average Conc. ug/L	Chronic Daily Intake mg/kg-day	Excess Lifetime Cancer Risk
MW088	ARSENIC	1.5	8.80	1.0E-04	1.5E-04
MW088	TRICHLOROETHENE	0.011	168.00	2.0E-03	2.2E-05
MW088		SUBTOTAL			2E-04
MW091	ARSENIC	1.5	1.00	1.2E-05	1.8E-05
MW091	BROMOFORM	0.0079	1.00	1.2E-05	9.3E-08
MW091	TRICHLOROETHENE	0.011	11.00	1.3E-04	1.4E-06
MW091		SUBTOTAL			2E-06
MW094	ARSENIC	1.5	3.10	3.6E-05	5.5E-05
MW094	TRICHLOROETHENE	0.011	45.33	5.3E-04	5.9E-06
MW094		SUBTOTAL			6E-05
MW154		SUBTOTAL			NCD
WMU003	BERYLLIUM	4.3	2.93	3.4E-05	1.5E-04
WMU003	TRICHLOROETHENE	0.011	10.40	1.2E-04	1.3E-06
WMU003	AROCLOR-1248	7.7	0.71	8.3E-06	6.4E-05
WMU003		SUBTOTAL			2E-04

Exposure Assumptions:

Rate Ingested (liters/day)	2
Body Weight (kg)	70
Exposure Frequency (days/year)	350
Exposure Duration (years)	30
Conversion Factor	0.001
Averaging Time	25550
Fraction Ingested	1

NCD = No Carcinogens Detected

Attachment 2-14 WMU 2/3
Summary of Hazard Indices by Well
for Groundwater Ingestion
Scenario: Future Potable Use of Groundwater

Station ID	Chemical Name	Reference Dose mg/kg-day	Average Concentration ug/l	Chronic Daily Intake mg/kg-day	Hazard Quotient
REGIONAL GRAVEL AQUIFER					
MW048	MANGANESE	0.005	564.5	1.5E-02	3
MW048	BARIUM	0.07	92.7	2.5E-03	0.04
MW048	VANADIUM	0.007	8.3	2.3E-04	0.03
MW048	ZINC	0.3	236.6	6.5E-03	0.02
MW048	CHROMIUM	0.005	4.3	1.2E-04	0.02
MW048	COPPER	0.037	10.9	3.0E-04	0.01
MW048	SUBTOTAL				3
MW050	1,2-DICHLOROETHENE (TOTAL)	0.01	2.0	5.5E-05	0.01
MW050	BERYLLIUM	0.005	2.3	6.3E-05	0.01
MW050	NICKEL	0.02	58.1	1.6E-03	0.08
MW050	CHROMIUM	0.005	46.0	1.3E-03	0.3
MW050	VANADIUM	0.007	39.1	1.1E-03	0.2
MW050	ARSENIC	0.0003	4.1	1.1E-04	0.4
MW050	ZINC	0.3	256.5	7.0E-03	0.02
MW050	BARIUM	0.07	81.6	2.2E-03	0.03
MW050	CADMIUM	0.0005	4.0	1.1E-04	0.2
MW050	MANGANESE	0.005	503.9	1.4E-02	3
MW050	COPPER	0.037	41.7	1.1E-03	0.03
MW050	SUBTOTAL				4
MW067	NICKEL	0.02	59.2	1.6E-03	0.08
MW067	BARIUM	0.07	81.8	2.2E-03	0.03
MW067	CYANIDE	0.02	5.7	1.6E-04	0.01
MW067	MANGANESE	0.005	20.5	5.6E-04	0.1
MW067	CHROMIUM	0.005	9.2	2.5E-04	0.05
MW067	SUBTOTAL				0.3
MW084	CHROMIUM	0.005	8.3	2.3E-04	0.05
MW084	MANGANESE	0.005	21.9	6.0E-04	0.1
MW084	BARIUM	0.07	40.4	1.1E-03	0.02
MW084	COPPER	0.037	4.7	1.3E-04	<0.01
MW084	SUBTOTAL				0.2
MW086	CHROMIUM	0.005	7.4	2.0E-04	0.04
MW086	BARIUM	0.07	174.0	4.8E-03	0.07
MW086	MANGANESE	0.005	655.0	1.8E-02	4
MW086	COPPER	0.037	4.7	1.3E-04	<0.01
MW086	SUBTOTAL				4

Attachment 2-14

WMU 2/3

Summary of Hazard Indices by Well
for Groundwater Ingestion
Scenario: Future Potable Use of Groundwater

Station ID	Chemical Name	Reference Dose mg/kg-day	Average Concentration ug/l	Chronic Daily Intake mg/kg-day	Hazard Quotient
MW087	NICKEL	0.02	6.3	1.7E-04	0.01
MW087	BARIUM	0.07	81.7	2.2E-03	0.03
MW087	VANADIUM	0.007	1.3	3.6E-05	0.01
MW087	CHROMIUM	0.005	3.0	8.2E-05	0.02
MW087	THALLIUM	0.00007	0.8	2.2E-05	0.3
MW087	ZINC	0.3	10.1	2.8E-04	<0.01
MW087	MANGANESE	0.005	213.5	5.8E-03	1
MW087	SUBTOTAL				2
MW089	BARIUM	0.07	253.0	6.9E-03	0.1
MW089	ARSENIC	0.0003	3.9	1.1E-04	0.4
MW089	CYANIDE	0.02	3.0	8.2E-05	<0.01
MW089	THALLIUM	0.00007	0.9	2.5E-05	0.4
MW089	ZINC	0.3	34.3	9.4E-04	<0.01
MW089	CHROMIUM	0.005	7.8	2.1E-04	0.04
MW089	NICKEL	0.02	14.6	4.0E-04	0.02
MW089	VANADIUM	0.007	7.6	2.1E-04	0.03
MW089	MANGANESE	0.005	3630.0	9.9E-02	20
MW089	COPPER	0.037	9.0	2.5E-04	0.01
MW089	SUBTOTAL				21
MW090	TOLUENE	0.2	2.0	5.5E-05	<0.01
MW090	DICHLORODIFLUOROMETHANE	0.2	2.0	5.5E-05	<0.01
MW090	BARIUM	0.07	49.1	1.3E-03	0.02
MW090	CHROMIUM	0.005	7.6	2.1E-04	0.04
MW090	MANGANESE	0.005	145.0	4.0E-03	1
MW090	ZINC	0.3	27.0	7.4E-04	<0.01
MW090	COPPER	0.037	9.0	2.5E-04	0.01
MW090	SUBTOTAL				1
MW092	DICHLORODIFLUOROMETHANE	0.2	2.0	5.5E-05	<0.01
MW092	SILVER	0.003	7.2	2.0E-04	0.07
MW092	ARSENIC	0.0003	2.9	7.8E-05	0.3
MW092	ZINC	0.3	80.3	2.2E-03	0.01
MW092	VANADIUM	0.007	12.0	3.3E-04	0.05
MW092	CHROMIUM	0.005	13.1	3.6E-04	0.07
MW092	MANGANESE	0.005	869.0	2.4E-02	5
MW092	BERYLLIUM	0.005	1.5	4.1E-05	0.01
MW092	BARIUM	0.07	170.0	4.7E-03	0.07
MW092	COPPER	0.037	10.2	2.8E-04	0.01
MW092	SUBTOTAL				5

Attachment 2-14 WMU 2/3

Summary of Hazard Indices by Well
for Groundwater Ingestion
Scenario: Future Potable Use of Groundwater

Station ID	Chemical Name	Reference Dose mg/kg-day	Average Concentration ug/l	Chronic Daily Intake mg/kg-day	Hazard Quotient
MW093	1,2,4-TRICHLOROBENZENE	0.02	21.5	5.9E-04	0.03
MW093	ACENAPHTHENE	0.06	23.5	6.4E-04	0.01
MW093	PHENOL	0.6	16.0	4.4E-04	<0.01
MW093	2-CHLOROPHENOL	0.005	41.0	1.1E-03	0.2
MW093	PENTACHLOROPHENOL	0.03	57.0	1.6E-03	0.05
MW093	PYRENE	0.03	26.0	7.1E-04	0.02
MW093	BARIUM	0.07	55.3	1.5E-03	0.02
MW093	MANGANESE	0.005	15.9	4.4E-04	0.09
MW093	SUBTOTAL				0.4
MW095	ZINC	0.3	56.3	1.5E-03	0.01
MW095	ARSENIC	0.0003	3.4	9.2E-05	0.3
MW095	CHROMIUM	0.005	8.2	2.2E-04	0.04
MW095	BARIUM	0.07	133.5	3.7E-03	0.05
MW095	VANADIUM	0.007	13.4	3.7E-04	0.05
MW095	MANGANESE	0.005	533.0	1.5E-02	3
MW095	COPPER	0.037	11.4	3.1E-04	0.01
MW095	SUBTOTAL				3
UPPER CONTINENTAL RECHARGE SYSTEM					
MW049	1,2-DICHLOROETHENE (TOTAL)	0.01	1.0	2.7E-05	<0.01
MW049	BENZOIC ACID	4	4.0	1.1E-04	<0.01
MW049	MANGANESE	0.005	1407.3	3.9E-02	8
MW049	SILVER	0.003	14.3	3.9E-04	0.1
MW049	MERCURY	0.0003	0.2	5.7E-06	0.02
MW049	CHROMIUM	0.005	18.6	5.1E-04	0.1
MW049	VANADIUM	0.007	31.9	8.7E-04	0.1
MW049	ARSENIC	0.0003	6.4	1.8E-04	1
MW049	NICKEL	0.02	72.6	2.0E-03	0.1
MW049	BARIUM	0.07	217.4	6.0E-03	0.09
MW049	ZINC	0.3	152.0	4.2E-03	0.01
MW049	BERYLLIUM	0.005	5.2	1.4E-04	0.03
MW049	COPPER	0.037	103.5	2.8E-03	0.08
MW049	SUBTOTAL				9

Attachment 2-14 WMU 2/3

Summary of Hazard Indices by Well
for Groundwater Ingestion
Scenario: Future Potable Use of Groundwater

Station ID	Chemical Name	Reference Dose mg/kg-day	Average Concentration ug/l	Chronic Daily Intake mg/kg-day	Hazard Quotient
MW074	NICKEL	0.02	125.4	3.4E-03	0.2
MW074	BARIUM	0.07	634.0	1.7E-02	0.2
MW074	ZINC	0.3	343.3	9.4E-03	0.03
MW074	VANADIUM	0.007	410.1	1.1E-02	2
MW074	CHROMIUM	0.005	139.8	3.8E-03	1
MW074	CADMIUM	0.0005	4.6	1.2E-04	0.2
MW074	SILVER	0.003	42.1	1.2E-03	0.4
MW074	MANGANESE	0.005	1535.3	4.2E-02	8
MW074	BERYLLIUM	0.005	15.8	4.3E-04	0.09
MW074	COPPER	0.037	95.9	2.6E-03	0.07
MW074	SUBTOTAL				12
MW085	TOLUENE	0.2	3.0	8.2E-05	<0.01
MW085	MANGANESE	0.005	4.9	1.3E-04	0.03
MW085	CHROMIUM	0.005	8.1	2.2E-04	0.04
MW085	BARIUM	0.07	48.7	1.3E-03	0.02
MW085	ZINC	0.3	3.6	9.9E-05	0.00
MW085	SUBTOTAL				0.09
MW088	CHROMIUM	0.005	5.6	1.5E-04	0.03
MW088	ARSENIC	0.0003	8.8	2.4E-04	1
MW088	ZINC	0.3	38.3	1.1E-03	<0.01
MW088	BARIUM	0.07	144.3	4.0E-03	0.06
MW088	MANGANESE	0.005	70.0	1.9E-03	0.4
MW088	VANADIUM	0.007	8.2	2.2E-04	0.03
MW088	COPPER	0.037	6.3	1.7E-04	<0.01
MW088	SUBTOTAL				1
MW091	BROMOFORM	0.02	1.0	2.7E-05	<0.01
MW091	VANADIUM	0.007	29.9	8.2E-04	0.1
MW091	ARSENIC	0.0003	1.0	2.7E-05	0.09
MW091	CHROMIUM	0.005	50.9	1.4E-03	0.3
MW091	ZINC	0.3	38.5	1.1E-03	<0.01
MW091	NICKEL	0.02	34.0	9.3E-04	0.05
MW091	BARIUM	0.07	103.0	2.8E-03	0.04
MW091	MANGANESE	0.005	24.6	6.7E-04	0.1
MW091	COPPER	0.037	10.8	3.0E-04	0.01
MW091	SUBTOTAL				1

Attachment 2-14 WMU 2/3

Summary of Hazard Indices by Well
for Groundwater Ingestion
Scenario: Future Potable Use of Groundwater

Station ID	Chemical Name	Reference Dose mg/kg-day	Average Concentration ug/l	Chronic Daily Intake mg/kg-day	Hazard Quotient
MW094	DICHLORODIFLUOROMETHANE	0.2	2.0	5.5E-05	<0.01
MW094	BARIUM	0.07	124.0	3.4E-03	0.05
MW094	NICKEL	0.02	26.5	7.3E-04	0.04
MW094	ZINC	0.3	84.0	2.3E-03	<0.01
MW094	VANADIUM	0.007	6.2	1.7E-04	0.02
MW094	CHROMIUM	0.005	19.1	5.2E-04	0.1
MW094	CYANIDE	0.02	9.1	2.5E-04	0.01
MW094	MANGANESE	0.005	56.7	1.6E-03	0.3
MW094	ARSENIC	0.0003	3.1	8.5E-05	0.3
MW094	COPPER	0.037	7.9	2.2E-04	0.01
MW094	SUBTOTAL				1
MW154	CHROMIUM	0.005	14.2	3.9E-04	0.08
MW154	NICKEL	0.3	5.9	1.6E-04	0.02
MW154	ZINC	0.3	46.7	1.3E-03	0.01
MW154	MANGANESE	0.005	177.0	4.8E-03	1
MW154	VANADIUM	0.007	4.4	1.2E-04	0.02
MW154	BARIUM	0.07	77.4	2.1E-03	0.03
MW154	SUBTOTAL				1
WMU003	1,2-DICHLOROETHENE (TOTAL)	0.01	15.7	4.3E-04	0.04
WMU003	1,1,1-TRICHLOROETHANE	0.09	1.0	2.7E-05	<0.01
WMU003	ACETONE	0.1	18.3	5.0E-04	0.01
WMU003	PYRENE	0.03	5.0	1.4E-04	<0.01
WMU003	FLUORANTHENE	0.04	1.0	2.7E-05	<0.01
WMU003	PHENOL	0.6	3.0	8.2E-05	<0.01
WMU003	2-CHLOROPHENOL	0.005	3.0	8.2E-05	0.02
WMU003	SILVER	0.003	111.7	3.1E-03	1
WMU003	MERCURY	0.0003	0.3	6.9E-06	0.02
WMU003	BERYLLIUM	0.005	2.9	8.0E-05	0.02
WMU003	MANGANESE	0.005	48.7	1.3E-03	0.3
WMU003	CADMIUM	0.0005	4.6	1.3E-04	0.3
WMU003	NICKEL	0.02	594.0	1.6E-02	1
WMU003	ANTIMONY	0.0004	20.4	5.6E-04	1
WMU003	BARIUM	0.07	77.1	2.1E-03	0.03
WMU003	ZINC	0.3	74.5	2.0E-03	0.01
WMU003	VANADIUM	0.007	9.2	2.5E-04	0.04
WMU003	COPPER	0.037	27.8	7.6E-04	0.02
WMU003	SUBTOTAL				4

Attachment 2-14 Summary of Hazard Indices by Well for Groundwater Ingestion Scenario: Future Potable Use of Groundwater					WMU 2/3
Station ID	Chemical Name	Reference Dose mg/kg-day	Average Concentration ug/l	Chronic Daily Intake mg/kg-day	Hazard Quotient
Exposure Assumptions:					
	Rate Ingested (liters/day)		2		
	Body Weight (kg)		70		
	Exposure Frequency (days/year)		350		
	Exposure Duration (years)		30		
	Converstion Factor		0.001		
	Averaging Time (days)		10950		
	Fraction Ingested		1		

Attachment 2-15 WMU 2/3

Summary of Radiological Cancer Incidence Risk
by Well for Groundwater Ingestion
Scenario: Future Potable Use of Groundwater

Station ID	Radionuclide	Average Concentration pCi/l	Chronic Daily Intake pCi	Ingestion DCF mrem/pCi	CEDE (1 yr intake) (mrem)	Total CEDE mrem	Cancer Incidence Risk Factor for Ingestion (pCi)-1	Cancer Incidence Risk
REGIONAL GRAVEL AQUIFER								
MW048	NEPTUNIUM-237	-0.09	NA	4.4E-03	NA	NA	2.2E-10	NA
MW048	PLUTONIUM-239	-0.01	NA	3.7E-04	NA	NA	2.3E-10	NA
MW048	TECHNETIUM-99	0.59	413	1.5E-06	6.03E-04	0.018	1.3E-12	1.6E-08
MW048	URANIUM-234	0.38	266	2.8E-04	7.53E-02	2.258	1.6E-11	1.3E-07
MW048	URANIUM-235	-0.29	NA	2.7E-04	NA	NA	1.6E-11	NA
MW048	URANIUM-238	1.3	910	2.6E-04	2.32E-01	6.962	2.8E-11	7.6E-07
MW048	SUBTOTAL							9E-07
MW050	TECHNETIUM-99	15	10500	1.5E-06	1.53E-02	0.460	1.3E-12	4.1E-07
MW050	THORIUM-230	0.64	448	5.5E-04	2.45E-01	7.338	1.3E-11	1.7E-07
MW050	URANIUM-234	1.1	770	2.8E-04	2.18E-01	6.537	1.6E-11	3.7E-07
MW050	SUBTOTAL							1E-06
MW067	NEPTUNIUM-237	-0.08	NA	4.4E-03	NA	NA	2.2E-10	NA
MW067	PLUTONIUM-239	0.28	196	3.7E-04	7.23E-02	2.170	2.3E-10	1.4E-06
MW067	THORIUM-230	-0.01	NA	5.5E-04	NA	NA	1.3E-11	NA
MW067	URANIUM-234	0.03	21	2.8E-04	5.94E-03	0.178	1.6E-11	1.0E-08
MW067	URANIUM-235	0.03	21	2.7E-04	5.59E-03	0.168	1.6E-11	1.0E-08
MW067	URANIUM-238	0.09	63	2.6E-04	1.61E-02	0.482	2.8E-11	5.3E-08
MW067	SUBTOTAL							1E-06
MW084	NEPTUNIUM-237	-0.3	NA	4.4E-03	NA	NA	2.2E-10	NA
MW084	PLUTONIUM-239	0.03	21	3.7E-04	7.75E-03	0.232	2.3E-10	1.4E-07
MW084	TECHNETIUM-99	466	326200	1.5E-06	4.76E-01	14.288	1.3E-12	1.3E-05
MW084	THORIUM-230	-0.12	NA	5.5E-04	NA	NA	1.3E-11	NA
MW084	URANIUM-234	0.14	98	2.8E-04	2.77E-02	0.832	1.6E-11	4.7E-08
MW084	URANIUM-235	0.01	7	2.7E-04	1.86E-03	0.056	1.6E-11	3.4E-09
MW084	URANIUM-238	0.23	161	2.6E-04	4.11E-02	1.232	2.8E-11	1.4E-07
MW084	SUBTOTAL							1E-05
MW086	NEPTUNIUM-237	0.59	413	4.4E-03	1.83E+00	55.012	2.2E-10	2.7E-06
MW086	PLUTONIUM-239	0.03	21	3.7E-04	7.75E-03	0.232	2.3E-10	1.4E-07
MW086	TECHNETIUM-99	0.18	126	1.5E-06	1.84E-04	0.006	1.3E-12	4.9E-09
MW086	THORIUM-230	-0.1	NA	5.5E-04	NA	NA	1.3E-11	NA
MW086	URANIUM-234	0.44	308	2.8E-04	8.72E-02	2.615	1.6E-11	1.5E-07
MW086	URANIUM-235	0.02	14	2.7E-04	3.72E-03	0.112	1.6E-11	6.7E-09
MW086	URANIUM-238	1.31	917	2.6E-04	2.34E-01	7.015	2.8E-11	7.7E-07
MW086	SUBTOTAL							4E-06

Attachment 2-15 WMU 2/3

Summary of Radiological Cancer Incidence Risk
by Well for Groundwater Ingestion

Scenario: Future Potable Use of Groundwater

Station ID	Radionuclide	Average Concentration pCi/l	Chronic Daily Intake pCi	Ingestion DCF mrem/pCi	CEDE (1 yr intake) (mrem)	Total CEDE mrem	Cancer Incidence Risk Factor for Ingestion (pCi)-1	Cancer Incidence Risk
MW087	NEPTUNIUM-237	0.4	280	4.4E-03	1.24E+00	37.296	2.2E-10	1.8E-06
MW087	PLUTONIUM-239	0.03	21	3.7E-04	7.75E-03	0.232	2.3E-10	1.4E-07
MW087	TECHNETIUM-99	1.6	1120	1.5E-06	1.64E-03	0.049	1.3E-12	4.4E-08
MW087	THORIUM-230	-0.16	NA	5.5E-04	NA	NA	1.3E-11	NA
MW087	URANIUM-234	0.22	154	2.8E-04	4.36E-02	1.307	1.6E-11	7.4E-08
MW087	URANIUM-235	0.02	14	2.7E-04	3.72E-03	0.112	1.6E-11	6.7E-09
MW087	URANIUM-238	0.09	63	2.6E-04	1.61E-02	0.482	2.8E-11	5.3E-08
MW087	SUBTOTAL							2E-06
MW089	NEPTUNIUM-237	0	NA	4.4E-03		NA	2.2E-10	NA
MW089	PLUTONIUM-239	0.03	21	3.7E-04	7.75E-03	0.232	2.3E-10	1.4E-07
MW089	TECHNETIUM-99	-0.8	NA	1.5E-06	NA	NA	1.3E-12	NA
MW089	THORIUM-230	-0.15	NA	5.5E-04	NA	NA	1.3E-11	NA
MW089	URANIUM-234	0.39	273	2.8E-04	7.73E-02	2.318	1.6E-11	1.3E-07
MW089	URANIUM-235	0.02	14	2.7E-04	3.72E-03	0.112	1.6E-11	6.7E-09
MW089	URANIUM-238	-0.09	NA	2.6E-04	NA	NA	2.8E-11	NA
MW089	SUBTOTAL							3E-07
MW090	NEPTUNIUM-237	0.04	28	4.4E-03	1.24E-01	3.730	2.2E-10	1.8E-07
MW090	TECHNETIUM-99	2.5	1750	1.5E-06	2.56E-03	0.077	1.3E-12	6.8E-08
MW090	THORIUM-230	-0.17	NA	5.5E-04	NA	NA	1.3E-11	NA
MW090	URANIUM-234	-0.02	NA	2.8E-04	NA	NA	1.6E-11	NA
MW090	URANIUM-235	0.01	7	2.7E-04	1.86E-03	0.056	1.6E-11	3.4E-09
MW090	URANIUM-238	-0.04	NA	2.6E-04	NA	NA	2.8E-11	NA
MW090	SUBTOTAL							3E-07
MW092	NEPTUNIUM-237	0.46	322	4.4E-03	1.43E+00	42.890	2.2E-10	2.1E-06
MW092	PLUTONIUM-239	0.17	119	3.7E-04	4.39E-02	1.317	2.3E-10	8.2E-07
MW092	TECHNETIUM-99	1.78	1246	1.5E-06	1.82E-03	0.055	1.3E-12	4.9E-08
MW092	URANIUM-234	0.26	182	2.8E-04	5.15E-02	1.545	1.6E-11	8.7E-08
MW092	URANIUM-235	0.01	7	2.7E-04	1.86E-03	0.056	1.6E-11	3.4E-09
MW092	URANIUM-238	0.08	56	2.6E-04	1.43E-02	0.428	2.8E-11	4.7E-08
MW092	SUBTOTAL							3E-06

Attachment 2-15 WMU 2/3

Summary of Radiological Cancer Incidence Risk
by Well for Groundwater Ingestion

Scenario: Future Potable Use of Groundwater

Station ID	Radionuclide	Average Concentration pCi/l	Chronic Daily Intake pCi	Ingestion DCF mrem/pCi	CEDE (1 yr intake) (mrem)	Total CEDE mrem	Cancer Incidence Risk Factor for Ingestion (pCi)-1	Cancer Incidence Risk
MW093	NEPTUNIUM-237	0.69	483	4.4E-03	2.14E+00	64.336	2.2E-10	3.2E-06
MW093	PLUTONIUM-239	0.16	112	3.7E-04	4.13E-02	1.240	2.3E-10	7.7E-07
MW093	TECHNETIUM-99	0.2	140	1.5E-06	2.04E-04	0.006	1.3E-12	5.5E-09
MW093	THORIUM-230	-0.03	NA	5.5E-04	NA	NA	1.3E-11	NA
MW093	URANIUM-234	0.1	70	2.8E-04	1.98E-02	0.594	1.6E-11	3.4E-08
MW093	URANIUM-235	0.14	98	2.7E-04	2.61E-02	0.782	1.6E-11	4.7E-08
MW093	URANIUM-238	0	NA	2.6E-04		NA	2.8E-11	NA
MW093	SUBTOTAL							4E-06
MW095	NEPTUNIUM-237	0.34	238	4.4E-03	1.06E+00	31.702	2.2E-10	1.6E-06
MW095	TECHNETIUM-99	0.85	595	1.5E-06	8.69E-04	0.026	1.3E-12	2.3E-08
MW095	THORIUM-230	-0.16	NA	5.5E-04	NA	NA	1.3E-11	NA
MW095	URANIUM-234	0.14	98	2.8E-04	2.77E-02	0.832	1.6E-11	4.7E-08
MW095	URANIUM-235	0.03	21	2.7E-04	5.59E-03	0.168	1.6E-11	1.0E-08
MW095	URANIUM-238	0.08	56	2.6E-04	1.43E-02	0.428	2.8E-11	4.7E-08
MW095	SUBTOTAL							2E-06
UPPER CONTINENTAL RECHARGE SYSTEM								
MW049	NEPTUNIUM-237	0.55	385	4.4E-03	1.71E+00	51.282	2.2E-10	2.5E-06
MW049	PLUTONIUM-239	0	NA	3.7E-04		NA	2.3E-10	NA
MW049	TECHNETIUM-99	170.23	119161	1.5E-06	1.74E-01	5.219	1.3E-12	4.6E-06
MW049	THORIUM-230	0.01	7	5.5E-04	3.82E-03	0.115	1.3E-11	2.7E-09
MW049	URANIUM-234	4.2	2940	2.8E-04	8.32E-01	24.961	1.6E-11	1.4E-06
MW049	URANIUM-235	0.38	266	2.7E-04	7.08E-02	2.123	1.6E-11	1.3E-07
MW049	URANIUM-238	7.83	5481	2.6E-04	1.40E+00	41.930	2.8E-11	4.6E-06
MW049	SUBTOTAL							1E-05
MW074	NEPTUNIUM-237	-0.1	NA	4.4E-03	NA	NA	2.2E-10	NA
MW074	PLUTONIUM-239	0.01	7	3.7E-04	2.58E-03	0.077	2.3E-10	4.8E-08
MW074	TECHNETIUM-99	192.25	134575	1.5E-06	1.96E-01	5.894	1.3E-12	5.2E-06
MW074	THORIUM-230	3.86	2702	5.5E-04	1.48E+00	44.259	1.3E-11	1.1E-06
MW074	URANIUM-234	2.65	1855	2.8E-04	5.25E-01	15.749	1.6E-11	8.9E-07
MW074	URANIUM-235	0.06	42	2.7E-04	1.12E-02	0.335	1.6E-11	2.0E-08
MW074	URANIUM-238	4.98	3486	2.6E-04	8.89E-01	26.668	2.8E-11	2.9E-06
MW074	SUBTOTAL							1E-05

Attachment 2-15 WMU 2/3

Summary of Radiological Cancer Incidence Risk

by Well for Groundwater Ingestion

Scenario: Future Potable Use of Groundwater

Station ID	Radionuclide	Average Concentration pCi/l	Chronic Daily Intake pCi	Ingestion DCF mrem/pCi	CEDE (1 yr intake) (mrem)	Total CEDE mrem	Cancer Incidence Risk Factor for Ingestion (pCi)-1	Cancer Incidence Risk
MW085	NEPTUNIUM-237	-0.39	NA	4.4E-03	NA	NA	2.2E-10	NA
MW085	PLUTONIUM-239	0.33	231	3.7E-04	8.52E-02	2.557	2.3E-10	1.6E-06
MW085	TECHNETIUM-99	219.67	153769	1.5E-06	2.25E-01	6.735	1.3E-12	6.0E-06
MW085	URANIUM-234	0.99	693	2.8E-04	1.96E-01	5.884	1.6E-11	3.3E-07
MW085	URANIUM-235	0.04	28	2.7E-04	7.45E-03	0.223	1.6E-11	1.3E-08
MW085	URANIUM-238	2.39	1673	2.6E-04	4.27E-01	12.798	2.8E-11	1.4E-06
MW085	SUBTOTAL							9E-06
MW088	NEPTUNIUM-237	0.23	161	4.4E-03	7.15E-01	21.445	2.2E-10	1.1E-06
MW088	PLUTONIUM-239	0.07	49	3.7E-04	1.81E-02	0.542	2.3E-10	3.4E-07
MW088	TECHNETIUM-99	1491.75	1044225	1.5E-06	1.52E+00	45.737	1.3E-12	4.1E-05
MW088	THORIUM-230	1.03	721	5.5E-04	3.94E-01	11.810	1.3E-11	2.8E-07
MW088	URANIUM-234	0.94	658	2.8E-04	1.86E-01	5.586	1.6E-11	3.2E-07
MW088	URANIUM-235	0.01	7	2.7E-04	1.86E-03	0.056	1.6E-11	3.4E-09
MW088	URANIUM-238	1.51	1057	2.6E-04	2.70E-01	8.086	2.8E-11	8.9E-07
MW088	SUBTOTAL							4E-05
MW091	NEPTUNIUM-237	0.14	98	4.4E-03	4.35E-01	13.054	2.2E-10	6.5E-07
MW091	PLUTONIUM-239	0.13	91	3.7E-04	3.36E-02	1.007	2.3E-10	6.3E-07
MW091	TECHNETIUM-99	21	14700	1.5E-06	2.15E-02	0.644	1.3E-12	5.7E-07
MW091	THORIUM-230	0.12	84	5.5E-04	4.59E-02	1.376	1.3E-11	3.3E-08
MW091	URANIUM-234	3.33	2331	2.8E-04	6.60E-01	19.790	1.6E-11	1.1E-06
MW091	URANIUM-235	0.53	371	2.7E-04	9.87E-02	2.961	1.6E-11	1.8E-07
MW091	URANIUM-238	0.74	518	2.6E-04	1.32E-01	3.963	2.8E-11	4.4E-07
MW091	SUBTOTAL							4E-06
MW094	NEPTUNIUM-237	-0.12	NA	4.4E-03	NA	NA	2.2E-10	NA
MW094	TECHNETIUM-99	750	525000	1.5E-06	7.67E-01	22.995	1.3E-12	2.0E-05
MW094	THORIUM-230	0	NA	5.5E-04		NA	1.3E-11	NA
MW094	URANIUM-234	0.76	532	2.8E-04	1.51E-01	4.517	1.6E-11	2.6E-07
MW094	URANIUM-235	0.02	14	2.7E-04	3.72E-03	0.112	1.6E-11	6.7E-09
MW094	URANIUM-238	1.05	735	2.6E-04	1.87E-01	5.623	2.8E-11	6.2E-07
MW094	SUBTOTAL							2E-05

Attachment 2-15 WMU 2/3

Summary of Radiological Cancer Incidence Risk
by Well for Groundwater Ingestion
Scenario: Future Potable Use of Groundwater

Station ID	Radionuclide	Average Concentration pCi/l	Chronic Daily Intake pCi	Ingestion DCF mrem/pCi	CEDE (1 yr intake) (mrem)	Total CEDE mrem	Cancer Incidence Risk Factor for Ingestion (pCi)-1	Cancer Incidence Risk
MW154	NEPTUNIUM-237	0.32	224	4.4E-03	9.95E-01	29.837	2.2E-10	1.5E-06
MW154	PLUTONIUM-239	0.18	126	3.7E-04	4.65E-02	1.395	2.3E-10	8.7E-07
MW154	TECHNETIUM-99	1000	700000	1.5E-06	1.02E+00	30.660	1.3E-12	2.7E-05
MW154	URANIUM-234	3.6	2520	2.8E-04	7.13E-01	21.395	1.6E-11	1.2E-06
MW154	URANIUM-235	0.14	98	2.7E-04	2.61E-02	0.782	1.6E-11	4.7E-08
MW154	URANIUM-238	27	18900	2.6E-04	4.82E+00	144.585	2.8E-11	1.6E-05
MW154	SUBTOTAL							5E-05
WMU003	NEPTUNIUM-237	1.08	756	4.4E-03	3.36E+00	100.699	2.2E-10	5.0E-06
WMU003	PLUTONIUM-239	-0.04	NA	3.7E-04	NA	NA	2.3E-10	NA
WMU003	TECHNETIUM-99	130.33	91231	1.5E-06	1.33E-01	3.996	1.3E-12	3.6E-06
WMU003	URANIUM-234	11.55	8085	2.8E-04	2.29E+00	68.642	1.6E-11	3.9E-06
WMU003	URANIUM-235	0.58	406	2.7E-04	1.08E-01	3.240	1.6E-11	1.9E-07
WMU003	URANIUM-238	57.2	40040	2.6E-04	1.02E+01	306.306	2.8E-11	3.4E-05
WMU003	SUBTOTAL							5E-05

Exposure Assumptions

Ingestion Risk = CW x IR x EF x ED x RF

Rate Ingested (liters/day)	2
Exposure Frequency (days/year)	350
Exposure Duration (years)	30

NA = Not Applicable; radionuclide concentration below detectable limit

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Works Cited

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Appendix A
Risk Estimate Calculations

Appendix A
Risk Estimate Calculations

Intake Equations

Carcinogenic Effects

A lifetime average intake (or chronic daily intake) of the chemical is estimated for carcinogens. This acts to prorate the total cumulative intake over a lifetime. An averaging time (AT) of a lifetime of 70 years (365 days/year) is used for carcinogens.

Noncarcinogenic Effects

The chemical intake of chemicals with noncarcinogenic effects is estimated over the appropriate exposure period or averaging time. The averaging time selected depends on the toxic endpoint being assessed.

When evaluating exposures to developmental toxicant, intakes are calculated by averaging over the exposure event (e.g., a day or single exposure incident). For an acute toxicant, intakes are calculated by averaging over the shortest exposure period that could produce an effect, usually an exposure event or one day. For both situations, it can be assumed that the averaging time and the exposure period are equal.

When evaluating exposure to systemic toxicant, intakes are calculated by averaging intakes over the period of exposure. The AT for noncarcinogenic effects is 365 days/year multiplied by the exposure duration, providing an average exposure for the year.

Medium-Specific Intakes

The following sections present the methodology for estimating intake from specific environmental media.

Ingestion of Drinking Water

Equation for intake of chemicals in drinking water [from the Environmental Protection Agency (EPA), 1989d]:

$$Intake\ (mg/kg\text{-}day) = \frac{CW \times IR \times EF \times ED}{BW \times AT}$$

Equation for intake of radionuclides in drinking water (from EPA, 1989d):

$$Intake\ (pCi) = RW \times IR \times EF \times ED$$

where

CW = chemical concentration in water (mg/L)
RW = radionuclide concentration in water (pCi/L)
IR = ingestion rate (L/day)
EF = exposure frequency (days/year)
ED = exposure duration (years)
BW = body weight (kg)
AT = averaging time (days)

Inhalation of Chemicals in Drinking Water

Equation for inhalation of chemicals in drinking water (from EPA 1991).

$$Inhalation\text{:}\ \ Inhaled\ dose\ (mg/kg\text{-}d) = (CW * VF * IR * EF * ED)/(BW * AT)$$

where

CW = chemical concentration in water (mg/L)
BW = body weight (kg)
ED = exposure duration (years)
EF = exposure frequency (d/year)
AT = averaging time (days)
IR = indoor inhalation rate (m3/day)
VF = volatilization factor (L/m3)

Ingestion of Soil

Equations for ingestion of chemicals in exposed soil or sediments (from EPA, 1989d):

$$Intake\ (mg/kg\text{-}day) = \frac{CS \times IR \times CF \times FI \times EF \times ED}{BW \times AT}$$

Equation for ingestion of radionuclides in exposed sediment (from EPA, 1989d):

$$Intake\ (pCi) = RS \times IR \times FI \times EF \times ED$$

where

CS = chemical concentration in soil/sediment (mg/kg)
RS = radionuclide concentration in soil sediment (pCi/g)
IR = ingestion rate (g/day)
CF = conversion factor (10^{-6} kg/mg)
FI = fraction ingested from contaminated source (unitless)
EF = exposure frequency (days/year)
ED = exposure duration (years)
BW = body weight (kg)
AT = Averaging time (days)

Dermal Contact with Soil

Equation for calculating the absorbed dose from dermal contact with chemicals from soil:

$$Intake\ mg/kg\text{-}day = (CS \times SA \times ABS \times AF \times EF \times ED \times CF)/(BW \times AT)$$

where

CS = chemical concentration in soil (mg/kg)
SA = skin surface area (cm^2/event)
ABS = absorption factor (fraction)
AF = adherence factor-soil to skin (mg/cm^2)
EF = exposure frequency (days/year)
ED = exposure duration (years)
BW = body weight (kg)
AT = averaging time (days)
CF = conversion factor (10^{-6} kg/mg)

Inhalation of Airborne (Sorbed to Dust) Contaminants

Equation for calculating chemical intake from inhalation of contaminants sorbed to airborne dusts:

$$Intake\ (mg/kg\text{-}day) = CS \times FR \times IR \times EF \times ED \times \frac{1}{PEF} \times (BW \times AT)^{-1}$$

Equation for calculating radionuclide intake from inhalation of contaminants sorbed to airborne dusts:

$$Intake\ (pCi) = (RA \times IR \times FR \times EF \times ED \times CF \times \frac{1}{PEF})$$

where

CS = chemical concentration in soil (mg/kg)
RA = radionuclide concentration in air (pCi/m^3)
IR = inhalation rate (m^3/day)
FR = fraction of dust in respirable range (assumed to be 1)
EF = exposure frequency (days/year)
ED = exposure duration (years)
BW = body weight (kg)
AT = averaging time (days)
CF = conversion factor (10^{-6} kg/mg)
PEF = particulate emission factor (m^3/kg) = 4.63×10^9

Exposure to Direct External Gamma Radiation

Equation for calculating risk from exposure to direct external gamma radiation from contaminated soils:

$$Risk = RS \times ERF \times Te \times ED \times (1 - Se)$$

where

RS = radionuclide concentration in soil (pCi/g)
ERF = external exposure risk factor (risk/year per pCi/g)
Te = fraction of year exposed (unitless)
ED = Exposure duration (years)
Se = gamma shielding factor (unitless)

Intake Parameters and Exposure Point Concentrations

Intake parameters used in the human health risk assessment are shown in Table A-1. Toxicity values and radiation dose and risk factors are shown in Tables A-2 through A-5. Exposure point concentrations (RME values) for each media are shown in the attachment to this appendix.

Table A-1
Intake and Exposure Parameters for All Scenarios
WMUs 2/3 and 7/30

Exposure Pathway	Future Potable Use of Groundwater	Current Worker/Intruder	Future Unrestricted Worker/Intruder
Soil			
External Exposure		8 hr/day	8 hr/day
Ingestion Rate		0.05 g/day	0.05 g/day
Inhalation Rate		20 m^3/day	20 m^3/day
Dermal Contact		Body Surface Area Hands: 0.082 m^2 Arms: 0.230 m^2 Adherence Factor: 1.0 mg/cm^2 Absorption Factor: Organics: 1% Inorganics: 0.1%	Body Surface Area Hands: 0.082 m^2 Arms: 0.230 m^2 Adherence Factor: 1.0 mg/cm^2 Absorption Factor: Organics: 1% Inorganics: 0.1%
Groundwater			
Ingestion Rate	2 L/day		
Inhalation of Vapor Phase Chemicals During Groundwater Use	15 m^3/day		
Volatilization Factor	0.0005 × 1000 L/m^3		
Soil and Groundwater			
Exposure Duration	30 yr	25 yr	25 yr
Exposure Frequency	350 days/yr	25 days/yr	250 days/yr
Body Weight	70 kg	70 kg	70 kg

Table A-2
Summary of Toxicity Values for Potential Noncarcinogenic Effects

Page 1 of 3

Chemical	RfD (mg/kg/day)	Confidence Level	Critical Effect	RfD Basis/ RfD Source	Uncertainty and Modifying Factors
Oral Route					
1,2,3,4,6,7,8-HpCDD	1E-06		Liver and thymus gland toxicity	EPA, 1989	
HpCDD (Total)	1E-06		Liver and thymus gland toxicity	EPA, 1989	
HpCDF (Total)	1E-06		Liver and thymus gland toxicity	EPA, 1989	
HxCDD (Total)	1E-08		Liver and thymus gland toxicity	EPA, 1989	
HxCDF (Total)	1E-08		Liver and thymus gland toxicity	EPA, 1989	
OCDD (Total)	1E-05		Liver and thymus gland toxicity	EPA, 1989	
OCDF (Total)	1E-05		Liver and thymus gland toxicity	EPA, 1989	
PcCDD (Total)	2E-09		Liver and thymus gland toxicity	EPA, 1989	
PcCDF (Total)	2E-09		Liver and thymus gland toxicity	EPA, 1989	
TCDD (Total)	1E-09	--	Liver and thymus gland toxicity	Water/EPA, 1987	UF=1000; MF=1
TCDF (Total)	1E-08		Liver and thymus gland toxicity	EPA, 1989	
Anthracene	0.3	L	Subchronic effects	Oral/I	UF=3000; MF=1
Acenaphthene	0.06	L	Liver toxicity	Oral/I	UF=3000; MF=1
Acetone	0.1	L	Liver and kidney toxicity	Oral/I	UF=1000; MF=1
Carbon Disulfide	0.1	M	Malformations, fetal toxicity	Gavage/I	UF=100; MF=1
Chloroform	0.01	M	Liner toxicity	Oral/I	UF=1000; MF=1
Ethylbenzene	0.1	L	Hepatotoxicity and nephrotoxicity	Oral/I	UF=1000; MF=1
Toluene	0.2	M	CNS effects	Oral/I	UF=1000; MF=1
Xylenes	2	M	Hyperactivity, decreased body weight, increased mortality	Oral/I	UF=100; MF=1
Benzoic Acid	4	M	Irritation, malaise	Diet/I	UF=1; MF=1
1,1-Dichloroethane	0.1	--	Liver toxicity	Diet/H	UF=1000; MF=1
2,4-Dimethylphenol	0.02	--	Neurological signs and hematological changes	Gavage/I	UF=3000; MF=1
1,1-DCE	0.009	M	Liver lesions	Oral/I	UF=1000; MF=1
1,2-DCE	0.01	--	Blood abnormalities	Oral/H	UF=1000; MF=1
1,4-Dichlorobenzene	0.1	--	Liver toxicity	Oral/H	UF=1000; MF=1
Fluoranthene	0.04	L	Nephropathy, liver weight, and hematological changes	Gavage/I	UF=3000; MF=1
Fluorene	0.04	L	Hematological changes (decreased RBC)	Gavage/I	UF=3000; MF=1
Isophorone	0.2	L	Liver toxicity	Oral/I	UF=1000; MF=1
4-Methylphenol	0.005	--	Reduced body weight and neurotoxicity	Oral/H	UF=1000; MF=1

Table A-2
Summary of Toxicity Values for Potential Noncarcinogenic Effects

Page 2 of 3

Napthalene	0.04	--	Anemia	Oral/H	UF=1000; MF=1
Pentachlorophenol	0.03	M	Liver and kidney pathology	Gavage/I	UF=100; MF=1
Phenol	0.6	L	Reduced fetal body weight	Gavage/I	UF=100; MF=1
Pyrene	0.03	L	Renal effects	Gavage/I	UF=3000; MF=1
Carbon Tetrachloride	0.0007	M	Kidney and liver toxicity	Oral	UF=1000; MF=1
1,1,2-Trichloroethane	0.004	M	Liver toxicity	Oral/I	UF=1000; MF=1
1,1,1-Trichloroethane	0.09	--	Liver toxicity	Oral/H	UF=1000; MF=1
Antimony	0.0004	M	Gastrointestinal effects	Oral/I	UF=3; MF=1
Arsenic	0.0003	M	Keratosis and hyperpigmentation	Oral/I	UF=1000; MF=1
Barium	0.07	M	Increased blood pressure	Water/I	UF=3; MF=1
Beryllium	0.005	L	No observed adverse effect level for beryllium salts	Water/I	UF=100; MF=1
Cadmium	0.0005	H	Renal damage	Oral/I	UF=10; MF=1
Chromium VI	0.005	L	No observed adverse effect level	Water/I	UF=500; MF=1
Copper	0.037	--	GI irritation, thyroid effects, and myelin degeneration	Oral/H	
Cyanide	0.02	M	Hematologic, hepatic, and renal toxicity	Diet/I	UF=100; MF=5
Manganese	0.005 (Water) 0.14 (Soil)	--	CNS effects	Water/I	UF=1; MF=1
Mercury	0.0003	--	Kidney effects	Oral/H	UF=1000; MF=1
Nickel (Soluble Salts)	0.02	M	Decreased body and organ weights	Diet/I	UF=300; MF=1
Selenium	0.005	H	Hair and nail loss; dermatitis	Diet/I	UF=3; MF=1
Silver	0.005	L	Argyria	Oral/I	UF=3; MF=1
Thallium (Carbonate)	0.00008	L	Blood abnormalities	Oral/I	UF=3000; MF=1
Vanadium (Metallic)	0.007	--	No observed adverse effect level	Water/H	UF=100; MF=1
Zinc	0.3	M	Anemia	Oral/I	UF=3; MF=1
Uranium (Soluble Salts)	0.003	M	Nephrotoxicity	Oral/I	UF=1000; MF=1

Table A-2
Summary of Toxicity Values for Potential Noncarcinogenic Effects

Chemical	RfC ($\mu g/m^3$)	Confidence Level	Critical Effect	RfD Basis/ RfD Source	Uncertainty and Modifying Factors
Inhalation Route					
Carbon Disulfide	0.01	M	Fetal toxicity	Inhalation/H	UF=1000; MF=1
1,1-Dichloroethane	0.5	--	Liver toxicity	Inhalation/H	UF=1000; MF=1
1,4-Dichlorobenzene	0.8	--	Liver toxicity	Inhalation/H	UF=100; MF=1
Ethylbenzene	1	L	Developmental toxicity	Inhalation/I	UF=300; MF=1
Toluene	0.4	M	CNS effects; eye and nose irritation	Inhalation/I	UF=300; MF=1
1,1,1-Trichloroethane	1	--	Liver toxicity	Inhalation/H	UF=1000; MF=1
Barium	0.0005	--	Fetotoxicity	Inhalation/H	UF=1000; MF=1
Chromium VI	0.000002	--	Nasal mucosa atrophy	Inhalation/H	UF=300; MF=1
Manganese	0.0004	M	CNS effects	Occupational/I	UF=300; MF=3
Mercury	0.0003	--	Neurotoxicity	Occupational/I	UF=30; MF=1

Confidence Levels:

L = Low
M = Medium
H = High

RfD Sources:

I = IRIS (Integrated Risk Information System; all values from IRIS, 1992).
H = HEAST (Health Effects Assessment Summary Tables; all values from HEAST, 1991).
EPA, 1987 – Drinking Water Health Advisory, U.S. EPA ODW, March 1987.
EPA, 1989 – Interim Procedures for Estimating Risks Associated with Exposures to Mixtures of Chlorinated Dibenzo-p-Dioxins and Dibenzofurans (CDDs and CDFs) and 1989 Update, EPA/625/3-89/016, March 1989.

Table A-3
Summary of Toxicity Values for Potential Carcinogenic Effects

Chemical	Oral SF $(mg/kg\text{-}day)^{-1}$	Weight of Evidence Class	Type of Cancer	SF Basis/ SF Source
Oral Route				
Chloroform	0.0061	B2	Liver	Oral/IRIS
Benzene	0.029	A	Leukemia	Water/IRIS
1,2-Dichloroethane	0.091	B2	Stomach	Oral/IRIS
1,1-DCE	0.6	C	Kidney	Water/IRIS
1,4-Dichlorobenzene	0.024	C	Kidney	Gavage/HEAST
4,4´-DDT	0.34	B2	Kidney	Water/IRIS
2,4-Dinitrotoluene	0.68	B2	Liver	Diet/IRIS
TCE	0.011	B2	Liver	Gavage/HEAST, 1991
1,1,2-Trichloroethane	0.057	C	Kidney	Oral/IRIS
Pentachlorophenol	0.12	B2	Liver, Adrenal, Circulatory System	Diet/IRIS
N-Nitrosodipropylamine	7	B2	Bladder, reticulum cell sarcoma	Diet/IRIS
Isophorone	0.0041	C	Kidney	Oral/IRIS
PCBs	7.7	B2	Liver	Diet/IRIS
1,2,3,4,6,7,8-HpCDD	1,500	B2	Multiple organs	EPA, 1989
HpCDD (Total)	1,500	B2	Multiple organs	EPA, 1989
HpCDF (Total)	1,500	B2	Multiple organs	EPA, 1989
HxCDD (Total)	15,000	B2	Multiple organs	EPA, 1989
HxCDF (Total)	15,000	B2	Multiple organs	EPA, 1989
PCDD (Total)	75,000	B2	Multiple organs	EPA, 1989
PCDF (Total)	7,500	B2	Multiple organs	EPA, 1989
OCDD (Total)	150	B2	Multiple organs	EPA, 1989
OCDF (Total)	150	B2	Multiple organs	EPA, 1989
2,3,7,8-TCDD (Total)	150,000	B2	Multiple organs	Diet/HEAST
TCDF (Total)	15,000	B2	Multiple organs	EPA, 1989
Carbon Tetrachloride	0.13	B2	Liver	Oral/IRIS
TCE	0.011	B2	Liver	Oral/HEAST, 1991
Tetrachloroethene	0.051	B2	Liver	Oral/HEAST, 1991
Vinyl Chloride	1.9	A	Liver	Oral/HEAST
PAHs[a]	7.3	B2	Liver, skin	Oral/IRIS

Table A-3
Summary of Toxicity Values for Potential Carcinogenic Effects

Page 2 of 3

Arsenic	1.75	A	Skin	Water/EPA, 1988
Beryllium	4.3	B2	Multiple organs	Water/IRIS

Chemical	Inh. Unit Risk $(\mu g/m^3)^{-1}$	Weight of Evidence Class	Type of Cancer	SF Basis/ SF Source
Inhalation Route				
Benzene	0.0000083	A	Leukemia	Inhalation/IRIS
Carbon Tetrachloride	0.000015	B2	Liver	Inhalation/IRIS
Chloroform	0.000023	B2	Liver	Inhalation/HEAST
1,1-DCE	0.00005	C	Kidney	Inhalation/IRIS
4,4′-DDT	0.000097	B2	Kidney	Inhalation/IRIS
TCE	0.0000017	B2	Lung	Inhalation/HEAST, 1991
1,2-Dichloroethane	0.000026	B2	Respiratory tract	Inhalation/IRIS
Tetrachloroethane	0.00000052	B2	Liver	Inhalation/HEAST, 1991
Vinyl Chloride	0.000084	A	Lung	Inhalation/IRIS
1,2,3,4,6,7,8-HpCDD	3.3E-07	B2	Multiple organs	EPA, 1989
HpCDD (Total)	3.3E-07	B2	Multiple organs	EPA, 1989
HpCDF (Total)	3.3E-07	B2	Multiple organs	EPA, 1989
HxCDD (Total)	3.3E-06	B2	Multiple organs	EPA, 1989
HxCDF (Total)	3.3E-06	B2	Multiple organs	EPA, 1989
PCDD (Total)	1.6E-05	B2	Multiple organs	EPA, 1989
PCDF (Total)	1.6E-05	B2	Multiple organs	EPA, 1989
OCDD (Total)	3.3E-08	B2	Multiple organs	EPA, 1989
OCDF (Total)	3.3E-08	B2	Multiple organs	EPA, 1989
2,3,7,8-TCDD	3.3E-05	B2	Multiple organs	Inhalation/HEAST
TCDD (Total)	3.3E-05	B2	Multiple organs	Inhalation/HEAST
TCDF (Total)	3.3E-05	B2	Multiple organs	EPA, 1989
1,1,2-Trichloroethane	0.000016	C	Respiratory Tract	Inhalation/IRIS
TCE	0.0000017	B2	Liver	Inhalation/HEAST, 1991
PAHs[a]	0.0017	B2	Lung	Inhalation/IRIS
Arsenic	0.0043	A	Respiratory tract	Inhalation/IRIS
Beryllium	0.0024	B2	Lung	Occupational/IRIS

Table A-3
Summary of Toxicity Values for Potential Carcinogenic Effects

Chemical	Inh. Unit Risk $(\mu g/m^3)^{-1}$	Weight of Evidence Class	Type of Cancer	SF Basis/ SF Source
Cadmium	0.0018	B1	Respiratory tract	Occupational/IRIS
Chromium VI	0.012	A	Lung	Occupational/IRIS
Nickel, Refinery Dust	0.00024	A	Respiratory tract	Occupational/IRIS

[a] Cancer potency of PAHs assumed similar to Benzo(a)pyrene.

IRIS – Integrated Risk Information System; all values from IRIS, 1992.
HEAST – Health Effects Assessment Summary Tables; all values from HEAST 1992, except where noted.
EPA, 1988 – Special Report on Ingested Inorganic Arsenic, July 1988, EPA/625/3-87/013.
EPA, 1989 – Interim Procedures for Estimating Risks Associated with Exposures to Mixtures of Chlorinated Dibenzo-p-Dioxins and Dibenzofurans (CDDs and CDFs) and 1989 Update, EPA/625/3-89/016, March 1989.

Table A-4
Summary of Current EPA-Recommended Radiation Risk Factors[a]

Risk	Significant Exposure Period	Risk Factor Effect/10^6 Rad	
		Nominal	Range
Low-LET			
Carcinogenic Effects			
Fatal Cancers	Lifetime	390	120-1,200
All Cancers	Lifetime	620	190-1,900
Genetic Effects			
Severe hereditary defects, all generations	30-year reproductive generation	260	60-1,100
Teratogenic Effects[b]			
Severe mental retardation	Weeks 8 to 15 of gestation	4,000	2,500-5,500
Malformation	Weeks 2 to 8 of gestation	5,000	---
Preimplantation loss	Weeks 0 to 2 of gestation	10,000	---
High-LET			
Carcinogenic Effects			
Fatal Cancers	Lifetime	3,100	960-9,600
All Cancers	Lifetime	5,000	1,500-15,000
Genetic Effects			
Severe hereditary defects, all generations	30-year reproductive generation	690	160-2,900

[a] Taken from Table 6-27 in EPA/520/1-89-005 (EPA, 1989d).

[b] The range assumes a linear, nonthreshold dose response. However, it is plausible that a threshold may exist for this effect.

Table A-5
Dose Conversion Factors and Risk Factors

Dose Conversion Factors				Risk Factors		
				Cancer Incidence		
Nuclide	**Ingestion (mrem/pCi)**	**Inhalation (mrem/pCi)**	**External Exposure (mrem-g/ pCi-hr)**	**Ingestion (pCi)$^{-1}$**	**Inhalation (pCi)$^{-1}$**	**External Exposure (risk-g/ pCi-yr)**
Np-237 + D	4.44×10^{-3}	5.4×10^{-1}	1×10^{-4}	2.2×10^{-10}	72.9×10^{-8}	4.3×10^{-7}
Pu-239	3.69×10^{-4}	3.08×10^{-1}	4.2×10^{-8}	2.3×10^{-10}	3.8×10^{-8}	1.7×10^{-11}
Tc-99	1.46×10^{-6}	8.31×10^{-6}	1.5×10^{-8}	1.3×10^{-12}	8.3×10^{-12}	6×10^{-13}
Th-230	5.46×10^{-4}	2.62×10^{-1}	1.2×10^{-7}	1.3×10^{-11}	2.9×10^{-8}	5.4×10^{-11}
U-234	2.83×10^{-4}	1.33×10^{-1}	5.7×10^{-8}	1.6×10^{-11}	2.6×10^{-8}	3.0×10^{-11}
U-235 + D	2.66×10^{-4}	1.23×10^{-1}	3.8×10^{-5}	1.6×10^{-11}	2.5×10^{-8}	2.4×10^{-7}
U-238 + D	2.55×10^{-4}	1.18×10^{-1}	7.5×10^{-6}	2.8×10^{-11}	5.2×10^{-8}	3.6×10^{-8}

Notes:

+ D indicates that daughter radionuclides are included in the risk and external dose calculations. Internal dose factors account for buildup of daughters, assuming intake of pure parent radionuclide.

Sources:

Internal dose factors were taken from EPA (1988e) and the DFINT program developed by K. F. Eckerman at the Oak Ridge National Laboratory (ORNL).
Cancer incidence factors were taken from the Health Effects Summary Tables (HEAST) (EPA, 1991a).
External dose factors were taken from NUREG/CR-5512, *Residual Radioactive Contamination from Decommissioning, Technical Basis for Translating Contaminant Levels to Annual Dose*, January 1990.

Appendix A
Attachments
Exposure Point Concentrations

Appendix A

Attachments

WMUs 7 & 30

EDMS CHEMICAL SUMMARY STATISTICS BY ANALYSIS
PADUCAH - WMU 2/3 (0-6' SOIL) RADIOLOGICAL
RAD23.TXT
SAMPLE ANALYSIS: RADIOACTIVE

Chem Code	Chemical Name	Conc Units	Total Count	Detected Count	Detected Frequency	Detected Minimum	Detected Maximum	Detected Average	Standard Deviation	Geometric Mean	95% Confidence Limit
NE7	NEPTUNIUM-237	PCI/G	6	2	0.3333	0.041	0.320	0.181	0.140	0.061	0.33
PL9	PLUTONIUM-239	PCI/G	3	2	0.6667	0.014	7.900	3.957	3.943	0.087	
T99	TECHNETIUM-99	PCI/G	5	2	0.4000	6.000	58.000	32.000	26.000	3.377	34,455.88
THO	THORIUM-230	PCI/G	6	6	1.0000	0.340	14.000	2.838	4.994	0.989	63.92
UR4	URANIUM-234	PCI/G	6	6	1.0000	0.210	18.000	5.057	6.289	1.863	1,886.73
UR5	URANIUM-235	PCI/G	6	6	1.0000	0.006	1.700	0.425	0.612	0.089	9,930.51
UR8	URANIUM-238	PCI/G	6	6	1.0000	0.240	69.000	23.195	29.694	4.450	1,970,462.81

EJECTED OBSERVATIONS ARE NOT INCLUDED IN ANY CALCULATIONS. DETECTED FREQUENCY = DETECTED COUNT/TOTAL COUNT.

```
EDMS CHEMICAL SUMMARY STATISTICS BY ANALYSIS
PADUCAH - WMU 2/3 (0-6' SOIL) CHEMICAL
CHEM23.TXT
SAMPLE ANALYSIS: Pesticides and  PCB's

Chem                                       Conc   Total  Detected  Detected   Detected     Detected     Detected     Standard     Geometric    95% Confidence
Code Chemical Name                         Units  Count  Count     Frequency  Minimum      Maximum      Average      Deviation    Mean         Limit
---- ------------------------------------- -----  -----  --------  ---------  -----------  -----------  -----------  -----------  -----------  -------------

AR5  AROCLOR-1248                          MG/KG      8         1     0.1250        0.210        0.210        0.210        0.000        0.090           0.22
AR7  AROCLOR-1260                          MG/KG      8         1     0.1250        0.130        0.130        0.130        0.000        0.140           0.48
```

REJECTED OBSERVATIONS ARE NOT INCLUDED IN ANY CALCULATIONS. DETECTED FREQUENCY = DETECTED COUNT/TOTAL COUNT.

```
EDMS CHEMICAL SUMMARY STATISTICS BY ANALYSIS
PADUCAH - WMU 2/3 (0-6' SOIL) CHEMICAL
CHEM23.TXT
SAMPLE ANALYSIS: Dioxins and Furans

Chem                                          Conc    Total  Detected  Detected    Detected     Detected     Detected     Standard     Geometric    95% Confidence
Code Chemical Name                            Units   Count  Count     Frequency   Minimum      Maximum      Average      Deviation    Mean         Limit
---- ---------------------------------------- -----   -----  --------  ---------   -----------  -----------  -----------  -----------  -----------  -------------

ODD  TOTAL-OCTACHLORODIBENZO-p-DIOXIN         UG/KG       1         1     1.0000         3.300        3.300        3.300        0.000        3.300           1.00




REJECTED OBSERVATIONS ARE NOT INCLUDED IN ANY CALCULATIONS.  DETECTED FREQUENCY = DETECTED COUNT/TOTAL COUNT.
```

EDMS CHEMICAL SUMMARY STATISTICS BY ANALYSIS
PADUCAH - WMU 2/3 (0-6' SOIL) CHEMICAL
CHEM23.TXT
SAMPLE ANALYSIS: Inorganics

Chem Code	Chemical Name	Conc Units	Total Count	Detected Count	Detected Frequency	Detected Minimum	Detected Maximum	Detected Average	Standard Deviation	Geometric Mean	95% Confidence Limit
AL	ALUMINUM	MG/KG	8	8	1.0000	4,960.000	12,900.000	7,881.250	2,283.120	7,585.547	9,922.38
AS	ARSENIC	MG/KG	8	8	1.0000	2.800	15.200	6.475	3.565	5.755	10.17
BA	BARIUM	MG/KG	8	8	1.0000	75.000	158.000	109.063	26.490	105.953	132.68
BE	BERYLLIUM	MG/KG	8	6	0.7500	0.460	0.880	0.650	0.139	0.611	0.74
CA	CALCIUM	MG/KG	8	8	1.0000	724.000	2,360.000	1,588.000	500.403	1,496.673	2,230.52
CR	CHROMIUM	MG/KG	8	7	0.8750	5.900	19.000	12.786	4.628	9.826	24.32
CO	COBALT	MG/KG	8	8	1.0000	4.500	13.200	8.238	3.313	7.599	12.05
CU	COPPER	MG/KG	8	8	1.0000	6.800	28.400	15.350	7.621	13.667	24.71
FE	IRON	MG/KG	8	8	1.0000	10,100.000	52,100.000	20,200.000	13,077.557	17,413.482	33,101.74
PB	LEAD	MG/KG	8	8	1.0000	9.000	25.900	13.375	5.692	12.441	18.48
MG	MAGNESIUM	MG/KG	8	8	1.0000	556.000	3,000.000	1,495.625	719.172	1,324.778	2,541.05
MN	MANGANESE	MG/KG	8	8	1.0000	146.000	655.000	294.875	163.961	259.304	476.70
HG	MERCURY	MG/KG	8	1	0.1250	0.150	0.150	0.150	0.000	0.122	0.71
NI	NICKEL	MG/KG	8	8	1.0000	7.100	29.000	15.288	7.512	13.572	25.10
K	POTASSIUM	MG/KG	8	8	1.0000	214.000	744.000	463.500	178.484	429.233	676.89
SE	SELENIUM	MG/KG	7	2	0.2857	0.430	0.480	0.455	0.025	0.296	0.40
AG	SILVER	MG/KG	8	3	0.3750	1.900	6.300	3.633	1.914	1.185	5.38
NA	SODIUM	MG/KG	8	3	0.3750	84.000	521.000	242.333	197.657	123.965	558.99
V	VANADIUM	MG/KG	8	8	1.0000	2.300	31.800	19.763	8.140	16.395	59.63
ZN	ZINC	MG/KG	8	8	1.0000	25.400	76.100	49.188	16.563	46.433	67.05

REJECTED OBSERVATIONS ARE NOT INCLUDED IN ANY CALCULATIONS. DETECTED FREQUENCY = DETECTED COUNT/TOTAL COUNT.

EDMS CHEMICAL SUMMARY STATISTICS BY ANALYSIS
PADUCAH - WMU 2/3 (0-6' SOIL) CHEMICAL
CHEM23.TXT
SAMPLE ANALYSIS: Semi-Volatile Organics

Chem Code	Chemical Name	Conc Units	Total Count	Detected Count	Detected Frequency	Detected Minimum	Detected Maximum	Detected Average	Standard Deviation	Geometric Mean	95% Confidence Limit
BPH	BIS(2-ETHYLHEXYL)PHTHALATE	MG/KG	8	3	0.3750	0.044	0.090	0.063	0.019	0.216	6.40
DBP	DI-N-BUTYL PHTHALATE	MG/KG	8	2	0.2500	0.091	0.450	0.271	0.180	0.350	0.68
PCP	PENTACHLOROPHENOL	MG/KG	8	1	0.1250	0.100	0.100	0.100	0.000	1.781	37.02

REJECTED OBSERVATIONS ARE NOT INCLUDED IN ANY CALCULATIONS. DETECTED FREQUENCY = DETECTED COUNT/TOTAL COUNT.

```
DMS CHEMICAL SUMMARY STATISTICS BY ANALYSIS
ADUCAH - WMU 2/3 (0-6' SOIL) CHEMICAL
HEM23.TXT
AMPLE ANALYSIS: Volatile Organics

hem                                          Conc   Total  Detected  Detected    Detected     Detected     Detected     Standard     Geometric    95% Confidence
ode Chemical Name                            Units  Count  Count     Frequency   Minimum      Maximum      Average      Deviation    Mean         Limit
---- ------------------------------------    -----  -----  --------  ---------   -----------  -----------  -----------  -----------  -----------  -------------

2BU  2-BUTANONE                              MG/KG      8         1     0.1250        0.009        0.009        0.009        0.000        0.012           0.01
MCL  METHYLENE CHLORIDE                      MG/KG      8         1     0.1250        0.140        0.140        0.140        0.000        0.020           0.09
```

REJECTED OBSERVATIONS ARE NOT INCLUDED IN ANY CALCULATIONS. DETECTED FREQUENCY = DETECTED COUNT/TOTAL COUNT.

EDMS CHEMICAL SUMMARY STATISTICS BY ANALYSIS
PADUCAH - WMU 2/3 (0-1' SOIL) RADIOLOGICAL
RAD231.TXT
SAMPLE ANALYSIS: RADIOACTIVE

Chem Code	Chemical Name	Conc Units	Total Count	Detected Count	Detected Frequency	Detected Minimum	Detected Maximum	Detected Average	Standard Deviation	Geometric Mean	95% Confidence Limit
NE7	NEPTUNIUM-237	PCI/G	1	1	1.0000	0.320	0.320	0.320	0.000	0.320	1.00
PL9	PLUTONIUM-239	PCI/G	1	1	1.0000	7.900	7.900	7.900	0.000	7.901	1.00
T99	TECHNETIUM-99	PCI/G	1	1	1.0000	58.000	58.000	58.000	0.000	57.974	1.00
THO	THORIUM-230	PCI/G	1	1	1.0000	14.000	14.000	14.000	0.000	13.999	1.00
UR4	URANIUM-234	PCI/G	1	1	1.0000	18.000	18.000	18.000	0.000	17.993	1.00
UR5	URANIUM-235	PCI/G	1	1	1.0000	1.700	1.700	1.700	0.000	1.701	1.00
UR8	URANIUM-238	PCI/G	1	1	1.0000	69.000	69.000	69.000	0.000	68.993	1.00

EJECTED OBSERVATIONS ARE NOT INCLUDED IN ANY CALCULATIONS. DETECTED FREQUENCY = DETECTED COUNT/TOTAL COUNT.

EDMS CHEMICAL SUMMARY STATISTICS BY ANALYSIS
PADUCAH - WMU 2/3 (0-1' SOIL) CHEMICAL
CHEM231.TXT
SAMPLE ANALYSIS: Pesticides and PCB's

Chem Code	Chemical Name	Conc Units	Total Count	Detected Count	Detected Frequency	Detected Minimum	Detected Maximum	Detected Average	Standard Deviation	Geometric Mean	95% Confidence Limit
AR7	AROCLOR-1260	MG/KG	2	1	0.5000	0.130	0.130	0.130	0.000	0.165	0.82

REJECTED OBSERVATIONS ARE NOT INCLUDED IN ANY CALCULATIONS. DETECTED FREQUENCY = DETECTED COUNT/TOTAL COUNT.

DMS CHEMICAL SUMMARY STATISTICS BY ANALYSIS
ADUCAH - WMU 2/3 (0-1' SOIL) CHEMICAL
HEM231.TXT
AMPLE ANALYSIS: Inorganics

hem ode	Chemical Name	Conc Units	Total Count	Detected Count	Detected Frequency	Detected Minimum	Detected Maximum	Detected Average	Standard Deviation	Geometric Mean	95% Confidence Limit
L	ALUMINUM	MG/KG	2	2	1.0000	4,960.000	6,690.000	5,825.000	865.000	5,761.770	12,035.94
S	ARSENIC	MG/KG	2	2	1.0000	2.800	15.200	9.000	6.200	6.521	1,852,161,180.70
A	BARIUM	MG/KG	2	2	1.0000	132.000	158.000	145.000	13.000	144.460	210.94
E	BERYLLIUM	MG/KG	2	2	1.0000	0.710	0.880	0.795	0.085	0.791	1.27
A	CALCIUM	MG/KG	2	2	1.0000	1,420.000	1,800.000	1,610.000	190.000	1,598.786	2,741.38
R	CHROMIUM	MG/KG	2	1	0.5000	9.200	9.200	9.200	0.000	4.889	233,193.77
O	COBALT	MG/KG	2	2	1.0000	10.300	13.200	11.750	1.450	11.658	20.70
U	COPPER	MG/KG	2	2	1.0000	13.500	27.100	20.300	6.800	19.125	497.79
E	IRON	MG/KG	2	2	1.0000	17,700.000	52,100.000	34,900.000	17,200.000	30,363.606	78,182,469.09
B	LEAD	MG/KG	2	2	1.0000	12.700	19.400	16.050	3.350	15.690	56.20
G	MAGNESIUM	MG/KG	2	2	1.0000	709.000	1,860.000	1,284.500	575.500	1,148.257	608,603.34
N	MANGANESE	MG/KG	2	2	1.0000	209.000	244.000	226.500	17.500	225.879	308.93
G	MERCURY	MG/KG	2	1	0.5000	0.150	0.150	0.150	0.000	0.141	0.18
I	NICKEL	MG/KG	2	2	1.0000	24.700	29.000	26.850	2.150	26.762	37.03
	POTASSIUM	MG/KG	2	2	1.0000	508.000	744.000	626.000	118.000	614.617	1,808.39
E	SELENIUM	MG/KG	1	1	1.0000	0.430	0.430	0.430	0.000	0.430	1.00
G	SILVER	MG/KG	2	2	1.0000	1.900	2.700	2.300	0.400	2.266	5.86
A	SODIUM	MG/KG	2	1	0.5000	521.000	521.000	521.000	0.000	379.935	5,747.68
	VANADIUM	MG/KG	2	2	1.0000	2.300	16.000	9.150	6.850	6.068	*****************
N	ZINC	MG/KG	2	2	1.0000	60.100	76.100	68.100	8.000	67.627	115.66

JECTED OBSERVATIONS ARE NOT INCLUDED IN ANY CALCULATIONS. DETECTED FREQUENCY = DETECTED COUNT/TOTAL COUNT.

Appendix B
Background Risk Estimates

Appendix B
Background Risk Estimates

Reference Sampling

"Reference samples" are those that are representative of naturally occurring conditions or conditions resulting from other, non-plant related, activities such as fallout. The reference levels presented in the Phase II Site Investigation (SI) Report are the maximum values detected from a set of reference samples taken for each medium and are used to calculate background risk.

Groundwater

Because of the presence of the subsurface terrace immediately upgradient of the plant, groundwater cannot be sampled to represent the quality of the water entering the Regional Gravel Aquifer (RGA) beneath the plant. Most of the water entering the RGA enters via seepage from the overlying Upper Continental Recharge System (UCRS). The wells installed into the gravel on top of the terrace and to either side of the plant were chosen as representative of water quality not affected by plant activities. Because the water quality in the shallow groundwater system is similar to that of the RGA, reference constituent analyses were conducted on all water samples regardless of the groundwater system. Data from MW-120, -129, -130, -131, -150, and -196, were used as reference data for groundwater. However, the radiological data from MW-196 were not included as reference data because of uncertainties surrounding the Tc-99 and Pu-239 results. Sample results for MW-196 (120 pCi/L Tc-99 and 42 pCi/L Pu-239) found during Stage A sampling were not confirmed during Stage B sampling, nor were they supported by gross alpha or gross beta results corresponding to that sample. The elevated radiological results in MW-196 were therefore not used.

Samples taken from the reference wells were analyzed for Target Analyte List (TAL) and Target Compound List (TCL) chemicals along with select radionuclides. Reference values for both dissolved and total metals and radionuclides are presented in the Phase II SI Report. The data set available for defining reference groundwater quality is fairly small. This most notably affects the reference level assigned to metals, as there is a wide variation in metals concentrations naturally occurring in the groundwater beneath the Paducah Gaseous Diffusion Plant (PGDP). Because of the small data set, the resulting metal reference levels are probably conservatively low and may not represent naturally higher levels of metals. See Figure 4-1 in the Phase II SI Report for the location of the selected reference monitoring wells and the reference sampling points for the other media.

Surface Soil

Five surface soil samples (the "UP" stations on Figure 4-1) were taken in areas outside the influence of plant activities. These samples were taken from zero to 0.5 ft in depth once the overlying vegetation and debris were removed. To reflect the potential range of naturally occurring conditions, these samples were taken from the three soil types found on the plant: Henry Silt Loam, Calloway Silt Loam, and Grenada Silt Loam. These reference soil samples were analyzed for metals, polychlorinated biphenyls (PCBs), and gross alpha and beta activity. One sample was analyzed for radionuclides. The results of the metal analysis for the reference samples have been compared to literature values of common range for soils. Cadmium reference values exceeded the literature values, but all other values were within the predicted range. For a more detailed discussion, see Section 4.2 of the Phase II SI Report.

In May and June of 1990, 33 surface soil samples (from zero to 12 in. in depth) were collected at least 5 miles east and southeast of the plant to provide soil radionuclide activity data indicative of naturally occurring conditions. The maximum activity detected and the frequency of detection are included in Table 4-4 of the Phase II SI Report as reference soil values for radionuclides. The presence of Np-237, Pu-239, and Tc-99 in the reference samples may be valid, even though these are manmade radionuclides; however, comparisons in the Phase II SI Report are made to the method detection limit (MDL). Detections of these radionuclides above 0.1 pCi/g have been considered indicators of plant-related activities.

Uranium-234 and -238 were detected at maximum activities of 1.24 ± 0.16 and 1.22 ± 0.16 pCi/g, respectively. These values are representative of natural conditions and are used in the addendum for comparison. Because U-235 was not detected in the reference samples, detections of U-235 in other samples may be indicative of plant activities. The maximum Th-230 activity detected was 7.26 ± 1.1 pCi/g; however, this value is more than three times greater than the next highest activity and nearly six times higher than its natural parent. For Th-230, the average detected activity, 1.85J pCi/g, is used as the reference value.

Background Risk Characterization

The maximum detected concentrations for reference samples were used as input values in the risk equations used to estimate risks associated with "background." While background risks based on naturally occurring constituents in soil and groundwater are not subtracted from site-related risks, this provides a basis for further evaluation of risks.

The background risk characterization evaluates the potential carcinogenic, noncarcinogenic, and radiological risks for each of the defined exposure pathways, including the following:

- Ingestion, inhalation, dermal absorption, or external radiation exposures to contaminated surface soil
- Ingestion and inhalation of contaminated groundwater through domestic use

The toxicity values describing the dose-response characteristics of the contaminants were integrated with the exposure intake estimates. Together, they were used to generate estimates of excess lifetime cancer risk for chemicals or radionuclides and the likelihood of noncarcinogenic effects for each exposure pathway due to background concentrations of inorganics and radionuclides in soil and groundwater.

Detailed tables showing carcinogenic, noncarcinogenic, and radiological risks are presented in Attachments B-1 through B-7. The tables summarize the assumptions incorporated in each analysis and show the risks calculated for each contaminant using the maximum detected values from the reference samples.

Surface Soil Exposure Pathways

The receptors under industrial-use scenarios included workers at two different frequencies of exposure designated:

Future Worker; Frequent Potential Exposure: 250 days/year
Current Worker, Remote Location/Intruder: 25 days/year

The second worker exposure frequency was conservative for intruders or visitors.

Routes of exposure associated with contaminants detected in reference surface soil samples include: ingestion, dermal absorption, inhalation, and external radiation.

Chemical risks associated with surface soil are summarized in Table B-1. The sum of cancer risks over all three pathways for unrestricted future worker exposure scenario is 2×10^{-5}. The sum for the worker/intruder scenario is 2×10^{-6}. The hazard indices (HIs) for the unrestricted future worker exposure scenario and worker/intruder exposure scenarios are 0.05 and 0.005, respectively.

The primary contributors to chemical carcinogenic risk via both the ingestion and dermal absorption routes of exposure is beryllium, using a maximum detected soil concentration of 17.3 mg/kg. For inhalation, Cr(VI) was the major contributor to the risk, although risks did not exceed 1E-8. Individual risk calculations for each detected compound in soil are provided in Attachments B-1 and B-4.

The major contributors to the noncarcinogenic risk, although HIs are less than 1, were arsenic, barium, and beryllium, primarily via the ingestion pathway. Cr(VI) is the major contributor to the noncarcinogenic risk estimate for the inhalation pathway, although the HI did not exceed 0.0002, using the naturally occurring background concentration. Individual HI calculations for detected compounds are shown in Attachments B-2 and B-5.

Table B-1
Summary Background of Risk Calculations

Direct Contact to Soil	Lower Bound Worker/Intruder (25 day/year)	Upper Bound Unrestricted Worker (250 day/year)	Contaminants Contributing to Risk Estimate
Cancer Risk Estimate			
Ingestion	2×10^{-6}	2×10^{-5}	Arsenic, Beryllium
Dermal Absorption	1×10^{-7}	1×10^{-6}	
Inhalation	2×10^{-9}	2×10^{-8}	
Sum of Pathways	2×10^{-6}	2×10^{-5}	
Chronic HI			
Ingestion	0.004	0.04	None
Dermal Absorption	0.0003	0.003	
Inhalation	0.00002	0.0002	
Sum of Pathways	0.005	0.05	
Radiological Cancer Risk Estimate			
Ingestion	2×10^{-9}	2×10^{-8}	U-238
Inhalation	4×10^{-10}	4×10^{-9}	
External Radiation	3×10^{-8}	3×10^{-7}	
Sum of Pathways	3×10^{-8}	3×10^{-7}	

Ingestion of Groundwater	Future Offsite Resident	Contaminants Contributing to Risk
Cancer Risk Estimate	MW-74	
Ingestion	---	
Inhalation	---	
Sum of Pathways	---	
Chronic HI	MW-74	
Ingestion	2.2	Manganese, Chromium
Inhalation	---	
Sum of Pathways	2.2	
Radiological Cancer Risk Estimate	MW-154	
Ingestion	9×10^{-7}	Th-230, U-238

Radiological risks were evaluated for ingestion, inhalation, and direct external gamma exposure for the unrestricted worker (future industrial) scenario and the worker/intruder (current industrial) scenario. The sum of radiological risks via the three exposure routes for the future worker and current worker scenarios are 3×10^{-7} and 3×10^{-8}, respectively, well below the lower bound of the acceptable risk range. Radiological constituents detected in reference soil samples included Th-230, U-234, and U-238. The highest risk estimate (3×10^{-7}) was via the external exposure route to U-238. Radiological risks associated with surface soil are summarized in Table B-1.

The primary contributor to the radiological risk estimate via the ingestion, inhalation, and external gamma radiation exposure pathways was U-238 and its daughters. The external gamma radiation exposure pathway had the highest risk estimate (3×10^{-7}). Radiological risk calculations for each surface soil exposure pathway are shown in Attachments B-3 and B-6.

Groundwater Exposure Pathway

No onsite use of groundwater occurs currently at the facility. Potential risks associated with naturally occurring constituents in groundwater were evaluated assuming potential future domestic use of groundwater using maximum detected constituent concentrations representing both the UCRS and RGA. Detailed chemical- and radionuclide-specific risk estimates for background concentrations in groundwater are shown in Attachments B-7 and B-8. Only noncarcinogenic risk and radiological cancer risks were estimated because no carcinogenic compounds were detected in reference groundwater samples. Table B-1 shows the risks estimated for groundwater.

HI values estimated for the reference groundwater samples, assuming future use of groundwater, is 2.2. Detailed risk calculations are summarized in Attachment B-7. The primary contributors to this value are manganese and chromium. The hazard quotient (HQ) for manganese is 1.8.

Radiological risks associated with background concentrations of radionuclides via groundwater ingestion is shown in Attachment B-8. The total radiological risk from groundwater ingestion is 9×10^{-7}, below the lower bound of the acceptable risk range. The radionuclides detected in the groundwater reference samples include Th-230 and U-238.

Appendix C
Soil to Groundwater Leaching Model

Appendix C
Soil to Groundwater Leaching Model

Modeling of the transport of selected contaminants at the Paducah Gaseous Diffusion Plant (PGDP) Waste Management Units (WMUs) was performed to evaluate whether selected contaminants that currently exist in soils at the site could adversely affect the quality of the groundwater underlying the site. The modeling estimated the concentration of selected soil contaminants that would be expected to leach from the soil matrix and eventually reach the groundwater below the WMUs. The modeling results were used to estimate the maximum allowable soil concentrations of these contaminants that would maintain groundwater concentrations below protective criteria.

The modeling was performed using the Summers transport model, which has been used by the Environmental Protection Agency (EPA) to simulate the transport of contaminants released from soils at a waste disposal unit into the underlying groundwater environment. The model incorporates the physical and chemical characteristics of the contaminants, the physical characteristics of the source, the physical characteristics of the unsaturated zone, and the characteristics of the receiving aquifer to simulate the migration of contaminants from source materials at the surface to the underlying groundwater.

Summers et al. (1980) investigated the potential for groundwater contamination from releases of geothermal fluids. Two types of releases were described as being of concern: (1) continuous releases such as those from surface ponds and certain well failures and (2) slug releases such as those from surface spills, well failures, and other short-term events.

For the more relevant release mode of a spill or soil contamination near the ground surface, a solution to the steady-state, two-dimensional equation was used that generated a value for the concentration of a contaminant at the point where it reaches the water table. This equation assumes a constant contaminant source with no dispersion or adsorption process, and is therefore considered conservative. The concentration at the water table was used in the following material-balance equation to estimate the concentration of the contaminant in the groundwater:

$$C_w = \frac{Q_p C_p + Q_a C_a}{Q_p + Q_a}$$

where:

Q_p = volumetric flow rate of water transporting the contaminant into the aquifer
C_p = concentration of the contaminant in the infiltrating water
C_w = downgradient concentration in the aquifer
Q_a = volumetric flow rate in the aquifer
C_a = upgradient concentration of the contaminant in the aquifer

In Summers et al. (1980), this model was coupled with a one-dimensional convection-dispersion equation. However, as typically applied (EPA, 1989a), the "Summers model" does not include the solution of this equation. The material-balance equation above is rearranged and used to solve for C_p at the water table, assuming the upgradient concentration in the groundwater is zero and the acceptable downgradient concentration C_w in the aquifer is a protective criteria value such as the Maximum Contaminant Level (MCL). The value of C_p is then used with the distribution coefficient (K_d) in the following equation to calculate the soil concentration in the soil:

$$C_s = C_p \times K_d$$

where:

C_s = concentration in the soil
Cp = concentration in the infiltrating water
Kd = distribution coefficient

This form of the solution will be referred to hereafter as the "Summers model." The Summers model has several assumptions that limit its accuracy. The approach assumes complete vertical mixing of the contaminant in that part of the aquifer directly underlying the contaminant source. Also, the effects of dispersion, volatilization, and degradation are not accounted for.

Simulations for the contaminants of potential concern were made using a single run of the model. No degradation process nor processes that retard or enhance transport were assumed. The initial contaminant concentration in the soil was defined as 1 mg/L, which allowed the generation of the contaminant concentration reaching the water table as a fraction of the initial concentration. This fraction was used as a dilution factor in back-calculating the maximum soil concentration that would maintain groundwater concentrations below protective criteria.

The protective criteria used in the simulation for groundwater were established using the following approach:

- The MCL is used whenever an MCL value exists for a given contaminant.

- When no MCL value exists, risk-based remediation goals are calculated for a target excess lifetime cancer risk of 1×10^{-5} or a target hazard index (HI) of 1.0.

- When no risk-based values exist or if no K_d factor could be estimated for a given contaminant, no simulation is made.

When available, physical data gathered directly from the site were used as input parameters for the model. Table C-1 lists the parameters measured at the site. If direct measurements did not exist, parameters were estimated using typical values for the existing soil conditions at the site. In particular, values for K_d for each contaminant were estimated using typical values.

The model is most sensitive to input parameters that describe the physical characteristics of the source and the flow of the receiving groundwater. Critical parameters include infiltration rate, length of the unit parallel to groundwater flow, and groundwater seepage velocity.

As shown in Table C-1, these input parameters were either measured directly at the site or derived from data gathered at the site.

Table C-1
Soil-to-Groundwater Leaching Model
Summers Model

Parameter	Symbol	Unit	WMU 2/3
INPUT PARAMETERS			
WMU length in direction of flow	L	m	75
WMU Width	w	m	210
Percolation rate through UCRS	I	m/day	3.8E-05
Hydraulic conductivity of RGA	k	m/day	26
Gradient in RGA	i	m/m	0.00027
Thickness of RGA	t	m	10
RESULTS			
Percolation Rate	Qp	m3/day	0.5985
Aquifer Flow Rate	Qa	m3/day	14.74
Dilution Factor	df	--	0.039

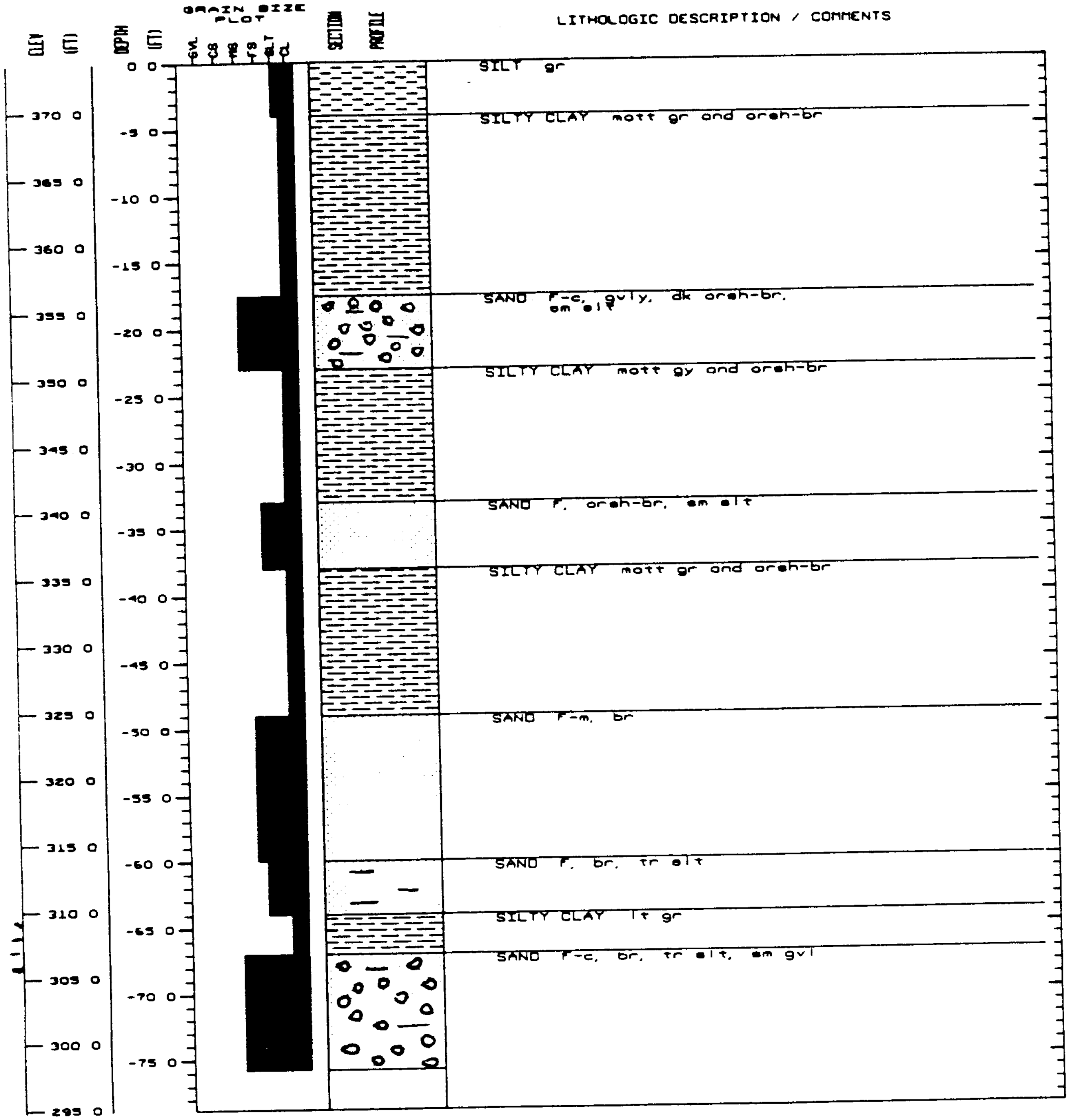
Qp = {L x W x I}
Qa = {k x i x t x W}
df = Qp/{Qp+Qa}

Appendix D

Boring Logs MW-48, MW-74 and MW-154
Walkover Gamma Survey for WMU-2

MW-48

373 6



SILT gr

SILTY CLAY mott gr and orsh-br

SAND f-c, gvly, dk orsh-br, sm slt

SILTY CLAY mott gy and orsh-br

SAND f, orsh-br, sm slt

SILTY CLAY mott gr and orsh-br

SAND f-m, br

SAND f, br, tr slt

SILTY CLAY lt gr

SAND f-c, br, tr slt, sm gvl

EDGe ENGINEERING, DESIGN & GEOSCIENCES GROUP, INC.
NASHVILLE, TENNESSEE

LOG OF BORING NO. 74
SHEET 1 OF 2

PROJECT MARTIN MARIETTA ENERGY SYSTEMS
PADUCAH GASEOUS DIFFUSION PLANT, KENTUCKY
C-404 POST-CLOSURE ACTIVITIES
PROJECT NO. ESO 16749

PROJECT NO. GA 87-435N EDGe 1178-1
DATE 10-8-87

SURFACE ELEVATION 372.05
BOTTOM OF HOLE DEPTH 42.0 ELEV 330.05
BORING LOCATION NW Corner of C-404 @ W6153, S827
COMPLETION DATE 10-8-87

DRILLER J. L. DeMoss
HELPER Martin & Chapman
DRILLED FOR C. M. Johnson
RIG CME 550 with Continuous Sampler
LOGGED BY W. S. Anderson

LITHOLOGY BREAK	SAMPLE NO.	FROM	TO	SAMPLE BLOW*	DESCRIPTIONS AND REMARKS
2.0		0.0	2.0		Gravel and silt, sandy, clayey, brown.
		2.0	4.0		Clay, very silty, brown to light gray.
5.4		4.0	5.4		Clay, silty, gray to light gray, occasionally mottled black
		5.4	9.0		Silt, very clayey, light brown.
18.5		14.0	18.5		Silt, very clayey, occasional sandy zones, light gray occasionally mottled reddish-brown.
18.8		18.5	18.8		Sand, medium, reddish-brown (damp).
		18.8	19.0		Silt, slightly clayey, light gray.
22.5		19.0	22.5		Silt, very sandy, very clayey with numerous gravel, light reddish-brown mottled gray.
		22.5	25.4		Sand, medium, very clayey, silty, yellowish to light reddish-brown with numerous gravel and cobbles.
		25.4	29.0		Sand, clayey, silty, reddish-brown.
29.0	1				Jar Sample 1 - 25.4 - 26.5.
33.0		29.0	33.0		Clay, silty, variably sandy, light gray mottled reddish-brown.
		33.0	34.0		Sand, medium, slightly silty, reddish-brown.
	2				Jar Sample 2 - 33.0 - 33.5.
		34.0	37.0		Sand, medium, slightly silty, reddish-brown with abundant gravel.
	3				Jar Sample 3 - 35.5 - 36.0. ●
		37.0	38.2		Sand, coarse with gravel, clayey (very wet).
38.2	4				Jar Sample 4 - 37.7 - 38.2. ●
		38.2	39.0		Clay, very silty, slightly sandy, light brown.
40.0		39.0	40.0		Clay, slightly silty, light gray mottled reddish-brown.

*NUMBER OF BLOWS PER 6" INTERVALS, TO DRIVE 1-3/8 I.D., 2" O.D. SPLIT BARREL SAMPLER WITH 140 POUND HAMMER FALLING 30 INCHES

● DENOTES SAMPLES ON WHICH GRAIN SIZE ANALYSES WERE PERFORMED.

E|D|G e ENGINEERING, DESIGN & GEOSCIENCES GROUP, INC.
NASHVILLE, TENNESSEE

LOG OF BORING NO. 74
SHEET 2 OF 2

PROJECT MARTIN MARIETTA ENERGY SYSTEMS
PADUCAH GASEOUS DIFFUSION PLANT, KENTUCKY
C-404 POST-CLOSURE ACTIVITIES
PROJECT NO. ESO 16749

PROJECT NO. GA 87-435N EDGe 1178-1
DATE 10-8-87

SURFACE ELEVATION 372.05
BOTTOM OF HOLE DEPTH 42.0 ELEV 330.05
BORING LOCATION NW Corner of C-404 @ W6153, S827
COMPLETION DATE 10-8-87

DRILLER J. L. DeMoss
HELPER Martin & Chapman
DRILLED FOR C. M. Johnson
RIG CME 550 with Continuous Sampler
LOGGED BY W. S. Anderson

LITHOLOGY BREAK	SAMPLE NO.	FROM	TO	SAMPLE BLOW*	DESCRIPTIONS AND REMARKS
41.0		40.0	41.0		Sand, fine, slightly silty, reddish-brown.
		41.0	42.0		Clay, slightly silty, light gray mottled reddish-brown.
					Terminated Boring @ 42.0. Temporary Well No. 74 was set to a depth of 42.0 feet. See construction diagram.

*NUMBER OF BLOWS PER 6" INTERVALS, TO DRIVE 1-3/8 I.D., 2" O.D. SPLIT BARREL SAMPLER WITH 140 POUND HAMMER FALLING 30 INCHES

●DENOTES SAMPLES ON WHICH GRAIN SIZE ANALYSES WERE PERFORMED.

Table D-1
Parameters in Summer's Model (EPA, 1989)[1]

Parameter	Symbol	Selected Value		Units	Reference/Justification
		Run 1 - Waste to UCRS	Run 2 - UCRS to RGA		
Volumetric flow rate of infiltration	Q_p	249.6	395.4	m^3/yr	Calculated by $Q_P = V_{dx} \times A_p$ (EPA, 1989)[1]
Darcy velocity in downward directions	V_{dx}	0.084	0.133	m/yr	Run 1 - annual rainwater percolating into UCRS = 3.3 in/yr (McConnell, 1992); Run 2 - $V_{dx} = (K_u)(I_u)$, where $K_u = 0.133$ m/yr, the assumed hydraulic conductivity in the confining clays between the UCRS and the RGA (Geotrans, 1993); and $I_u = 1$, representing a complete vertical migration pattern in the confining zone.
Horizontal area of contamination	A_p	2973	2973	m^2	Area 1 extent of contaminant - 160 ft X 200 ft
Volumetric flow rate of groundwater	Q_a	14.6	31053.2	m^3/yr	Calculated by $Q_a = V_d \times h \times w$ (EPA, 1989)
Hydraulic conductivity	K	5.12	47267	m/yr	Run 1 - (McConnell, 1992)[6] Run 2 - (Geotrans, 1993)[8]
Hydraulic gradient	I	0.017	0.0007	unitless	Run 1 - (McConnell, 1992)[6] Run 2 - (Geotrans, 1993)[8]
Darcy velocity in aquifer	V_d	0.087	56.5	m/yr	Calculate by $V_d = K \times 1$
Aquifer thickness	h	3.05	10	m	Run 1 - (McConnell, 1992)[6] Run 2 - (Geotrans, 1993)[8]
Perpendicular spill width	w	78	78	m	Assumes that the water at the site flows approximately perpendicular to the diagonal length of the unit: sqr(160^2 ft + 200^2) ft
Soil-water distribution coefficient	K_d	1600	1600	l/kg	Sheppard and Thibault 1990[7], value representing mean of data for clayey soils. A distribution of values was used for the Monte Carlo run.

Table D-2
Uranium Activity Concentrations from Mass Concentrations

Uranium Activity Concentrations in the UCRS				
U concentration =	6117.71	μg/L		
Isotopes	**Isotopic Ratios for Depleted Uranium unitless**	**Mass Concentration for each Isotope μg/L**	**Specific Activity pCi/μg**	**Activity Concentration for each Isotope pCi/L**
U-238	0.998	$6.11E^{+03}$	0.33	$2.01E^{+03}$
U-234	0.00006	$3.67E^{-01}$	$6.20E^{+03}$	$2.28E^{+03}$
U-235	0.002	$1.22E^{+01}$	2.16	$2.64E^{+01}$
Uranium Activity Concentrations in the RGA				
U concentration =	99.97	μg/L		
Isotopes	**Isotopic Ratios for Depleted Uranium unitless**	**Mass Concentration for each Isotope μg/L**	**Specific Activity pCi/μg**	**Activity Concentration for each Isotope pCi/L**
U-238	0.998	$9.98E^{+01}$	0.33	$3.29E^{+01}$
U-234	0.00006	$6.00E^{-03}$	$6.20E^{+03}$	$3.72E^{+01}$
U-235	0.002	$2.00E^{-01}$	2.16	$4.32E^{-01}$

Appendix D Attachments

Science Applications International Corporation

Summers Model for Uranium

DOE/OR/06-1246&D0

DRAFT

Feasibility Study / Environmental Assessment for Solid Waste Management Units 2 and 3 of Waste Area Grouping 22 at the Paducah Gaseous Diffusion Plant Paducah, Kentucky

April 1994

Prepared by
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DE-AC05-91OR21950

Prepared for
U.S. Department of Energy
Environmental Restoration Division

DRAFT

A.3.3.2 Exposure Point Concentrations

For the baseline risk assessment of future ground water uses, it was assumed that current detected concentrations in nearby wells could be used to represent future ground water concentrations. For this RERA, a contaminant leaching model has been developed to predict future potential concentrations of uranium and trichloroethene (TCE) in the ground water at the boundary of the waste unit.

Potentially the most important long-term migration and exposure pathway of concern for decision-making is contaminant leaching from the source to ground water. The EPA has developed several models for use in determining potential contaminant migration to the ground water. One such model is the revised Summers Model (EPA, 1989).[2] The Summers Model is a simple one-dimensional analytical model that can be used to describe contaminant leaching when data on a site are limited. Based on the Summer's equation, the concentration of a chemical that reaches the ground water is a function of the amount of the chemical infiltrating through the soil column, the amount of chemical already present in the aquifer, and the volume of water into which the leachate is dissolved. Figure A-3.1 illustrates the conceptual model for leaching from the waste containers inside SWMU 2 to the ground water.

proposed alternatives. The following assumptions were used to determine the exposure points:

- The engineering control proposed for Alternative 2 will prevent direct contact with the waste in perpetuity.
- Because Alternative 2 does nothing to cover or treat the wastes and soils, indirect contact may still occur via the ground water and air transport pathways and via external penetrating radiation. The potential future exposure point for each of these pathways is the boundary of the waste unit.
- It is assumed that Alternative 3, the excavation scenario, removes all potential exposure pathways. For this alternative, the exposure point for determining compliance with RGOs is anywhere in the waste unit.
- It is assumed that Alternative 4, the capping and dewatering scenario, eliminated all direct contact pathways for an unspecified time period. However, since capping can not completely eliminate infiltration of rainwater through the waste, or contaminant migration to the ground water, potential future exposures associated with contaminants in the ground water are evaluated at the boundary of the waste unit.

Soil exposure point concentrations for Alternatives 1 and 2 are identified in the baseline risk assessment and summarized in Table A.3.4. These are the values identified as representative chemical concentrations in the baseline risk assessment.

A.3.3.2 Exposure Point Concentrations

For the baseline risk assessment of future ground water uses, it was assumed that current detected concentrations in nearby wells could be used to represent future ground water concentrations. For this RERA, a contaminant leaching model has been developed to predict future potential concentrations of uranium and trichloroethene (TCE) in the ground water at the boundary of the waste unit.

Potentially the most important long-term migration and exposure pathway of concern for decision-making is contaminant leaching from the source to ground water. The EPA has developed several models for use in determining potential contaminant migration to the ground water. One such model is the revised Summers Model (EPA, 1989).[2] The Summers Model is a simple one-dimensional analytical model that can be used to describe contaminant leaching when data on a site are limited. Based on the Summer's equation, the concentration of a chemical that reaches the ground water is a function of the amount of the chemical infiltrating through the soil column, the amount of chemical already present in the aquifer, and the volume of water into which the leachate is dissolved. Figure A-3.1 illustrates the conceptual model for leaching from the waste containers inside SWMU 2 to the ground water.

Table A.3.4 Quantitative data used to develop fate and transport source term and exposure point concentrations for SWMU 2 contaminants of concern, by medium

Contaminant	Waste[1] (from process knowledge and waste inventory data)	Surrounding Soils[2] (μg/kg; pCi/g)	Ground water[3] (μg/l;pCi/l)
Metals			
Antimony	NC	NC	20.40
Arsenic	NC	10.17	3.35
Barium	NC	NC	634
Beryllium	NC	NC	15.80
Cadmium	NC	NC	4.60
Chromium	NC	NC	140
Manganese	NC	NC	1535.3
Nickel	NC	NC	125
Silver	NC	NC	42
Thallium	NC	NC	0.90
Uranium, total	270 tons (2.45x10^5 kg)	NC	Summers Model[4]
Vanadium	NC	NC	410.10
Organic Compounds			
1,4-Dichlorobenzene	NC	NC	21
2-Chlorophenol	NC	NC	41
2,4-Dinitrotoluene	NC	NC	18.50
N-nitroso-di-n-propylamine	NC	NC	22
Pentachlorophenol	NC	NC	57
PCBs	unknown	NC	NC
Trichloroethene	450 gal.	NC	Summers Model[4]

Table A.3.4 Quantitative data used to develop fate and transport source term and exposure point concentrations for SWMU 2 contaminants of concern, by medium (continued)

Contaminant	Waste [1] (from process knowledge and waste inventory data)	Surrounding Soils [2] (µg/kg; pCi/g)	Ground water [3] (µg/l;pCi/l)
Radionuclides			
^{237}Np	NC	NC	0.32
^{99}Tc	NC	NC	1000 (UCRS)/ 44 (RGA)
^{234}U	see U-total	NC	3.6
^{235}U	see U-total	69 pCi/g	NC
^{238}U	see U-total	58 pCi/g	27

[1] Sources: DOE, 1993[5];

[2] From DOE, 1993[5] - from analytical data results in soil boring surrounding the waste.

[3] From DOE, 1993[5] - from analytical data results in nearby ground water wells.

[4] Ground water concentrations were estimated from waste inventory data using the Summer's Model (EPA, 1989).[1] See section A.3.3.2.

NC - Not a Chemical of Concern ; the cancer risk is less than 10^{-6} or the hazard quotient is <0.1.

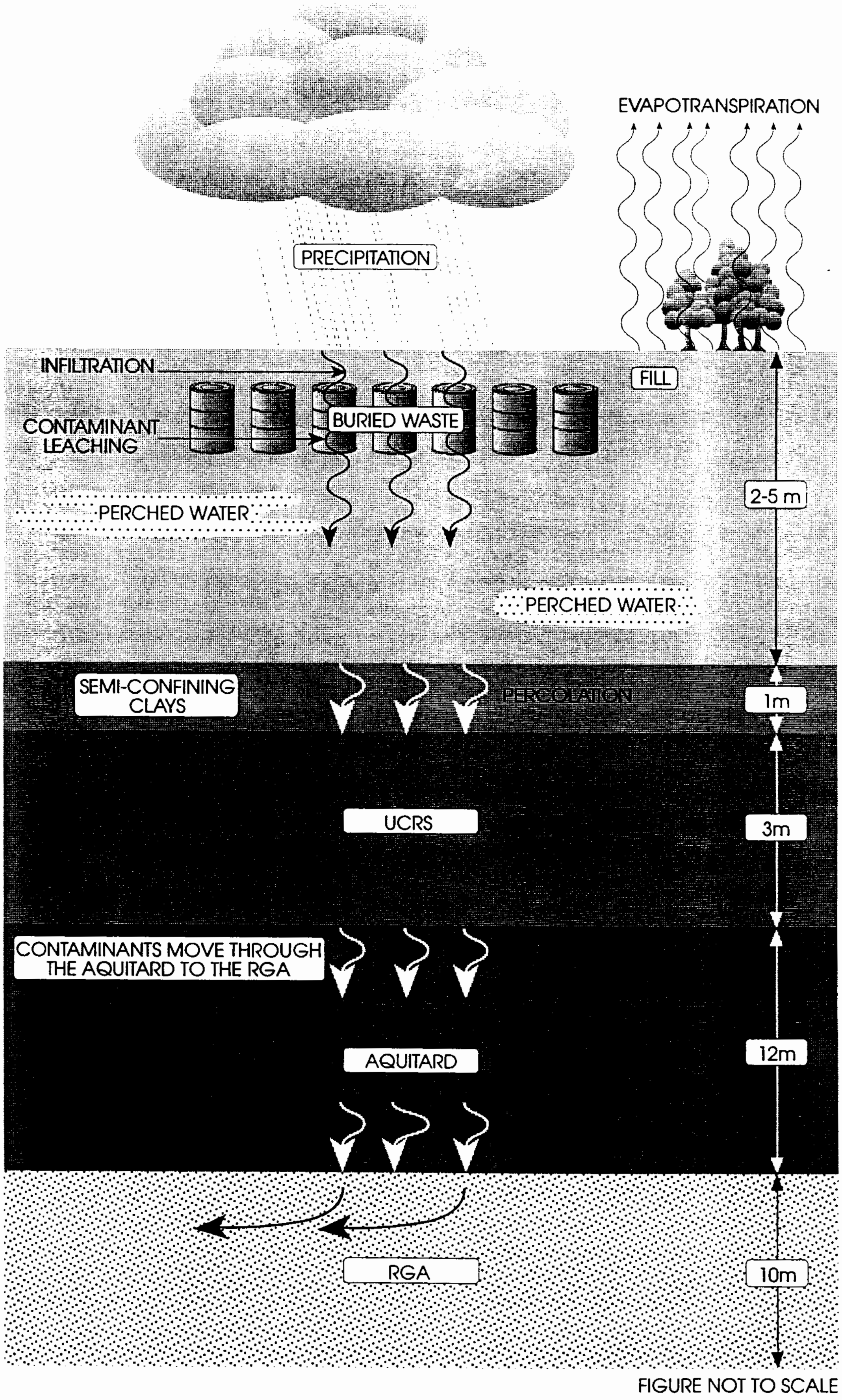

Figure A-3.1. Conceptual Model for Summers Model Runs

The governing equation for the Summers Model is:

$$C_w = \frac{(Q_p C_l)+(Q_a C_a)}{Q_p + Q_a}$$

where:

C_w = Concentration in ground water (mg/l)

Q_p = Volumetric flow rate of infiltration into the aquifer (ft^3/day), where

$Q_p = (V_{dz})\ (A_p)$, and

V_{dz} = Darcy velocity in downward direction (ft/day)
A_p = Horizontal area of spill (ft^2)

C_l = Concentrations of chemical in the infiltration at the unsaturated-saturated zone interface (mg/l), where

$C_l = C_s / K_d$, and

C_s = Concentration of chemical in the soil/source (mg/kg)
K_d = Soil/water equilibrium partitioning coefficient (ml/g)

Q_a = Volumetric flow rate of ground water (ft^3/day), where
$Q_a = (V_d)\ (h)\ (w)$, and

V_d = Darcy velocity in aquifer (ft/day)
h = Aquifer thickness (ft)
w = Width of spill perpendicular to flow direction in aquifer (ft)

C_a = Initial or background concentration of pollutant in aquifer (mg/l). It is assumed that the background concentrations of the chemicals (C_a) are equal to zero.

V_{dz} is estimated as the average annual precipitation minus surface runoff and evapotranspiration for the area, assuming that all precipitation infiltrates through the soil. The Darcy velocity in the aquifer (V_d) is estimated by:

$$V_d = (K)(I)$$

where

K = Hydraulic conductivity (ft/day)
I = Hydraulic gradient (unitless)

The revised Summers Model makes the following assumptions:

- The soil/water system is at equilibrium;
- No contaminant degradation is occurring;
- The unsaturated soil zone is homogeneous down to the aquifer; and
- Contaminants are mixed throughout the depth of the aquifer beneath the contaminant source.

It was determined that uranium is the primary COC for the future leaching pathway at SWMU 2, mainly due to the large mass of uranium estimated to be buried in the waste unit (270 tons, or 2.45 x 10^5 kg), and the longevity of uranium in the environment. Trichloroethene (TCE) was determined to be a COC for the future leaching pathway also, due to the large volume (450 gal.) estimated to have been buried at the SWMU and its toxicity to a human receptor.

Figure A.3.1. presents the conceptual setting for performing the baseline Summer's Model runs for uranium in SWMU 2. The primary assumptions used in the model development include:

- Depth of the buried waste is 7-17 feet (2 - 5 m); dimensions of the waste unit are 200 ft x 160 ft;
- The primary saturated zone of the UCRS is somewhere between 10 and 20 ft (3 and 6 m) below ground surface, more likely closer to 20 ft;
- Shallower confined layers also exist in and around the waste, as suggested by the water level in Well MW58 and MW154;
- Uranium concentrations in MW58 are representative of uranium leachate for the SWMU 2 waste, since it is assumed that uranium in the shallow zone is the result of the saturated waste reaching equilibrium conditions with the water; and
- Low uranium concentration in wells screened in the lower saturated portion of the UCRS suggest the following:

  —Clays in the UCRS between the perched zones and the completely saturated zone are semiconfining;

  —There has been little vertical uranium migration from the perched water zones to the saturated portion of the UCRS since waste disposal ended in 1977; and

  —Once uranium interacts with the clays in the UCRS, it is transformed into a relatively immobile form.

Using these assumptions, two model runs were made for estimating baseline concentrations in ground water for both uranium and TCE. The first estimates the potential uranium concentration in the UCRS that results from leaching from the waste source. The second estimates the future potential uranium concentration in the RGA that results from vertical migration of uranium from the UCRS to the RGA. This second run assumes that C_1, the initial concentration in the UCRS leachate, is equal to the concentration of uranium in the UCRS estimated by the first model run. The parameters used for the "leachate" modeling are listed in Table A.3.5 along with the reference or justification for their use. Many of the hydrologic parameters have been obtained from a 1992 effort to model flow in the C-404 Landfill Area (McConnell, 1992).[6] Some of the hydrologic parameters vary from the information presented in the WAG 22 RI Addendum. The major differences are the values used for hydraulic conductivity in both the UCRS and the RGA (as shown in Table A.3.6).

Table A.3.5 Parameters in Summer's Model (EPA, 1989)[1]

Parameter	Symbol	Selected Value		Units	Reference/Justification
		Run 1- Waste to UCRS	Run 2 - UCRS to RGA		
Volumetric flow rate of infiltration	Q_p	249.6	395.4	m^3/yr	Calculated by $Q_p = V_{dz} \times A_p$ (EPA, 1989)[1]
Darcy velocity in downward direction	V_{dz}	0.084	0.133	m/yr	Run 1 - annual rainwater percolating into UCRS = 3.3 in/yr (McConnell, 1992) ; Run 2 - $V_{dz} = (K_u)(I_u)$, where $K_u = 0.133$ m/yr, the assumed hydraulic conductivity in the confining clays between the UCRS and the RGA (Geotrans, 1993); and $I_u = 1$, representing a complete vertical migration pattern in the confining zone.
Horizontal area of contamination	A_p	2973	2973	m^2	Areal extent of contaminant - 160 ft x 200 ft
Volumetric flow rate of ground water	Q_a	14.6	31053.2	m^3/yr	Calculated by $Q_a = V_d \times h \times w$ (EPA, 1989)
Hydraulic conductivity	K	5.12	47267	m/yr	Run 1- (McConnell, 1992)[6] Run 2 - (Geotrans, 1993)[8]
Hydraulic gradient	I	0.017	0.0007	unit-less	Run 1- (McConnell, 1992)[6] Run 2 - (Geotrans, 1993)[8]
Darcy velocity in aquifer	V_d	0.087	56.5	m/yr	Calculate by $V_d = K \times I$
Aquifer thickness	h	3.05	10	m	Run 1- (McConnell, 1992)[6] Run 2 - (Geotrans, 1993)[8]

Table A.3.5 Parameters in Summer's Model (EPA, 1989)[1] (continued)

Parameter	Symbol	Selected Value		Units	Reference/Justification
		Run 1- Waste to UCRS	Run 2 - UCRS to RGA		
Perpendicular spill width	w	78	78	m	Assumes that water at the site flows approximately perpedicular to the diagonal length of the unit: sqr(160^2 ft + 200^2)ft
Soil-water distribution coefficient	K_d	1600	1600	l/kg	Sheppard and Thibault 1990[7], value representing mean of data for clayey soils. A distribution of values was used for the Monte Carlo run

Table A.3.6 Comparison of Hydraulic Conductivity Values (K) and Distribution Coefficients (K_d) in RI Addendum to FS/EA

Parameter	Units	Values in RI	Values used for this assessment	Justification for values used in this assessment
Hydraulic Conductivity: UCRS	m/year	11.35	5.12	McConnell, 1992[6]
Hydraulic Conductivity: RGA	m/year	3784.3	47267	Geotrans, 1993[8]
Uranium Soil-Water Distribution Coefficient	l/kg	45	1600	Sheppard and Thibault, 1990[7] for clayey soils; partially validated by measured soil and ground water uranium concentrations
TCE Soil Water Distribution Coefficient	l/kg	NA	2.14	K_{oc} = 214 f_{oc} =0.1 $K_d = K_{oc} \times f_{oc}$

Experience with the Summers Model has shown that the K_d is the parameter that contributes the most to the potential variability in the output. The K_d is the simple parameter that lumps all operating geochemical retention mechanisms into one value. The K_d for inorganic substances is dependent on the metal species, which is strongly correlated with soil type.

For the SWMU 2 leaching assessment, several methods were used to attempt to understand the best K_d value to use for uranium. These included a review of the literature and some rough calculations using site soil and ground water data, assuming that this data could represent partitioning between the waste soils and water to date. Given that:

$$K_d = C_{soil}\,[\text{mg/kg}]/C_{water}\,[\text{mg/l}]$$

It was assumed that available ground water and soil data could give some indication of partitioning that has occurred. Estimates of uranium concentration in the waste source were made using inventory data, soil density, and the dimensions of SWMU 2. This calculation estimates that the concentration is approximately 10,600 mg/kg, or approximately 3,545 pCi/g ^{238}U. This concentration can be used in conjunction with data from MW58 to estimate the K_d. This well is used since it is assumed that the uranium water concentrations in this well represent uranium partitioning under saturated and equilibrium conditions. The ^{238}U value in this well is 3333 pCi/l. A rough K_d estimated using these soil and water values is:

$$K_d = 1060 \ \text{l/kg}$$

A second rough estimate was made using uranium soil data from H221 and ground water data from well MW58. While worthwhile, this analysis may not be as valid since the soils concentrations at H221 represent uranium in soils outside of the waste source. The results of this analysis suggest the uranium K_d could be an order of magnitude higher than the results of the first analysis.

The third attempt to understand the best K_d to use for the leaching analysis of uranium involved a search of available literature on K_ds for different soil type. The best compendium of information on K_ds was found in Sheppard and Thibault (1990).[7] The review compiles K_ds from the literature by element and soil type and estimates the mean and standard deviation of the distribution of values. The values listed for uranium in clay soils are:

7.3	-	natural log of observed values
2.9	-	standard deviation of the natural log of observed values
1600	-	geometric mean of the observed values
46	-	minimum value (µg/g)
395,100	-	maximum value (µg/g)

The geometric mean value estimated by Sheppard and Thibault, while not necessarily conservative, matched well with the estimated values performed using soil and ground water data from the site. The use of the relatively high K_d is also partially validated by the fact that the concentrations currently seen in UCRS ground water wells other than MW58 are extremely low, suggesting that the uranium is actually not migrating from the source. Thus, the 1600 l/kg value is assumed to represent the central tendency of K_ds for clay soils; however, it was also determined that since the range of potential K_ds is so large, a Monte Carlo run would be performed as part of the leaching modeling in order to identify a range of potential future uranium ground water concentrations.

In addition, model runs had to be made to determine the effectiveness of the proposed Alternative 4 RCRA Cap at decreasing the uranium and TCE migration to the ground water over time. The Hydrologic Evaluation Landfill Performance (HELP) model (EPA, 1984)[9] was used to determine the effectiveness of a RCRA cap at decreasing rainwater infiltration into the wastes. Major assumptions used in developing the model are provided in Table A.3.7. Using these parameter values, the HELP model estimates that the RCRA cap will decrease vertical infiltration (Qp) through the waste from 395.4 m^3/yr (no cap) to a range of 7.1×10^{-5} m^3/yr [assuming the flexible membrane liner (FML) disintegrates] to 7.0×10^{-9} m^3/yr (assuming the FML remains intact).

Table A.3.7. HELP Model Parameters

Parameter	Value	Units
Cap layers		
Vegetative soil layer	24	inches
Drainage layer	12	inches
Clay liner with Flexible Membrane Liner (FML)	24	inches
Vertical leakage fraction allowed from the membrane	0.0001 to 0.001	percent
Drainage length	50-200	ft
Cap slope	5 to 10	percent

Results of the uranium leaching model runs are presented in Table A.3.8. The results represent predicted uranium concentrations in the ground water under equilibrium, steady-state conditions. As a point of reference, the proposed risk-based maximum contaminant level (MCL) for natural uranium in potable water is 0.02 mg/l (Proposed Rule, 56 Fed. Reg. 33050, July 18,1991). The concentrations calculated for the UCRS for Alternatives 1 and 2 are the only ones to exceed this value. The concentrations are the uranium ground water exposure point concentrations for evaluating future potential exposure to SWMU 2 waste via ground water migration.

Table A.3.8. Predicted Future Ground Water Exposure Point Concentrations from Leaching Model Results

	Total Uranium Concentration in Water (mg/l)			
Water zone	Alternative 1	Alternative 2	Alternative 3	Alternative 4
UCRS	6.12	6.12	0	6.7×10^{-2} to 6.7×10^{-6}
RGA	0.010	0.010	0	not estimated

Trichloroethene was considered a contaminant of concern for future residential exposure via ground water ingestion based on review of process knowledge and waste inventory data. A soil concentration of 0.315 mg/kg was calculated for TCE from the waste inventory data of 450 gal and density and area data. A K_d of 2.14 was calculated from a TCE K_{oc} of 214 and a soil f_{oc} of 0.01 using the equation: $K_d = K_{oc}\ f_{oc}$. All other conditions and values used in the Summers model for uranium listed in Table A.3.5 were assumed the same in the TCE leachate model. The exposure point concentrations for evaluating future potential exposure to TCE from SWMU 2 waste via ground water migration and ingestion are summarized in Table A.3.9.

Table A.3.9 Predicted Future Ground Water Exposure Point Concentrations from Leaching Model Results

	Total TCE Concentration in Water (mg/l)			
Water zone	Alternative 1	Alternative 2	Alternative 3	Alternative 4
UCRS	1.4×10^{-1}	1.4×10^{-1}	0	1.5×10^{-3} to 1.5×10^{-7}
RGA	2.2×10^{-3}	2.2×10^{-3}	0	not estimated

The equations used to quantify soil intake for both long-term and short-term exposures are (EPA, 1989)[2]:

Radionuclides: $I_s = (C_s)(ED)\ ([(IR_s)(EF)(10^3 g/mg)]+[(1/PEF)(IR_a)(10^3)(EF)]+[(1-S_e)(T_e)])$

Chemicals: $I_s = (EF)(ED)\ ([(C_s)(IR_s)(10^{-6}\ kg/mg)]+[(C_s)(1/PEF)(IR_a)])/(BW)(AT)$

where

I_s = intake from soil (pCi) (mg/kg-day)
C_s = concentration in soil (pCi/g) (mg/kg)
ED = exposure duration (yr)
IR_s = soil ingestion rate (g/day) (mg/day)
EF = exposure frequency (days/yr)

PEF = particulate emission factor (m^3/kg)
IR_a = inhalation rate (m^3/day)
S_e = gamma shielding factor (unitless)
T_e = gamma exposure factor (unitless)
BW = body weight (kg)
AT = Averaging time (days); for noncarcinogens, AT_{nc} equals (ED)(350 days/yr [EPA, 1991]^4); for carcinogens, AT_c equals (70-year lifetime)(365 days/yr)

The equations used to quantify potential future intakes of uranium and TCE in ground water are:

(radionuclide) $I_w = (C_w)(IR)(ED)(EF)$
(chemical form) $I_w = (C_w)(IR)(ED)(EF)/(BW)(AT)$

where

I_w = intake from drinking water (pCi) (mg/kg-day)
C_w = concentration in water (pCi/l) (mg/l)
IR = ingestion rate (l/day)
EF = exposure frequency (day/yr)
ED = exposure duration (yr)
BW = body weight (kg)
AT = averaging time (days); for noncarcinogens, AT_{nc} equals (ED)(350 days/yr [EPA ,1991]^4)

A.3.3.3 Exposure Parameters

Table A.3.10 presents the exposure parameters used to quantify long-term and short-term intakes and exposures. Most of the parameter values were those used to quantify risks in the baseline risk assessment (DOE, 1993)^5 and thus are used for the "No Action" alternative. Some exposure values are different for the other alternative, mainly the assumed exposure time and exposure duration. Values for these parameters for Alternatives 2, 3 and 4 were taken from man-hour estimates used for alternative cost estimates and from some assumptions about work crew sizes.

A.3.3.4 Rate of uranium migration to RGA

In addition to predicting the potential future uranium concentrations in ground water, rough calculations were performed to understand when the uranium would likely reach the RGA at the predicted levels. This is important since the RGA is the primary aquifer of concern at the PGDP. Ground water modeling results (Geotrans, 1993;^{8} McConnell 1992)^6 in the area have found that of the water coming into the UCRS, 7.1% discharges to creeks, 1.2% discharges to the Ohio River, and approximately 91.7% moves vertically through the aquitard between the UCRS and the RGA. A simple calculation can be performed to show the rate of vertical migration from the UCRS to the RGA.

Based on the calculations, it can be concluded that although more than 90% of the water that leaves the UCRS recharges the RGA, contaminant migration to the RGA from the UCRS will be minimal because of the clays ability to retard contaminant movement. Most of the organics assumed to have been buried in SWMU 2 will likely biodegrade before they reach the RGA, and metals, including uranium, will likely take thousands of years to reach the RGA.

Table A.3.10 Exposure parameters used for quantitative risk evaluation

Alternative	Long-Term Risk		Short-Term Risk
	Resident	Worker	Remediation Worker
1 - No Action	Soil exposures Ground water exposures (from baseline): IRw = 2 l/d EF = 350 d/yr ED = 30 yr BW = 70 kg ATc = 70 yr x 365 d ATnc = ED x 365 d IRa = 15 m^3/d VF = 0.5 See Section A.3.3 for leaching parameters	Soil exposures (from baseline): IRs = 0.05 g/d IRa = 20 m^3/d ET = 8 hr/d EF = 250 d/yr ED = 25 yr BW = 70 kg ATc = 70 yr x 365 d ATnc = ED x 365 d PEF = 4.63E+09 m^3/kg Se = 0.2 Te = 0.24	No Exposures
2 - Limited Action - installation of fence around waste unit	Same as above	Same as above, except: EFsoil = 5 d/yr	Soil Exposures IRa = 20 m^3/d ET = 8 hr/d EF = 14 d/yr ED = 1 yr BW = 70 kg ATc = 70 yr x 365 d ATnc = ED x 365 d PEF = 4.63E+09 m^3/kg Se = 0.2 Te = 0.24
3 - Excavation, treatment, and disposal	Qualitative - assume excavation to acceptable risk level for public exposures	Qualitative - assume excavation to acceptable risk level for worker exposures	Same as Alt 2 except IRs = 0.05 g/d EF = 250 d/yr ED = 2 yr See Section A.5.2 for construction and transportation risk parameters
4 - RCRA-type cap with dewatering options: pumping wells or french drain	Soil pathways: no exposures	No exposures	Same as Alt 2 except IRs = 0.05 g/d EF = 74 d/yr See Sect. A.5.2 for construction risk parameters

A.6 APPENDIX A REFERENCES

1. Summers et al., *Determining Soil Response Action Levels Based on Potential Migration to Ground Water: A Compendium of Examples* U.S. EPA, 1989.

2. *Risk Assessment Guidance for U.S. Superfund: Human Health Evaluation Manual, Part A, Interim Final,* EPA/540/1-89/002, U.S. EPA, Office of Emergency and Remedial Response, (OSWER) Washington, DC., 1989.

3. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA.* EPA/540 G-89/004, U.S. EPA, Office of Emergency and Remedial Response, (OSWER) Washington, DC., 1988.

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