RSALOP

Radionuclide Soil Action Levels Oversight Panel

Panel Work Session Records

1999

January - May

Compiled by:

AIMSI

Advanced Integrated Management Services, Inc
5460 Ward Road, Suite 370
Arvada, CO 80002
(303) 456-0884 fax. (303) 456-0858

DOCUMENT CLASSIFICATION REVIEW WAIVER PER CLASSIFICATION OFFICE

1998/1999

1/553

SW-A-004869

City of Broomfield
~~KATHRYN K. SCHNOOR~~
Environmental Services Administrator

ROOM RESERVATION

FYI - Diane 438 6360

Phone: 303-438-6363
E-mail: kschnoor@compuserve.com Fax: 303-438-6234
One DesCombes Drive • Broomfield, CO 80020

Meeting Dates: See below **Meeting Time:** 2:30 pm to 7:00 pm
Thursdays - Jan 14, Mar 11, Apr 8, May 13, June 10, July 8, Aug 12, Sep 9, Oct 14, Nov 11

Room Requested: Bal Swan (2:30-7:00) and Zang Spur (3:30-7:00)

Meeting Purpose: RF - Soil Action Level Panel Meetings

Number Attending: 35+ **Staff Person Responsible:** Kathy Schnoor/Hank Stovall

Special Instructions/Requests:

Will need partition pushed back to open areas into one room at about 3:30 pm

Requested By: Diane Eismann **Date:** 1/6/99

* Please remember to return the chairs and tables to their original set-up.
If you need assistance with any room please contact Jim Turner at x6361.

ROOM RESERVATION FORM

Meeting Date: Thurs, Feb 11, 1999 Meeting Time: 11:30 am to 7:00 pm

Room Requested: Bal Swan and Zang Spur

Meeting Purpose: RF - Soil Action Level Workshop

Number Attending: 35+ Staff Person Responsible: Kathy Schnoor/Hank Stovall

Special Instructions/Requests:

Will need partition pushed back to open areas into one room

Requested By: Diane Eismann Date: 1/6/99

* Please remember to return the chairs and tables to their original set-up.
If you need assistance with any room please contact Jim Turner at x6361.

1/14/99
Session

4

5

P. 1 of 3

RADIONUCLIDE SOIL ACTION LEVEL OVERSIGHT PANEL
MEETING ATTENDEES
January 14, 1999

NAME	ORGANIZATION	
CARLA SANDA	AIMSI	[redacted]
KATHY SCHNOOR	CITY OF BROOMFIELD	
Will Neff	RFLII	
Carl Spreng	CDPHE	
Russell McCallister	DOE/RFFO	
Ken Korkia	RFCAB	
Brady Wilson	CAB staff	
Kathleen Meyer	RAC	
Jill Weber	RAC	
Tim Rehder	U.S. EPA	
Joe Goldfield	CCANW	
Mary Harlow	City of ~~Broom~~ Westy	
Hank Stovall	City of Broomfie[redacted]	

6

RADIONUCLIDE SOIL ACTION LEVEL OVERSIGHT PANEL
MEETING ATTENDEES
January 14, 1999

NAME	ORGANIZATION
Diane Niedzwiecki	CDPHE
Laura Till	Facilitator
VICTOR Holm	RFCAB
Ken Starr	JEFFCO DEPT HEALTH + ENVIRONMENT
TODD MARGULIES	TM CONSULTING
NIELS SCHONBECK	Metro State College
JOEL SELBIN	UC Boulder Chem. Dept
LeRoy Moore	RMPJC
Dean Hal	CSU
HEATHER BALSER	CITY OF LOUISVILLE
Steve Gunderson	CDPHE
Erin Rogers	RFCAB staff
Shawn Burke	RFCAB member

[redacted]

RADIONUCLIDE SOIL ACTI[illegible] LEVEL OVERSIGHT PANEL
MEETING ATTENDEES
January 14, 1999

NAME	ORGANIZATION	[redacted]		
John Corsi	Kaiser- Hill	[redacted]		
Dave Shelton	Kaiser- Hill	[redacted]		
(for Benita Duran) KARA DINHOFFER	CITY OF BOULDER	[redacted]		
Carol Lyons	Arvada	[redacted]		
Laura Brooks	Kaiser - Hill	[redacted]		
Rick Roberts	Rocky Mountain Remediation Serv.	[redacted]		

AGENDA

RFSALOP Meeting – January 14, 1999
Broomfield City Building - Zang's Spur Conference Room
4:00 - 7:00 P.M.

4:00 - 4:10	OPENING	Mary Harlow
	• Introductions	
	• Minutes corrections/approval	
	• Sign-In	
	• Agenda Review	Facilitator
	• Group Agreements	Facilitator
4:10 - 4:30	CO-CHAIRS UPDATES	
	• Reply to Karpatkin letter	Mary Harlow
	• Assistance to RAC for computer codes	Hank Stovall
	• RSAL Working Group Meeting	Hank Stovall
	• Risk Workshop	Mary/Hank
	• Public Meeting	Mary/Hank
4:30 - 4:45	PEER REVIEW SUBCOMMITTEE REPORT	Dr. LeRoy Moore, RFSALOP
4:45 - 5:00	PROJECT UPDATE	Dr. Kathleen Meyer, *RAC*
5:00 - 5:05	PUBLIC COMMENT	
5:05 - 5:50	SENSITIVITY ANALYSIS	Jill Weber, RAC
5:50 – 6:00	BREAK	
6:00 - 6:50	PROJECT SCENARIOS	Dr. Kathleen Meyer, *RAC*
6:50 - 6:55	ANNOUNCEMENTS	
6:55 – 7:00	PUBLIC COMMENT OTHER TOPICS/FUTURE AGENDA ITEMS/ ACTION ITEMS	

UPCOMING MEETINGS/ACTIVITIES

February 11	RFSALOP Meeting	4-7 P.M. Broomfield City Bldg.*
March 11	RFSALOP Meeting	4-7 P.M. Broomfield City Bldg.*
April 8	RFSALOP Meeting	4-7 P.M. Broomfield City Bldg.*
May 13	RFSALOP Meeting	4-7 P.M. Broomfield City Bldg.*
June 10	RFSALOP Meeting	4-7 P.M. Broomfield City Bldg.*
July 8	RFSALOP Meeting	4-7 P.M. Broomfield City Bldg.*

IMPORTANT NOTE: TECHNICAL DISCUSSIONS ARE SCHEDULED FROM 2:30 – 3:30 IN THE BAL SWAN CONFERENCE ROOM – ADJACENT TO ZANG'S SPUR – PRIOR TO ALL MEETINGS

*Broomfield City Building, One Descombes Dr. - Zang's Spur/Bal Swan Conference Rooms (lower level)

INTERNAL MEMORANDUM

AIMSI

TO: RFSALOP General Distribution

FROM: Anna Corbett & Carla Sanda

DATE: January 11, 1999

SUBJECT: RFSALOP INFORMATION

Attached are the Agenda for the 1/14/99 RFSALOP meeting, list of meeting topics, and Peer Review Recommendations memo.

Please read & review the memo prior to Thursday's meeting. It will be discussed and acted upon by the Panel at the meeting.

Anna

5460 Ward Road, Suite 370 ∃ Arvada, CO 37830 ∃ Phone: 303-456-0884 ∃ FAX: 303-456-0858

RFSALOP

Rocky Flats Soil Action Levels Oversight Panel

RFSALOP TECHNICAL DISCUSSION

January 14, 1999 - 2:30 - 3:30 P.M.
Broomfield City Building - Bal Swan Meeting Room
(Adjacent to Zang's Spur)

In response to requests from Panel members, representatives from Risk Assessment Corporation will be available from 2:30 - 3:30 to provide time for in-depth technical discussions prior to the regularly scheduled meeting, which will be held in the Zang's Spur Conference Room from 4 - 7 p.m.

Members are not required to attend the technical discussion -- this is simply a time set aside for those members who would like to spend additional time on particular aspects of the project.

RISK WORKSHOP

In response to a request from the RFSALOP, Dr. John Till has arranged for Dr. Charlie Meinhold to present a Risk Workshop immediately prior to the regularly scheduled February RFSALOP meeting, as follows:

WHEN: Thursday, February 11, 1999
12:00 - 3:30 p.m.

WHERE: Broomfield City Building, One Descombes Dr. - Bal Swan Conference Room
(lower level)

Attendees may bring a brown-bag lunch if desired. Beverages will be provided. Further details will be provided at January 14 meeting.

UPCOMING RFSALOP MEETINGS

All future meetings will be held from 4 - 7 p.m. at the Broomfield City Building, One Descombes Dr., Broomfield, CO - Zang's Spur/Bal Swan Conference Rooms, on the following dates:

February 11, 1999	March 11	April 8
May 13	June 10	July 8
August 12	September 9	October 14
November 11		

PUBLIC MEETING

The first public meeting will be held from 6:30 - 9:00 p.m. on Wednesday, March 10, 1999.

To: Rocky Flats Soil Action Levels Oversight Panel 14 January 1999
From: Peer Review Subcommittee
Re: Recommendations

RECOMMENDATION OF PROPOSED REVIEWERS

The Peer Review Subcommittee was charged with the task of proposing names of five persons to conduct peer review of the following five tasks of RAC's work on the RSALs:

1. Setting radionuclide soil action levels.
2. Analyzing RESRAD and other potentially relevant computer programs.
3. Analyzing inputs and assumptions for the RSALs.
4. Assessing independent calculations for the RSALs.
5. Analyzing soil-sampling protocols.

To do its job the subcommittee gathered names from numerous sources (including from those who initially bid on the project, from DOE and the regulators, from members of the Oversight Panel, etc.). After compiling a list of the strongest candidates (based on how well they matched the tasks to be reviewed plus absence of obvious conflict of interest), telephone contact was made to determine each potential candidate's interest in performing the peer review activity for the proposed honorarium of $2000 plus expenses. This process resulted in a shortened list of seventeen finalists. The subcommittee then examined the qualifications of this group to come up with a list of persons who together can provide competent, convincing, and credible peer review of the five tasks.

Accordingly, the subcommittee recommends the following list of names. The top five names on this list are the subcommittee's first choice as peer reviewers; the other names are alternates listed in order of preference, to be contacted only if any of the first five decline the invitation to fill this role (note that the final alternate is intended to replace only a specific person from the first five, should that person decline):

1) Lynn R. Anspaugh, Ph.D., Research Prof, U. of Utah Radiology Division (much work on radionuclides in soil, health and risk assessment, RESRAD)

2) Steven L. Simon, Ph.D., Senior staff officer with Board of Radiation Effects Research of National Academy of Sciences (specializes in measurement of ionizing radiation, environmental transport processes, computer modeling, uncertainty and statistical analyses)

3) F. Ward Whicker, Ph.D., Prof. in Dept. of Radiological Health Sciences, Colorado State U. (experienced in studying radionuclide transport in aquatic and terrestrial ecosystems, foodchain transport, soil sampling, computer modeling)

4) Paula A. Labieniec, Ph.D., consultant in hazardous waste and contaminated soil risk assessment, Chesterfield, VA (knowledgeable in software development, contaminant fate and transport, setting remediation goals for contaminated soil, risk assessment)

5) William J. Bair, Ph.D., retired from Life Sciences Center, Battelle Pacific Northwest National Laboratory, Richland, WA (involved in setting Enewetak RSALs, internationally recognized specialist on inhalation of radionuclides)

ALTERNATES

6) Allan C. B. Richardson, M.S., private consultant on radiation protection matters, Washington, DC (played a key role in developing EPA standards for radiation, a specialist on tabulating doses for internal and external exposure to radiation, helped develop evolving regulatory framework for DOE)

7) Glenn Paulson, Ph.D, President, Paulson and Cooper, Jackson Hole and Chicago (a specialist on radiation safety and on environmental science and policy, former Chief Radiation Officer for NJ, helped developed NJ Superfund Law [which antedated US law])

8) Bernd Franke, Director of Environmental Programs, Institute for Energy and Environmental Research, Takoma Park, MD (involved in setting and reviewing RSALs for Marshall Islands, on Scientific Management Team of Rongelap Resettlement Project)

ALTERNATE ONLY TO LABIENIEC IN THE EVENT SHE DECLINES

9) Mitchell J. Small, Ph.D., Prof of Civil and Environmental Engineering and Engineering and Public Policy, Caregie Mellon U. (knows computer modeling, statistical analysis and uncertainty, risk assessment)

RECOMMENDATION REGARDING FOLLOWUP

The subcommittee recognizes that the RFSALOP needs to establish some means for coordination and ongoing oversight of the peer review process. Initially there is the need to deal with things like providing the reviewers with guidelines, a background packet, a work schedule, a list of expectations, a contract or letter of agreement. Later there will be the need to handle questions or issues that may emerge in the course of the work, including serving as a conduit to get RFSALOP concerns to peer reviewers. The RFSALOP can deal with this by creating a new subcommittee or by asking the present subcommittee to continue with this new charge (opening it to new members who may wish to be involved in this task). Or there may be some other alternative.

The subcommittee recommends that the RFSALOP take appropriate action to deal with this need.

ALTERNATES

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ADVANCED INTEGRATED MANAGEMENT SERVICES, INC.

AIMSI

FACSIMILE TRANSMITTAL SHEET

TO: DISTRIBUTION	FROM: Carla Sanda & Anna Corbett
COMPANY: RFSALOP	DATE: 1/11/99
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SENDER'S PHONE NUMBER: (303) 456-0884	SENDER'S FAX NUMBER: (303) 456-0858

RE: RFSALOP MEETING AGENDA FOR 1/14/99

☐ URGENT ☑ FOR REVIEW ☐ PLEASE COMMENT ☐ PLEASE REPLY ☐ PLEASE SIGN

DISTRIBUTION

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	David Abelson	Cong. Skaggs' Ofc	[redacted]		
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P	Carol Lyons	City of Arvada			
A	Lydia Stinemeyer	City of Arvada			
SP	Lisa Morzel	City of Boulder			
A	John Tayer	City of Boulder			
A	Benita Duran	City of Bouler			
A	Kathy Schnoor	City of Broomfield			
SP	Hank Stovall	City of Broomfield			
P	Tom Davidson	City of Louisville			
A	Heather Balser	City of Louisville			
A	Sam Dixion	City of Westminster			
SP	Mary Harlow	City of Westminster			
	Dr. Norma Morin	CDPHE			
E	Steve Gunderson	CDPHE			
	Carl Spreng	CDPHE			
P	Dean Heil	CSU			
C	John Till	RAC			
C	Kathleen Meyer	RAC			
	Autar Rampertaap	DOE HQ			
E	Jeremy Karpatkin	DOE			
	Jessie Roberson	DOE/RFFO			
	Russell McCallister	DOE			
E	Tim Rehder	EPA			
P	Ken Starr	Jefferson County			
	John Corsi	Kaiser Hill			
	Dave Shelton	Kaiser Hill			
P	Niels Schonbeck	Metro State			
A	John Shepherd	Physician/Soc Resp			lease call when faxing
A	Victor Holm	RFCAB			
SP	Bob Kanick	RFCAB			
	Ken Korkia	RFCAB			
A	Tom Marshall	RFCAB			
SP	LeRoy Moore	RMPJC			
	Deanne Butterfield	RFLII			
	Will Neff	RFLII			
P	Joel Selbin	UCD Chem Dept			
P	Todd Margulies	TM Consulting			
P	Joe Goldfield	CCANW			
C	Laura Till	Facilitator			

(**SP**=Steering Committee Panel Member, **P**=Panel Member, **A**=Alternate, **E**=Ex-Officio, **C**=Contractor),

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P	Carol Lyons	City of Arvada		
A	Lydia Stinemeyer	City of Arvada		
SP	Lisa Morzel	City of Boulder		
A	John Tayer	City of Boulder		
A	Benita Duran	City of Boulder		
A	Kathy Schnoor	City of Broomfield		
SP	Hank Stovall	City of Broomfield		
P	Tom Davidson	City of Louisville		
A	Heather Balser	City of Louisville		
A	Sam Dixion	City of Westminster		
SP	Mary Harlow	City of Westminster		
	Dr. Norma Morin	CDPHE		
E	Steve Gunderson	CDPHE		
	Carl Spreng	CDPHE		
P	Dean Heil	CSU		
C	John Till	RAC		
C	Kathleen Meyer	RAC		
	Autar Rampertaap	DOE HQ		
E	Jeremy Karpatkin	DOE		
	Jessie Roberson	DOE/RFFO		
	Russell McCallister	DOE		
E	Tim Rehder	EPA		
P	Ken Starr	Jefferson County		
	John Corsi	Kaiser Hill		
	Dave Shelton	Kaiser Hill		
P	Niels Schonbeck	Metro State		
A	John Shepherd	Physician/Soc Resp		e call when faxing
A	Victor Holm	RFCAB		
SP	Bob Kanick	RFCAB		
	Ken Korkia	RFCAB		
A	Tom Marshall	RFCAB		
SP	LeRoy Moore	RMPJC		
	Deanne Butterfield	RFLII		
	Will Neff	RFLII		
P	Joel Selbin	UCD Chem Dept		
P	Todd Margulies	TM Consulting		
P	Joe Goldfield	CCANW		
C	Laura Till	Facilitator		

(SP=Steering Committee Panel Member, P=Panel Member, A[redacted]),

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15

LAST TRANSACTION REPORT FOR HP FAX-700 SERIES VERSION: 01.03

FAX NAME:
FAX NUMBER: 3034560858

DATE: 11-JAN-99
TIME: 19:17

DATE	TIME		REMOTE FAX NAME AND NUMBER	DURATION	PG	RESULT	DIAGNOSTIC
11-JAN	19:17	S	JOHN TILL 19035341995	0:00:00	0	NO ANS	423563140000000

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LAST TRANSACTION REPORT FOR HP FAX-700 SERIES VERSION: 01.03

FAX NAME:
FAX NUMBER: 3034560858

DATE: 11-JAN-99
TIME: 18:40

DATE	TIME		REMOTE FAX NAME AND NUMBER	DURATION	PG	RESULT	DIAGNOSTIC
11-JAN	18:40	S	B.KANICK 3034440072	0:00:00	0	NO ANS	423663840000000

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LAST TRANSACTION REPORT FOR HP FAX-700 SERIES VERSION: 01.03

FAX NAME:
FAX NUMBER: 3034560858

DATE: 11-JAN-99
TIME: 17:01

DATE	TIME		REMOTE FAX NAME AND NUMBER	DURATION	PG	RESULT	DIAGNOSTIC
11-JAN	17:01	S	D. ABELSON 3036507893	0:00:00	0	NO ANS	423663840000000

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32 TRANSACTION REPORT FOR HP FAX-700 SERIES VERSION: 01.03

FAX NAME:
FAX NUMBER: 3034560858

DATE: 12-JAN-99
TIME: 12:06

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11-JAN	17:05	S	H. STOVALL 3034386296	0:02:44	6	OK	663840300190
11-JAN	17:09	S	303 429 5113	0:03:41	6	OK	56314030018C
11-JAN	17:22	S	3036739043	0:02:42	6	OK	66384030018C
11-JAN	17:25	S	3032809113	0:02:43	6	OK	66384030018C
11-JAN	17:28	S	3037820188	0:02:50	6	OK	663840300190
11-JAN	17:31	S	3037595355	0:02:46	6	OK	66384030019E
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11-JAN	17:38	S	9704910564	0:03:48	6	OK	55314030018C
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11-JAN	17:45	S	3019033877	0:02:44	6	OK	663840300188
11-JAN	17:48	S	303 966 6633	0:02:51	6	OK	66384030018C
11-JAN	17:52	S	303 966 6054	0:02:42	6	OK	66384030018C
11-JAN	17:55	S	303 966 3710	0:02:42	6	OK	66384030018C
11-JAN	17:58	S	T. REHDER 3033126067	0:02:41	6	OK	663840300088
11-JAN	18:01	S	K. STARR 3032715702	0:03:14	6	OK	663840300098
11-JAN	18:05	S	303 966 6153	0:03:23	6	OK	66384030018C
11-JAN	18:09	S	303 966 6214	0:02:53	6	OK	66384030018C
11-JAN	18:12	S	303 556 5399	0:02:42	6	OK	66384030016C
11-JAN	18:15	S	3036504403	0:02:55	6	OK	65384030016A
11-JAN	18:19	S	8326234	0:04:28	6	OK	96414030016C
11-JAN	18:25	S	3034207579	0:02:50	6	OK	663840300190
11-JAN	18:28	S	4446523	0:02:45	6	OK	66384030019E
11-JAN	18:40	S	~~B.KANICK 3034440072~~	0:00:00	0	NO ANS	423663840000000
11-JAN	18:41	S	4446523	0:03:20	6	OK	66384030019E
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11-JAN	18:49	S	303 940 6088	0:03:42	6	OK	56314030018C
11-JAN	18:53	S	303 492 5894	0:02:43	6	OK	663840300188
11-JAN	18:59	S	3036739043	0:02:42	6	OK	66384030018C
11-JAN	19:10	S	3034470077	0:03:43	6	OK	563140300170
11-JAN	19:17	S	~~JOHN TILL 19035341995~~	0:00:00	0	NO ANS	423563140000000
12-JAN	06:17	R	303 8440530	0:01:07	1	OK	6A3813001100
12-JAN	08:27	R	303 8440530	0:01:08	1	OK	6A3813001100

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MINUTES

Radionuclide Soil Action Level Oversight Panel
January 14, 1999 - 4:00p.m. - 7:00 p.m.
Broomfield City Building - Zang's Spur/Bal Swan Conference Rooms

NOTE: Minutes are presented in draft form and should not be quoted or distributed until receiving final approval by the Rocky Flats Soil Action Level Oversight Panel at its February 11, 1999 meeting.

Mary Harlow, Co-Chair, convened the regular meeting of the Radionuclide Soil Action Level Oversight Panel (Oversight Panel or Panel) at 4:10 p.m. and opened with the introduction of the following attendees:

Hank Stovall, City of Broomfield
Niels Schonbeck, HAP & MSCD
Russell McCallister, DOE-RFFO
Dave Shelton, Kaiser-Hill
Heather Balser, City of Louisville
Laura Brooks, Kaiser-Hill
Carl Spreng, CDPHE
Steve Gunderson, CDPHE
Joe Goldfield, CCANW
Todd Margulies, TM Consulting
Jill Weber, *RAC*
Mary Harlow, City of Westminster
Dean Heil, CSU
Laura Till, Facilitator
Victor Holm, RFCAB
Carla Sanda, AIMSI
Edd Kray, CDPHE
Kathleen Meyer, *RAC*
Ken Korkia, RFCAB
Diane Niedzwiechi, CDPHE
LeRoy Moore, RMPJC
Kara Dinhoffer, City of Boulder
Carol Lyons, City of Arvada
Tim Rehder, US EPA
Brady Wilson, RFCAB Staff
John Corsi, Kaiser-Hill
Ken Starr, JEFFCO
Rick Roberts, RMRS
Joel Selbin, UCB
Will Neff, RFLII
Kathy Schnoor, City of Broomfield
Shawn Burke, RFCAB
Erin Rogers, RFCAB

MINUTES REVIEW/APPROVAL

Minutes of the November 12, 1998 meeting of the Oversight Panel were reviewed and approved with one correction: the spelling of Jill Weber's surname has been corrected from Webber to Weber.

AGENDA REVIEW

Laura Till reviewed the Agenda as well as the Group Agreements. The agenda was approved as distributed; the meeting was turned back to the Co-Chairs.

CO-CHAIRS UPDATES

The City of Arvada has transmitted a letter to the Panel advising the appointment of Lydia Stinemeyer as their new alternate to Carol Lyons.

Copies of a response from Risk Assessment Corporation responding to a December 10, 1998 letter from Jeremy Karpatkin, DOE-RFFO, were available at the meeting. The letter will be transmitted to Mr. Karpatkin with a transmittal letter from the Panel co-chairs. This correspondence will become part of the ongoing project responsiveness summary.

Mr. Stovall reported that copies of both the GENIII and MEPAS computer codes have been obtained and forwarded to *RAC* representatives. Mr. Stovall expressed his appreciation to Russell McCallister, DOE-RFFO and Tim Rehder, EPA for their assistance in obtaining these materials.

Members of the RFSALOP attended the RSAL Working Group held at the EPA offices in December. Mr. Stovall proposed that minutes of these meetings be obtained and distributed to the Panel as a whole. The Panel agreed to this approach but requested that they be notified of upcoming meetings. These meetings are publicized on the meeting schedule that is distributed to the community. The next meeting is scheduled for Tuesday, January 19, 1999

20

at 9:00 a.m. in Building 460 - Rm. 122A at the Rocky Flats site. Any members interested in attending this meeting should contact John Corsi at 303-966-6526 to arrange for a visitor's badge.

In response to a request from the RFSALOP, Dr. John Till has arranged for Dr. Charlie Meinhold to present a Risk Workshop immediately prior to the regularly scheduled February RFSALOP meeting, as follows:

WHEN: Thursday, February 11, 1999 - 12:00 - 3:30 p.m.

WHERE: Broomfield City Building, One Descombes Dr. - Bal Swan Conference Room (lower level)

Attendees may bring a brown-bag lunch if desired. Beverages will be provided by the City of Broomfield.

The project's first public meeting is scheduled from 6:30 - 9:00 p.m. on March 10, 1999 -- location TBD. The meeting will consist of a 30-minute open house to provide an opportunity for attendees to read and discuss project storyboards and interact with panel members. This will be followed by a project introduction by the Panel Co-Chairs, who will then turn the meeting over to *RAC* representatives for discussion regarding project progress.

PEER REVIEW SUBCOMMITTEE REPORT - Discussion Lead: Dr. LeRoy Moore, RFCAB

A memo from Dr. Moore was distributed to the meeting attendees to describe in detail the efforts of the Peer Review Subcommittee. In short: several months ago a Peer Review Subcommittee was formed comprised of the following RFSALOP members: LeRoy Moore (Subcommittee Chair), Joel Selbin, Carol Lyons, Niels Schonbeck and Dean Heil. Subcommittee members formulated the criteria for a peer review and compiled a list of potential candidates for the peer review effort. That list was then given to Carla Sanda, AIMSI, who compiled a Peer Review Task Plan, phoned each candidate to determine their interest in serving on the peer review team, and forwarded the Task Plan to each. She also received additional referrals/recommendations, who were also called. Seventeen individuals have expressed interest in this effort.

The Subcommittee has selected nine individuals from varying technical arenas as final candidates for the Peer Review Team. From that list, the Subcommittee has selected the top five individuals as their first choice for peer reviewers; the other individuals are recommended as alternates to be contacted only if any of the first five decline the invitation to fill the role.

As contract administrator on this project, Ken Korkia will work with the Subcommittee to issue a Letter of Agreement to the Peer Review Team that will reflect the schedule and agreed-upon remuneration. Mary Harlow asked that the Subcommittee develop an agreement that will spell out the specific schedule and our expectations for adherence to that schedule to assure that the study will not be delayed by the peer review effort. In connection with the funding for this effort, Ms. Harlow requested an update from Ken Korkia regarding receipt of the funds from RFLII. Mr. Korkia responded that he has transmitted an invoice to RFLII, but no funds have been received to date. Will Neff, RFLII, stated that he would follow up on the invoice and report back to Mr. Korkia on its payment.

The Panel approved the subcommittee's selection and also approved continuation of the subcommittee to continue with this effort by providing a letter of agreement, background packet, work schedule and list of expectations. In addition, the subcommittee will work together through the course of the study to handle questions or issues that may emerge and will serve as a conduit to resolve any potential RFSALOP concerns to peer reviewers.

PROJECT UPDATE* - Discussion Lead: Dr. Kathleen Meyer, *Risk Assessment Corporation*
*Copies of presentation materials may be requested from Anna Corbett, AIMSI, 303-456-0884

Dr. Meyer reviewed the specifics of Milestone I, which was due on January 8, 1999, and briefly discussed completion each of the requirements of Milestone I. Details on this milestone were covered in handout materials from Dr. Meyer entitled *Rocky Flats Soil Action Levels Project* and *Rocky Flats Soil Action Level Project - Milestone Report 1.*

A progress report will be presented at the next meeting on Task 1 - cleanup standards at other sites, with the written draft report due in February 1999.

As discussed earlier in the meeting, *RAC* has now received all candidate computer programs and associated codes: RESRAD, MEPAS, GENIII, MMSOILS, and DandD. These are now being run and evaluated by a *RAC* representative.

Dr. Meyer provided a list of references related to the biokinetics of plutonium after ingestion. This may provide a starting point for review of this topic. Most of the work on this topic was done in the 1980s; there doesn't seem to be much additional material being generated today. This information is being furnished in response to earlier discussions and questions from panel members. The referenced studies looked at the effects of age, chemical properties and stomach content, dietary iron intake, and nutritional factors on the absorption of plutonium from the gastrointestinal tract. However, it is important to note that most of the studies are empirical in nature and if such changes in speciation occur in the gut, they are effectively accounted for in the measurements. What the studies have looked at is the uptake or biokinetics of transport of different forms of plutonium -- some may be considered insoluble, but some may be considered soluble. Some of them then measured how much was transported into the blood, which can then be transported throughout the body. Generally, they don't see a big difference between chemical forms, so even though we may not understand the chemistry that is actually going on; or we may be concerned about insoluble plutonium being changed into a soluble form, we see the results of the experiments. Contact Dr. Meyer if you would like copies of any of the referenced reports.

Panel Discussion
Question: How will this information be used in this study? Dr. Meyer responded that this data might be useful in terms of calculation of dose or dose conversion factors, which takes into account how plutonium moves throughout the body.

PUBLIC COMMENT

None

SENSITIVITY ANALYSIS* - Discussion Lead: Jill Weber, Risk Assessment Corporation
*Copies of presentation available by calling Anna Corbett - 303-456-0884

Ms. Weber began the discussion with a very basic definition of sensitivity; i.e. "...of such a nature as to be easily affected." So when we talk about the sensitivity of our model with changes to the parameter, we are talking about how affected our model result may be with changes to the parameter. Sensitivity, it turns out is a function of two very basic things: the mathematical relationship of the parameter of interest to the other parameters; and the range of possible values for the parameter. A relatively simple equation is used to "walk through" these two basic ideas. The equation consists of: y = A multiplied by e raised to the B power, where: e = 2.718, a constant used frequently in mathematics, and A and B are variables in the equation. Ms. Weber began with two solutions for the referenced equation. For constant A, changing B strongly influences the solution to the equation. For constant B, changing A has less of an effect. This is illustrated in the handout materials.

There are two primary types of sensitivity analysis: Monte Carlo and Single factor: Monte Carlo typically consists of parameters having a distribution of possible values; uses that range of possible values to calculate a solution to the equation of a number of times (trials); displays distribution of solutions, and can compute the relative contribution (sensitivity) of each parameter. Single factor sensitivity analysis, on the other hand, can only change one factor at a time, and watches the result of the equation change to discover sensitivity of that parameter.

Ms. Weber than walked through a demonstration of the single factor sensitivity analysis by changing one factor at a time in RESRAD. The only thing focused on today was the DOE residential parameters -- the 85 mRem tier 1 action level, and Plutonium 239. She then walked the panel through a demonstration of changing only one parameter at a time within reasonable limits -- what is the impact of that change on the maximum dose which occurs at time (T=0) due to the nature of the radionuclides, and what is the impact of the change in the parameter on the soil action level for plutonium 239 for that particular scenario. In each scenario discussed, Ms. Weber's handout materials showed the solution to the RESRAD 85 mRem tier 1 action level in the first column and the effects of one change in the parameter were shown in the second column. She then went through a number of parameters including: adding milk and meat ingestion pathways; increasing by 10X and decreasing by 10X the contaminated zone erosion rate; irrigation rate; fruit/non-leafy vegetable/grain consumption from 40 to 80 kg/year; leafy vegetable consumption from 2 to 20 kg/yr; mass loading for foliar deposition increased by 10x; exposure duration; inhalation shielding factor from 1 to 0.8; thickness of contaminated zone from 0.15 m to 2 m; cover depth from 0 to 0.1 m; soil ingestion from 70 to 140 g/yr, assuming that plutonium is soluble instead of insoluble; increase soil ingestion and keep soluble form of plutonium.

It is important to understand the number of things that don't change versus the number of things that do change -- which is about three.

Ms. Weber also discussed the issue of mass loading vs. resuspension factor as applied in October 1995 at Standley Lake during construction and resuspension factors for wind resuspension over a 3-year period in a field east of the 903 Pad area.

At this point, it appears that the most sensitive parameters come down to only a few parameters: solubility of plutonium/dose conversion factor and the mass loading factor. Less sensitive parameters seem to be the cover depth, breathing rate, and soil ingestion -- but the range of possible values limits the sensitivity.

Panel Discussion
Solubility vs. insolubility of plutonium continues to remain the key issue. RAC representatives are working closely with the site and will be obtaining copies of ongoing studies on this issue.

Both solubility vs. insolubility and resuspension are critically important issues in this study. Add to this mix, the potential for colloidal transport and we are left with a challenging handful of issues. It seems important that any parameters that are developed should take into account all of these issues and not take an exclusionary approach to review and recommendation.

All of the work done so far indicates that levels drop off very rapidly over time -- this would imply that one option would be to put a fence around the site, wait 30 years, and things will be OK. Since this is not a proven fact at this time, it is important to carefully analyze this assumption to determine what time does or does not do the levels. For example, at year 800 there appears to be a spike in groundwater exposure, so the distribution coefficient should be looked at more closely.

Solubility of plutonium is evolving into an extremely important consideration that will need to be carefully evaluated, as reflected in these numbers.

In reference to the issue of groundwater: it's important to remember why the groundwater option was "turned off" in RESRAD -- there's essentially no groundwater on the site, and RESRAD does not model groundwater off the site. Therefore, turning this option on may be interesting, but it's academic -- there is some groundwater, but certainly not enough for a well to serve as a source of potable water for residents. The point here is that RESRAD is not a very good way to model groundwater contamination. Plugging the groundwater into this creates bizarre results that are not at all meaningful.

PROJECT SCENARIOS* - Discussion Lead: Dr. Kathleen Meyer, *Risk Assessment Corporation*
*Copies of presentation available by calling Anna Corbett - 303-456-0884

At the meeting in November, Dr. Meyer provided an overview of scenario development and why they are used. Her presentation began with a brief recap of that presentation:

Soil action levels are developed to protect people who may, in the future, come into contact with a site where radionuclides contaminated the soil at levels above background radiation levels. Looking into the future, we are tasked with developing plausible, credible scenarios that may exist at that time, but using the information today -- so it becomes a bit trickier. Soil action levels take into consideration three primary things: environmental transport models, annual radiation dose limits, and standards for comparison -- known as exposure scenarios. It becomes important, then, to develop "fixed" scenarios.

Exposure scenarios describe the characteristics and behaviors of hypothetical individuals who might have some contact with the radionuclides in the soil at the site. Characteristics include variables that are correlated with dose; e.g., average breathing rate or dietary habits. Behaviors include activities such as time spent indoors and outdoors or ingesting foods from contaminated sources -- which may be the family garden. Another thing to remember is that exposure scenarios provide assumptions about the nature and extent of possible contact that people might have with the site. In developing exposure scenarios, both the pathway and the exposure mode must be considered. There are a lot of pathways in the environment that could transport radioactive materials from the source out into the broader environment. Potential pathways may include things like: meat and dairy product ingestion, resuspension, inhalation, water ingestion, soil to air to garden produce and pasture grass, or soil to surface water runoff to streams, as well as numerous others.

Exposure modes refer to the manner in which the exposure to body organs and tissues occurs. Internal exposure occurs through inhalation, ingestion, or absorption through the skin. External exposure, on the other hand, occurs when a person is near a contaminated area outside the body so that gamma rays from the radionuclides deliver dose

23

to the person's organs. People can be exposed in many different ways. Exposure to airborne releases appears to be the most important pathway for persons living near the site. So if we combine both exposure and pathways, then we can discuss certain situations; e.g., inhalation of radionuclides that are resuspended from the ground's surface or perhaps discharged from a facility's stack; ingestion of contained soil, either directly or from produce; drinking contaminated surface water from a stream that has received runoff from contaminated soil; or perhaps eating produce grown on contaminated soil. Some of the scenario parameters that we have discussed include breathing rates for various activity levels and ages; soil ingestion rates; fraction of time spent both indoors and outdoors; using water from the area; and age considerations. It's important to remember that scenarios will focus on the time a person actually spent on the site versus time spent elsewhere throughout the day.

An important thing to keep in mind is that breathing rates vary with age group and activity. The scenario that Dr. Meyer focused on deals with a resident rancher. Therefore, she described in detail how breathing rates for the rancher scenario might be calculated and the things that go into that calculation.

Dr. Meyer then proposed five preliminary scenarios focused on lifestyle and age: resident rancher, infant of resident, child of resident, onsite office worker, and recreational land user. She then briefly reviewed the assumptions for lifestyle, exposure, pathways, breathing rate, and soil ingestion for each scenario.

Fixed scenarios will reflect a cooperative effort between the Panel and RAC. Once established, the scenario characteristics should be considered fixed. Scenario parameters are based on a distribution of parameters from scientific literature; behavioral characteristics must be plausible.

The last sheet in the handout is a worksheet that may be used by panel members to begin developing potential scenarios.

NOTE: The slide entitled "Breathing Rates for Scenarios Based on Daily Activities" was difficult to read. Dr. Meyer has provided a clearer copy which is attached.

Panel Discussion

Are burrowing animals being considered in the pathway analysis? Dr. Meyer responded that burrowing animals are certainly a consideration at Rocky Flats, and numerous studies have been done on this subject. Burrowing animals can affect the redistribution of plutonium in the soil, in other words it could bring it up to higher levels. We wouldn't really consider that in a scenario since we are primarily looking at scenarios directly related to human exposure.

We always speak of two distinct pathways, but it appears that think of ingestion being separate from inhalation. However, that may not always be the case. When considering people breathing through their mouth, it's likely that materials is taken in that could deposit in the gut rather than in the lungs. Even breaths going through the nostrils may result in some material being deposited in the gut. Is this ever taken into consideration in models? Dr. Meyer responded that this is included in existing models, which describe the effects of breathing through the mouth, and those studies will be used to determine internal dose conversion factor.

If we're ultimately concerned about appropriately cleaning up the site, why should we consider anybody except the one who is on site all the time. In other words, the site will likely not be cleaned up to standards that will be suitable for the runner who is only on site occasionally. We should probably assume that somebody is going to permanently settle at the site, so why should we consider scenarios for occasional visitors? Dr. Meyer responded that we want to come up with plausible scenarios for plausible future uses. Part of our job is to come up with something that we think may actually occur in the future. It's difficult to make the assumption that it will only be used by permanent residents. Discussion continued with the concern that if we look at all these potentials, we will end up with an infinite set of scenarios, and that is likely not the standard to which the site will be cleaned.

We've assumed that the resident scenario will occur after the loss of institutional controls. However, some of us still believe that the site can be cleaned up to assure that it will be safe for residents. On the other hand, some people believe that the site should never be used for residential purposes. In reality, it is likely that at some time in the future it will be, so it seems that it should be cleaned up to those standards. Scenarios must be based upon the rules and precedents of the regulatory agencies rather than being based, for example, upon a person who may have a particular health condition that renders them more susceptible to radiation. Although that may be the "right thing" to do, the scenarios must be credible and follow existing regulations.

There is also something to be said about credibility with the public for the scenario: it may be important to have several scenarios to demonstrate to the public that more than one situation was considered for the future.

seems that the key question to answer is "who is the maximally exposed individual". There may be one answer while there are institutional controls remaining at the site, but there may be a very different answer when those institutional controls no longer exist.

Another panel member reflected that from his experience on the Health Advisory Panel, it might be important to consider a number of scenarios due to the fact that when speaking with the public, there are all kinds of questions regarding various exposures. Although this study relates only to on-site situations, later there may be concerns to off-site situations as well. Therefore, we will should probably have a range of scenarios for both public and regulator credibility.

PUBLIC COMMENT

None

ANNOUNCEMENTS

The Technical Review Group will meet immediately following this meeting in the Zang's Spur Conference Room.

FUTURE AGENDA ITEMS

- Task I Progress Report

MEETING WAS ADJOURNED AT 7:05 P.M.

Upcoming Meetings & Activities

l future meetings will be held from 4 - 7 p.m. at the Broomfield City Building, One Descombes Dr., Broomfield, CO - Zang's pur/Bal Swan Conference Rooms, on the following dates:

February 11, 1999	March 11	April 8
May 13	June 10	July 8
August 12	September 9	October 14
November 11		

In addition, please note your calendars for the following events:
Risk Workshop - February 11, 1999 - 12 - 3:30 p.m., Broomfield City Bldg. Bal Swan Conference Room
Public Meeting - March 10, 1999 - 6:30 - 9:00 p.m. - location TBD

NOTE: The previously-elected Steering Committee, made up of: Mary Harlow, Hank Stovall, Leroy Moore and Lisa Morzel routinely meets each Monday prior to the regularly scheduled meeting to plan the agenda. Panel members may attend this meeting. To confirm meeting date, time and place, please contact either Mary Harlow or Hank Stovall.

Breakdown of breathing rates based on daily activities for scenarios

Scenario	Daily Activity	Location	Time onsite per day (hour)	Time offsite per day (hour)	Breathing Rate m^3 per hr	Breathing vol. onsite per day m^3	Breathing vol. onsite per yr m^3	Time onsite per year (hour)
Resident rancher	Sleeping	East of present 903 area	7		0.45	3.15		
Assume 23 hr per day,	Work outdoors (light activity)	East of present 903 area	7		1.5	10.5		
365 days per year	Work outdoors (heavy activity)	East of present 903 area	3		3	9		
	Indoors (sitting)	East of present 903 area	4		0.5	2		
	Indoors (light activity)	East of present 903 area	2		1.5	3		
	Indoors (light activity)	Offsite		1				
	Onsite values					28	**10220**	**8400**
Infant of	Sleeping	East of present 903 area	16		0.16	2.56		
resident rancher	Awake (sedentary)	East of present 903 area	6		0.35	2.10		
(NB-2 yr)	Awake (active)	East of present 903 area	1.5		0.55	0.83		
Assume 23.5 hr per day,	**Onsite values**	Offsite		0.5		5	**1825**	**8600**
365 days per year								
Child of	Sleeping	East of present 903 area	8		0.35	2.8		
resident rancher	Personal time (wash, eat,dress)	East of present 903 area	3		1.2	3.6		
(5-17 yr)	At school	Offsite		8		0		
Assume 16 hr per day,	Homework, reading, TV--sitting	East of present 903 area	2		0.4	0.8		
365 days per yr	Playing (light activity)	East of present 903 area	1		1.2	1.2		
	Playing (heavy activity)	East of present 903 area	2		2	4		
	Onsite values					12	**4380**	**5800**
Office worker	Work (sitting)	Site	4		0.5	2		
(Sedentary work)	Work (light activity)	Site	4		1.5	6		
Assume 5 days per week,	Lives offsite			16				
50 weeks per yr	**Onsite values**					8	**2000**	**2000**
Recreational User	Light activity	Site	1		1.5	1.5		
(Active onsite)	Heavy activity	Site	2		3	6		
Assume 2 days per week,	Lives offsite			21				
50 weeks per yr	**Onsite values**					7.5	**750**	**300**

From Kathleen Meyer at (970) 229 0828

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P	Niels Schonbeck	Metro State	[redacted]	[redacted]
A	John Shepherd	Physician/Soc Resp	[redacted]	[redacted]
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A	Tom Marshall	RFCAB	[redacted]	[redacted]
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	Deanne Butterfield	RFLII	[redacted]	[redacted]
	Will Neff	RFLII	[redacted]	[redacted]
P	Joel Selbin	UCD Chem Dept	[redacted]	[redacted]
P	Todd Margulies	TM Consulting	[redacted]	[redacted]
P	Joe Goldfield	CCANW	[redacted]	[redacted]
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	05:21 PM	NIELS SCHONBECK	3'31"	9	SEND	OK	010	
	05:25 PM	JOHN SHEPHERD	4'21"	9	SEND	OK	010	
	05:29 PM	VICTOR HOLM	8'11"	9	SEND	OK	010	
	05:38 PM	KEN KORKIA RFCAB	3'42"	9	SEND	OK	010	
	05:42 PM	TOM MARSHALL	4'57"	9	SEND	OK	010	
	05:47 PM	LEROY MOORE	4'57"	9	SEND	OK	010	
	05:52 PM	DEANNE BUTTERFIELD	6'27"	9	SEND	OK	010	
	05:59 PM	WILL NEFF	6'27"	9	SEND	OK	010	
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	06:56 PM	LAURA TILL	18'06"	20	SEND	BUSY	(01) 010	

TOTAL : 2H 50M 36S PAGES: 347

28

Working Session for Scenario Development for Soil Action Level Work

Kathleen R. Meyer, Ph.D.

Rocky Flats Soil Action Level
Oversight Panel Meeting
January 14, 1999

Risk Assessment Corporation

Soil Action Levels Are...

- Developed to protect people who may, in the near or distant future, come into contact with a site where radionuclides contaminate the soil at levels above background
- Quantities that consider environmental transport models, annual radiation dose limits, and standards for comparison that are called *exposure scenarios*

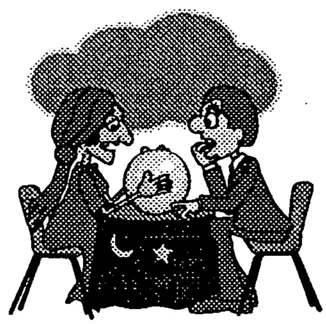
Exposure Scenarios

- Describe the *characteristics* and *behaviors* of hypothetical individuals who might have some contact with the radionuclides in the soil at the site
  - *Characteristics* include variables correlated with dose such as average breathing rate or dietary habits
  - *Behaviors* include time spent indoors and outdoors or eating foods from contaminated sources (e.g. family garden)

K. Meyer Jan 1999 RAC

Exposure Scenarios

- Exposure scenarios provide assumptions about the nature and extent of possible contact that people *might* have with the site
- In developing the exposure scenarios, both the pathway and the exposure mode must be considered



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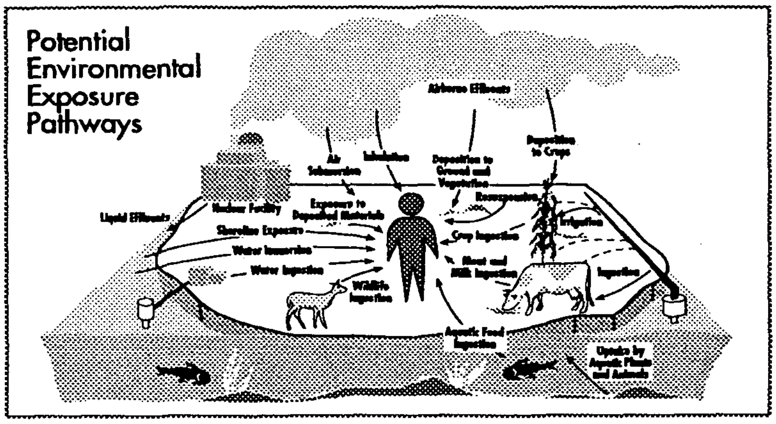
Possible Exposure Pathways



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Pathways

- Refer to the succession of environmental media through which the radionuclides move
- Pathways that the radionuclides will follow from the soil to the potentially exposed individuals
- Includes soil to air, soil to air to garden produce and pasture grass, or soil to surface water runoff to streams

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31

Exposure Modes

- Refer to the manner in which the exposure to body organs and tissues occurs
- Internal exposure occurs through inhalation, ingestion, or absorption through skin
- External exposure occurs when a person is near a contaminated area outside the body so that gamma rays from the radionuclides deliver dose to the person's organs

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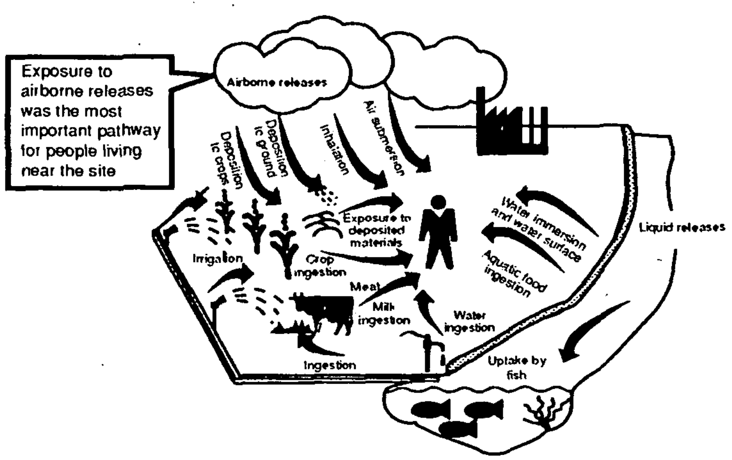
People Can Be Exposed in Different Ways



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Combining Exposure and Pathways

- Inhalation of radionuclides that are resuspended from the ground surface
- Ingestion of contained soil, either directly or from produce
- Drinking contaminated surface water from a stream that has received runoff from contaminated soil
- Eating produce grown on contaminated soil

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Scenario Parameters

- Breathing rates for various activity levels and ages
- Soil Ingestion rates
- Fraction of time spent indoors and outdoors
- Using water from area
- Age considerations

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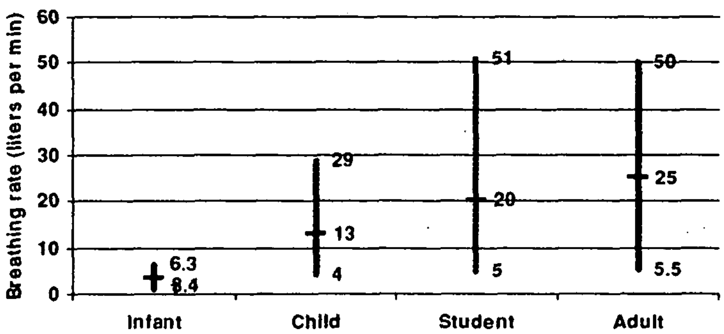
33

Breathing rates vary with age group and activity



From Roy and Courtay (1991), Layton (1993), and EPA (1985)

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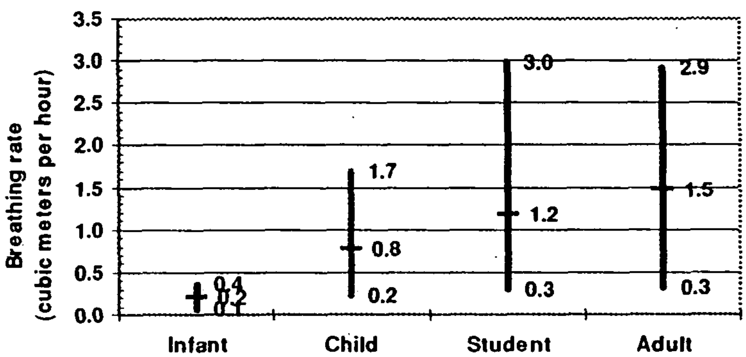
Breathing rates vary with age group and activity



From Roy and Courtay (1991), Layton (1993), and EPA (1985)

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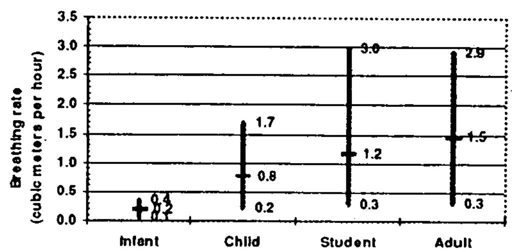
Calculating breathing rates for rancher scenario

Scenario	Daily Activity	Time onsite per day (hour)	Time offsite per day (hour)	Breathing Rate m^3 per hr	Breathing vol. onsite per day m^3	Breathing vol. onsite per yr m^3	Time onsite per year (hour)
Resident rancher	Sleeping	7		0.45	3.15		
Assume 23 hr per day,	Work outdoors (light activity)	7		1.5	10.5		
365 days per year	Work outdoors (heavy activity)	3		3	9		
	Indoors (sitting)	4		0.5	2		
	Indoors (light activity)	2		1.5	3		
	Indoors (light activity)		1				
	Onsite values				28	10200	8400



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Breathing rates for scenarios based on daily activities

Scenario	Daily Activity	Time onsite per day (hour)	Time offsite per day (hour)	Breathing Rate m per hr	Breathing vol. onsite per day m	Breathing vol. onsite per yr m	Time onsite per year (hour)
Resident rancher	Sleeping	[illegible]		[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]		1.5	[illegible]		
[illegible]	[illegible]	[illegible]		3	[illegible]		
	[illegible]	1		[illegible]	[illegible]		
	[illegible]	[illegible]		1.5	3		
	[illegible]		1				
	Onsite values				28	10200	8400
Infant of	[illegible]	[illegible]		[illegible]	[illegible]		
resident rancher	[illegible]	[illegible]		[illegible]	[illegible]		
(NB-2 yr)	[illegible]	[illegible]		[illegible]	0.83		
[illegible]	**Onsite values**		[illegible]		5	1800	8600
[illegible]							
Child of	Sleeping	8		[illegible]	2.8		
resident rancher	[illegible]	3		[illegible]	[illegible]		
(5-17 yr)	At school		8		0		
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		
[illegible]	[illegible]	1		[illegible]	[illegible]		
	[illegible]	[illegible]		2	[illegible]		
	Onsite values				12	4400	5000
Office worker	[illegible]	4		[illegible]	[illegible]		
(Sedentary work)	[illegible]	4		1.5	6		
[illegible]	[illegible]		[illegible]				
[illegible]	**Onsite values**				8	2000	2000
Recreational User	[illegible]	1		[illegible]	[illegible]		
(Active onsite)	[illegible]	[illegible]		[illegible]	[illegible]		
[illegible]	[illegible]		[illegible]				
[illegible]	**Onsite values**				7.5	760	300

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Soil Ingestion Rates (grams per day)

	Child	Adult
low	0.02	0.02
average	0.04	0.07
high	1.20	0.25

From Kimbrough et al. 1983; Calabrese et al. 1989, Thompson and Burmaster 1991, Haley 1985

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Five Preliminary Scenarios Focused on Lifestyle and Age

- Resident Rancher
- Infant of resident
- Child of resident
- Onsite office worker
- Recreational land user

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Resident Rancher Scenario

- *Lifestyle:* Assume loss of institutional control; rancher leads active life at the site; spends good part of time outdoors
- *Exposure :* Assume onsite 23 hour per day, 365 days per year, or 8400 hr/year
- *Pathways:* Inhalation; ingestion of produce from garden irrigated with some water from site stream for 3 months of year
- *Breathing rate:* 10,000 m^3 per year, based on a breakdown of daily activities
- *Soil Ingestion:* 90 grams per year, or 0.25 g per day

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Infant Scenario

- *Lifestyle:* Infant in rancher family; assume loss of institutional control; age from 0 to 2 yr
- *Exposure :* Assume onsite 23.5 hours per day, 365 days per year, or 8600 hr/year
- *Pathways:* Inhalation; some ingestion of produce from garden irrigated with site stream water; soil ingestion
- *Breathing rate:* 1800 m^3 per year, based on a breakdown of daily activities
- *Soil Ingestion:* 15 grams per year, or 0.04 g per day

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37

Child Scenario

- *Lifestyle:* Child of rancher family; assume loss of institutional control; age from 5 to 17 yr
- *Exposure :* Assume onsite 16 hours per day, 365 days per year, or 5800 hr/year
- *Pathways:* Inhalation; some ingestion of produce from garden irrigated with site stream water; soil ingestion
- *Breathing rate:* 4400 m^3 per year, based on a breakdown of daily activities
- *Soil Ingestion:* 438 grams per year, or 1.2 g per day

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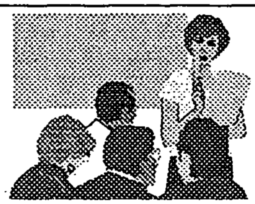
Office Worker



- *Lifestyle:* Works at office onsite; sedentary; indoors
- *Exposure :* Assume onsite 8 hours per day, 5 days per week, 50 weeks per year, or 2000 hr/year
- *Pathways:* Inhalation; some soil ingestion
- *Breathing rate:* 2000 m^3 per year, based on a breakdown of daily activities
- *Soil Ingestion:* 25 grams per year, or 0.1 g per day

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Recreational Land User

- *Lifestyle:* Visits site for recreation activities like hiking, biking, or running
- *Exposure :* Assume onsite 3 hours per day, 2days per week, 50 weeks per year, or 300 hr/year
- *Pathways:* Inhalation; some soil ingestion
- *Breathing rate*: 750 m^3 per year, based on a breakdown of daily activities
- *Soil Ingestion*: 12.5 grams per year, or 0.25 g per day

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Selected Parameters for Scenarios

	DOE/EPA/CDPHE Scenarios			RAC Scenarios				
	Open Space	Office worker	Resident	Resident rancher	Infant of resident rancher	Child of resident rancher	Office worker	Recreational land user
Breathing rate (m^3 per yr)	175	1660	7000	10000	1800	4400	2000	750
Breathing rate (m^3 per day	33.6	20	20	28	5	12	8	7.5
Exposure time (hr per yr)	125	2000	8400	8400	8600	5800	2000	300
Soil ingestion (g/year)	2.5	12.5	70	90	15	438	25	12.5
Soil ingestion (g/day)	0.1	0.05	0.2	0.25	0.04	1.2	0.1	0.25

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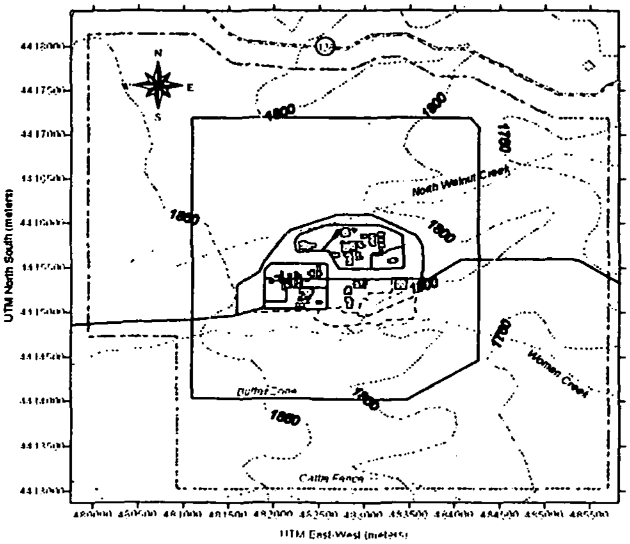
Rocky Flats Site



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Summary

- Developing these scenarios is a cooperative effort between RAC and the panel
- Once established, the scenario characteristics should be considered fixed
- Scenario parameters are based on a distribution of parameters from scientific literature; behavioral characteristics must be plausible
- Use the scenario worksheet to provide your input

K. Meyer Jan 1999 | *RAC*

47

WORKSHEET FOR SOIL ACTION LEVEL SCENARIO DEVELOPMENT FOR ROCKY FLATS
Input for some key scenario parameters

Parameter	DOE/EPA/CDPHE Scenarios: Open Space	DOE/EPA/CDPHE Scenarios: Office worker	DOE/EPA/CDPHE Scenarios: Resident		RAC Scenarios: Resident rancher	RAC Scenarios: Infant of resident rancher	RAC Scenarios: Child of resident rancher	RAC Scenarios: Office worker	RAC Scenarios: Recreational land user
Breathing rate (m^3 per yr)	175	1660	7000		10000	1800	4400	2000	750
Breathing rate (m^3 per day)	33.6	20	20		28	5	12	8	7.5
Breathing rate (m^3 per yr)									
Breathing rate (m^3 per day)									
Exposure time (hr per yr)	125	2000	8400		8400	8600	5800	2000	300
Exposure time (hr per yr)									
Soil ingestion (g/year)	2.5	12.5	70		90	15	438	25	12.5
Soil ingestion (g/day)	0.1	0.05	0.2		0.25	0.04	1.2	0.1	0.25
Soil ingestion (g/year)									
Soil ingestion (g/day)									

Sensitivity Analysis for RESRAD parameters

Jill M. Weber
for *Risk Assessment Corporation*
January 14, 1999
Rocky Flats Soil Action Level Oversight Panel

RAC

1/99 J.M. Weber

Sensitivity

Sensitive *adj* (sensitivity *n*):
"...of such a nature as to be easily affected."

Sensitivity is a function of two things:

- The mathematical relationship of the parameter of interest to the other parameters
- Range of possible values for the parameter

RAC

1/99 J.M. Weber

The mathematical relationship to other parameters...

$$y = Ae^B$$

where:

e = 2.718, a constant used frequently in mathematics

and A and B are variables in the equation

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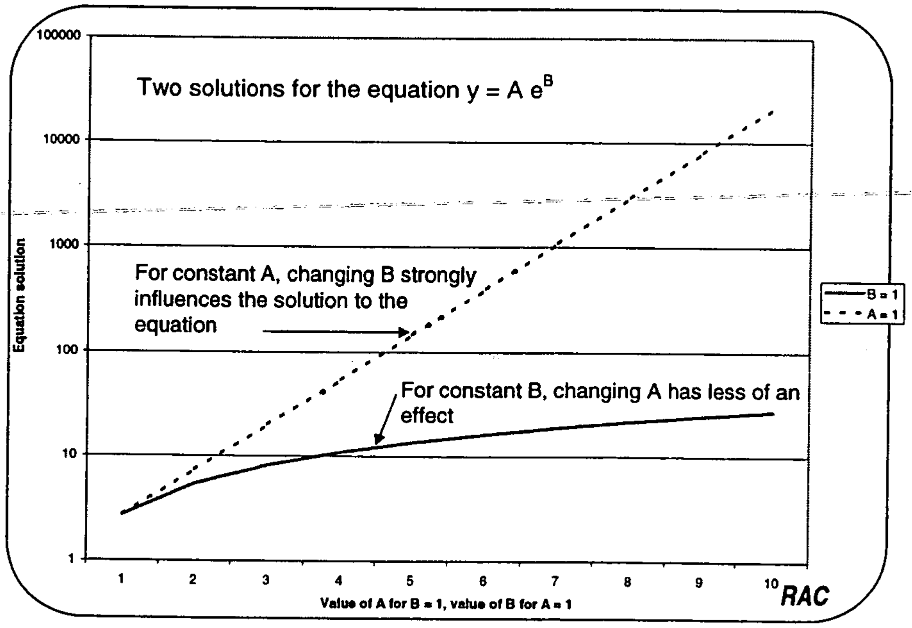

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43

Range of possible values...

Range of A = from 1 to 1000

Range of B = 1 to 2

For a constant B = 1, value of equation ranges from

y = 2.7 to y = 2700

For a constant A = 1, value of equation ranges from

y = 2.7 to y = 7.4

RAC

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2 kinds of sensitivity

- Monte Carlo:
  - parameters have a distribution of possible values
  - use that range of possible values to calculate solution to the equation a number of times (trials)
  - display distribution of solutions
  - can compute the relative contribution (sensitivity) of each parameter
- Single factor sensitivity
  - only change one factor at a time
  - watch the result of the equation change to discover sensitivity of that parameter

RAC

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Sensitivity of RESRAD parameters

- Will always look at the DOE Residential Scenario parameters (85 mrem Tier I action level)
- Changing one parameter at a time (within reasonable limits), what is the impact of the change on the t=0 dose (maximum dose) and the soil action level for the residential scenario?

RAC

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Contaminated area from 40000 m^2 (10 acres) to 1.54×10^6 m^2 (385 acres)

Total dose:	145 mrem/y	Total dose:	146 mrem/y
Pu-239	1429 pCi/g	Pu-239	1413 pCi/g

RAC

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Add the milk and meat ingestion pathways

Total dose:	145 mrem/y	Total dose:	149 mrem/y
Pu-239	1429 pCi/g	Pu-239	1425 pCi/g

RAC

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Contaminated zone erosion rate increased by 10x and decreased by 10x (from 0.0000749 to 0.000749 or 0.00000749)

Total dose:	145 mrem/y	Total dose:	145 mrem/y
Pu-239	1429 pCi/g	Pu-239	1429 pCi/g

result does not change because parameter is not sensitive to change

RAC

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Irrigation rate
from 1 m^3/m^2year to 10 m^3/m^2year

Total dose:	145 mrem/y	Total dose:	145 mrem/y
Pu-239	1429 pCi/g	Pu-239	1429 pCi/g

RAC

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Fruit/non-leafy vegetable/grain consumption from 40 to 80 kg/yr

Total dose:	145 mrem/y	Total dose:	149 mrem/y
Pu-239	1429 pCi/g	Pu-239	1421 pCi/g

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217

Leafy vegetable consumption from 2 to 20 kg/yr

Total dose:	145 mrem/y	Total dose:	147 mrem/y
Pu-239	1429 pCi/g	Pu-239	1425 pCi/g

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Mass loading for foliar deposition (how much soil is resuspended from ground to plant surface) increased by 10x

Total dose:	145 mrem/y	Total dose:	146 mrem/y
Pu-239	1429 pCi/g	Pu-239	1426 pCi/g

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Exposure duration

This parameter has no impact since the maximum dose, which determines the soil action level, occurs at time t = 0

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Inhalation shielding factor from 1 to 0.8 (so indoor air contamination is 80% of outdoor air)

Total dose:	145 mrem/y	Total dose:	137 mrem/y
Pu-239	1429 pCi/g	Pu-239	1755 pCi/g

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Thickness of contaminated zone from 0.15 m to 2 m (RESRAD default)

Total dose:	145 mrem/y	Total dose:	167 mrem/y
Pu-239	1429 pCi/g	Pu-239	1386 pCi/g

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Cover depth from 0 to 0.1 m (decreases available soil for resuspension)

Total dose:	145 mrem/y	Total dose:	36 mrem/y
Pu-239	1429 pCi/g	Pu-239	4220 pCi/g

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Soil ingestion from 70 to 140 g/yr

Total dose:	145 mrem/y	Total dose:	177 mrem/y
Pu-239	1429 pCi/g	Pu-239	1347 pCi/g

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Why doesn't increasing soil ingestion change the dose and soil action level very significantly??

- Insoluble plutonium - makes inhalation the primary pathway of concern
- Soluble plutonium - makes ingestion the primary pathway of concern (more readily absorbed into the gut)

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51

Assume plutonium is soluble instead of insoluble (increases dose conversion factor)

Total dose:	145 mrem/y	Total dose:	258 mrem/y
Pu-239	1429 pCi/g	Pu-239	242 pCi/g

RAC

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Increase soil ingestion (140 g/yr) AND keep soluble form of plutonium

Total dose:	385 mrem/y
Pu-239	142 pCi/g

RAC

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Mass loading coefficient (concentration of soil particles in air) increased 10x and 2x

		Total dose:	471 mrem/y
Total dose:	145 mrem/y	Pu-239	153 pCi/g
Pu-239	1429 pCi/g		
		Total dose:	181 mrem/y
		Pu-239	741 pCi/g

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Mass loading vs. resuspension factor

- DOE mass loading factor from average PM-10 concentration from June - October, 1995 at Standley Lake during construction
- Resuspension factors for wind resuspension from bare soil measured by Gerhard Langer over 3 year period from November 1982 - August 1985 in field east of 903 Area range from:

  1×10^{-10} to 1×10^{-13} m^{-1}

RAC

1/99 J.M. Weber

How do these compare??

For mass loading: $Conc_{air} = Conc_{soil} \cdot mass\ loading$

$$Conc_{air} = \frac{1\ Ci}{g} \cdot \frac{2.6\times10^{-5}\ g}{m^3}$$

$$\boxed{Conc_{air} = 2.6\times10^{-5}\ \frac{Ci}{m^3}}$$

For resuspension factor: $Conc_{air} = r_f \cdot Conc_{soil} \cdot \rho_{soil} \cdot depth$

$$Conc_{air} = \frac{10^{-10}}{m} \cdot \frac{1\ Ci}{g} \cdot \frac{1.5\times10^{6}\ g}{m^3} \cdot 0.15\ m$$

$$\boxed{Conc_{air} = 2.25\times10^{-5}\ \frac{Ci}{m^3}}$$

RAC

1/99 J.M. Weber

BUT, work of Sehmel

- Calculated resuspension factors for wind and mechanical stresses at field east of 903 Area (two weeks in July 1973)
- Estimated resuspension factors ranging from 1×10^{-5} to $1 \times 10^{-9}\ m^{-1}$

SO, the story is not complete, but at least we have some information to lead us to a well-supported estimate of mass loading/resuspension

RAC

1/99 J.M. Weber

Breathing rate

Heavy activity = 70 m^3/day, for 4 hours a day

Moderate activity = 25 m^3/day, for 13 hours a day

Sedentary = 10 m^3/day, for 7 hours a day

Total daily breathing rate = 28 m^3/day

Annual breathing rate (daily x 365) = 10265 m^3/year

RAC

1/99 J.M. Weber

Breathing rate from 7000 m^3/year to 10265 m^3/year

Total dose:	145 mrem/y	Total dose:	162 mrem/y
Pu-239	1429 pCi/g	Pu-239	997 pCi/g

RAC

1/99 J.M. Weber

Breathing rate from 7000 m^3/year to 9125 m^3/year (light activity all day)

Total dose:	145 mrem/y	Total dose:	156 mrem/y
Pu-239	1429 pCi/g	Pu-239	1115 pCi/g

RAC

1/99 J.M. Weber

Most sensitive parameters - comes down to only a few parameters

- Solubility of plutonium / dose conversion factor
- Mass loading factor

Less sensitive parameters

- Cover depth
- Breathing rate
- Soil ingestion

BUT, range of possible values limits the sensitivity

RAC

1/99 J.M. Weber

56

January 14,1999

To: RF Soil Action Level Oversight Panel
From: RAC

Topics: References related to the biokinetics of plutonium after ingestion

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The following references studied the effect of age, chemical properties and stomach content, dietary iron intake, and nutritional factors on the absorption of plutonium from the gastrointestinal tract . It is important to remember that most of the data are empirical and if such changes in speciation occur in the gut they are effectively accounted for in the measurements.

Bomford, J. and J. Harrison. 1986. The absorption of ingested Pu and Am in newborn guinea pigs. Health Physics 51: 804-808.

Bulman, R.A.1983. Complexation of transuranic elements: A look at factors which may enhance their biological availability. In Ecological Aspects of Radionuclide Release. Special Publication Series of the British Ecological Society, (Eds. P.J. Coughtrey, J.N.B. Bell and J.M. Roberts), No.3. pp.105-114. Blackwell Scientific Publications.

Harrison, J.D., J.W. Stather, H. Smith and G.N. Stradling. 1979. The influence of environmental factors on the gastrointestinal absorption of plutonium and americium. In: Actinides in Man and Animals (Ed. M.E. Wrenn), pp.323-336. RD Press, Salt Lake City.

Reummler, P. and R. Buschbom. 1986. Influence of iron on plutonium absorption by the adult and neonatal rat. Toxicol. Appl. Pharmacol. 85: 239-247.

Stather, J., J. Harrison and H. Smith. 1980. The influence of fasting and valence on the gastrointestinal absorption of plutonium in hamsters and rabbits. Health Physics 39: 334-338.

Sullivan, M., B. Miller, and L. Gorham. 1983. Nutritional influences on plutonium absorption from the gastrointestinal tract of the rat. Radiation Research 96: 580-591.

Sullivan, M., P. Reummler, and R. Buschbom. 1986. Influence of iron on plutonium absorption by the adult and neonatal rat. Toxicol. Appl. Pharmacol. 85: 239-247.

Sullivan, M., B. Miller, and J. Goebel. 1988. Absorption of ^{233}U, ^{237}Np, ^{238}Pu, ^{241}Am and ^{244}Cm from the gastrointestinal tracts of rats fed an iron-deficient diet. Health Physics 54: 311-316.

These papers looked at the oxidation state, administrative media, extent of polymer formation, rate of hydrolysis and their effects on the absorption of plutonium.

Harrison, J. and A. David. 1987. The effect of ingested mass on Pu absorption in the rat. Health Physics 53: 187-189.

Harrison, J., and J. Stather. 1982. The tissue distribution and excretion of actinides absorbed from the gastrointestinal tract of rodents. Health Physics 43: 283-285.

Stather, J., J. Harrison and A. David. 1981. The gastrointestinal absorption of plutonium in the hamster after ingestion at low concentrations in drinking water. Health Physics 41: 780-783.

Stevens, W., F. Bruenger, and B. Stover. 1968 In vivo studies on the interaction of Pu(IV) with blood constituents. Radiation Research. 33:490- 500.

Wildung, R. and T. Garland. 1980. The relationship of microbial processes to the fate and behavior of transuranic elements in soils, plants, and animals. In: Hanson, W., ed. Transuranic elements in the environment. Technical Information Center, U.S. Department of Energy, Springfield, VA. NTIS no. DOE/TIC-22800.

Rocky Flats Soil Action Level Project

Milestone Report 1
Risk Assessment Corporation

January 1999

The main deliverable for the Soil Action Levels Project between the Rocky Flats Citizen Advisory Board and *Risk Assessment Corporation* (*RAC*) will be a comprehensive report issued at the end of the project (November 1999). The main body of the report will be written for the public and will summarize *RAC*'s findings and recommendations. Appendices will provide the technical details of the work. The seven milestone reports will outline *RAC*'s progress in completing the Work Tasks and Deliverables, and the compensation requested according to the schedule provided in the contract. The purpose of this first milestone report is to describe the activities that *RAC* has accomplished to date

Milestone 1 (1/8/99)

- *RAC* will review the approaches to interpretation of data and results in simulation ("methodologies") and develop a discussion of these approaches for the panel. A presentation of *RAC*'s findings will be made to the panel.
- *RAC* will provide review of the existing procedures and protocols for sampling.
- *RAC* will meet with the Actinide Migration Panel and provide a written summary of the meeting.
- *RAC* will attend the monthly panel meetings and provide summaries of the discussion points.

The first milestone was completed at the November 1998 meeting with a presentation by *RAC* of a discussion of the methodologies for interpreting data and results of a simulation. The second milestone was met at the October 1998 meeting with a presentation by *RAC* of the review of Soil Sampling Protocol. *RAC* attended the Actinide Migration Panel meeting and is providing a written summary of the topics covered with this report. *RAC* has also attended and contributed to all monthly panel meetings to date.

- ***RAC will review the approaches to interpretation of data and results in simulation (methodologies") and develop a discussion of these approaches for the panel. A presentation of RAC's findings will be made to the panel.***

At the November 12, 1998 meeting, Art Rood discussed the methodology for determining soil action levels for this project. Mr. Rood began the presentation by stating that the overall objective of establishing Soil Action Levels is to define activity levels in soil (SAL) such that subsequent human exposure does not result in radiation dose that exceeds specified standards. The goal is to protect people who may, in the near or distant future, come into contact with a site where radionuclides contaminate the soil at levels above background. Soil action levels are quantities that quantities that are computed on the basis of environmental transport models, annual radiation dose limits, and exposure scenarios about the nature and extent of possible contact that people might have with the site. Art introduced two approaches for determining SALs: deterministic (data and parameters are represented by fixed values) and stochastic (data and parameters are represented by probability distributions rather than by single values). The stochastic approach considers the uncertainty around true parameter values and often uses Monte Carlo methods to propagate the uncertainty in parameter values to the final value. *RAC*'s proposed method used a stochastic approach to establish acceptable concentrations in soil at Rocky Flats. The ratios of measured or hypothesized radionuclide levels divided by the soil action levels are summed for all of the radionuclides, and if the sum exceeds 1 for one or more of the exposure scenarios, some action or remediation is indicated. Otherwise, the calculation has predicted that no annual dose limit would be exceeded, and the radionuclide levels are acceptable. The panel will be instrumental in helping to define acceptable probability levels for which dose limits will not be exceeded (high probability) or for which dose limits will be exceeded (low probability).

A part of this project is to review the RESRAD program, a DOE product developed for assessing radionuclides in soil, along with other programs that might be preferred for this work. *RAC* is currently considering five computer programs that may apply to this project: RESRAD, MEPAS, GENII,. MMSOILS, and DandD. Mr. Rood demonstrated how only several of the RESRAD parameters appear to control the proposed SALs.

- ***RAC will provide review of the existing procedures and protocols for sampling (part of Appendix C).***

RAC attended its first RF SAL panel meeting in October 1988, and, at that time, David J. Thorne described a soil sampling strategy that supports the soil action level concept. In this presentation, Mr. Thorne outlined the steps and strategies for determining the nature and extent of existing contamination (characterization) and verifying that cleanup levels have in fact, been achieved (verification). Both characterization and verification will be based on soil action level assumptions and methodologies that are currently under development. Verification that cleanup levels have been achieved will require the panel's help in several steps of the process. Their input will help specify those areas known to be contaminated or areas with different physical or chemical characteristics. They can provide input into determining sample size, sampling scheme (random or systematic), small areas of elevated residual radioactivity of concern,. and an acceptable level of confidence (i.e. 95%) that the sampling has adequately characterized the soil concentration

- ***RAC will meet with the Actinide Migration Panel and provide a written summary of the meeting.***

Kathleen Meyer represented *RAC* at the Actinide Migration Panel meeting on November 19, 1998 at the Arvada City Hall. The Actinide Migration Studies (AMS) group was established by DOE in 1996 and these periodic meetings are a way for Kaiser-Hill (K-H)and contractors to report on the current studies at Rocky Flats that deal with the actinide transport modeling of ^{239,240}Pu, ^{241}Am, and U in the site environment. The group meets about every 6-8 weeks and the next meeting is January 21, 1999. There are four reports from K-H and Rocky Mountain Remediation Services (RMRS) that are currently available about the work:

RMRS. 1998. Loading Analysis for the Actinide Migration Studies at the Rocky Flats Environmental Technology Site. Rev. 0. RF/RMRS-98-277. UN. September. [Available surface water discharge and actinide activity data from site monitoring programs during the 1990s were compiled to compute actinide loads on a storm-specific and annual basis. The analysis was done for Woman Creek, Walnut Creek and the South Interceptor Ditch (SID) drainage basins, which is part of the Woman Creek watershed].

RMRS. 1998. Actinide Content and Aggregate Size Analyses for Surface Soil in the Walnut Creek and Woman Creek Watersheds at the Rocky Flats Environmental Technology Site. Rev. 1. RF/RMRS-98-281.UN. September. [Reports ^{239,240}Pu, and ^{241}Am activity in surface soil sampled in FY98 from the Walnut and Woman Creek watersheds. Particle size distribution of the soil and sediment samples were done at the Colorado School of Mines. Data will be used as source of actinides to streams via stormwater runoff and to calibrate the Watershed Erosion Prediction Project (WEPP) model to estimate soil erosion and associated actinide transport].

RMRS. 1998. Conceptual Model for Actinide Migration Studies at the Rocky Flats Environmental Technology Site. No number on cover. October.

RMRS. 1998. Preliminary Report on Soil Erosion/Surface Water Sediment Transport Modeling for the Actinide Migration Study at the Rocky Flats Environmental Technology Site. Fiscal year 1998. RF/RMRS-98-285.UN. November. [Provides preliminary modeling results that will be used for calibrating the soil erosion and surface water transport modeling effort for the Rocky Flats watersheds. This report describes results for the SID watershed, which drains into Pond C-2].

At the November 19, 1998 meeting, there were two major topics: (1) Soil erosion and sediment transport modeling FY99 work (a summary of the November 1998 report above) reported by Win Chromec and Ken Spitze, (2) Air Modeling FY99 work that will be done by Radian International reported by Martha Hyder and Arney Srackangast. Radian International is just beginning the current air modeling work and will focus on "improving estimates of airborne actinide migration and deposition in the conceptual model," (paper three above) "preparing a modeling tool to use in evaluating various emission scenarios, and providing preliminary air pathway dose estimates." They plan to do this by reviewing published studies of contaminated soils resuspension to determine resuspension mechanisms, and then to identify resuspension models to use in estimating emissions of actinides from contaminated soils into the air. They then plan to combine the Industrial Source Complex (ISC) air dispersion model with CAP 88 to provide air pathway dose estimates around the site. They plan to use Rocky Flats met data and are looking at current conditions there. In relation to the work that Radian will be doing, Dr. Meyer described the dose reconstruction work *RAC* has been doing on air dispersion model comparison, the 903 suspension and source term work, and the historic monitoring data evaluation. As a follow-up, Kathleen sent Susan Templeman of Radian, copies of four *RAC* reports from their work for the Historic Public Exposure Studies on Rocky Flats:

Task 2: The Rocky Flats Plant 903 Area Characterization. H. R. Meyer, S. K. Rope, T. F. Winsor, P. G. Voillequé, K. R. Meyer, L. A. Stetar, J. E. Till and J. M. Weber. *RAC* Report No. 2-CDPHE-RFP-1996. December 1996.

Task 2: Development of the Rocky Flats Plant 903 Area Plutonium Source Term. Task 2: Independent Analysis of Exposure, Dose, and Health Risk to Offsite Individuals. J. M.

Weber, A. S. Rood, H. R. Meyer and J. E. Till. *RAC* Report No. 8-CDPHE-RFP. October 1998.

Task 3: Evaluation of Atmospheric Transport Models. A. S. Rood and J. E. Till. *RAC* Report No. 3-CDPHE-RFP-1997. December 1997.

Task 4: Evaluation of Historical Environmental Data. S. K. Rope, K. R. Meyer, M. Case, D. W. Schmidt, T. Winsor. M. Dreicer, J. Till. *RAC* Report No. 1 CDPHE-RFP-1997. March 1997.

- ***RAC will attend the monthly panel meetings and provide summaries of the discussion points.***

RAC has been involved in the monthly panel meetings with formal presentations, informal discussions, and questions and answer sessions. *RAC* has also welcomed the opportunity to participate in the RF SALOP technical discussions that began in response to requests from some panel members for time for more in-depth discussions. Following is a short summary of the topics and *RAC* members involved in the meetings.

October 8, 1998: John Till, Art Rood, David Thorne, and Kathleen Meyer attended for *RAC*. John provided a project overview emphasizing the importance of the panel's involvement in key decisions as the project progresses. Art Rood discussed the overall objective of the study with the panel, described several calculations that would be used throughout the study, and explained how various environmental pathways and time can affect the outcome. As outlined under bullet 2 above, David Thorne explained the importance of selecting a soil sampling strategy that supports the soil action level concept.

November 12, 1998: Art Rood and Kathleen Meyer attended for *RAC*.
As described in the first bullet above, Mr. Rood discussed *RAC*'s methodology for determining soil action levels. Kathleen Meyer described the process and importance of developing exposure scenarios for the SAL project, and for making this a cooperative effort that requires input from the oversight panel and citizens. An exposure scenario is a profile of a hypothetical individual with particular and fixed characteristics. This individual can help account for some of the variations in physiology, lifestyle, and age. The scenario parameters are based on scientific literature, and the behavioral characteristics must be plausible and relevant to the exposure situations. A goal for designing the scenarios in this study is that if the hypothetical individual is protected by the dose limits, then it is reasonable to assume that others will be protected.

December 10, 1998: John Till, Art Rood, and Jill Weber attended for *RAC*.
There was a preliminary meeting ahead of time where Jill, Art, and John met with the panel and others for about 2 hours to discuss several issues in more depth than can be done during a regular meeting. The panel is fine with *RAC* proposing scenarios and then, they will check and approve them. They also agreed that we do not need to consider uncertainty in the scenarios (like breathing rates, etc.), as long as they are confident we include the extremes of lifestyles in a scenario. As we and the panel are beginning to see clearly, the calculation of RSALs will rest on a few key parameters. DOE submitted a list of questions that we answered informally with the panel and followed up with written responses the following week. We emphasized that we will be documenting everything we do thoroughly, so the panel could review it.

During the regular meeting, Art Rood describe the rationale for fixing receptor scenario parameters, John Till discussed the possibility of providing a workshop on risk to provide the panel a better baseline of information on this subject. The risk workshop will be held on February 11 beginning at noon with Dr. Charles Meinhold of the National Council for Radiation Protection and Measurements. The regular meeting will follow from 4 to 7 p.m. Jill Weber updated the panel on the Task 1 work on cleanup levels at other sites. She has gathered all of the documents sited in Joe Goldfield's paper, *Health Effects of Plutonium Contaminated Soil*, along with some others that will be useful in evaluating cleanup and action levels at other sites. During her presentation, Jill did a preliminary comparison of cleanup levels at Rocky Flats, Colorado, Hanford, Washington, and Maralinga, Australia. The first draft Task report, *Cleanup Levels at Other Sites*, will be available on February 8, 1999.

Rocky Flats Soil Action Levels Project

Kathleen R. Meyer
Jill M. Weber

Rocky Flats Soil Action Level
Oversight Panel Meeting
January 14, 1999

Risk Assessment Corporation

K. Meyer Jan 1999 *RAC*

Milestone Reports

Milestone 1 (Jan 1999)

- *RAC* will review the approaches to interpretation of data and results in simulation ("methodologies") and develop a discussion of these approaches for the panel. A presentation of *RAC*'s findings will be made to the panel
- *RAC* will provide review of the existing procedures and protocols for sampling

K. Meyer Jan 1999 *RAC*

64

Milestone 1 (continued)

- *RAC* will meet with the Actinide Migration Panel and provide a written summary of the meeting
- *RAC* will attend the monthly panel meetings and provide summaries of the discussion points.

K. Meyer Jan 1999 *RAC*

Update on Issues

- *RAC* provided written responses to DOE questions from Dec 10, 1998
- Progress on Task 1 described at Dec RFSALOP meeting; draft report by next meeting
- For Task 2, *RAC* now has received all candidate computer programs: RESRAD, MEPAS, GENII, MMSOILS and DandD
- Chemistry of plutonium after intake - references provided today

K. Meyer Jan 1999 *RAC*

References on the biokinetics of plutonium after ingestion

The following references studied the effect of age, chemical properties and stomach content, dietary iron intake, and nutritional factors on the absorption of plutonium from the gastrointestinal tract.

Bomford, J. and J. Harrison. 1986.
Bulman, R.A. 1983.
Harrison, J., J. Stather, H. Smith and G.Stradling. 1979.
Reummler,P. and R. Buschbom. 1986.
Stather, J., J. Harrison and H. Smith. 1980.
Sullivan, M., B. Miller, and L. Gorham. 1983.
Sullivan, M., P. Reummler, and R. Buschbom. 1986.
Sullivan, M., B. Miller, and J. Goebel. 1988.

These papers looked at the oxidation state, administrative media, extent of polymer formation, rate of hydrolysis and their effects on the absorption of plutonium.

Harrison, J. and A. David. 1987.
Harrison, J., and J. Stather. 1982.
Stather, J., J. Harrison and A. David. 1981.
Stevens, W., F. Bruenger, and B. Stover. 1968
Wildung, R. and T. Garland. 1980.

K. Meyer Jan 1999 *RAC*

Update on Issues (continued)

- Solubility of plutonium in soil -relevant studies under review
- Sensitivity of parameters in the RESRAD model-Jill Weber today
- Developing scenarios - Kathleen Meyer and Panel today
- Risk Workshop - *RAC* and panel have arranged for Dr. Charles Meinhold of the NCRP to discuss risk on February 11

K. Meyer Jan 1999 *RAC*

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DEC 28 1998

RAC
Radiological Assessments Corporation
"Setting the standard in environmental health"

417 Till Road
Neeses, South Carolina 29107
803-536-4883
FAX 803-534-1995

December 19, 1998

Ken Korkia
Rocky Flats Citizens Advisory Board
9035 Wadsworth Parkway, Suite 2250
Westminster, Colorado 80021

Re: Responses to letter from Mr. Jeremy Karpatkin of the DOE Field Office to Hank Stovall, Co-chair of the RSALs Oversight Panel

Dear Mr. Korkia:

Attached to this letter are our responses to the letter from Mr. Jeremy Karpatkin of december 10, 1998. Please forward these responses to the Oversight Panel for their use in preparing a response to the department of energy.

Although I did provide an oral response to the questions, this written response should be considered official, and includes additional consideration from *RAC* regarding the questions asked.

Sincerely,

John E. Till, Ph.D.
President

enclosure

67

Responses from *RISK ASSESSMENT CORPORATION (RAC)*
To a letter from Jeremy Karpatkin of the DOE Field Office to Hank Stovall, Co-chair of the RSALs Oversight Panel

Questions asked in the letter are repeated below, followed by a response from *RAC*

1. The parameters of 1) Breathing rate, 2) Soil ingestion rate, 3) Fraction of time spent indoors (And Fraction of time spent outdoors?), 4) Gamma shielding factor and 5) Inhalation shielding factor are not being assessed as distributions in the uncertainty analysis. Please explain why *RAC* is assuming fixed rates for these parameters and not being assessed as distributions since these are sensitive parameters significantly affecting the radiation dose.

Answer. The parameters mentioned are associated with the exposure scenarios. *RAC* recommends that the exposure scenarios for a prospective assessment for radiation dose limitation be treated as standards, and not as simulations of real individuals. We would like to derive the probability that these dose limitation standards will (or will not) be met, and we would like for that probability to represent uncertainty about present and future environmental states and behavior. It is difficult to interpret the probability that a standard will be met when the standard itself is considered uncertain. We are recommending that the scenarios be developed with full consideration of the uncertainty distributions mentioned in the question and of any others that are relevant. But in arriving at the version of the scenario that expresses the standard, we advocate using high (or low, as the case may be) percentiles of the distributions as needed to extend protection to atypical people who *might* come into contact with the site. Thus, for example, one might use a 95th percentile for a scenario subject's average breathing rate. However, we recommend that this procedure be constrained to include only the possible; for example, an individual breathing 24 hours per day at the maximum rate for an Olympic athlete during a strenuous performance is not credible and should not be used to establish an average breathing rate. The fixed values of the scenario parameters should be derived from such considerations. We will be exhibiting sample sets of scenarios and discussing their derivation.

2. The uncertainty in the internal/external Dose Conversion Factors (DCF) is going to be assessed by *RAC*. These DCFs are promulgated for use by the International Commission on Radiological Protection and the National Council on Radiation Protection and Measurements as fixed values. These fixed DCFs have been adopted for use by the Department of Energy (DOE), Nuclear Regulatory Commission and the Environmental Protection Agency (EPA). How is *RAC* going to address the international consensus on DCFs. [sic] How will the uncertainty in the DCFs be quantified?

Answer. If the regulatory interpretation of the DCFs is acceptable to all parties as the standard for dose and risk in deriving the soil action levels, then *RAC* has no quarrel with that interpretation. However, questions have been raised about the reliability of some internal DCFs as representations of energy absorbed per unit intake of the corresponding radionuclides and therefore as measures of risk per unit intake. *RAC* developed considerable information on this topic for plutonium in the Rocky Flats Dose Reconstruction, and it would seem appropriate to share this information and examine its possible implications for the questions that this project seeks to answer.

3. *RAC* is proposing to use actual soil concentrations and evaluate the uncertainty in the "Sum of Ratios" method for a given site. The RSALs were derived without the use of actual soil concentrations so they could be applied to a number of sites with varying soil concentrations and ratios. What soil concentrations does *RAC* believe are applicable to their study? How will the uncertainty in the "Sum of Ratios" method be compared with the current RSALs?

Answer. This question is based on a possible misinterpretation. Soil action levels, by their definition, are independent of radionuclide levels in the soil. *RAC* never intended to suggest that their derivation would depend on particular values for the radionuclide concentrations. When a sum of ratios is formed, however, it combines hypothesized or measured radionuclide concentrations in the soil with the soil action levels to obtain a value that is compared with 1. Thus, the sum of ratios does depend on particular radionuclide concentrations and will reflect uncertainties in both the radionuclide concentrations and in the soil action levels. *RAC* has reservations about the general applicability among sites of particular sets of soil action levels. Soil action levels depend not only on environmental pathway models that are appropriate for the site under study, but also on exposure scenarios that express the potential for people to receive dose from the site. The pathways and the scenarios are inextricably linked, and it is important that for any specific site, everyone is persuaded that the scenarios and pathways considered lead to soil action levels that will assure dose limitation for anyone whose contact with the site can reasonably be foreseen.

4. Due to the public concern over the appropriate model(s) that could be used to calculate radionuclide contamination levels in soils based on a given dose rate, the Rocky Flats Soil Action Level Oversight Panel specifically requested that the independent reviewer provide a description of available models and a recommendation for the most appropriate model(s) which could be used to calculate radionuclide contamination levels in soils based on a given dose rate. Will *RAC* be describing and evaluating available models and recommending the most appropriate for use at Rocky Flats? Why is a review of environmental transport models more important than understanding specific applicable computer models? Which environmental transport models need to be assessed?

Answer. *RAC* must follow its proposal and contract. The proposal accepted the required review of applicable computer programs specified by the RFP, and *RAC* will review programs that it judges to be the leading candidates for applicability to this problem. The framers of the RFP would have to answer the second question regarding their decision to take this particular approach. The programs under review will be listed in the Task 2 report, and their identities will probably be disclosed before that time at a meeting of the Oversight Panel.

5. The *RAC* proposal says that *RAC* is going to develop a computer interface with the RESRAD code that will perform an uncertainty analysis using RESRAD. Will this newly developed computer interface be independently verified and validated?

Answer. To the extent that *RAC* develops scripting interfaces to RESRAD and other programs to carry out uncertainty calculations, the code for such interfaces will be turned over to the Oversight Panel at the end of the project. *RAC* would consider their purpose to be for demonstration of the methods *RAC* is proposing. Beyond that, if the Oversight Panel and the agencies choose to pursue the methods, we assume they would want to seek independent verification or possibly to develop the approaches further. Validation is a different question. We expect to relate recommended transport models to Rocky Flats environmental data at some baseline level, to the extent possible, and thus one would say that the models incorporated in the methodology for which this exercise could be carried out had undergone site-specific validation.

6. EPA issued "Guiding Principles for Monte Carlo Analysis" in March 1997 (EPA/630/R-97/001) for use as guidance when performing an uncertainty analysis like the one being performed by *RAC*. Will *RAC* be following the guidelines in this document?

Answer. *RAC* is familiar with this document. Its guidelines are similar to the ones *RAC* generally follows, and they will be considered and followed where appropriate in this work. *RAC* also has considerable experience in developing uncertainty analytic methods for nonroutine situations.

The methods used will presumably be subject to peer review.

7. The shape of the parameter distributions is a key concept in uncertainty analysis since this will directly affect the output distribution. Is *RAC* going to develop a methodology for choosing the shape of these distributions? EPA's "Development of Statistical Distributions for Exposure Factors" dated March 18, 1998 from the Research Triangle Institute is a methodology that may be applicable.

Answer. Choosing the form of parameter distributions is a complicated question, and the methods can range from nonlinear parameter estimation methods to eliciting a consensus of judgment by a panel of experts. Of fundamental importance is that interested parties accept that the choices are reasonable. *RAC*'s principles of uncertainty analysis were summarized in the proposal. We searched the EPA web sites for the document mentioned in the question and found no document with a similar title. If the poser of the question could provide more information (such as a report number and author list) or a copy of the document, we would be glad to examine it to see whether it might contribute new information.

70

To: Rocky Flats Soil Action Levels Oversight Panel — 14 January 1999
From: Peer Review Subcommittee
Re: Recommendations

RECOMMENDATION OF PROPOSED REVIEWERS

The Peer Review Subcommittee was charged with the task of proposing names of five persons to conduct peer review of the following five tasks of RAC's work on the RSALs:

1. Setting radionuclide soil action levels.
2. Analyzing RESRAD and other potentially relevant computer programs.
3. Analyzing inputs and assumptions for the RSALs.
4. Assessing independent calculations for the RSALs.
5. Analyzing soil-sampling protocols.

To do its job the subcommittee gathered names from numerous sources (including from those who initially bid on the project, from DOE and the regulators, from members of the Oversight Panel, etc.). After compiling a list of the strongest candidates (based on how well they matched the tasks to be reviewed plus absence of obvious conflict of interest), telephone contact was made to determine each potential candidate's interest in performing the peer review activity for the proposed honorarium of $2000 plus expenses. This process resulted in a shortened list of seventeen finalists. The subcommittee then examined the qualifications of this group to come up with a list of persons who together can provide competent, convincing, and credible peer review of the five tasks.

Accordingly, the subcommittee recommends the following list of names. The top five names on this list are the subcommittee's first choice as peer reviewers; the other names are alternates listed in order of preference, to be contacted only if any of the first five decline the invitation to fill this role (note that the final alternate is intended to replace only a specific person from the first five, should that person decline):

1) Lynn R. Anspaugh, Ph.D., Research Prof, U. of Utah Radiology Division (much work on radionuclides in soil, health and risk assessment, RESRAD)

2) Steven L. Simon, Ph.D., Senior staff officer with Board of Radiation Effects Research of National Academy of Sciences (specializes in measurement of ionizing radiation, environmental transport processes, computer modeling, uncertainty and statistical analyses)

3) F. Ward Whicker, Ph.D., Prof. in Dept. of Radiological Health Sciences, Colorado State U. (experienced in studying radionuclide transport in aquatic and terrestrial ecosystems, foodchain transport, soil sampling, computer modeling)

4) Paula A. Labieniec, Ph.D., consultant in hazardous waste and contaminated soil risk assessment, Chesterfield, VA (knowledgeable in software development, contaminant fate and transport, setting remediation goals for contaminated soil, risk assessment)

5) William J. Bair, Ph.D., retired from Life Sciences Center, Battelle Pacific Northwest National Laboratory, Richland, WA (involved in setting Enewetak RSALs, internationally recognized specialist on inhalation of radionuclides)

ALTERNATES

6) Allan C. B. Richardson, M.S., private consultant on radiation protection matters, Washington, DC (played a key role in developing EPA standards for radiation, a specialist on tabulating doses for internal and external exposure to radiation, helped develop evolving regulatory framework for DOE)

7) Glenn Paulson, Ph.D, President, Paulson and Cooper, Jackson Hole and Chicago (a specialist on radiation safety and on environmental science and policy, former Chief Radiation Officer for NJ, helped developed NJ Superfund Law [which antedated US law])

8) Bernd Franke, Director of Environmental Programs, Institute for Energy and Environmental Research, Takoma Park, MD (involved in setting and reviewing RSALs for Marshall Islands, on Scientific Management Team of Rongelap Resettlement Project)

ALTERNATE ONLY TO LABIENIEC IN THE EVENT SHE DECLINES

9) Mitchell J. Small, Ph.D., Prof of Civil and Environmental Engineering and Engineering and Public Policy, Caregie Mellon U. (knows computer modeling, statistical analysis and uncertainty, risk assessment)

RECOMMENDATION REGARDING FOLLOWUP

The subcommittee recognizes that the RFSALOP needs to establish some means for coordination and ongoing oversight of the peer review process. Initially there is the need to deal with things like providing the reviewers with guidelines, a background packet, a work schedule, a list of expectations, a contract or letter of agreement. Later there will be the need to handle questions or issues that may emerge in the course of the work, including serving as a conduit to get RFSALOP concerns to peer reviewers. The RFSALOP can deal with this by creating a new subcommittee or by asking the present subcommittee to continue with this new charge (opening it to new members who may wish to be involved in this task). Or there may be some other alternative.

The subcommittee recommends that the RFSALOP take appropriate action to deal with this need.

Session
2/11/99

74

RADIONUCLIDE SOIL ACT[illegible] LEVEL OVERSIGHT PANEL
MEETING ATTENDEES
February 11, 1999

NAME	ORGANIZATION	PHONE	FAX	E-MAIL
CARLA SANDA	AIMSI	[redacted]		
KEN STARR				
Marv Harlow	City of Westminster			
HANK STOVALL	BROOMFIELD			
LeRoy Moore	RMPJC			
Niels Schonbeck	Metro State			
TODD MARGULIES	TM CONSULTING			
Steve Gunderson	CDPHE			
Joseph [illegible]	CCANW			
VICTOR HOLM	RFCAB			
Carol Lyons				
John Till	RAC			
Kathleen Meyer	RAC	[redacted]		

RADIONUCLIDE SOIL ACTION LEVEL OVERSIGHT PANEL
MEETING ATTENDEES
February 11, 1999

NAME	ORGANIZATION	PHONE	FAX	E-MAIL
Jill Weber	RAC			
✓ Tim Rehder	U.S. EPA	[redacted]		
Laura Till	Facilitator			
Kathy Schnoor	City of Broomfield			
HEATHER BALSER	CITY OF LOUISVILLE			
Tom Pentecost	State Health Dept.			
EDD KRAY	CDPHE	[redacted]		
Carl Spreng	CDPHE			
Brady Wilson				
Ken Korkia	RFCAB			
Laura Brooks				
Rick Roberts	RMRS	[redacted]		
Dave Shelton	Kaiser-Hill	on file		

RADIONUCLIDE SOIL ACTION LEVEL OVERSIGHT PANEL
MEETING ATTENDEES
February 11, 1999

NAME	ORGANIZATION	[redacted]	[redacted]	[redacted]
Anne W. Callison	Barbour Communications Inc. for ITRC	[redacted]	[redacted]	[redacted]
John Corsi	Kaiser-Hill	[redacted]	[redacted]	[redacted]
Will Neff	RFLII	[redacted]	[redacted]	[redacted]
Russell McCallister	DOE/RFFO	[redacted]	[redacted]	[redacted]
ANDREW KLOTZ	CITY OF BOULDER	[redacted]	[redacted]	[redacted]
DIANE NIEDZWIECKI	CDPHE	[redacted]	[redacted]	[redacted]
Dean Hill	CSU	[redacted]	[redacted]	[redacted]

RADIONUCLIDE SOIL ACTION LEVEL OVERSIGHT PANEL
RISK WORKSHOP ATTENDEES
February 11, 1999

NAME	ORGANIZATION	[redacted]		
Anna Corbett	AIMSI	[redacted]		
Kathy Schnoor	City of Broomfield	[redacted]		
Ken Starr	JEFFCO DEPT HEALTH+ENV	[redacted]		
Laura Brooks	Kaiser-Hill	[redacted]		
Tom Pentecost	Colorado Dept of Health Lab and Radiation Services	[redacted]		
Rick Roberts	Rocky Mountain Remediation Serv.	[redacted]		
Victor Holm	RFCAB	[redacted]		
Jill Weber	RAC	[redacted]		
Kathleen Meyer	RAC	[redacted]		
Charles [illegible]	NCRP	[redacted]		
Todd Margulies	TM Consulting	[redacted]		
Steve Gunderson	CDPHE	[redacted]		
Carol Lyons	City of Arvada			

John Till

RISK WORKS[illegible]P ATTENDEES
Febru[illegible] 11, 1999

NAME	ORGANIZATION
Tom Marshall	Rocky Mountain Peace and Justice Center
JOEL SELBIN	UCB Chem. Dept
Carl Spreng	CDPHE
Ken Korkia	RFCAB
LeRoy Moore	RMPJC
HANK STOVALL	CITY OF BROOMFIELD
[illegible]	City of Westminster
John Corsi	Kaiser-Hill
Russell McCallister	DOE/RFFO
Nancy M. Daugherty	CDPHE-HMWMD
Will Neff	RFLII
Brady Wilson	CAB

[redacted]

AGENDA

RSALOP Meeting - February 11, 1999
Broomfield City Building - Zang's Spur Conference Room
4:00 - 7:00 P.M.

4:00 - 4:10	OPENING	Hank Stovall
	• Introductions	
	• Minutes corrections/approval	
	• Sign-In	
	• Agenda Review	Facilitator
	• Group Agreements	Facilitator
4:10 - 4:30	CO-CHAIRS UPDATES	
	• Public Meeting	Hank Stovall
	• MEPAS Source Code	Hank Stovall
4:30 - 4:40	PEER REVIEW SUBCOMMITTEE REPORT	Dr. LeRoy Moore, RFSALOP
4:40 - 5:10	PROJECT UPDATE	Dr. John Till, *RAC*
5:10 - 5:15	PUBLIC COMMENT	
5:15 - 5:30	BREAK	
5:30 - 6:15	TASK I REPORT REVIEW	Jill Weber, *RAC*
6:15 - 6:45	SCENARIO DEVELOPMENT REVIEW	Dr. Kathleen Meyer, *RAC*
6:45 - 6:50	PUBLIC COMMENT	
6:50 - 6:55	ANNOUNCEMENTS	
6:55 - 7:00	OTHER TOPICS/FUTURE AGENDA ITEMS/ ACTION ITEMS	Facilitator

UPCOMING MEETINGS/ACTIVITIES

March 10	Public Meeting	6:30 - 9 P.M. Westminster City Hall**
March 11	RFSALOP Meeting	4-7 P.M. Broomfield City Bldg.*
April 8	RFSALOP Meeting	4-7 P.M. Broomfield City Bldg.*
May 13	RFSALOP Meeting	4-7 P.M. Broomfield City Bldg.*
June 10	RFSALOP Meeting	4-7 P.M. Broomfield City Bldg.*
July 8	RFSALOP Meeting	4-7 P.M. Broomfield City Bldg.*

*Broomfield City Building, One Descombes Dr. - Zang's Spur/Bal Swan Conference Rooms (lower level)
** Westminster City Hall - 4800 W. 92nd Avenue - Westminster, CO 80030

RSALOP

Radionuclide Soil Action Levels Oversight Panel

REMINDER

RISK WORKSHOP

WHEN: Thursday, February 11, 1999
12:00 - 3:30 p.m.

WHERE: Broomfield City Building, One Descombes Dr. - Zang's Spur/Bal Swan Conference Rooms (lower level)

KEYNOTE SPEAKER: *Mr. Charles Meinhold will be conducting the workshop and brings with hir a diversified foundation in both the nuclear industry and risk issues, including:*

- *President, National Council of Radiation Protection Measurements*
- *Vice Chairman, International Commission on Radiological Protection*
- *Senior Scientist, Brookhaven National Laboratory*
- *Past President, International Radiation Protection Association*
- *Honorary Professor, The China Institute of Atomic Energy*
- *Honorary Professor, The China Institute of Radiation Protection*

Attendees may bring a brown-bag lunch if desired. Beverages & light snacks will be provided.

RSALOP TECHNICAL DISCUSSION

To provide time for the Risk Workshop, no technical discussion will be conducted prior to the regular Panel meeting.

UPCOMING RSALOP MEETINGS

All future meetings will be held from 4 - 7 p.m. at the Broomfield City Building, One Descombes Dr., Broomfield, CO - Zang's Spur/Bal Swan Conference Rooms, on the following dates:

March 11	April 8	May 13
June 10	July 8	August 12
September 9	October 14	November 11

PUBLIC MEETING

The first public meeting will be held from 6:30 - 9:00 p.m. on Wednesday, March 10, 1999 at the Westminster City Hall - 4800 W. 92nd Avenue - Westminster, CO 80030

80

ADVANCED INTEGRATED MANAGEMENT SERVICES, INC.

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RE: RFSALOP MEETING AGENDA FOR 2/11/99

☐ URGENT ☑ FOR REVIEW ☐ PLEASE COMMENT ☐ PLEASE REPLY ☐ PLEASE SIGN

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A	Sam Dixion	City of Westminster	303-426-1202	303-429-5113	
SP	Mary Harlow	City of Westminster	303-430-2400x 2174	303-650-1643	
	Dr. Norma Morin	CDPHE	303-692-2645	303-782-0188	
E	Steve Gunderson	CDPHE	303-692-3367	303-759-5355	
	Carl Spreng	CDPHE	303-692-3358	303-759-5355	
P	Dean Heil	CSU	970-491-6516	970-491-0564	
C	John Till	RAC	803-536-4883	803-534-1995	
C	Kathleen Meyer	RAC	970-229-0828	970-229-0829	
	Autar Rampertaap	DOE HQ	301-903-8191	301-903-3877	
E	Jeremy Karpatkin	DOE	303-966-2080	303-966-6633	
	Jessie Roberson	DOE/RFFO	303-966-2025	303-966-6054	
	Russell McCallister	DOE	303-966-9692	303-966-3710	
E	Tim Rehder	EPA	303-312-6293	303-312-6067	
P	Ken Starr	Jefferson County	303-271-5714	303-271-5702	
	Nanette Neelan	Jefferson County		303-271-5702	
	John Corsi	Kaiser Hill	303-966-6526	303-966-6153	
	Dave Shelton	Kaiser Hill	303-966-9877	303-966-6214	
P	Niels Schonbeck	Metro State	303-556-8327	303-556-5399	
A	John Shepherd	Physician/Soc Resp	303-650-4460	303-650-4403	Please call when faxing
A	Victor Holm	RFCAB	303-989-9086	303-980-9076	
SP	Bob Kanick	RFCAB	303-444-0049	e-mail or call	
E	Ken Korkia	RFCAB	303-420-7855	303-420-7579	
A	Tom Marshall	RFCAB	303-444-6981	303-444-6523	
SP	LeRoy Moore	RMPJC	303-444-6981	303-444-6523	
	Deanne Butterfield	RFLII	303-940-6090	303-940-6088	
	Will Neff	RFLII	303-940-6090	303-940-6088	
P	Joel Selbin	UCD Chem Dept	[redacted]	303-492-5894	
P	Todd Margulies	TM Consulting	303-279-6699	Mail or e-mail	
P	Joe Goldfield	CCANW	303-321-7276	Mail or e-mail	
C	Laura Till	Facilitator		303-447-0077	

(SP=Steering Committee Panel Member, P=Panel Member, A=Alternate, E=Ex-Officio, C=Contractor), List Revised 1/28/99

5460 WARD ROAD, SUITE 370, ARVADA, COLORADO 80002, 303-456-0884, FAX: 303-456-0858

TRANSACTION REPORT

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82

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FEB-09	03:33 PM	DAVID ABELSON	**'**"	0	SEND	BUSY	081	
	03:22 PM	JIM MCCARTHY	1'08"	3	SEND	OK	081	
	02:23 PM	CAROL LYONS	1'02"	3	SEND	OK	081	
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	02:29 PM	KATHY SCHNOOR	1'31"	3	SEND	OK	081	
	02:30 PM	HANK STOVALL	1'03"	3	SEND	OK	081	
	02:32 PM	TOM DAVIDSON	1'02"	3	SEND	OK	081	
	03:25 PM	HEATHER BALSER	1'02"	3	SEND	OK	081	
	02:34 PM	SAM DIXION	1'52"	3	SEND	OK	081	
	02:36 PM	MARY HARLOW	1'02"	3	SEND	OK	081	
	02:38 PM	DR NORMA MORIN	1'06"	3	SEND	OK	081	
	02:39 PM	S GUNDERSON CDPHE	1'04"	3	SEND	OK	081	
	02:41 PM	CARL SPRENG CDPHE	1'03"	3	SEND	OK	081	
	02:42 PM	DEAN HEIL CSU	1'37"	3	SEND	OK	081	
	02:44 PM	JOHN TILL RAC	39"	3	SEND	OK	081	
	03:26 PM	KATHLEEN MEYER	1'53"	3	SEND	OK	081	
	02:46 PM	AUTAR RAMPERTAAP DOE	1'03"	3	SEND	OK	081	
	02:48 PM	JEREMY KARPATKIN DOE	1'03"	3	SEND	OK	081	
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	03:34 PM	JOHN CORSI	**'**"	0	SEND	BUSY	081	
	02:56 PM	DAVE SHELTON	1'59"	3	SEND	OK	081	
	02:58 PM	NIELS SCHONBECK	1'01"	3	SEND	OK	081	
	03:31 PM	JOHN SHEPHERD	1'53"	3	SEND	OK	081	
	03:01 PM	VICTOR HOLM	2'20"	3	SEND	OK	081	
	03:03 PM	KEN KORKIA RFCAB	1'05"	3	SEND	OK	081	
	03:05 PM	TOM MARSHALL	1'20"	3	SEND	OK	081	
	03:06 PM	LEROY MOORE	1'20"	3	SEND	OK	081	
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	03:10 PM	WILL NEFF	1'53"	3	SEND	OK	081	
	03:13 PM	JOEL SELBIN UCD	1'02"	3	SEND	OK	081	
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TOTAL : 45M 31S PAGES: 108

MINUTES

Radionuclide Soil Action Levels Oversight Panel
February 11, 1999 - 4:00p.m. - 7:00 p.m.
Broomfield City Building - Zang's Spur/Bal Swan Conference Rooms

NOTE: Minutes are presented in draft form and should not be quoted or distributed until receiving final approval by the Rocky Flats Soil Action Level Oversight Panel at its March 11, 1999 meeting.

Hank Stovall, Co-Chair, convened the regular meeting of the Radionuclide Soil Action Level Oversight Panel (Oversight Panel or Panel) at 4:10 p.m. and opened with the introduction of the following attendees:

Hank Stovall, City of Broomfield
Niels Schonbeck, HAP & MSCD
Russell McCallister, DOE-RFFO
Dave Shelton, Kaiser-Hill
Heather Balser, City of Louisville
Laura Brooks, Kaiser-Hill
Carl Spreng, CDPHE
Ken Korkia, RFCAB
Joe Goldfield, CCANW
Todd Margulies, TM Consulting
Jill Weber, *RAC*
Mary Harlow, City of Westminster
Dean Heil, CSU
Laura Till, Facilitator
Victor Holm, RFCAB
Carla Sanda, AIMSI
Edd Kray, CDPHE
Kathleen Meyer, *RAC*
Will Neff, RFLII
Diane Niedzwiechi, CDPHE
LeRoy Moore, RMPJC
Andrew Klotz, City of Boulder
Carol Lyons, City of Arvada
Tim Rehder, US EPA
Brady Wilson, RFCAB Staff
John Corsi, Kaiser-Hill
Ken Starr, JEFFCO
Rick Roberts, RMRS
Steve Gunderson, CDPHE
Jane W. Callison, Barbour Comm.
Kathy Schnoor, City of Broomfield
Shawn Burke, RFCAB
John Till, *RAC*

MINUTES REVIEW/APPROVAL

Minutes of the January 14, 1999 meeting of the Oversight Panel were reviewed and approved as printed.

AGENDA REVIEW

Laura Till reviewed the Agenda as well as the Group Agreements. The agenda was approved as distributed; the meeting was turned back to the Co-Chairs.

CO-CHAIRS UPDATES

Copies of a letter dated February 8, 1999 from Jeremy Karpatkin, DOE-RFFO to Mary Harlow were available to the Panel. The letter enclosed technical questions developed by DOE-RFFO from the January 14, 1999 Panel meeting. The questions have been transmitted to Risk Assessment Corporation, who will provide a written response.

Mr. Stovall expressed his appreciation to Russell McCallister, DOE-RFFO for his assistance in obtaining information on the MEPAS computer code and transmitting on to *RAC* representatives.

Copies of a memorandum to the Panel from Victor Holm regarding RSAL Regulatory Guidance and panel input to the contractor were available on the information table.

Mary Harlow reported that copies of the December 16, 1998 RFCA RSAL Working Group Meeting Minutes are available on the information table. Copies of that group's meeting minutes will be available at all future meetings of the RSALOP.

Carla Sanda reported on the details of the upcoming public meeting:
The project's first public meeting is scheduled from 6:30 - 9:00 p.m. on March 10, 1999 -- at the Westminster City Hall in the City Council Chambers. The meeting will consist of a 30-minute open house to provide an opportunity for attendees to read and discuss project storyboards and interact with panel members. This will be followed by a project introduction by the Panel Co-Chairs, who will then turn the meeting over to *RAC* representatives for discussion regarding project progress. Ample time will also be provided for attendee questions and answers. Seven storyboards measuring 24" x 36" each will provide the background of the project to meeting attendees. The storyboards will be placed on easels outside the Council Chambers for review and discussion by meeting attendees during the open house portion of the meeting. Several RSALOP members will be asked to staff this area and interact with meeting attendees. In addition, a 4-page fact sheet has been developed. Copies of the resume

84

portion of the fact sheet were distributed for final review by panel members and contractors to assure the accuracy of the information. A display ad has been developed which will run in the Transcript-Sentinel weekly newspaper in the March 4 edition. We are planning also to place an ad in the Boulder Daily Camera. In addition, the display ad will be printed on postcards and mailed to ~650 individuals and entities -- both locally and nationally. In addition, the web site is up and running and can be accessed for latest project information, in addition to relevant reports, and the fact sheet. Ms. Sanda expressed her appreciation to Erin Rogers, RFCAB, for her assistance in getting the web site up and running. Panels members were encouraged to access the web site at: ***www.rfcab.org/SALOP.html.*** Copies of the fact sheet will be available at the meeting and can be mailed to interested individuals. In addition, it will be transmitted via fax to the project's mailing list. Copies of the Task 1 report will also be available at the meeting. All panel members and attendees were encouraged to invite colleagues, friends, and business associates to the public meeting.

✔ ***Action Item: Carla Sanda will contact several panel members regarding their assistance at the public meeting.***

PEER REVIEW SUBCOMMITTEE REPORT - Discussion Lead: Dr. LeRoy Moore, RFCAB

As of February 10, 1999 a 5-member peer review team has been assembled, comprised of the following individuals:

- Dr. Steven L. Simon, National Academy of Sciences;
- Dr. Paula Labieniec, independent consultant in hazardous waste and contaminated soil risk assessment;
- Dr. Ward Whicker, Dept. of Radiological Health Sciences, Colorado State University;
- Allan C. B. Richardson, consultant on radiation protection and former member of EPA staff involved in developing much of the EPA radiation standards;
- Dr. Glenn Paulson, President of Paulson & Cooper (Jackson, WY & Chicago, IL), hazardous & radioactive waste management.

The peer review committee will continue working to phase the Peer Review Team into the project. Any panel member who would like to become a member of that committee, is welcome. Please contact either LeRoy Moore or Ken Korkia. Funding from the former Rocky Flats Local Impacts Initiative has been received for the peer review effort.

A conference call will be placed with the peer review team, members of the Peer Review Subcommittee, Ken Korkia, Carla Sanda, and Panel Co-Chairs. Panel members were also invited to participate in the call. Both Joe Goldfield and Robert Kanick expressed interest in participating in the conference call.

✔ ***Action Item: AIMSI staff will coordinate conference call logistics.***

PROJECT UPDATE* - Discussion Lead: Dr. John Till, *Risk Assessment Corporation*
*Copies of presentation materials may be requested from Anna Corbett, AIMSI, 303-456-0884

Task I: *RAC* is trying to determine the differences in cleanup levels at other sites and identify the reasons for those differences. *RAC* wants to obtain a clearer understanding of why those levels are different and better understand assumptions and assessments at other sites.

Dr. Till then reviewed the project deliverables by task:

- Task 1 draft report was delivered last week, with the final report due by May 8, 1999. This report is not scheduled for peer review.
- Task 2 draft report on Computer Models will be delivered by March 8, 1999, with the final report due on July 8, 1999. This report will be transmitted to the Peer Review team on or about March 12, 1999, with their comments due by April 2, 1999.
- Task 3 draft report on Inputs & Assumptions will be delivered by July 8, 1999, and a final report delivered by October 8, 1999. The peer review team has been asked to provide their input by July 30, 1999.
- Task 4 dealing with Methodology is now complete and has been reported on to the Panel. No written report is due on this task.
- Task 5 draft report on Independent Sampling Calculation is due by September 8, 1999, with a final report delivered by November 8, 1999. Peer reviewers have a deadline of October 1 for their comments.
- Task 6 draft report on Soil Sampling Protocols is due by May 8, with final report by August 8, 1999. The peer review team's deadline for comments is June 4, 1999.
- Task 7 consists of ongoing interaction with the Actinide Migration Panel.
- Task 8 provides for interfacing with the public and maintaining a responsiveness summary for all written project questions and answers.
- Task 9 is the major project deliverable, which consists of the draft comprehensive report to be delivered by October 8, 1999 and final report completed and delivered by November 8, 1999.

Although it is extremely compressed, the schedule is proceeding as planned. There have been some minor road bumps in some areas, while in other areas the *RAC* team is ahead of schedule. No project areas are lagging behind the schedule.

Dr. Till then expanded on Task 2 - Computer Models. He reported that Mr. George Killough, a member of the *RAC* team, has sorted through a number of computer codes found to date as potential codes for use to calculate soil action levels. This draft report will be published next month and will provide a fairly comprehensive analysis of some of the different models. Dr. Till went on to explain that none of the codes are completely satisfactory to *RAC*. When anyone designs a computer code used to make these kinds of calculations, and one in turn "forces" that code to fit a particular site, there will never be a perfect fit. Those are the types of things that *RAC* is uncomfortable with. As a result, Dr. Till has instructed Mr. Killough to move ahead, select a code, insert some parameters, and make some decisions. Dr. Till also believes it is important to formally document some of the weaknesses of the codes. Although there won't be time to fix any code, it is important to note the shortcomings and in turn sort out what appears to be the best code(s) to work with. At this point, the *RAC* team has narrowed the codes down to two: RESRAD (Argonne National Laboratory) and the GENIII model (Battelle Northwest Laboratories). The MEPAS program also showed some promise; however, due to the inability to obtain the source code which is considered proprietary, the *RAC* team will likely rule this program out. Good progress is being made on both RESRAD and GENIII.

Panel Discussion

- *Will RAC be able to detail what potential improvements to those codes might mean to the final result? Dr. Till responded that they do plan to document their findings to the extent possible and include explanations for any beneficial enhancements that may be made to the codes that could be helpful. That would certainly benefit any of the sites to know potential weaknesses and recommendations for improvement.*
- *Are there compensatory measures that could be taken if the code falls short -- are there other ways to provide inputs to cover that? Dr. Till indicated that this s not likely within the scope of the study, but RAC would point out where any weaknesses exist. Mr. Killough is one of the best mathematical modelers today -- so he will try to document in detail what could be done to make the codes operate more effectively. Mr. Killough is working full-time on this task to thoroughly review the source code and add the uncertainty component that appears to be best for this project. RAC will be focusing on the two codes with the most utility for this study -- RESRAD and GENIII. Victor Holm inquired as to why the D&D program was not considered or selected? Dr. Till responded that although he knows that D&D did not turn out to be a good candidate, he does not know the specifics -- but can provide this information at a later date.*
- *Mr. Holm went on to say that there is another aspect to this to consider: to increase the credibility associated with the final recommended number, it could be useful if it was supplied by an organization that works on license issues because the guidance that goes with it would be applicable. D&D has that aspect behind it. In effect, we are weighing the best scientific code with the one that is going to have the most credibility with the policy makers. Dr. Till agreed with that point, but timing and schedule is also a consideration. However, one of the things that RAC can do is look at the progress, make selection decisions, and determine whether or not there are some additional resources that will allow them to make those calculations. D&D may not have an uncertainty component, so it would be difficult to take the time to add that component. Dr. Till will review this with Mr. Killough. Mr. Holm additionally suggested that the Panel spend some time discussing issues like credibility vs. science -- and how important is uncertainty? If that means losing a code because it does not contain an uncertainty component, then that may indicate the need for further discussion.*
- *Steve Gunderson also reflected the same general concern as Victor Holm and indicated that the RFCA RSAL Working Group has been looking at redesigning the D&D program, so they too will be interested in these findings as well.*

Dr. Till then discussed the issue of plutonium solubility in the soil at Rocky Flats. The assumptions about solubility of plutonium in soil are very critical in terms of the final answer. *RAC* has been trying to gather relevant literature and has just received information from the site on plutonium solubility that will be carefully reviewed. Between now and the next meeting, another team member will be focusing on this issue. Dr. Till reflected his concern that some persons may be confusing the terms *"solubility"* vs. *"mobility"*. Even very insoluble plutonium may be more mobile than originally thought, but this does not mean that it changes its chemical form. The chemical form is what is important. Obviously, not even the site knows everything there is to know about the chemical form of plutonium -- and even the long-term chemical form; but based upon the literature, it is possible to make some sound assumptions.

RAC representatives have attended two Actinide Migration Panel meetings. However, *RAC* has had difficulty learning when the meetings are to take place -- or finding out only one day prior to the meeting. *RAC* needs a meeting schedule to be certain they are able to attend.

Panel Discussion:
John Corsi, Kaiser-Hill, responded that he had notified the Panel Co-Chair of the last meeting and invited the Panel & RAC to attend the open session. Kaiser-Hill has also made a commitment to meet with RAC on a quarterly basis with the Actinide Panel staff is in town and is scheduled for April 1999. Kaiser Hill representatives will call Kathleen Meyer to advise of upcoming meetings as well as notify the Panel. Meetings are held on a quarterly basis. Dr. Till expressed his appreciation for advance notice and reiterated the importance of being at these meetings.

Review of Task Reports: A schedule has been established for panel and peer review of task reports. There will also be a number of comments that the Panel may have on the draft reports before transmitting for external peer review. Dr. Till asked that the Panel establish a schedule that will allow *RAC* to incorporate any relevant Panel comments prior to sending the report out for peer review.

Dr. Till also touched briefly on ICRP and NCRP. It is obvious that we don't know everything there is to know about radiation and health effects, nor do we know everything about the environmental transport or dosimetry of radionuclides. But, the other point is: we do know something -- we're not working in the dark. In this work, which spans the scope of both chemicals and radionuclides, Dr. Till feels more comfortable dealing with radiation and radionuclides than chemicals -- the industry is probably a decade or so ahead in this area. Nevertheless, there is still a tremendous amount left to learn. Both ICRP and NCRP are dealing with a couple of things that the Panel is struggling with -- one of which is uncertainty. The agencies have recommended dose limits with which we are working, but neither the agencies, the ICRP, nor the NCRP have told us how to compare those limits when calculating the distribution of doses. In other words, if we come up with a possible range, what are we going to compare to that limit in order to make decisions? In addition, neither ICRP nor NCRP has provided guidance in dealing with future generations and the kinds of assumptions to make. The ICRP will come out with a statement on exposure to future generations, but that is likely several years away. There is a lot to consider. We must protect future generations at least to the same degree as we currently protect our own generation. There are people who argue that we should protect them to a greater degree than our own. As discussed in the Risk Workshop, over a period of thirteen years, the risk limits have gone up by a factor of four. Does that mean that we can expect the same thing to occur in the future? We don't have those answers, but ICRP will be considering those possibilities and will eventually provide some recommendations. For now, Dr. Till is recommending that we protect future generations to the same degree as we protect our own.

Overall, the project is right on the mark both budget and schedule wise, and perhaps even a bit under-budget.

Panel Discussion:
Jeremy Karpatkin asked Dr. Till to elaborate on his comments regarding the lack of guidance and how to deal with the distribution of a range of possible doses. Dr. Till responded as follows: Let's assume that we have a dose limit that we are using to calculate a dose to a member of the public. When we calculate that dose today from a release, we don't calculate a single value. We calculate a distribution of possible doses. Let's also say that a limit to the public is 10 mR outside the site. We calculated a distribution of doses that may run from ~1 mR perhaps up to the 95% percentile value of 15 mR. So, what are we going to compare to that 10 mR limit? This is basically what he is talking about when making comparisons over a range of possible doses.

Dr. Till indicated that he received a letter yesterday from DOE-RFFO with questions from the last meeting. He reflected that it would have been much more helpful if they could have received those questions earlier so that they could have come to this meeting with written responses. Dr. Till encourages the group to make every attempt to clear up questions at the meetings, or try to provide questions immediately after the meeting so they can be addressed at the next meeting.

PUBLIC COMMENT

None

Task 1: CLEANUP LEVELS AT OTHER SITES* - Discussion Lead: Jill Weber, *Risk Assessment Corporation*
*Copies of presentation and Task 1 report available by calling Anna Corbett - 303-456-0884

Ms. Weber indicated that some Panel members might have received incomplete or misprinted reports. Corrected copies are available at this evening's meeting.

87

Ms. Weber reminded the Panel that the purpose of this Task was not to make judgements, but rather explore soil action levels at Rocky Flats and various other sites; show their differences and elaborate on the cause of the differences. In short, the Task 1 Report reports upon the action levels, explains how and why the action levels are different, what was learned from the differences, and how *RAC* can take this information through the remainder of the study.

Ms. Weber began the discussion by describing how the comparison was done and walked the Panel through the calculation performed for Johnston Atoll. In all cases, the report compares concentrations at other sites to the RFETS 85 mR for a hypothetical future resident. That is the level below which no cleanup is required, and for a full-time resident is the maximum exposure scenario. In every case also, they have taken a look at Pu 239 and Pu 240. Ms. Weber reviewed the method used for comparison: soil action level divided by dose, which equals the soil action level to dose ratio which is given in units of pCi per gram per mR. The report includes numbers both for soil action level to dose (a true normalization), as well as dose to soil action level.

The general technique taken to look at soil action levels was to identify the methods used for calculation at each facility. Whenever possible, parameters for Rocky Flats were put into the facility-specific calculation; or, input the facility parameters into Rocky Flats calculation; and then compare the magnitude of ratios after parameter replacement. This then resulted in soil action level to dose ratios that can be compared in pCi per gram per mR. It was *RAC*'s role to try to determine why that difference exists. Without exception, in every case it has to do almost exclusively with dose conversion factors and mass loading factors. Ms. Weber then stepped the Panel through the calculation made at Johnston Atoll, as shown in her presentation. After describing the calculation formulas used for both Johnston Atoll and Rocky Flats, it was interesting to see that although the original Johnston Atoll soil action level to dose ratio was 0.85 pCi/g/mR, and the original Rocky Flats soil action level to dose ration was 17 pCi/g/mR -- when determining the Johnston Atoll soil action level to dose ratio with Rocky Flats parameters, the resulting number was 17.8 pCi/g/mR. However, the key thing to remember is that *RAC* now knows *why* it is different.

In conclusion, the soil action levels at Rocky Flats are significantly higher than those at other facilities, even when normalized to dose. However, *RAC* understands the reasons for these elevated levels. The outcome of the RESRAD calculation is strongly controlled by a few parameters, and almost without exception, it is these parameters that affect the differences in the soil action levels for a unit dose between sites. These parameters are:

1. Dose conversion factor
2. Mass loading
3. Breathing rate

Task 1 has identified the input model parameters that are of primary importance in determining the soil action levels, so they can be carefully reviewed when completing Task 3, Inputs and Assumptions.

Panel Discussion:
One panel member reflected that Americium 241 is also a contaminant and asked why it is not being included in the calculations? Ms. Weber responded that it is primarily because it was not included at other sites. In most cases, only Pu239 was available for comparison. The panel member reflected that if americium should get off the site it could be a very significant factor in the future.

A panel member commented that it is fascinating that some of the other sites assume that Pu is in a soluble form, and it appears that Hanford may have made that decision, which is very different from Rocky Flats. Minutes from the Actinide Migration Studies indicate that as much as 90% of the Pu in the soil at Rocky Flats is in organic form and therefore is susceptible to being soluble. There was some discussion of that information at a later date, but this issue clearly needs to be further explored to determine the basis for that information.

An ex-officio member of the Panel indicated that Hanford used the default RESRAD parameter for solubility, and they, like us, will be revisiting this issue for years.

BREAK

REVIEW OF SCENARIO DEVELOPMENT* - Discussion Lead: Dr. Kathleen Meyer, *Risk Assessment Corporation*
*Copies of presentation available by calling Anna Corbett - 303-456-0884

Dr. Meyer distributed a folder of references on breathing rates and soil ingestion. Although this is not comprehensive, it does provide extensive resources for in-depth information on this topic. She then provided an update to the Panel on scenario development. *RAC* is continuing to develop and revise scenarios. Uncertainty distributions are being generated for breathing rates using a range of reports and data, including a reference provided in a recent report by Joe Goldfield. In addition a scenario featuring a current Rocky Flats worker has been added, per the suggestion of LeRoy Moore. The rancher scenario that was discussed at the last meeting has been modified to a residential scenario. Dr. Meyer also reiterated the importance of breathing rates in scenario development and reviewed the formula used for estimating breathing rate. Several studies were reviewed to provide the Panel with a better understanding of some of the key parameters and conditions used in those studies. A chart was also provided to illustrate the typical daily time budget of adults that may also be helpful when discussion and developing project scenarios. Dr. Meyer also provided some discussion regarding a newer approach to estimating breathing rates that is based on basal metabolism and measures food-energy intakes and energy expenditures. This newer method is based on oxygen uptake associated with energy expenditures and a ventilation rate that relates minute volume to oxygen uptake. The 1993 Layton studies used statistics on basal metabolic rate, food intake, body weight and physical activities to calculate breathing rates. Highlights of several of the better-known studies were also discussed. In summary, Dr. Meyer reminded the group that it is important to use a wide range of references and studies to compile information on parameters. A distribution of values using Monte Carlo techniques can be generated. This approach considers available studies equally. Two additional scenarios were included in the handout materials for review and consideration: resident and current on-site worker. These tend to be a little conservative but are not unrealistic. The data incorporates some key elements including outdoor activity. Based upon discussions at and since the last meeting, it may be more realistic to consider a residential scenario rather than a rancher scenario. It would also be reasonable to look at an onsite worker scenario as well.

Panel Discussion:
Dr. Meyer briefly responded to the written questions received from DOE-RFFO: One question asked for an explanation of the methodology used for the resident rancher -- why was a resident rancher chosen? Dr. Meyer responded that it is her opinion that it is not unreasonable to consider the potential for future resident ranching at the site. In addition, it is important to consider the potential for a child being at the site as well and reflect how those numbers are gathered and evaluated. Detailed responses to the DOE-RFFO questions will be provided in writing.

The Panel inquired as to what timeline we are looking at for scenario development. Dr. Meyer replied that a section on scenario development will be included in the Task 2 report due in March, but most of the scenario development will be part of the Task 3 report. Scenario development should be completed by the June meeting.

PUBLIC COMMENT

A member of the public requested clarification from page 7 of the Task 1 Report. The report references a change in the Rocky Flats dose conversion factor -- was that a single factor that was changed or were multiple factors changed? Ms. Weber replied that factors for both inhalation and ingestion were changed.

ANNOUNCEMENTS

Ken Korkia briefly reviewed the peer review schedule and compensation schedule. Copies of the Letter of Agreement that details compensation are available to any interested parties.

Panel members were asked to provide comments to Carla Sanda at the AIMSI office no later than close of business on Monday, March 8, 1999. Those comments will then be transcribed and delivered to *RAC* representatives at the March 11 meeting.

A conference call will be scheduled with the Peer Review Team -- if any panel members are interested in participating in this call, please call either LeRoy Moore, Carla Sanda, or Ken Korkia. Both Joe Goldfield and Robert Kanick indicated immediate interest in participating. Available dates will be explored for this conference call.

FUTURE AGENDA ITEMS

- Discussion of Joe Goldfield paper
- Discussion on codes
- Report from RFCA regulators
- Scenario Development/Selection/Credibility Issues
- Discussion regarding comments from the Panel to *RAC*; i.e., what process should be in place to assure that *RAC* clearly knows what comments have been approved by the Panel for them to act on versus comments that were merely discussion points at the meeting

MEETING WAS ADJOURNED AT 7:00 P.M.

Upcoming Meetings & Activities

All future meetings will be held from 4 - 7 p.m. at the Broomfield City Building, One Descombes Dr., Broomfield, CO - Zang's Spur/Bal Swan Conference Rooms, on the following dates:

March 11	April 8	May 13	June 10	July 8
August 12	September 9	October 14	November 11	

Public Meeting - March 10, 1999 - 6:30 - 9:00 p.m. - Westminster City Hall

NOTE: The previously-elected Steering Committee, made up of: Mary Harlow, Hank Stovall, Leroy Moore and Lisa Morzel routinely meets each Monday prior to the regularly scheduled meeting to plan the agenda. Panel members may attend this meeting. To confirm meeting date, time and place, please contact either Mary Harlow or Hank Stovall.

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	Carl Spreng	CDPHE	303-692-3358	303-759-5355
P	Dean Heil	CSU	970-491-6516	970-491-0564
C	John Till	RAC	803-536-4883	803-534-1995
C	Kathleen Meyer	RAC	970-229-0828	970-229-0829
	Autar Rampertaap	DOE HQ	301-903-8191	301-903-3877
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	Jessie Roberson	DOE/RFFO	303-966-2025	303-966-6054
	Russell McCallister	DOE	303-966-9692	303-966-3710
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SP	Bob Kanick	RFCAB	303-444-0049	e-mail or call
E	Ken Korkia	RFCAB	303-420-7855	303-420-7579
A	Tom Marshall	RFCAB	303-444-6981	303-444-6523
SP	LeRoy Moore	RMPJC	303-444-6981	303-444-6523
	Deanne Butterfield	RFLII	303-940-6090	303-940-6088
	Will Neff	RFLII	303-940-6090	303-940-6088
P	Joel Selbin	UCD Chem Dept	[redacted]	303-492-5894
P	Todd Margulies	TM Consulting	303-279-6699	Mail or e-mail
P	Joe Goldfield	CCANW	303-321-7276	Mail or e-mail
C	Laura Till	Facilitator		303-447-0077

(SP=Steering Committee Panel Member, P=Panel Member, A=Alternate, E=Ex-Officio, C=Contractor), List Revised 2/18/99

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TO: RSALOP Members
FROM: V Holm
SUBJ.: RSAL regulatory guidance
DATE: February 9, 1999

The RFCA parties have recently convened a working group to examine the regulatory basis for soil action levels. They are discussing the regulatory basis and the applicable guidance for the SALs. They will also examine what factors should be considered in adapting institutional controls and ALARA. Both the EPA and the NRC have released regulatory guidance documents that address these questions in detail and the working group is examining these. A list of the NRC documents are attached. The panel may wish to have someone from the working group update the panel on their progress.

These questions are receiving attention across the complex. At the Nevada Test Site RESRAD was used initially; but, now the State of Nevada is studying whether the NRC regulations are more appropriate. Several other sites are also considering the NRC guidance. A recently formed working group at the national level will also, in part, examine the technology available to assist in implementing this guidance. The main advantage of using existing guidance instead of using ad hoc values chosen by the panel is it would add credibility to the process. The original RSAL's did not have this type of guidance giving the panel an advantage if it adopts the new guidance.

My other concern is early in the process of establishing the RSALOP it was decided that the study should be an independent creditable scientific process with substantial public input. The ongoing work being performed by RAC is going well; but, the panel has yet to decided the type and extent of its input into the process. The panel has also not addressed how it will convince the RFCA parties and the general public that its result have more creditably than the existing RSALs. This work is not specifically within the scope of the RAC contract and we should not assume that they will undertake the task.

RAC is presently examining the parameters to be used in the modeling. Many of these parameters will be based on published, peer reviewed, accepted values. Neither RAC nor the panel will likely wish to change these parameters. A few parameters are be based on behavioral or subjective values. These are the parameters that RAC has suggested the panel may wish to have input. The other area the panel could have input is in the selection of the scenarios. These scenarios and parameters can result in very large changes in the value of the SAL. If the panel uses this opportunity for input in an arbitrary or cuprous manner they risk losing credibility with the RFCA parties.

I am concerned that the panel is not keeping ahead of the work that RAC is doing. I am also concerned that the level of presentation being given by RAC at the meetings is too superficial. During the monthly meetings routine business and updates from RAC consume most of the time, leaving little time for the detailed education and lengthy discussion necessary if the entire panel is to make decisions on scenarios and parameters. There would seem to be two options open to

96

the panel:

- We can ask RAC to use its professional judgment to select which scenario and parameters to use. This is within the scope of the present contract. RAC would then justify the choices based on the guidance discussed above. I believe this work could also be integrated into the contract without requiring a change in scope. The panel would then ratify the Soil Action Levels recommended by RAC.

- We can ask RAC to run many different scenarios using parameters suggested by panel members. This will result in many different SALs. The panel would then chose the final SAL. The most credible way of making this choice would be for the panel to examine the guidance discussed above. If the panel chooses this course it will require much more time than the panel has presently allocated in its schedule.

I recommend that the panel discuss these options or others at Thursday's meeting. .

Attachment

<u>10CFR Part 20 Radiological Criteria for Licence Termination</u> : requires that certain criteria must be meet before institutional controls can be considered. It also specifies that a formal ALARA process must be performed.

<u>NUREG-1549 Decision Methods for Dose Assessment to Comply with Radiological Criteria for License Termination:</u> Specifies twelve steps that must followed be before a SAL is accepted. Specifies the justification that is required before site-specific parameters can be used.

<u>DG-4006 Demonstrating Compliance with the Radiological Criteria for License Termination:</u> Discusses the steps needed to be followed before institutional controls can be adapted. Specifies the protocols and sampling procedure to be followed to determine when the SALs are meet. This guide also gives detailed cost formulas to be used in order to prove that ALARA has been meet.

<u>NUREG-1575 Multi-Agency Radiation Survey and Site Investigation Manual</u> : Discusses the survey and statistical methods to be used to determine what areas need to be cleaned and to determine compliance.

<u>NUREG-5512 Residual Radioactive Contamination from Decommissioning</u> Specifies the models to be used or if other models are used what justification is needed.

97

RFCA RSAL Working Group Meeting Minutes
December 16, 1998

NOTE: During the working group review of these meeting minutes, some members of the RRWG felt that some areas of the minutes contained insufficient detail to describe the discussion that occurred during the actual working group meeting. Rather than attempt to revise the meeting minutes, the RRWG members agreed to addend comments from RRWG members to the meeting minutes. The addendum is not subsidiary to the original minutes, but is added to further clarify points made during the original discussion.

Mission Reminder
The Rocky Flats Cleanup Agreement (RFCA) Radionuclide Soil Action Level (RSAL) Working Group (RWG) is tasked with evaluating new information and determining its impact to the RSALs. (See, RFCA paragraph 5 and the Responsiveness Summary for Soil Action levels released on November 6, 1996.) This includes developing an understanding of how the information impacts the RSALs. The RWG will evaluate the pluses and minuses of different approaches to developing RSALs.

Attendance
The RWG convened on December 16, 1998 at EPA. In attendance for DOE was Russell McCallister; attendees for EPA were Tim Rehder and Mark Aguilar; attendees for CDPHE were Steve Gunderson, Diane Niedzwiecki, Edd Kray, Tom Pentecost, and Carl Spreng; attendees for the Kaiser Hill Team were Laura Brooks, John Corsi, and Rick Roberts. Also in attendance were Flo Phillips, Kaiser-Hill; and the following members of the public: Victor Holm, Lydia Stinemeyer, Joe Goldfield, and Hank Stovall.

Tim Rehder and Steve Gunderson opened the working group meeting by providing an overview of why the RWG was formed and what the mission of the RWG is. Everyone acknowledged that the working group meetings are working sessions. Ideas and viewpoints discussed during the work sessions are not necessarily representative opinions of the RFCA Parties or the Kaiser-Hill Team. Open discussions are encouraged to assist the RWG in its goal of evaluating new information and determining its impact to the RSALs as well as the RWG evaluation of the pluses and minuses of the different approaches available to deriving an RSAL. While members of the public are invited to the technical working sessions, it is acknowledged that not all items and/or issues the public may wish to discuss are appropriate for the technical working group sessions and that another forum may be provided to the public to discuss items and/or issues that are outside the RWG. It is anticipated that at some point in the future, the RFCA Parties will provide some type of document that will summarize the FY99 efforts of the RWG. This document may include recommendations to the RFCA Parties and/or RFCA Principals.

Members of the public requested that information previously provided to the Agencies also be reviewed, including papers provided to the RFSALOP. The RWG has these documents and will include them in the RWG review. Questions were raised on the status of NUREG 1500. This NUREG has been revised and replaced by DG-4006, which is under review by the RWG.

Agenda
Review/approval of RWG Meeting Minutes – 11/24/98
Report from the NRC Workshop held December 1 through 2, 1998
Continuation of RWG Action 1, Conduct a Regulatory analysis
Discussion on application of NRC rule and ALARA to RFCA and the Rocky Flats Vision
Update on Actions
Other Items
Path Forward

Review/Approval of RWG Meeting Minutes – 11/24/98
The RWG reviewed and approved the meeting minutes from the November 24, 1998 meeting with the following clarification to the discussion on Annual Average PM-10 Values: (1) not all RWG members agree with the approach taken in 1996 to select the amount of resuspended dust in the air; and (2) the PM-10 sampler, i.e., the air monitor that provided data selected for the amount of resuspended dust in the air,

98

was located upwind of the Standley Lake surface water construction site and may not be representative of a residential scenario.

The RWG decided to make the clarification as part of the meeting minutes for the December 16, 1998, working group meeting rather than revise the meeting minutes from November 24, 1998.

Report from the NRC Workshop held December 1 through 2, 1998
Rick Roberts attended the public NRC Workshop on License Termination Criteria held on December 1 through 2, 1998. The workshop is the first of six workshops being hosted by the NRC on this topic. The next workshop will be held on January 21 through 22, 1999. The workshop attendees included NRC licensees, EPA HQs, DOE HQs, and DOE contractors. The major points from this workshop were:

1. The NRC has stated that the NRC radiation dose-based methodology is currently applicable to licensees desiring license termination.
2. Licensees can use the screening levels in the DandD code as cleanup criteria.
3. NRC has not published screening level cleanup criteria for soils other than to have the DandD code available for use.
4. The parameters within the DandD code are very important and need to be examined closely during the next year. The entire first day of the next five workshops will be on parameter selection within the DandD code.
5. There will be a two-day workshop dedicated to the ground water modelling module within the DandD code.
6. Soil assessment was not discussed extensively during the workshop. Most discussions centered on building cleanup criteria.
7. The RESRAD code may be used to calculate cleanup criteria with adequate parameter justification.
8. The Electric Power Research Institute (EPRI) is currently comparing the RESRAD code with the DandD code. A draft report on this comparison can be found on the NRC's license termination home page.

Continuation of RWG Action 1, Conduct a Regulatory Analysis/ Discussion on application of NRC rule and ALARA to RFCA and the Rocky Flats Vision

The RWG started discussing in-depth the final NRC rule. To analyze the rule, the discussion was started with a brief explanation of a traditional CERCLA Applicable or Relevant and Appropriate Requirements (ARARs) analysis and a recommendation that the rule should be analyzed and the analysis summarized following a traditional CERCLA ARARs analysis approach. First, the definitions of applicable requirements and relevant and appropriate requirements were discussed.

Applicable requirements means those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable. 40CFR300.5

The basic criterion for an applicable requirement is that it directly and fully addresses or regulates the hazardous substance, pollutant, contaminant, action being taken, or other circumstances at a site. Applicability is established by the terms of the laws and regulations promulgating the requirements being analyzed. To determine whether a particular requirement would be legally applicable, it is necessary to refer to the specific terms or jurisdictional prerequisites of the statute or regulation. All pertinent jurisdictional prerequisites must be met for the requirement to be applicable. (See, Guidance from the CERCLA Compliance with Other Laws Manual, EPA/540/G-89/006, August 1988 (EPA 1988), section 1.2.4.2 General Procedure for Determining if a Requirement is Applicable.)

Relevant and appropriate requirements means those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not "applicable" to a hazardous substance, pollutant,

99

contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate. 40CFR300.5

The basic considerations for determining whether a requirements is relevant and appropriate are whether the requirement (1) regulates or addresses problems or situations sufficiently similar to those encountered at the CERCLA site, and (2) is appropriate to the circumstances of the release or threatened release, such that its use is well suited to the particular site. (See, EPA 1988, section 1.2.4.3 General Procedure for Determining if a Requirement is Relevant and Appropriate.)

Guidance from EPA 1988 was handed out, including two flow charts outlining: (1) the General Procedure for Determining if a Requirement is Applicable and (2) the General Procedure for Determining if a Requirement is Relevant and Appropriate. The RWG discussed that a requirement may be relevant but not appropriate for a specific site. Only those requirements that are determined to be both relevant and appropriate must be complied with. While some requirements within a regulation will be relevant and appropriate, other requirements in that same regulation may be relevant (in that they address in a broad sense the same problem as faced at the CERCLA site), but not appropriate because the requirement is not well-suited to the circumstances at the CERCLA site, or to the threat to human health and the environment posed by the circumstances of the release.

Factors relating to origin and objective of the requirement in question, i.e., NRC Radiological Criteria for License Termination:
Specific goals and objectives of the requirement
Purpose of Requirements in Program of origin
Media Regulated/Affected by Requirement
Substances Covered by Requirement
Entities Regulated/Affected
Action or Activity Regulated by Requirements
Variances, Waivers, or Exemptions of Requirement
Type of Physical Location Regulated or Affected
Type of Structure or Facility Regulated or Affected
Requirement's consideration of use or Potential Use of Affected Resources

Factors Relating to Problem present at CERCLA Site or Operable Unit that Must be Addressed by Remedial Action:
Specific Goals and Objectives of CERCLA Remedial Action at site
Use of requirement at Site consistent with Purpose
Media contaminated/Affected by Cleanup
Substances Involved at Site
Entities Affected
Remedial Action Contemplated at the Site and Duration of Activity
Circumstances at Site-Do they fit requirements for variances, waivers or exceptions
Type of Physical Location Involved
Type of Structure of Facility Involved
Use or Potential Use of Resources Involved

20.1401 General Provisions and Scope
10 CFR section 20.1401, provides the general provisions and scope of Subpart E, Radiological Criteria for License Termination. **Section 20.1401(a)** states that "the criteria in this subpart apply to the decommissioning of facilities licensed under parts 30, 40, 50, 60, 61, 70, and 72 of this chapter, as well as other facilities subject to the Commission's jurisdiction under the Atomic Energy Act of 1954, as amended, and the Energy Reorganization Act of 1974, as amended . . . ."

The Rocky Flats Environmental Technology Site is not an NRC facility licensed under parts 30, 40, 50, 60, 61, 70 or 72. RFETS is not subject to the Nuclear Regulatory Commission under the Atomic Energy Act of

/100

1954, as amended, or the Energy Reorganization Act of 1974, as amended. Therefore, RFETS does not meet the criteria in (a).

10 CFR section 20.1401(b) states that the criteria is this subpart do not apply to sites that have been decommissioned prior to the effective date of the rule; or have previously submitted and received NRC approval on a License Termination Plan. RFETS does not meet the criteria is (b).

Because the NRC, Subpart E, Radiological Criteria for License Termination, jurisdictional prerequisites are not met at RFETS, the RWG has agreed that Subpart E, Radiological Criteria for License Termination, is not applicable to RFETS.

However, the RWG has agreed that the NRC rule is relevant to RFETS. RFETS has soil that may contain radioactivity due to the possession or use of source, byproduct, or special nuclear material that is distinguishable from background radiation. The NRC amended its regulations regarding decommissioning of licensed facilities to provide specific radiological criteria for the decommissioning of lands and structures. The NRC will apply these criteria in determining the adequacy of remediation of residual radioactivity resulting from the possession or use of source, byproduct, and special nuclear material. The RWG believes that the NRC rule may be appropriate to RFETS since RFETS may have media contaminated by substances covered under the NRC rule and because there is not a promulgated regulation that is available that more fully matches the circumstances at RFETS. The RWG acknowledges that EPA HQ may have some concerns over the protectiveness of the NRC rule.

10 CFR section 20.1401(c): After a site has been decommissioned and the license terminated in accordance with the criteria in this subpart, the Commission will require additional cleanup only if, based on new information, it determines that the criteria of this subpart were not met and residual radioactivity remaining at the site could result in significant threat to public health and safety.

An NRC requirement for additional cleanup after a site has been decommissioned if, based on new information, it is determined that the criteria of this rule were not met and residual radioactivity remaining at the site could result in significant threat to public health and safety is relevant to RFETS. This requirement is consistent with the specific goal and objective of the requirement, i.e., to provide specific radiological criteria for the decommissioning of lands and to apply these criteria to determine the adequacy of remediation of residual radioactivity resulting from the possession or use of source, byproduct, and special nuclear material. The requirement impacts the media regulated and substances covered by the rule.

However, some members of the RWG question whether the requirement is appropriate to RFETS. There are environmental laws and requirements that may more fully match the circumstances (i.e., the need to require additional cleanup based on new information that the residual radioactivity remaining at the site could result in significant threat to public health and safety). For example, CERCLA and the NCP require a review of sites where the selected remedial action results in any hazardous substance, pollutants, or contaminants remaining at the site no less than every five years. See, 42 USC9621(c), Cleanup Standards – Review and 40CFR300.430 (a)(5)(iii)(C), RI/FS and Selection of the Remedy – Documenting the Decision. A similar requirement is also found in RFCA Paragraph 254. In addition, CERCLA and the NCP would also address significant threats to the environment.

10 CFR section 20.1401(d): When calculating TEDE to the average member of the critical group the licensee shall determine the peak annual TEDE dose expected within the first 1000 years after decommissioning.

The RWG discussed sections 20.1401(d) and 20.1402 jointly. Many questions were raised and the RWG agreed that further discussions were needed at the next RWG working group meeting. The original RSALs considered a Reasonable Maximally Exposed (RME) individual. This is consistent with approaches taken at CERCLA sites. The RWG needs to evaluate the RME approach and the TEDE to the average member of the critical group approach to understand the differences and perhaps recommend one over the other, some combination, or some approach that the RWG believes will be best for RFETS. The original RSALs considered the peak dose expected within the first 1000 years. The RWG needs to evaluate what the 1000-

year period after decommissioning under the NRC rule means to RFETS. This necessitates further discussions on future land use at RFETS and possible institutional controls. The RWG recognizes that there are other organizations involved with the closure of RFETS that are evaluating future land use and institutional controls.

20.1402 Radiological criteria for unrestricted use.
A site will be considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a TEDE to an average member of the critical group that does not exceed 25 mrem per year, including that from groundwater sources of drinking water, and the residual radioactivity has been reduced to levels that are as low as reasonably achievable (ALARA). Determinations of the levels which are ALARA must take into account consideration of any detriments, such as deaths from accidents, expected to potentially result from decontamination and waste disposal.

The RWG had many questions on this section, including the questions raised in the section 20.1401(d) discussion. Other questions included: Is unrestricted use (25 mrem) the goal? Why or why not? Should, and if yes, how are dose(s) from ground water and surface water incorporated? Is ALARA required at RFETS? If yes, how will ALARA be determined at RFETS? How does the 15 mrem required in RFCA Attachment 5 impact/relate to the NRC rule. How are other sites in Colorado approaching similar requirements, e.g., can anything be learned by looked at radium and/or uranium cleanups? Should land use assumptions made today be assumed for the 1000 year period?

The Working Group agreed to continue discussions on the NRC rule at the next RWG working group meeting. The discussions will continue to look at the rule section by section. The RWG agreed that there is a benefit to going through the detailed process because it aids the RWG members in their understanding of how the NRC rule impacts the RSALs and the pluses and minuses of the different approaches to developing RSALs.

Update on Actions
•EPA prepared a draft Radiation Risk Assessment Guidance document in 1996. Tim Rehder reported that the document is currently being reworked at EPA HQ and that there is an EPA HQ directive stating that the document is not to be used. Tim has the action to obtain a copy of the document and provide copies to members of the RWG as a historical reference.

Copies provided to the RWG on December 16, 1998.

•In 1997, there was an effort among the NRC Agreement States, which includes Colorado, to draft a letter to EPA stating the Agreement States disagreement with EPA's regulatory approach in draft 40CFR196 and OSWER Directive 9200.4-18. Tom Pentecost has the action to follow-up on whether such a letter was ever finalized and, if so, did representatives from the State of Colorado sign the letter.

To date, representatives from the State of Colorado have not signed a letter on this subject.

•EPA and DOE representatives have the action to share information with their respective Headquarters (HQ) personnel on the approach the RWG is taking for the evaluation on the approaches available for the derivation of RSALs. While HQ timely approval is desirable, the RWG will not stop its efforts while awaiting approval. The RWG acknowledges that the respective HQs may have comments later in the process.

Ongoing.

•Tim Rehder has the action to contact EPA HQ and get a BEIR (Biological Effects of Ionizing Radiation) status update.

Contact has been made. On December 17, 1998, Tim forwarded an e-mail message to Laura Brooks that stated that the BEIR VII study began in November 1998 and is a three-year study. The National Academy of Science is finalizing the members of the Academy committee that will be performing the study. The

102

progress of the study will be posted on a regular basis on the web beginning in January (www.nas.edu). Laura Brooks forwarded the message to the RWG on December 17, 1998.

•DOE and the Kaiser-Hill Team have prepared a list of questions for the RFSALOP co-chairs. These questions arose during the RFSALOP meeting on November 12, 1998. John Corsi has the action to forward these questions to the RWG. The RFCA Parties may decide to send the questions in a letter jointly to the RFSALOP co-chairs or DOE may decide to send the questions in a letter independently.

These questions were forwarded to the RWG. DOE sent the questions to the RFSALOP Co-Chairs.

•For actions regarding the average annual PM-10 values for Laura Brooks and Diane Niedzwiecki, see above.

Discussions will continue at the next RWG meeting.

•All RWG members have the action to re-read the final NRC rule, Radiological Criteria for License Termination dated July 21, 1997.

•All RWG members have the action to review the Draft Regulatory Guide DG-4006, Demonstrating Compliance with the Radiological Criteria for License Termination.

•All RWG members have the action to re-read OSWER Directive 9200.4-18, Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination.

The above three actions were completed and further discussions will occur at the next RWG meeting.

•Tom Pentecost has an action to provide Diane Niedzwiecki the NRC website.

Complete.

•The Draft Fact Sheet requested by DOE addressing cleanup levels at other sites and frequently asked questions was forwarded to all members of the RWG. Initial comments were discussed. At a minimum, the RWG recommended separating the information into two separate documents. All RWG members have the action to provide comments to John Corsi by December 1, 1998.

Complete.

•Edd Kray has the action to reach a contact that he knows regarding information on the Johnston Atoll.

Complete

•For actions regarding the bio-availability of plutonium for Laura Brooks and Rick Roberts, see above.

Actions are in progress; additional information will be shared at the next RWG meeting.

New Actions
Rick Roberts will track information on the next NRC Workshop currently scheduled for January 21 through 22, 1999. Rick will let all RWG members know when the date and agenda have been finalized for the workshop.

Diane Niedzwiecki has the action to provide the RWG with a definition of "Reasonable maximally Exposed" (RME) individual.

Rick Roberts has the action to provide the RWG with a definition of "average member of the critical group."

Other Information

•Tom Pentecost reported that CDPHE is planning on presenting the decommissioning standards used by the NRC to the Colorado Board of Health in January 1999 for adoption in Colorado. Once the State of Colorado adopts decommissioning standards, the standards will be reviewed by the RFCA Parties during the annual review process required by RFCA paragraph 5.

•Edd Kray provided new information on the cleanup at the Johnston Atoll. Edd provided a partial handout on "Independent Verification of Plutonium Decontamination on Johnston Atoll (1992-1996)" from the Oak Ridge National Laboratory (ORNL/TM-13397). The ORNL tam performed an independent verification of the cleanup levels previously calculated. The established cleanup criteria is 500Bq of TRU elements/kg of soil (approximately 13pCi/g).

The independent verification was accomplished by review of the rationale and calculations used to derive the cleanup levels at JA. The level was compared to EPA's Proposed Guidance on Dose Limits for Persons Exposed to Transuranium Elements in the General Environment, 1988. The calculations were performed exclusively for an inhalation pathway; other exposure pathways were excluded. ORNL concluded that the cleanuplevel of 13 pCi/g "are within established regulatory guidelines and provide an adequate level of protection to the worker, the public, and the environment at JA." They also concluded that: "this is an acceptable cleanup standard, based on comparison to cleanup guidelines at similar sites."

•Carl Spreng provided new information on the cleanup at the Johnston Atoll. The following information came from Ray Arguello, a health phycisist with Coleman Research, who used to be a project manager at the atoll, and Dr. John Estrel with the Defense Threat Reduction Agency – Pu Remediation Project, which oversees the cleanup. Capt. David Rynders is the current manager for the agency. Pu contamination at the atoll resulted from 3 accidents in 1962: the destruction of 2 off-course rockets at high altitude and 1 on-pad explosion. Other contaminants include dioxin, Agent Orange, and oil. The original remedy was to push the upper 4 inches of soil in some areas into a lagoon and to pave over other areas. The 13.5 pCi/g originated in a 1988 or 1989 document and is currently being revised. In a contract that began October 1, 1998, GeoCenters is reviewing and revisiting the cleanup levels using "more realistic" receptors (e.g., eco-tourists, part-time caretaker). A draft of their report is due in March 1999. US Fish & Wildlife will eventually manage the atoll, beginning about 2002.

The next RFSALOP Meeting is scheduled for January 14, 1999, from 4:00 to 7:00 at the Broomfield City Hall.

The next RWG meeting is scheduled for January 13, 1999, at 9:00 at the Rocky Flats Environmental Technology Site in Building 460, conference room 122.

The proposed agenda for the next meeting is:

Review of 12/16/98 Meeting Minutes
Update on Actions
Completion of RWG Action 1, Conduct a Regulatory Analysis
Discussion on application of NRC rule and ALARA to RFCA and the Rocky Flats Vision (This is a continuation of the detailed review of the NRC rule started on December 16, 1998.)
Other Items
Path Forward

The following are a series of three e-mail messages that the RRWG members agreed to add to the meeting minutes. This addendum is not subsidiary to the original minutes, but is added to further clarify points made during the original discussion.

Brooks, Laura

From:	TOM PENTECOST [wtpentec%smtpgate.dphe.state.co.us@inet.rfets.gov]
Sent:	Friday, January 15, 1999 10:26 AM
To:	Edd.Kray@smtpmta.rfets.gov; Laura.Brooks@exchange.rfets.gov
Cc:	dmniedzw%smtpgate.dphe.state.co.us@inet.rfets.gov;

104

sgunders%smtpgate.dphe.state.co.us@inet.rfets.gov

Subject: WG Minutes -Reply

I would like to reinforce the comments made by Mr. Kray. The topics covered are difficult and may at times be the subject of considerable controversy. It is essential that the minutes keep track of the discussion of the "difficult issues". After all, we are having these meeting to deal with the hard issues.

>>> <Edd.Kray@rfets.gov> 01/15/99 09:15am >>>

Thanks for the preliminary copy of the WG minutes. Looking at the minutes, I have several comments and requests for expansion in some areas, as follows. Suggested additions in wording are "bolded":

1) In terms of general format and content, an observation is that, often times, the WG notes go beyond the actual group discussion in terms of citing information which was not part of the actual discussion within the group. For example, the minutes on the bottom of page 2 and first 2/3 of page 3, dealing with the definitions of relevant and appropriate contain much legal background info on the interpretation of these terms, with concepts and background which were not discussed at the meeting itself. Although the material is important to the group and factually accurate, I question if it is appropriate for the minutes to go off in this direction at the expense of describing what was actually discussed by the meeting attendees.

My perception is that a description of issues actually discussed by the group has been abbreviated and background material such as in this section has replaced a detailed description of the dialogue.

In the future I would recommend that background information, not discussed at the meeting but felt necessary for clarity of the minutes be somehow designated as such within the minutes. We could use quotation marks for items actually discussed by the group; or separate items not discussed by brackets; or add these items as footnotes to the description of items discussed by the WG. We do need to separate the groups' discussions from the background information in some way.

2) During the discussion of relevance of the NRC rule (sec 20.1401) we noted that: Tom Pentecost reported that the Colorado Rules and Regulations Pertaining to Radiation Control will be modified to include the provisions of the NRC rule on decommissioning. The modification to the state regulations should go to the Board of Health for adoption next year and will include the 25 mrem dose based criteria for land and structures.

3) (Under 20.1402) Since discussion this section took up the majority of the meeting, it seems that more than one paragraph should be devoted to it within the meeting minutes. My notes and I have recollection of the following discussions:

The NRC rule requires that annual doses not exceed 25 mrem over a 1000-year period from completion of decommissioning. The group discussed the implications of this requirement and the need to choose input parameters for dose modeling with this criteria in mind. Some members believe that this principle needs to be considered when current site data is proposed for use as input criteria in the dose modeling. Current data will not likely be the most reasonably conservative when viewed over the required 1000-year period.

The criteria to use "current land uses" in dose modeling were also noted as inconsistent with the need to model for the reasonable maximally exposed individual over the 1000-year period. Although we can not accurately predict land uses far into the future, it is likely that they will change and conservative assumptions on these changes were felt to be necessary by some in devising scenarios to be consistent with the 1000-year criteria. The group discussed how the 1000-year criteria are used in devising reclamation plans for NRC/State regulated uranium facilities. Modelers must look at climatologic and geological changes which might occur over the period, including erosion and stream or groundwater flow and usage. What extremes in weather might occur to provide for higher doses in future years? Would "dust bowl" conditions such as in the 1930's be likely to occur again?

I don't have good notes on our discussion of RME vs AMCG but remember we spent quite a bit of time on this issue. Shouldn't we have more in the minutes?

Discussion took place on the need for incorporation of water borne pathways into the dose analysis. In a residential farming scenario, where will residents obtain their water supply? Is the assumption that groundwater onsite is inadequate in quantity and quality correct? If so, how much surface water could be used by an onsite resident? The historical existence of a ranch, the Lindsey ranch, onsite was proposed as evidence that resident farming is a credible scenario and that such residents would need to find a water source which could contribute to water ingestion Doses and/ or doses from other water-borne paths such as irrigation. Stock watering, fish ingestion and so forth.

I remember Tom Pentecost asking who has the job of advising the governors office and DOE HQ of the fact that the regulatory basis for RFCA has changed and that this will likely require some changes in RFCA itself. How should we word this discussion in our minutes?

On Page 5, near the middle of the page: "To date, representatives from the state of Colorado have not signed a letter on this subject." we should add that they have stated they concur [with the letter on EPA's regulatory approach]

In addition I recall a discussion on the OSWER directive: WG members discussed the OSWER directive: Inconsistencies from the OSWER directive were noted, specifically EPA seems to believe that 25 mrem (NRC) is inadequately protective vs the EPA 15 mrem standard. Still they fail to note that in terms of risk, 15 mrem (a 5x10-4 risk) is not consistent with the CERCLA limit of 1x10-4. Some WG members believed that if we are to be strict with the CERCLA standards rad risk needs to be held to the 1x10-4 level which equates with 3 mrem. (This would fit into the text after the statement on OSWER on p 5)

On p 4, where we discuss the 5 year CERCLA review I would like to see recount of the following discussion: In discussing the 5 year review cycle in CERCLA, some believed the provision was unrealistic in that no guarantee of this review exists. We do not know that the currently existing regulatory agencies will be in existence far into the future (1000 years), much less the current provisions of environmental law. Therefore, planning for a full cleanup which will assure compliance with the dose standards over the 1000-year period was seen by some as important.

Brooks, Laura
From: Roberts, Rick
Sent: Thursday, January 28, 1999 7:52 AM
To: Brooks, Laura
Subject: RSAL Working Group Meeting Minutes From 12/16/98

Your meeting minutes from the RSAL Working Group meeting on 12/16/98 look very good. I just have a few points I would like to add. These are:

1. The NRC and EPA use current land use and demographic data to assess the future use exposure scenarios at a given site for dose and risk assessment. I believe the reason for this is that speculative exposure scenarios could drive remediation levels to an unreasonable level.

106

2. There have been calculations to show that the ground water available on site would not support a hypothetical future resident. These calculations are reflected in the RFCA framework. Therefore, it is not appropriate to assess a ground water ingestion pathway when calculating RSALs.
3. Given the demographics of the Rocky Flats area, it is not reasonable to assume that a resident would construct a pond at Rocky Flats in the future and ingest all water from this pond. This type of resident is not consistent with the development occurring in the Denver-Boulder corridor.

If you have any questions or comments on the above, please call.

107

Department of Energy

ROCKY FLATS FIELD OFFICE
P.O. BOX 928
GOLDEN, COLORADO 80402-0928

FEB 8 1999

99-DOE-07780

Ms. Mary Harlow
City of Westminster
4800 West 92nd Avenue
Westminster, CO 80030

Dear ~~Ms. Harlow:~~ Mickey,

Enclosed are technical questions developed by Rocky Flats Field Office and Kaiser-Hill technical staff from the January 14 Radionuclide Soil Action Level Oversight Panel meeting. As usual, Site technical staff will try to meet with RAC prior to the February 11 meeting to discuss these questions informally.

Once again, thank you for all your efforts on behalf of a safer, better cleanup of Rocky Flats.

Sincerely,

Jeremy Karpatkin, Director
Closure Project Communications

Enclosure

DRAFT

TECHNICAL QUESTIONS ON RAC PRESENTATION ON JANUARY 14

1. The agencies in formulating the RSALs relied on the land use assumptions of the Rocky Flats Cleanup Agreement: the onsite office worker and open space user. These in turn were based on consensus community recommendations contained in the Future Site Use Working Group report and in CAB recommendations. As a basis for comparison, the agencies compared these scenarios to one of institutional control breakdown, defined as a residential scenario. At the January 14 RSAL OP meeting, the RAC briefed the RSAL OP on some potential exposure scenarios that RAC will analyze in the coming months. While realizing that these are not necessarily the final scenarios that will be chosen by the RAC, the initial scenarios do raise some questions. Please explain the methodology for choosing the use of the resident rancher, infant of resident rancher and child of resident rancher exposure scenarios. Why was a resident rancher chosen for assessment given the urban nature of the areas encroaching on Rocky Flats? Are these scenarios intended to be scenarios of institutional control breakdown or of reasonably anticipated future land uses? Does RAC believe that these scenarios more accurately capture institutional control failure than the scenarios analyzed by the agencies? If so, why? Does RAC believe the agencies erred in their determination of the reasonably anticipated future land use? Or does the RAC believe that clean up standards should not be based on reasonably anticipated land uses? If it is the latter, please explain what the basis for clean up should be other than reasonably anticipated land uses?
2. RAC has developed exposure parameter (i.e., breathing rate, soil ingestion rate, etc.) values to be used with their chosen exposure scenarios. RAC presented graphs on potential ranges for the breathing rate exposure parameter based on three studies. Given the range of studies available on this topic, including the studies surveyed in a 1997 EPA Handbook (see below) why did RAC choose these three studies? How did RAC choose a specific breathing rate from the range of values given in these three studies? What methodology was used to decide that these breathing rates were most appropriate to use at Rocky Flats? EPA's OSWER Directive 9285.6-03, "Human Health Evaluation Manual, Supplemental Guidance: 'Standard Default Exposure Factors'," dated 3/25/91, and in EPA's Exposure Factors Handbook (EPA/600/P-95/002F), dated August 1997, are considered by the Site to be authoritative studies in these areas. Can RAC explain why it chose not to reference these studies in developing exposure parameters?

Rocky Flats Soil Action Level Oversight Panel Meeting February 11, 1999

- Project update and issues: John Till
- Task I Report review: Jill Weber
- Scenario Update: Kathleen Meyer

RAC

PROJECT DELIVERABLES BY TASK

Task 1. Cleanup Levels at Other Sites

A draft report will be delivered by February 8, 1999.
A final report will be delivered by May 8, 1999.

Task 2. Computer Models

A draft report will be delivered by March 8, 1999.
A final report will be delivered in July 8, 1999.

Task 3. Inputs and Assumptions

A draft report will be delivered by July 8, 1999.
A final report will be delivered in October 8, 1999.

RAC

110

PROJECT DELIVERABLES BY TASK (CONTINUED)

Task 4. Methodology

Meet with Oversight Panel and present methodology (COMPLETED)

Task 5. Independent Calculation

A draft report will be delivered by September 8, 1999.
A final report will be delivered by November 8, 1999.

Task 6. Sampling Protocols

A draft report will be delivered by May 8, 1999.
A final report will be delivered by August 8, 1999.

RAC

PROJECT DELIVERABLES BY TASK (CONTINUED)

Task 7. Actinide Migration

Incorporate findings into final reports.

Task 8. Public Interface

Deliver the record of questions asked during the course of the project.

Task 9. Major Project Deliverables and Peer Review

A draft comprehensive project report will be delivered by October 8, 1999.
A final comprehensive project report will be delivered by November 8, 1999.

RAC

Other Issues

- Update on Task 2: Computer Models
- Plutonium solubility in soil at Rocky Flats
- Actinide Migration Panel meetings and interaction
- Communication
- Review of our task reports

112

Task 1: Cleanup Levels at Other Sites

Jill M. Weber
for *Risk Assessment Corporation*
February 11, 1999
Rocky Flats Soil Action Level Oversight Panel

RAC

Outline of Report

- Introduction
- Rocky Flats Soil Action Level Calculation
- Method of Comparison
- Action Levels at Other Sites
  - Hanford, Washington
  - Nevada Test Site
  - U.S. NRC DandD Code
  - Johnston Atoll, Marshall Islands
  - Enewetak Atoll, Marshall Islands
  - Maralinga, Australia

RAC

Outline, cont.

- Action Levels at Other Sites, cont.
  - Semipalatinsk Nuclear Range, Kazakhstan
  - Thule, Greenland
  - Palomares, Spain
- Conclusions

RAC

2/99 J.M. Weber

Comparison to RFETS

- Compare all concentrations at other sites to RFETS 85 mrem hypothetical future resident
  - level below which no cleanup is required, per DOE recommendations
  - full-time resident is the maximum exposure scenario, and is used at other facilities for similar purposes

RAC

2/99 J.M. Weber

Method of Comparison

- Because dose levels are different for every facility, sometimes chosen and sometimes calculated, the soil action level will always be normalized to dose for means of comparison:

$$\frac{Soil\ action\ level}{Dose} = Soil\ action\ level\ to\ dose\ ratio\left(\frac{pCi}{mrem}\right)$$

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General technique

- Identify calculational methods for each facility
- Input Rocky Flats parameters into facility-specific calculation, when possible.
- OR, input facility parameters into Rocky Flats calculation
- Compare magnitude of ratios after parameter replacement

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115

Ratios for comparison

Location	Soil action level to dose ratio
Rocky Flats	17
Hanford	2.3
Nevada Test Site	4.1
NRC remediation code	7.4
Johnston Atoll	0.85
Maralinga	0.56
Semipalatinsk	8.8
Palomares	12.3

RAC

2/99 J.M. Weber

Johnston Atoll Calculation

- Plutonium concentrations in the soil resulted from two accidents.
- Cleanup was completed and an independent verification of the cleanup was performed by Oak Ridge
- Calculated a Soil Screening Limit (SSL)

$$SSL = \frac{C_{air,acceptable}}{ML \cdot EF}$$

RAC

2/99 J.M. Weber

To calculate acceptable air concentration:

$$Dose = V_{inhaled} \cdot C_{air} \cdot DCF$$

$$C_{air} = \frac{Dose}{V_{inhaled} \cdot DCF}$$

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For Johnston Atoll (Wilson-Nichols et al 1997):

For a dose of 20 mrem, an air concentration of 0.0026 pCi m^{-3} was calculated (W-N 1997).

With a mass loading of 0.0001 g m^{-3} and an enrichment factor of 1.5, the SSL for Johnston Atoll was calculated to be 17 pCi g^{-1}.

This SSL is for a 20 mrem dose, so the soil action level to dose ratio is 0.85 (pCi g^{-1}) $mrem^{-1}$

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Insert RFETS parameters into JA calculation:

To calculate acceptable air concentration, maintain the JA dose of 20 mrem, use RFETS volume inhaled of 7000 m^3 y^{-1} and dose conversion factor of 0.308 mrem pCi^{-1} to obtain an air concentration of 0.0093 pCi m^{-3}.

Use this air concentration, mass loading of 0.000026 g m^{-3}, and enrichment factor of 1 to calculate SSL of 356 pCi g^{-1} for dose of 20 mrem.

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Johnston Atoll soil action level to dose ratio:

0.85 (pCi g^{-1}) $mrem^{-1}$

Rocky Flats soil action level to dose ratio:

17 (pCi g^{-1}) $mrem^{-1}$

Johnston Atoll soil action level to dose ratio with Rocky Flats parameters:

17.8 (pCi g^{-1}) $mrem^{-1}$

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Parameters changed:

- Volume inhaled (breathing rate): from 8395 m^3 y^{-1} to 7000 m^3 y^{-1}
- Dose conversion factor (calculated from JA acceptable air concentration, dose, and volume inhaled): from 0.91 mrem pCi^{-1} to 0.308 mrem pCi^{-1}
- Mass loading: from 0.0001 g m^{-3} to 0.000026 g m^{-3}
- Enrichment factor: from 1.5 to 1

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119

Table 9. Summary of Comparisons between RFETS Calculations and Those for Other Facilities

Location	Parameter change	Soil action limit to dose ratio ([pCi g^{-1}] $mrem^{-1}$)	Dose to soil action limit ratio (mrem [pCi g^{-1}]$^{-1}$)
Rocky Flats	Original calculation	17	0.06
Hanford	Original calculation	2.3	0.44
	Remove meat, milk, fish, and drinking water pathways and change to RFETS dose conversion factor and mass loading	34	0.03
Rocky Flats	Original calculation	17	0.06
	Change to NTS dose conversion factor	2.8	0.36
Nevada Test Site	Original calculation	4.1	0.24
Rocky Flats	Original calculation	17	0.06
	Change to NRC mass loading	4.6	0.22
NRC DandD Code	Original calculation	7.1	0.14
Rocky Flats	Original calculation	17	0.06
Johnston Atoll	Original calculation	0.85	1.2
	Change to RFETS mass loading, enrichment factor, and calculate air concentration using RFETS dose conversion factor and breathing rate	17.8	0.056
Rocky Flats	Original calculation	17	0.06
Maralinga	Original calculation	0.56	1.8
	Change to RFETS mass loading, breathing rate, dose conversion factor	17.8	0.056
Rocky Flats	Original calculation	17	0.06
Semipalatinsk Nuclear Range	Original measurement	8.8	0.11
Rocky Flats	Original calculation	17	0.06
	Change to Palomares breathing rate	14.1	0.07
Palomares	Original calculation	12.3	0.08

Scenario Development Update and Issues

Kathleen R. Meyer, Ph.D.

Rocky Flats Soil Action Level
Oversight Panel Meeting
February 11, 1999

Risk Assessment Corporation

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Update on Issues

- Continued to develop and revise scenarios
- Generated uncertainty distributions for breathing rates using range of reports and data, including reference Joe Goldfield cited in his report
- Added a current Rocky Flats worker scenario based on Leroy Moore's recommendation
- Modified the rancher scenario to a residential scenario

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Selected References for Breathing Rates Data

- Beyeler, W.E., T.J. Brown, W.A. Hareland, S. Conrad, N. Olague, D. Brosseau. E. Kalinina, D.P. Gallegos, and P.A. Davis. 1998. *Review of Parameter Data for the NUREG/CR-5512 Residential Farmer Scenario and Probability Distributions for the DandD Parameter Analysis.* Report JCN W6227. January 30.
- Finley, B., D. Proctor, P. Scott, N. Harrington, D. Paustenbach, P. Price. 1994. *Recommended Distributions for Exposure Factors Frequently Used in Health Risk Assessment.* Risk Analysis 533-553.
- Layton, D.W. 1993. *Metabolically Consistent Breathing Rates for Use in Dose Assessments.* Health Physics 64(1): 23-36.
- NCRP. 1984. *Radiological Assessment: Predicting the Transport, Bioaccumulation, and Uptake by Man of Radionuclides Released to the Environment.* NCRP Report No. 76: 208-217

123

Selected References (cont'd.)

- Roy, M. and C. Courtay. 1991. *Daily Activities and Breathing Parameters for Use in Respiratory Tract Dosimetry.* Radiation Protection Dosimetry. 35(3): 179-186.
- Silverman, L., G. Lee, T. Plotkin. L.A. Sawyers, and A.R. Yancey. 1951. *Air Flow Measurements on Human Subjects With and Without Respiratory Resistance at Several Work Rates.* Arch. Industrial Hygiene, Vol. 3: 461-478.
- Thompson, S.E., and W.A. Robison. 1983. *A Summary of Ventilation Rates as a Function of Age, Sex, Physical Activity, Climatic Conditions and General Health State.* Report No. UCRL 89037. Lawrence Livermore National Laboratory.
- U.S. EPA. 1989. *Exposure Factors Handbook.* EPA Report No. EPA/600/8-89/043. July.
- U.S. EPA. 1997. *Exposure Factors Handbook.* (Update to 1989 version). EPA Report No EPA/600/P-95/002FA.

Breathing Rates

- Affects the transport of airborne contaminants to the respiratory tract and also influences their deposition onto surfaces of the airways and pulmonary region
- A standard measure of respiration is called the *minute volume*, which is simply the volume of air that is exhaled in a minute (V_E).
- Historic approach is to calculate a time-weighted-average of ventilation rates associated with physical activities of varying durations

Estimating Breathing Rate

$$V_E = \frac{1}{T} \sum_{i=1}^{k} V_{E,i} t_i$$

V_E is the time-weighted-average minute volume (L min^{-1})

t_i is the duration of the ith activity (min)

$V_{E,i}$ is the corresponding minute volume

k is the number of activity periods

T is the total minutes of the exposure period (e.g. 1 hour, 10 min)

Silverman, Lee, Plotkin, Sawyers, and Yancey 1951

- Studied air flow characteristics of males for the design of protective respiratory equipment and pumps to simulate human breathing
- The study evaluated subjects at rest (sedentary) and riding bicycle ergometer at increasing work loads of 0, 208, 415, 622, 830, 1107, 1384, and 1660 kg-m
- Respiratory resistance (moderate and high) was added to inspiratory and expiratory measurements to simulate various breathing conditions

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Silverman et al. 1951 (cont'd)

- At each level, the maximum inspiration and expiration was determined to ensure design of respiratory equipment for maximum conditions.
- At rest (sitting on bicycle for 5 min) with minimum resistance, minute volume or breathing rate was 9.1 ± 1.3 liters per min; max air flow was 40 l/min.
- At maximum level and resistance, average breathing rate for athletes was 68 ± 11 liters per min, and for nonathletes 75 ± 11 liters per min; max air flow was about 200 l/min.

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M. Roy and C. Courtay, 1991

- Calculated ventilation parameters based on time budgets and activity of adults, teenagers, children and infants
- Used extensive surveys of time budgets of various age groups from studies in 1972, 1978, 1981 (30,000 people in 12 countries) provided detailed averages for various activities during average day of an average week in the year for several groups of people.

Daily Time Budgets of Adults

Status	Housewife + two children	Housewife childless	Employed men	Employed women
In hours and minutes per day				
At home				
Sleep	8h 46	9h 10	8h 25	8h 29
Physiological time	2h 51	3h 30	2h 55	2h 476
Housework	8h 00	6h 20	2h 00	4h 54
Free time	2h 34	3h 05	2h 07	1h 41
TV	(2h 30)	(2h 30)		
Total	22h 11	22h 05	15h 27	17h 51
Indoors, elsewhere				
Work			5h 32	3h 52
Other	0h 32	0h 35	1h 00	0h 32
Total	0h 32	0h 35	6h 32	4h 24
Outdoors				
Shopping, handywork	0h 44	0h 50	0h 41	0h 30
Travel	0h 12	-	1h 00	1h 00
Sport, Walk	1h 17	Oh 30	0h 20	0h 15
Total		1h 20	2h 01	1h 45

Time Budgets as Percentage of the Day

Status	Housewife + two children	Housewife childless	Employed men	Employed women
As percentage of daytime				
At home	92.5	92	64.5	74.5
Indoors, elsewhere	2	2.5	27.5	18.5
Outdoors	5.5	5.5	8	7

[a] From summary of time budget studies reported in Roy and Courtay 1991.

M. Roy and C. Courtay, 1991

Gender	Age (y)	Resting/sleeping Breathing rate (l/min)	Light Exercise Breathing rate (l/min)	Heavy Exercise Breathing rate (l/min)
INFANT	NB	1	1.5	na
	1	2.55	5.8	na
	2	3.3	6.3	na
	Average	2.3	4.5	
CHILD	10 (boy)	5.2	18.6	37
	10 (girl)	5.2	18.6	30.6
TEENAGER	15 (boy)	7	23.0	48.6
	15 (girl)	5.75	21.6	42.9
ADULT	30 (male)	7.5	25.0	50
	30 (female)	5.4	21.0	45

Second Approach to Estimating Breathing Rates

- This newer approach is based on basal metabolism and measured food-energy intakes and energy expenditures.
- This newer method is based on oxygen uptake associated with energy expenditures and a ventilation rate that relates minute volume to oxygen uptake.
- Layton (1993) used statistics on basal metobolic rate, food (energy) intake, body weight and physical activities to calculate breathing rates.

131

Layton 1993

Gender/age	No. of individuals	Ventilation or breathing rate: Average (liter per min)	Ventilation or breathing rate: Range based on activity during day (liter per min)
Males			
Under 1	54	3.1	1.6-4.3
1 to 3	108	4.7	2.9-6.4
3 to 10	338	6.4	4.1-13
10 to 18	734	10.4	6.1-15
18 to 30	2879	11.8	7.1-13
30 to 60	646	11.1	7.0-12
60+	50	9.0	5.6-11
Females			
Under 1	54	3.1	1.6-4.3
1 to 3	108	5.3	2.9-6.4
3 to 10	413	5.9	4.1-13
10 to 18	575	8.3	5.3-11
18 to 30	829	7.6	5.3-8.8
30 to 60	372	7.6	5.4-8.2
60+	38	6.8	4.8-7.7

RAC Distributions

Breathing rates are lognormally distributed (liter per min)

Example RAC distributions combine the Layton, Thompson and Robison, Roy and Courtnay, EPA, and Silverman et al. data using Monte Carlo techniques and 3000 trials

Group	5th	50th	95th	99th
Men (18-30) resting	7.6	12	17.5	
Men (18-30) max activity	19.6	35	61.5	77.9

Summary on Breathing Rates

- Gender -- little difference through about age 12; teen through adulthood, 40-50% higher in males than females
- Age -- about factor of 3 different between young children and adults
- Level of activity -- can be most significant parameter; breathing rates can be 15 times higher under max work than resting. Important for acute exposure of a few hours, less important for continuous chronic exposure (year)

Selected References for Soil Ingestion Data

- Binder, S., D. Sokal, D. Maughan. 1986. *Estimating the Amount of Soil Ingested by Young Children through Tracer Elements*. Arch. Environ. Health 41: 341-345.
- Calabrese, E.J., H. Pastides, R. Barnes, C. Edwards, P.T. Kostecki, E.J. Stanek III, P. Veneman, and C.E. Gilbert. 1990. *How Much Soil Do Young Children Ingest: An Epidemiological Study*. In Petroleum Contaminated Soils, Volume 2, Chapter 30, 363-397.
- Hawley, J.K. 1985. *Assessment of Health Risk from Contaminated Soil.* Risk Analysis 5(289).
- Kimbrough, R.D., H. Falk, P. Stehr, and G. Fries. 1984. *Health Implications of 2,3,7,8-TCDD Contamination of Residual Soil*. J. Toxicol. Environ. Health 14: 47-93.

Highlights of studies

- In 1984, the Centers for Disease Control (CDC) estimated age specific soil ingestion at about 10 grams per day based on observations of behaviors of children of 1 to 4 years of age (Kimborugh et al. 1984).
- In 1986, one of the first quantitative assessments of human soil ingestion was carried out using tracer elements in the soil (aluminum, silicon, titanium)(Binder et al. 1986).
- In 1990, Calabrese et al (1990) studied soil ingestion rates in adults and children using a mass balance approach and more controlled procedures.

135

Breakdown of breathing rates for residential and onsite worker scenarios

Scenario	Daily Activity	Time onsite per day (hour)	Time offsite per day (hour)	Breathing Rate l/min	Breathing vol. onsite per day liters	Breathing vol. onsite per yr liters
Resident in neighborhood	Sleeping	8		12	5760	
50 weeks per year	Indoors (physiological time)	2		15	1800	
350 days per year	Indoors (light activity)	2		18	2160	
7875 hr/yr	Indoors(employed, sedentary)	8		12	5760	
	Outdoors (gardening and yard activities	1		20	1200	
Works at home;	Outdoors (moderate physical activity)	1		35	2100	
exercises in neighborhood	Outdoors (heavy physical activity)	0.5		80	2400	
	Travel		1.5			
	Onsite values	22.5			21180 (21 m^3 per day)	7413000 (7400 m^3 per yr)
Current onsite worker	Sleeping		8			
Assume 8.5 hr per day,	At home		7.5			
250 days per year	Work (heavy activity)	4		40	9600	
2125 hours per year	Work (moderate)	3		20	3600	
	Work (light to sedentary)	1.5		14	1260	
	Onsite values	8.5			14460 (15 m^3 per day)	3615000 (3600 m^3 per yr)

Comparison of Key Scenario Parameters

	DOE/EPA/CDPHE Scenarios			RAC Scenarios	
	Open Space	Office worker	Resident	Resident	Onsite worker
Breathing rate (m^3 per yr)	175	1660	7000	7400	3600
Breathing rate (m^3 per day)				21	15
Exposure time (hr per yr)	125	2000	8400	7875	2125
Soil ingestion (g/year)	2.5	12.5	70	88	16
Soil ingestion (g/day)	0.1	0.05	0.2	0.25	0.25

K. Meyer Feb 1999: preliminary scenario development

RAC

136

137

Summary

- Use a wide range of references and studies to compile information on parameters
- We can generate a distribution of values using Monte Carlo techniques; this considers available studies equally
- Residential scenario is more realistic than a rancher; considering an onsite worker scenario is reasonable

RAC Report No. 3-RFCAB-RFSAL-1999-DRAFT

DRAFT REPORT

Task 1: Cleanup Levels at Other Sites

Rocky Flats Citizens Advisory Board
Rocky Flats Soil Action Level Oversight Panel

February 1999

Submitted to the Rocky Flats Citizens Advisory Board in Partial Fulfillment of Contract between RAC and RFCAB

"Setting the standard in environmental health"

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138

DRAFT REPORT

Task 1: Cleanup Levels at Other Sites

Rocky Flats Citizens Advisory Board
Rocky Flats Soil Action Level Oversight Panel

February 1999

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Submitted to the Rocky Flats Citizens Advisory Board
in Partial Fulfillment of Contract between RAC and RFCAB

139

CONTENTS

TASK 1: CLEANUP LEVELS AT OTHER SITES

INTRODUCTION

The soil action levels for radionuclides calculated for the Rocky Flats Environmental Technology Site (RFETS) by the U.S. Department of Energy (DOE), U.S. Environmental Protection Agency (EPA), and the Colorado Department of Public Health and Environment (CDPHE) have come under scrutiny because of lack of public involvement throughout their development. A soil action level is calculated to identify the concentration of radionuclides in the soil above which action should be taken to prevent people from receiving unacceptable radiation dose levels. As a result of public concern, DOE provided funds to the Rocky Flats Citizen's Advisory Board to establish the Rocky Flats Soil Action Level Oversight Panel and to hire a contractor to conduct an independent assessment and calculate soil action levels for Rocky Flats. *Risk Assessment Corporation (RAC)* was hired to perform the study.

The first task of the study (Task 1: Cleanup Levels at Other Sites) was designed to provide the Oversight Panel with a clear and unbiased evaluation and comparison of soil action levels developed for the RFETS and other facilities. This report documents the findings of Task 1.

ROCKY FLATS SOIL ACTION LEVEL CALCULATION

A 1996 report documents the original calculation of soil action levels for the RFETS (DOE 1996). The RESRAD computer code (Yu et al. 1993) was used, and action levels were calculated for three different land use scenarios at two different effective dose equivalent levels.

The three scenarios established for Rocky Flats were (1) an open space exposure scenario that assumed no development in the area, (2) an office worker exposure scenario, and (3) a hypothetical future resident scenario. Action levels were calculated for ^{241}Am, ^{238}Pu, ^{239,240}Pu, ^{241}Pu, ^{242}Pu, ^{234}U, ^{235}U, and ^{238}U. Public concern has been the highest for the ^{239,240}Pu action level; therefore, we focused our efforts on the this action level during the Task 1 study.

The open space and office worker scenarios were based on the principle that the land currently occupied by the RFETS will remain under institutional control for 1000 years. Under institutional control, no person would be allowed to live on current site property; however, the site would be occupied by office buildings and open recreational space. If institutional control failed, anything could happen to the land, and the scenarios with the largest potential exposure would be assumed to occur. This large exposure is represented by the hypothetical future resident scenario, which describes a resident who lives full-time on the former site, farming and eating crops grown on the land.

The dose levels that drive the calculations of action levels for the scenarios are annual effective dose equivalents of 15 and 85 mrem, depending on the scenario and the status of the institutional controls. These dose levels were selected based upon combined regulatory guidance from the EPA and DOE and are presumed to be protective of human health (DOE 1996).

The Task 1 study uses the hypothetical future resident 85 mrem y^{-1} action level because it is the DOE recommended action level above which no remediation would be required, and it is the most readily comparable action level to those at other facilities. This report uses the 85 mrem y^{-1} action level to make all comparisons.

Pathways Considered

The original RFETS calculation, documented in DOE (1996), established a site conceptual model based on the environment at Rocky Flats. Pathway analyses were performed based upon this model. This analysis allowed DOE to select the appropriate pathways in RESRAD for use in the RFETS soil action level determination. Potential pathways available in RESRAD are:

- External gamma exposure
- Soil inhalation
- Plant ingestion
- Meat ingestion
- Aquatic food ingestion
- Groundwater and surface water ingestion
- Soil ingestion
- Radon exposure.

Of these pathways, only external gamma exposure, soil inhalation, plant ingestion, and soil ingestion were assessed for the hypothetical future resident. As described in DOE (1996), the other pathways were eliminated from consideration because of inconsistencies with the site conceptual model, absence of pathways within the Rocky Flats environment, or insignificant contribution to the total dose. For example, aquatic food ingestion is not consistent with the site conceptual model because there are no surface water sources on the site that can sustain a fish population (DOE 1996). Differences in pathways analyses among the sites compared in this paper are noted in the following paragraphs.

Important Parameters

Initial sensitivity analyses of the RESRAD code and parameters used for the hypothetical future resident scenario (85 mrem y^{-1} dose level) show that a few parameters dominate the outcome of the action level calculation. These parameters were identified using a single-parameter sensitivity analysis (that is, only one parameter was altered at a time to explore the sensitivity of the calculation to changes in the parameter). This sensitivity analysis was helpful in conducting Task 1 because it helped identify those parameters that controlled the soil action level. For example, when an action level at another site was significantly different from the RFETS value, we could identify what was likely controlling the difference. Two parameters at the RFETS emerged from the sensitivity analysis as most important and most sensitive to change: mass loading factor and the dose conversion factor. The mass loading factor for the RFETS calculations was 0.000026 g m^{-3}. The dose conversion factor was 0.308 mrem pCi^{-1}. This dose conversion factor is consistent with Class Y (insoluble) plutonium with a particle size of 1 μm activity median aerodynamic diameter (AMAD). These parameters will be explored in more detail in Tasks 2 and 3, but their importance affects the Task 1 study.

METHOD OF COMPARISON

Action and cleanup levels are sometimes determined independent of dose levels or are based on a different dose than the 85 mrem y^{-1} used in the RFETS hypothetical future resident scenario

DRAFT

142

calculation. This fact makes direct comparison more difficult; therefore, we compared different soil action levels among sites by normalizing the action level to annual dose. In the remainder of this paper, annual dose is understood, and dose is represented in units of millirem. Normalization means that a ratio was calculated for action level to dose level, representing the action level for a unit dose, or 1 mrem. This equitable comparison allows for straightforward identification of pathway, scenario, and parameter differences that affect the ratio. If these differences can be identified among the RFETS and other sites, the ratios between sites should be comparable.

Each ratio is identified in two ways:

1. Dose to soil action level (millirem per picocurie per gram) (mrem $[pCi\ g^{-1}]^{-1}$) and
2. Soil action level to dose (picocurie per gram per millirem) ($[pCi\ g^{-1}]\ mrem^{-1}$).

These ratios are reciprocals. They each have their merits and many different readers find one of the two easier to understand. For a true normalization to dose, focus on the soil action level to dose ratio, which identifies the action level per unit dose, or the soil concentration for each site consistent with a 1 mrem effective dose level. Therefore, if the soil action level to dose ratio is higher for the RFETS than it is for another site, then the allowable soil concentration is greater for the same dose. The opposite situation may also be true. In all cases, this paper identifies possible sources for the difference in ratios and calculates the effect of each difference on the ratio to equate the ratios.

Because the primary goal of this task was to understand why Rocky Flats soil action levels are consistently greater than those at other sites, gaining an understanding of the parameters that drive the action levels to such high levels allowed us to limit our calculations. Identifying and comparing critical parameters for the RFETS in comparison with each site was the endpoint of each investigation. Precisely equating the soil action level to dose ratio between other sites and the RFETS was not our goal. Instead, it was important for us to identify the parameters controlling the action level and show their impact, thereby making the RFETS action level more transparent.

In some cases, cleanup at a site was conducted independent of dose, and a dose calculation could not be found in the available literature. In these cases, we describe the cleanup level along with the soil concentration, but we did not make an effective or meaningful comparison. Without a ratio and some indication of how the calculation was completed, it was impossible to identify the differences among the sites in a way that is meaningful for this study.

SOIL ACTION LEVELS AT OTHER SITES

We identified several sites and alternate action level calculations for comparison in the Task 1 report. These included

- Hanford, Washington
- Nevada Test Site
- U.S. Nuclear Regulatory Commission (NRC) codes for remediation
- Johnston Atoll, Marshall Islands
- Enewetak Atoll, Marshall Islands
- Maralinga, Australia
- Semipalatinsk Nuclear Range, Kazakhstan
- Thule, Greenland

- Palomares, Spain.

Table 1 identifies the dose to soil action level and soil action level to dose ratios for each site where information was available. All ratios are shown for $^{239,240}Pu$ unless otherwise indicated. The ratio for the most comparable scenario to the RFETS residential scenario is shown for each site. In each case, this is a residential scenario where remediated land would be lived on and, in some cases, farmed. Ratios and scenarios are described in more detail in the following sections.

Table 1. Ratios for Comparison among Different Sites[a]

Site	Soil action level to dose ratio ([pCi g^{-1}] $mrem^{-1}$)	Dose to soil action level ratio (mrem [pCi $g^{-1}]^{-1}$)
Rocky Flats, Colorado	17	0.06
Hanford, Washington	2.3	0.44
Nevada Test Site[b]	4.1	0.24
NRC remediation codes	7.4	0.14
Johnston Atoll[c]	0.85	1.2
Maralinga, Australia	0.56	1.8
Semipalatinsk Nuclear Range	8.8	0.11
Palomares, Spain	12.3	0.08

[a] References identified in appropriate section of text.
[b] Ratios from Clean Slate Site 1.
[c] Dose from all alpha particles, soil action level for $^{239,240}Pu$.

It is clear that the values are not the same for all sites. In fact, the soil action level to dose ratio is less than 1 in some cases. We will now step through a site-by-site analysis of each ratio and why it differs from the ratio for the RFETS hypothetical future resident.

Hanford, Washington

The Hanford Site in Washington was part of the nuclear weapons production complex and it still operates as a DOE laboratory. Dose reconstruction and cleanup efforts are underway at the facility. As a part the clean up, soil action levels were calculated for the facility using parameter evaluation techniques similar to those undertaken at the RFETS. The Hanford calculation is described in detail in a document issued by the State of Washington (WDOH 1997). All parameter values for Hanford cited and used in this section come from WDOH (1997).

The soil action level to dose ratio at Hanford is 2.3, over 7 times smaller than the same ratio at Rocky Flats. This ratio is for the Hanford rural residential scenario. This scenario represents a person who lives on the current Hanford site all year, eating crops and livestock grown onsite, drinking from site streams, inhaling air and ingesting soil. Hanford soil action levels were calculated using the RESRAD computer code.

The most obvious difference between the Rocky Flats residential scenario and the Hanford rural residential scenario is the active exposure pathways. The Hanford residential scenario includes all exposure pathways represented in RESRAD except the radon pathway. Compared to Rocky Flats, Hanford includes four additional pathways: ingestion of drinking water, ingestion of meat from animals raised on contaminated land, ingestion of milk from animals raised on contaminated land, and ingestion of locally caught fish containing radionuclides.

Holding all other parameters in the Hanford calculation constant, removing these pathways makes very little difference to the calculation's outcome. The ratio of soil action level to dose for $^{239,240}Pu$ changes indistinguishably. It is interesting to note that the ingestion pathways (milk, meat, fish, and drinking water) have almost no effect on the ratio for $^{239,240}Pu$. The largest change in soil action level to dose occurs for ^{137}Cs and ^{90}Sr because the transport of these radionuclides is primarily through such food chains. These radionuclides are not of concern for the RFETS, so we focused primarily on changes in the $^{239,240}Pu$ calculation.

The two parameters identified in the RFETS sensitivity calculation (mass loading factor and dose conversion factor) differ between the RFETS and Hanford calculations. We examined these parameters to see how changes affect the Hanford and RFETS calculations.

A major difference between the Hanford and RFETS calculation is that plutonium at the Hanford reservation is assumed to be in a soluble form in the environment. Because of this assumption, the dose conversion factors used in the Hanford calculation are larger than those used in the RFETS calculation, where plutonium is assumed to be insoluble. Maintaining our previous pathway modification and now assuming the plutonium at Hanford is in an insoluble form like RFETS plutonium, the soil action level to dose ratio for $^{239,240}Pu$ changes from 2.3 to 9.9. This ratio is much closer to the RFETS ratio of 17, indicating that the form of plutonium identified in the environment plays a significant role in the difference between these two calculations.

The mass loading factor used in the Hanford calculation was 0.0001 g m^{-3}, compared to the value used in the RFETS calculation of 0.000026 g m^{-3}. Maintaining all previous modifications to the Hanford calculation and altering the mass loading factor to match the RFETS value, the soil action level to dose ratio for $^{239,240}Pu$ changes from 9.9 to 34. This large increase in the ratio occurs for two reasons. First, assuming the plutonium is in an insoluble form made inhalation the dominant pathway for dose. Second, decreasing the mass loading factor put less plutonium in the air, making less plutonium available for inhalation. The combination of these two changes increases the allowable concentration of plutonium in soil, and correspondingly increases the soil action level for a unit dose.

When the Hanford calculations using RESRAD are run implementing the RFETS pathways and parameter values for mass loading and dose conversion factor, the soil action level to dose ratio for Hanford exceeds that for the RFETS. Table 2 shows the incremental change in the soil action level to dose ratio when the parameters in the Hanford calculation were altered.

Table 2. Soil Action Level to Dose Ratio for $^{239,240}Pu$ Changes with Parameter Alteration for Hanford and RFETS Calculations

Location	Parameter change	Soil action level to dose ratio ($[pCi\ g^{-1}]\ mrem^{-1}$)	Dose to soil action level ratio ($mrem\ [pCi\ g^{-1}]^{-1}$)
Rocky Flats	Original calculation	17	0.06
Hanford	Original calculation	2.3	0.44
	Remove meat, milk, fish, drinking water	2.3	0.44
	+ change dose conversion factor	9.9	0.10
	+ change mass loading	34	0.03

Nevada Test Site

The Nevada Test Site (NTS) was the location of numerous nuclear tests in the 1940s and 1950s during the buildup of the nation's nuclear arsenal. Two documents calculated doses to individuals who might live or work onsite after cleanup. One document assumes very realistic scenarios for future site uses. Calculations were performed for scenarios such as an industrial worker, bomb detonation, removal of safe munitions, aircraft crew flying overhead, ground troops being deployed onsite, explosive ordinance demolition, and a construction worker. In short, these scenarios were designed assuming that the site will be under military control in the future. Ratios associated with these scenarios are large; they are not discussed here because they do not relate even marginally to the Rocky Flats scenarios (DOE 1998).

Another document assessed dose for presumed cleanup levels given scenarios similar to those we have looked at for the RFETS (DOE-NV 1997). This assessment was performed with RESRAD but in reverse to the RFETS calculations.

The 100 mrem y^{-1} public dose standard is presumed to be the primary standard for protection of the public based on the DOE Order 5400.5 (DOE-NV 1997). DOE-NV (1997) cited a number of studies detailing soil action levels that resulted in doses similar to or less than this standard. Based upon this information, this dose assessment assumed that the soil needed to be cleaned to a level not exceeding 200 pCi g^{-1} of $^{239,240}Pu$. Given existing concentrations in soils, hypothetical concentrations after remediation were identified, and dose calculations using RESRAD were completed to assess the dose resulting from both the unremediated and remediated soils. If these doses were less than the 100 mrem y^{-1} public limit, the remediation was termed adequate, or even unnecessary, if the precleanup levels met the dose requirement.

The rancher scenario resulted in the maximum dose for the same soil concentrations. In this scenario, a person lives on and farms the land for personal livelihood, eating many of the crops and livestock produced. For a soil concentration before remediation of 326 pCi g^{-1}, for Clean Slate Site 1, the corresponding dose was 78.3 mrem y^{-1}. The soil action level to dose ratio for this facility was 4.2 (pCi g^{-1}) mrem^{-1}. The same ratio applied to the post-remediation soil concentration level of 162 pCi g^{-1} and dose of 38.9 mrem y^{-1}.

The primary difference between the RESRAD calculations for the NTS and the RFETS is the assumed solubility class of plutonium. The NTS calculation used the RESRAD default value for plutonium dose conversion factor, which corresponds to Class W (soluble) plutonium. When dose conversion factors for soluble plutonium are used in the Rocky Flats calculation, which originally used Class Y (insoluble) plutonium dose conversion factors, the soil action level changes from 1429 to 242 pCi g^{-1}, and the soil action level to dose ratio changes from 17 to 2.8 (pCi g^{-1}) mrem^{-1}. This single parameter accounts for the difference between these two calculations. Table 3 summarizes the differences between the ratios and the parameter changes employed.

Table 3. Soil Action Level to Dose Ratio for $^{239,240}Pu$ Changes with Parameter Alteration for the NTS and RFETS Calculations

Location	Parameter change	Soil action level to dose ratio ([pCi g^{-1}] $mrem^{-1}$)	Dose to soil action level ratio (mrem [pCi $g^{-1}]^{-1}$)
Rocky Flats	Original calculation	17	0.06
	Change dose conversion factor	2.8	0.36
Nevada Test Site	Original calculation	4.1	0.24

U.S. Nuclear Regulatory Commission DandD Code Scenarios

The NRC produced its own computer code using models similar to those in RESRAD. This code, called DandD, was designed for use by NRC agencies as a guideline for cleanup and remediation of contaminated sites. Two sets of scenarios were developed for generic use with DandD: (1) scenarios for the release of buildings and (2) scenarios for the release of contaminated land. Only the contaminated land scenarios are comparable to the RFETS calculations. Of the land use scenarios, the residential use, or surface soil, scenario is the most directly comparable to the situation at Rocky Flats.

This scenario assumes residential use of land with limited gardening activities. The three major pathways considered are inhalation, ingestion of food products grown in contaminated soil, and external gamma exposure. Indoor radon is not considered. Of particular interest in the DandD code is the distinction between time spent indoors, outdoors, and outdoors gardening and the different mass loading factors applied to each time period. All NRC mass loading factors are larger than the RFETS mass loading factor of 0.000026 g m^{-3}.

The total effective dose equivalent for the residential scenario for $^{239,240}Pu$, assuming surface soil activity of 1 pCi g^{-1}, is 0.14 mrem. This gives a dose to soil action level ratio of 0.14 mrem (pCi $g^{-1})^{-1}$ and a soil action level to dose ratio of 7.1 (pCi g^{-1}) $mrem^{-1}$ (NRC 1990).

The dose conversion factor used for inhalation is the same as that used for the RFETS calculation, so we might assume that the difference in the value of the mass loading factor causes the difference between the NRC and RFETS ratios. To explore this possibility, we used the Rocky Flats RESRAD calculation and input NRC mass loading factors.

The three mass loading factors used in the NRC calculation are for indoor mass loading, outdoor mass loading, and outdoor mass loading during gardening activities. Because the RFETS RESRAD calculation assumes indoor air concentration is equal to outdoor air concentration and gardening activities are not included, we used the NRC outdoor mass loading factor of 0.0001 g m^{-3} to input into the RFETS calculation. This mass loading factor changed the soil action level to dose ratio for ^{239}Pu from 17 to 4.6 (pCi g^{-1}) $mrem^{-1}$.

The single change in magnitude of mass loading made the adapted RFETS soil action level to dose ratio (4.6) smaller than the same NRC ratio (7.1), indicating less allowable soil concentration for the same dose.

In the DandD code, the dose conversion factors are maximized for each intake pathway. That is, for soil ingestion, soluble plutonium dose conversion factors are used, and for inhalation, insoluble dose conversion factors are used. Using different dose conversion factors maximizes the dose and minimizes the acceptable soil action level. Overall, the NRC code appears to be very conservative, and the parameter values for each scenario were chosen to promote conservatism. If certain parameters about the site are not known, these conservative values can be used as defaults. Within the text of the NRC reports discussing this code, however, it is cautioned that if site-specific values are available, they should be used to provide a more realistic assessment of the cleanup needs (NRC 1990).

Table 4 summarizes the ratios for the NRC DandD code and the RFETS calculations, and it documents the changes made to account for the differences between the values.

Table 4. Soil Action Level to Dose Ratio for $^{239,240}Pu$ Changes with Parameter Alteration for NRC DandD and RFETS Calculations

Location	Parameter change	Soil action level to dose ratio ([pCi g^{-1}] $mrem^{-1}$)	Dose to soil action level ratio (mrem [pCi $g^{-1}]^{-1}$)
Rocky Flats	Original calculation	17	0.06
	Change mass loading	4.6	0.22
NRC DandD Code	Original calculation	7.1	0.14

Johnston Atoll, Marshall Islands

Plutonium contamination in the environment at the Johnston Atoll in the Marshall Islands resulted from three accidents in 1962: the destruction of two offcourse rockets at high altitude and one explosion on the rocket launching pad (Spreng 1999). Using mining techniques, the soil was cleaned to about 15 pCi g^{-1} (Bramlitt 1988). An independent verification of the cleanup was performed by Oak Ridge National Laboratory (Wilson-Nichols et al. 1997). Currently, a company called GeoCenters is reviewing the cleanup levels and revising the calculations using more realistic receptors. A draft report of this work is due in March 1999 (Spreng 1999).

Using existing information, the soil action level to dose ratio for a Johnston Atoll resident was calculated to be 0.85 (pCi g^{-1}) $mrem^{-1}$ (Wilson-Nichols et al. 1997). The soil concentration was calculated for doses only from inhaled alpha emitters. The soil screening limit, *SSL*, (or soil action level) was calculated using Equation (1).

$$SSL = \frac{C_{air,acceptable}}{ML \cdot EF} \quad (1)$$

where

$C_{air,\,acceptable}$ = acceptable air concentration (pCi m^{-3})
ML = mass loading (g m^{-3})
EF = enrichment factor (unitless).

The acceptable air concentration is calculated for the accepted annual committed dose. For the Johnston Atoll calculation, the annual committed dose limit was 20 mrem y^{-1}, which corresponds to an air concentration of 2.6×10^{-3} pCi m^{-3} for plutonium or americium compounds emitting alpha radiation with a quality factor of 20 (Wilson-Nichols et al. 1997). This air concentration was calculated for Class Y (insoluble) compounds of plutonium that are retained in the lung for years. The committed dose applies to the pulmonary region of the lung.

It is important to note that this calculation was performed based upon a significantly older version of the International Commission on Radiological Protection (ICRP) lung model than that currently in use. The lung model was described in ICRP Publication 19 (ICRP 1972) when recommendations from ICRP 2 (ICRP 1959) were outdated, but ICRP 30 (ICRP 1978) had not yet been published. The ICRP 19 (ICRP 1972) document was prepared by a task group and described an updated version of the lung model. However, ICRP 19 did not yet include calculation of total body dose; the emphasis at this time was still on organ-specific dose. As a result, acceptable air concentrations for the Johnston Atoll were calculated based only on doses to the pulmonary region of the lung. In contrast, the RFETS calculation, which was founded on later ICRP recommendations, describes dose to the entire body. Therefore, the ratios should be compared with caution.

The mass loading factor selected for this calculation was 0.0001 g m^{-3}, as defined by the EPA for developing a soil screening limit (EPA 1977). Even during clean up and soil disturbance activities at the Johnston Atoll site, mass loading factors were smaller than this value, so the 0.0001 g m^{-3} value was assumed to be a conservatively high (Wilson-Nichols et al. 1997).

The enrichment factor considers how the $^{239,240}Pu$ concentration in the respirable fraction of the soil compares to plutonium concentrations in soil of all particle sizes. An EPA study that looked at five sites in the U.S., including the RFETS, listed enrichment factors for each site (EPA 1977). According to this study, Rocky Flats had the largest enrichment factor of the sites studied across the U.S.. To be conservative, the Johnston Atoll study used an average of the Rocky Flats data to develop an enrichment factor of 1.5.

Using this information and Equation (1), the soil screening limit for the Johnston Atoll was calculated to be 17 pCi g^{-1} for a committed dose equivalent of 20 mrem y^{-1}, giving the ratios cited above. Using Rocky Flats data in this equation helps clarify the differences between the ratios for Johnston Atoll and the ratios for the RFETS.

The first step was to determine the difference between dose conversion factors for the two sites. To extract the Johnston Atoll dose conversion factor from the existing information, we used an equation for effective dose from inhaled material. Equation (2) calculates dose (in units of millirem) from inhaled material.

$$Dose = V_{inhaled} \cdot C_{air} \cdot DCF \qquad (2)$$

where
$V_{inhaled}$ = volume inhaled (m^3 y^{-1})
C_{air} = concentration in air (pCi m^{-3})
DCF = dose conversion factor (mrem pCi^{-1}).

The volume inhaled in the Johnston Atoll calculation was 8395 m^3 y^{-1}, based on the ICRP reference man (ICRP 1975). The concentration in air was 2.6×10^{-3} pCi m^{-3} for a 20 mrem dose. The dose conversion factor that results from inputting these values and rearranging Equation (2) is 0.91 mrem pCi^{-1}. This contrasts with the RFETS dose conversion factor for insoluble plutonium of 0.308 mrem pCi^{-1}. It is important to remember that the RFETS dose conversion factor is for total body dose, and the Johnston Atoll dose conversion factor is only for dose to the pulmonary region of the lung.

Equation (2) can be used to calculate an acceptable air concentration for Johnston Atoll using RFETS parameters. For a Johnston Atoll limit of 20 mrem effective dose limit, RFETS volume inhaled of 7000 m^3 y^{-1} and RFETS dose conversion factor identified above, the concentration in air is equal to 9.27×10^{-3} pCi m^{-3}.

Equation (1) is used to calculate the Johnston Atoll soil screening limit using Rocky Flats values. The Rocky Flats value for mass loading was 0.000026 g m^{-3}. The air concentration was calculated above, and in the RFETS calculation, no enrichment factor was employed. The soil screening limit for Johnston Atoll using RFETS parameter values is 356 pCi g^{-1}, giving a soil action level to dose ratio of 17.8 (pCi g^{-1}) $mrem^{-1}$, which matches that of the RFETS. Table 5 summarizes the results of this analysis.

Table 5. Soil Action Level to Dose Ratio for $^{239,240}Pu$ Changes with Parameter Alteration for Johnston Atoll and RFETS Calculations

Location	Parameter change	Soil action level to dose ratio ([pCi g^{-1}] $mrem^{-1}$)	Dose to soil action level ratio (mrem [pCi g^{-1}]$^{-1}$)
Rocky Flats	Original calculation	17	0.06
Johnston Atoll	Original calculation	0.85	1.2
	Calculate concentration in air using RFETS dose conversion factor and volume inhaled	3.1	0.32
	+ change to RFETS mass loading	11.9	0.08
	+ change to RFETS enrichment factor	17.8	0.056

Enewetak Atoll, Marshall Islands

The cleanup levels established for the Enewetak Atoll are difficult to compare to the Rocky Flats soil action levels. This cleanup was driven more by time, money, and military concerns than an identified limit for concentrations in soil.

The Defense Nuclear Agency published a book describing the cleanup of Enewetak Atoll after numerous U.S. nuclear tests took place there in the 1950s and 1960s (DNA 1981). This book primarily documents the cleanup efforts and decisions made throughout the process; it does not provide a clear assessment of doses and accepted cleanup levels for the islands.

The cleanup of the Marshall Islands was one of the first efforts of its magnitude. Although accidents had occurred at other facilities, guidance was just beginning to be developed for nuclear material soil standards, particularly for transuranics. The EPA guidance on transuranic elements in the environment had not yet been released, and ICRP models for dose were still limited at the time of cleanup.

DRAFT

As a result of limited guidance, decisions about soil cleanup came slowly and only after considerable discussion, disagreement, and finally consensus. As many as three committees produced recommendations for the Enewetak Atoll cleanup, and all committees agreed on some levels and disagreed on others.

The first remediation goal, established by the Environmental Research and Development Agency (ERDA) in conjunction with the U.S. Army Support Command, was to reduce plutonium concentrations in soil to levels below 40 pCi g^{-1}. This concentration level would qualify the land for residential and agricultural use (DNA 1981).

At a workshop held to discuss ERDA plans for the Marshall Islands, doubts and objections to this cleanup strategy were raised, questioning whether the guidelines for soil removal were supportable. As a result of these questions, ERDA convened a panel of scientists, known as the Bair Committee, to review Atomic Energy Commission recommendations. An Atomic Energy Commission task group that suggested 400 pCi g^{-1} as an acceptable limit in soil because it was conservatively equivalent to the maximum permissible concentration in air for radiologically unrestricted areas. The task group then introduced a safety margin of a factor of 10, recommending that no cleanup was required below 40 pCi g^{-1}. The areas with soil concentrations between 40 and 400 pCi g^{-1} would be assessed on a case-by-case basis depending on the use of the land. Finally, this task group suggested that after cleanup was initiated, soil levels should be reduced to the lowest possible level (DNA 1981).

Following the AEC recommendations, ERDA established an Operating Plan recognizing that cleanup of all areas to below 40 pCi g^{-1} would require removing large quantities of soil for no appreciable benefit. The Operating Plan suggested conditions for soil use. Condition A specified that an island could be used for food gathering if surface plutonium did not exceed 400 pCi g^{-1}. Condition B allowed agricultural use of land if surface plutonium did not exceed 100 pCi g^{-1}. Residential use, outlined by Condition C, required cleanup to levels below 40 pCi g^{-1}. The final condition involved using the land for all three purposes if the surface conditions met the appropriate requirements and subsurface plutonium concentrations did not exceed 400 pCi g^{-1}.

The Bair Committee approved of the ERDA Operating Plan cleanup criteria and suggested that more specific guidance be established for the soil concentrations between 40 and 400 pCi g^{-1}. When the 1977 EPA guidance on transuranics was released, the Bair Committee adapted its recommendations for agricultural land soil concentrations to 80 pCi g^{-1} and food gathering land soil concentrations to 160 pCi g^{-1}. These values were apparently based on a dose assessment study performed by Lawrence Livermore Laboratory. A first study done by Lawrence Livermore Laboratory was based on the original soil cleanup criteria, but the results were deemed incorrect because of a mathematical error. The Laboratory performed a new dose assessment. Results from this new dose assessment influenced the Bair Committee's decisions concerning action levels for different soil uses.

We could not locate the Lawrence Livermore Laboratory study in the literature. The Defense Nuclear Agency document lists the doses from this study only in radiation doses in millirad; however, these values cannot be converted to effective doses without knowing more about the dose model used to make the calculations. We can assume that Lawrence Livermore Laboratory scientists used the same model as that used in the Johnston Atoll study, with a large dose conversion factor. However, we would need to have access to the Lawrence Livermore Laboratory study to make comparisons to RFETS values.

Maralinga, Australia

Nuclear weapons trials conducted between 1953 and 1963 by the United Kingdom contaminated the Maralinga site in Australia. This land was the home of semi-traditional Aboriginal tribes, and it became necessary to restore it for their use. A rehabilitation project was undertaken in 1996 because of the extensive $^{239,240}Pu$ contamination in the area. This facility is more difficult to compare to Rocky Flats because RESRAD calculations were not performed. However, a dose evaluation was performed and cleanup criteria were established, so we do have some mechanism to compare the facilities. Doses for the Maralinga facility were calculated for a resident living in a semi-traditional Aboriginal life style, but they focused only on doses from inhalation.

In the context of the Maralinga site, the term soil action level is used loosely because cleanup criteria is a more appropriate term. However, we use the term soil action level here for consistency.

The soil action level to dose ratio for the Maralinga site is 0.56 (pCi g^{-1}) $mrem^{-1}$. This ratio was calculated by rearranging the equation used at the Maralinga site to calculate dose. Equation (3) shows the dose calculation used at the Maralinga facility.

$$Dose\,(mrem\ y^{-1}) = C_{air} \cdot BR \cdot DCF \qquad (3)$$

where

C_{air} = concentration in air (pCi m^{-3})
BR = breathing rate ($m^3\ y^{-1}$)
DCF = dose conversion factor (mrem pCi^{-1})

and

$$C_{air} = C_{soil} \cdot ML \qquad (4)$$

where

C_{soil} = soil concentration (pCi g^{-1})
ML = mass loading (g m^{-3}).

Combining and rearranging Equations (3) and (4) yields Equation (5), which gives a direct calculation of the dose to soil action level ratio. The reciprocal of Equation (5) is the soil action level to dose ratio.

$$\frac{Dose\,(mrem)}{C_{soil}\,(pCi\ g^{-1})} = ML \cdot BR \cdot DCF \qquad (5)$$

where all quantities are as previously defined.

The values used in Equation (5) for the Maralinga calculation and the information about the site were extracted from two sources: the journal of *Health Physics* (Johnston et al. 1992) and the Australian Radiation Laboratory (ARL 1998).

Mass loading for the site was determined by simulating some Aboriginal dust raising activities. These data were the only data available to the Australian Radiation Laboratory group, and a value of 0.001 g m^{-3} was used for adults. Breathing rates were taken by the Australian

Radiation Laboratory from Haywood (1987). For adults, an annual breathing rate of 8400 $m^3\ y^{-1}$ was used. The dose conversion factors were extracted from ICRP 56 (ICRP 1989), but they were corrected for 5 µm AMAD particles because a study indicated this particle size best represented the respirable fraction at the Maralinga site. The dose conversion factor for $^{239,240}Pu$ was calculated assuming the worst case scenario translocation rate for the Australian test sites would be represented by 25% of the plutonium being Class W (soluble) and 75% being Class Y (insoluble). This series of conversions results in a dose conversion factor for $^{239,240}Pu$ of 0.215 mrem pCi^{-1}.

The three parameter values used in Equation (5) lead to a dose to soil action level ratio of 1.8 mrem $(pCi\ g^{-1})^{-1}$ and a soil action level to dose ratio of 0.56 $(pCi\ g^{-1})\ mrem^{-1}$ for the Maralinga site.

To compare this to the Rocky Flats ratio, we inserted RFETS parameter values into the Maralinga calculation. Using the Rocky Flats values for mass loading (0.000026 $g\ m^{-3}$), breathing rate (7000 $m^3\ y^{-1}$), and $^{239,240}Pu$ inhalation dose conversion factor (0.308 mrem pCi^{-1}) in Equation (5), yields a dose to soil action level ratio of 0.056 mrem $(pCi\ g^{-1})^{-1}$ and a soil action level to dose ratio of 17.8 $(pCi\ g^{-1})\ mrem^{-1}$.

Using the Rocky Flats values in Equation (5) accounts for the difference in the two ratios. Table 6 summarizes the changes in the ratios between Maralinga and the RFETS by altering the parameter values used in the calculation.

Table 6. Soil Action Level to Dose Ratio for $^{239,240}Pu$ Changes with Parameter Alteration for Maralinga and RFETS Calculations

Location	Parameter change	Soil action level to dose ratio $[(pCi\ g^{-1})\ mrem^{-1}]$	Dose to soil action level ratio $[mrem\ (pCi\ g^{-1})^{-1}]$
Rocky Flats	Original calculation	17	0.06
Maralinga	Original calculation	0.56	1.8
	Change to RFETS breathing rate	0.67	1.5
	+ change to RFETS mass loading	26	0.039
	+ change to RFETS dose conversion factor	17.8	0.056

Semipalatinsk Nuclear Range, Kazakhstan

At this location in the former Soviet Union, 124 atmospheric nuclear tests were carried out between 1949 and 1962 (Zeevaert et al. 1997). These tests resulted in environmental contamination and radiation exposure. The contamination was extensively documented and radiation dose rates measured. The results from this work do not yield a soil cleanup level, but they do document existing contamination and resulting doses, allowing us to create a soil concentration to dose ratio.

It is important to point out that the values given in the literature usually document either a range of surface radiation levels associated with a single dose or a range of doses associated with a single radiation level. It is very difficult to correlate dose to corresponding soil concentration, but this paper presents the best ratios we could determine. Zeevaert et al. (1997) should be carefully reviewed if more information is desired.

For settlements at the Semipalatinsk site, maximum soil activity was given as 11 kBq m^{-2}, corresponding to a soil concentration of 1.32×10^6 pCi g^{-1}. We assumed a depth of contamination of 15 cm and a soil density of 1.5 g m^{-3} because these factors were not given in Zeevaert et al. (1997). The dose resulting from this concentration is identified as 1.5 Sv, or 150,000 mrem. It is not clear that this dose is due to inhalation of contamination because it is identified only as the estimated individual dose to the population.

The resulting soil concentration to dose ratio is 8.8 (pCi g^{-1}) $mrem^{-1}$. This ratio is fraught with uncertainties, both in measurement techniques and capabilities and difficulty correlating dose to soil concentration in the literature. While this is smaller than the Rocky Flats ratio, it is difficult to account for the differences because the Semipalatinsk soil concentration was measured in the environment, not calculated. Furthermore, Zeevaert et al. (1997) does not describe the dose calculation techniques.

Another territory affected by the Semipalatinsk tests was Ouglovski, with soil concentrations of 6.6×10^5 pCi g^{-1}. The doses cited for this region are external doses, however, and cannot be applied to obtain a ratio.

Table 7 outlines the differences between Rocky Flats and the Semipalatinsk Nuclear Range. It is important to remember the differences in the source of these values. They are presented here in an attempt to make this review as complete as possible.

Table 7. Soil Concentration to Dose Ratio for $^{239,240}Pu$ for Semipalatinsk Nuclear Range Measurements and RFETS Calculations

Location	Soil action level to dose ratio ([pCi g^{-1}] $mrem^{-1}$)	Dose to soil action level ratio (mrem [pCi $g^{-1}]^{-1}$)
Rocky Flats	17	0.06
Semipalatinsk Nuclear Range	8.8	0.11

Thule, Greenland

Near the Air Force Base at Thule, Greenland, on January 21, 1968, a military plane carrying four nuclear weapons crashed and burned. Plutonium contamination was spread about the crash site on the ice, with a maximum contamination level of 14.8 kBq m^{-2}. This site had to be cleaned up before the ice melted in the spring, dictating the time frame of the project. As a result, the only data we have from this crash site are concentrations of plutonium in sediments and estimated dose data from ingestion of sea mussels. Comparisons between this site and the RFETS are impossible because of lack of appropriate data and dissimilar pathway analyses. We report the dose and concentration data in this paper for completeness.

After cleanup, the maximum concentration of ^{239}Pu in sediments under the crash site was 1.85 Bq g^{-1}, or 50 pCi g^{-1}. Inhalation is not an appropriate pathway because plutonium is contained in sediments, not dry soil; therefore, the pathway of interest is consumption of mussels. In 1974 (6 years after the accident), the average concentration of plutonium in the edible part of mussels was 0.74 Bg g^{-1} (20 pCi g^{-1}). With a consumption rate of 100 g d^{-1} of mussels for 70

DRAFT

years, the annual committed dose rate to the bone was calculated to be 0.75 mGy (75 mrad) (Church 1998).

Palomares, Spain

Another nuclear accident occurred in Palomares, Spain, on January 17, 1966, when a U.S. Air Force bomber collided with its tanker and exploded above the town. Two of the bomber's four nuclear weapons impacted very near the town and released plutonium. Plutonium oxide contaminated about a 225-hectare (560-acre) area of brushland, farmland, and urban area.

The contamination of this area was so great that immediate cleanup was warranted. Soil concentrations measured just after the accident indicated areas of $^{239,240}Pu$ contamination ranging from 212 μCi g^{-1} (2.12×10^8 pCi g^{-1}) down to 2.12 μCi g^{-1} (2.12×10^6 pCi g^{-1}) (Iranzo et al. 1987). Cleanup was immediately undertaken, with the soil layer at the highest contamination level removed (10 cm deep) and disposed of as radioactive waste. The remainder of the soil was irrigated thoroughly, plowed to a depth of about 30 cm, and homogenized to move contaminated soils to lower levels. At lower levels, the soil would not be available for resuspension to become a potential source of inhalation and dose to residents (Iranzo et al. 1987).

At the time, a dose assessment based on these contamination levels was not performed. The contamination was so widespread that cleanup was the issue at hand. After the cleanup was complete, a monitoring program was established, which included air sampling, soil sampling, crop sampling, and urine and lung counting of the residents.

Air concentrations measured in the environment were compared to (a) annual limits on intake and (b) derived air concentrations from these limits as recommended by the ICRP for radiation workers (ICRP 1978). Because values for acceptable air concentrations for the public were not provided in ICRP (1978), the radiation worker values were multiplied by the ratio of dose limits recommended for the public to those recommended for radiation workers (0.1). This concentration was again reduced to account for ICRP recommendations that effective dose equivalent throughout the life of a member of the exposed population does not exceed the value resulting from a 1 mSv (100 mrem) annual effective dose equivalent. Therefore, acceptable concentration values for members of the public were set at 1.2 mBq m^{-3} (3.2×10^{-2} pCi m^{-3}) for Class Y (insoluble) compounds of plutonium and 0.5 mBq m^{-3} (1.35×10^{-2} pCi m^{-3}) for Class W (soluble) compounds of plutonium. In the context of the RFETS parameter values, with insoluble Class Y plutonium and a mass loading factor of 0.000026 g m^{-3}, this air concentration corresponds to a soil concentration of 1230 pCi g^{-1}.

Using these values to establish a soil concentration to dose ratio (for the 100 mrem dose for which the air concentration was calculated) results in a ratio for $^{239,240}Pu$ of 12.3 (pCi g^{-1}) $mrem^{-1}$. This ratio is only for inhaled plutonium, and it is based upon the ICRP reference man, who breathes at a rate of 23 m^3 d^{-1} (ICRP 1975). For an exposure time of 8760 h y^{-1} (a full-time resident), this corresponds to an annual breathing rate of 8395 m^3 y^{-1}, which contrasts with the RFETS breathing rate of 7000 m^3 y^{-1}.

Placing the breathing rate of 8395 m^3 y^{-1} into the RFETS calculation yields a soil action level of 1202 pCi g^{-1} and a soil action level to dose ratio of 14.1 (pCi g^{-1}) $mrem^{-1}$. We did not discover the reason for the remaining difference between these two ratios during this assessment. We have requested additional documents and we will complete a further analysis before the final draft of this paper is prepared in an attempt to identify the parameter(s) that accounts for the remaining difference.

Table 8 summarizes the changes made to the RFETS calculation and ratio.

Table 8. Soil Action Level to Dose Ratio for $^{239,240}Pu$ Changes with Parameter Alteration for Palomares and RFETS Calculations

Location	Parameter change	Soil action limit to dose ratio ([pCi g^{-1}] $mrem^{-1}$)	Dose to soil action level ratio (mrem [pCi g^{-1}]$^{-1}$)
Rocky Flats	Original calculation	17	0.06
	Change breathing rate	14.1	0.07
Palomares	Original calculation	12.3	0.08

It is important to note that at the Palomares site, the air concentrations measured in the environment after cleanup were almost always below the acceptable limits, with the exception of four 10–day periods during 1966–1969. During these periods, the increases in contaminated air above the acceptable level could be attributed to cultivation activities, which were hypothesized to raise contaminated soil to the surface and make it available for resuspension (Iranzo et al. 1987).

CONCLUSIONS

The soil action levels at the RFETS are significantly higher than action or cleanup levels at other facilities, even when normalized to dose. However, we understand the reasons for these elevated levels. The outcome of the RESRAD calculation is strongly controlled by a few parameters, and almost without exception, it is these parameters that affect the differences in the soil action levels for a unit dose between sites. The parameters are

- Dose conversion factor (solubility class of plutonium),
- Mass loading (resuspension), and to a lesser degree
- Breathing rate.

Breathing rate is less significant because the range of possible values is limited to within reasonable boundaries. The dose conversion factor varies depending on the assumed solubility of plutonium. For soluble Class W plutonium, the inhalation dose conversion factor is 0.429 mrem pCi^{-1} and the ingestion dose conversion factor is 0.0035 mrem pCi^{-1}. For insoluble Class Y plutonium, the inhalation dose conversion factor is 0.308 mrem pCi^{-1} and the ingestion dose conversion factor is 0.000052 mrem pCi^{-1} (ICRP 1978). When soluble plutonium is assumed, the ingestion pathway dominates dose and the dose per unit intake is much greater. For the RFETS, we can determine the appropriate assumption based upon the oxidation state of the plutonium found in the soil at Rocky Flats.

The mass loading parameter can vary over orders of magnitude depending on assumed environmental conditions. Mass loading and similar resuspension parameters have been extensively measured at Rocky Flats under a variety of conditions, and it will be important to use this information to establish a plausible range of values for this parameter. If insoluble plutonium is assumed, inhalation will dominate dose, and mass loading will become a critical parameter.

DRAFT

We reviewed the soil action level to dose ratios for the other sites studied during Task 1 in terms of the calculations, models, and parameters used to calculate soil concentrations and/or dose. In almost every case, differences between sites could be explained by the different assumptions made for one or more of the key parameters identified above.

With Task 1, we have identified the input model parameters that are of primary importance in determining the soil action levels so we can carefully review them when completing Task 3, Inputs and Assumptions.

Table 9. Summary of Comparisons between RFETS Calculations and Those for Other Facilities

Location	Parameter change	Soil action limit to dose ratio ($[pCi\ g^{-1}]\ mrem^{-1}$)	Dose to soil action limit ratio ($mrem\ [pCi\ g^{-1}]^{-1}$)
Rocky Flats	Original calculation	17	0.06
Hanford	Original calculation	2.3	0.44
	Remove meat, milk, fish, and drinking water pathways and change to RFETS dose conversion factor and mass loading	34	0.03
Rocky Flats	Original calculation	17	0.06
	Change to NTS dose conversion factor	2.8	0.36
Nevada Test Site	Original calculation	4.1	0.24
Rocky Flats	Original calculation	17	0.06
	Change to NRC mass loading	4.6	0.22
NRC DandD Code	Original calculation	7.1	0.14
Rocky Flats	Original calculation	17	0.06
Johnston Atoll	Original calculation	0.85	1.2
	Change to RFETS mass loading, enrichment factor, and calculate air concentration using RFETS dose conversion factor and breathing rate	17.8	0.056
Rocky Flats	Original calculation	17	0.06
Maralinga	Original calculation	0.56	1.8
	Change to RFETS mass loading, breathing rate, dose conversion factor	17.8	0.056
Rocky Flats	Original calculation	17	0.06
Semipalatinsk Nuclear Range	Original measurement	8.8	0.11
Rocky Flats	Original calculation	17	0.06
	Change to Palomares breathing rate	14.1	0.07
Palomares	Original calculation	12.3	0.08

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DRAFT

January 21, 1999

Local group to oversee Flats regulatory decisions

by Nancy Bachtel

The nation's eyes are on a local committee as it reviews the facts in a U.S. Department of Energy decision.

The Soil Action Level Oversight Panel is the first community organization in history to have been funded by the D.O.E. to double-check one of its regulatory decisions. The panel is examining the plutonium levels which will be allowed to remain in the soil once Rocky Flats is cleaned up.

Plutonium is a radioactive material that was used at Rocky Flats to make nuclear weapons components. Rocky Flats is located immediately west of Westminster in Jefferson County.

The level set by D.O.E. in 1996 for Rocky Flats is the highest allowable level of plutonium in the world, far exceeding allowable levels set at Bikini Atoll and Trinity Site where the first nuclear weapons were tested, Hiroshima and Nagasaki where the first nuclear bombs were dropped and the Nevada Test Site where weapons were tested regularly until the testing ban went into effect.

"We just want to make sure what they set is protective," Westminster Rocky Flats Coordinator Mary Harlow said. "We want to make sure it was properly done because of risks to our community down the road, we want to make sure it was done right the first time."

The panel, which was established in October, will hold a public information meeting in March and expects to release the results of its study in September.

The study will review solubility levels of plutonium at Rocky Flats. The D.O.E. reports indicate 95 to 98 percent of the material with a half-life of 24,065 years is in a solid phase which does not pose as significant a health hazard as does the radioactive material in a liquid state.

The study will also examine the D.O.E.'s determinations on how plutonium particles move through the environment. Information gathered by air quality monitoring systems at Rocky Flats was averaged over a three-year period to determine exposure levels from airborne particles. The averaging removes the effect of single exposures caused by high wind gusts which are common to the area.

Harlow said the risks of exposure will then be compared to local resident lifestyles – a rancher, a jogger in the open space park which surrounds the site, an average resident, a child playing in the Walnut Creek ditch which is filled with water run-off from Rocky Flats and passes through Westminster neighborhoods – to determine what an acceptable level of plutonium in the soil would be.

"We will be setting a precedent for the nation," Harlow said. "This will be a community determined level."

All communities across the country who are impacted by government nuclear sites will be looking to the panel's study to determine how they might deal with D.O.E. decisions in their own back yards.

The review panel includes representatives from the six local governments impacted by Rocky Flats, the Environmental Protection Agency, the Colorado Department of Public Health and Environment, the D.O.E., Kaiser-Hill, a scientist from Colorado State University, a scientist from the University of Colorado, a scientist from Metropolitan State College and an independent soil expert.

Risk Assessment Corporation, a South Carolina company, was hired by the panel to perform the study.

Window on Westminster

Rocky Flats computers distributed to schools

Five area elementary, junior high and senior high schools received refurbished computers from the U.S. Department of Energy's Rocky Flats Site as part of a program aimed at helping prepare today's students for tomorrow's technology. The donation was organized through Operation S.E.E.D.S., a coalition program established in 1996 by Congressman Scott McGinnis of Grand Junction which provides excess electronic equipment from government agencies and private companies to urban and rural schools in a four-state region.

February 1999

To: Rocky Flats Soil Action Level Panel

From: Kathleen R. Meyer

Topic: Summary of Scenarios from the Rocky Flats Cleanup Agreement and Proposed by RAC

Scenarios describe the characteristics and behaviors of hypothetical individuals who might have some contact with the radionuclides in the soil at the site. The people described by the scenarios live, work, or use the Rocky Flats site for recreational purposes. For the soil action level assessment, a succession of hypothetical individuals over time (for example, 1000 years) is considered. A goal for designing the scenarios in this study is that if the hypothetical individuals are protected by specified dose limits, then it is reasonable to assume that others will be protected. The reference scenarios are standards against which the soil action levels can be measured.

Selecting appropriate parameters for the scenarios depends upon a thorough review of the scientific literature, and fully considering the range of reported values for the relevant parameters. *RAC* believes that it is important to go back to the original studies when possible to evaluate the data for use in developing the possible range of values for the scenario parameters. After compiling data on the parameters, we generate a distribution of values using Monte Carlo techniques. These distributions can be characterized with a central value such as the median and some measure of the spread of the distribution, such as the 5th and 95th percentiles of the distribution. From these uncertainty distributions, we select appropriate parameter values for the scenarios. In developing a particular scenario, we can use a high (or low) percentile of the distribution as needed to extend protection to people who might come into contact with the site in the near or distance future. Once a parameter value is selected from our distribution of values for use in a scenario, the scenario is considered fixed just as standards are fixed.

RAC is evaluating the three scenarios described in the final report, *Action Levels for Radionuclides in Soils for the Rocky Flats Cleanup Agreement*, dated October 31, 1996, along with seven additional scenarios that we have proposed and described at the monthly RSALs meetings. We believe that it is important to provide the panel with a broad range of scenarios for evaluation and to consider a number of likely scenarios before we decide on the final scenarios for the project. The following table summarizes key parameters for those scenarios. We present short descriptions of each scenario below, beginning with the current RF Cleanup Agreements scenarios.

1. The future residential exposure scenario assumes that an individual resides onsite all year and grows and consumes homegrown produce. This person would be exposed to radioactive materials in soils by directly ingesting the soils, by inhaling resuspended soils, by external gamma exposure from contaminated soil and by ingesting produce grown in contaminated soil. This scenario is from the current Rocky Flats Cleanup Agreement.
2. The open space exposure scenario assumes the person visits the site 25 times per year, spending 5 hours per visit at the site. The person would be exposed to radioactive materials in the soil by directly ingesting the soils, by inhalation of resuspended soils, and by external gamma exposure from the soils. This scenario is from the current Rocky Flats Cleanup Agreement.
3. The office worker exposure scenario represents an individual who works a 40-hour per week, 50-week per year job indoors in a building complex at the site. It is assumed that this person

would be exposed to radioactive material in soils by directly ingesting the soils, by inhaling resuspended soils, and by external gamma exposure from soils. This scenario is from the current Rocky Flats Cleanup Agreement.

4. The resident rancher scenario assumes loss of institutional control where the rancher is raising a family. The rancher maintains a garden and leads an active life at the site, spending 23 hours per day, 365 days per year or 8400 hours at the site. Of that time, over 40% is spent out of doors. The potential pathways of exposure for this person include inhalation; eating produce from garden irrigated with some water from site stream, direct soil ingestion from outdoor activities, and direct gamma exposure from the soils. The annual breathing rate is 10,000 m^3 per year, based on a time-weighted average of breathing rates and activity levels as described during the monthly RSALs meetings. *RAC* proposed this scenario for consideration at the January 1999 RSALs meeting.
5. Infant in rancher family is 0 to 2 years of age, and onsite 23.5 hours per day, 365 days per year, or 8600 hr/year. The infant's potential pathways of exposure include inhalation, some ingestion of produce from family garden, some direct soil ingestion from outdoor activities, and direct gamma exposure from soils. *RAC* proposed this scenario for consideration at the January 1999 RSALs meeting.
6. The child of the rancher family is assumed to be 5 to 17 years of age, and onsite 16 hours per day, 365 days per year, or 5800 hr/year. The potential pathways of exposure include inhalation, eating produce from garden irrigated with site stream water, direct soil ingestion, and gamma exposure from soils. *RAC* proposed this scenario for consideration at the January 1999 RSALs meeting.
7. The office worker scenario is quite similar to the office worker scenario already described in the current Rocky Flats Cleanup Agreement. The differences are a higher breathing rate of 200 m^3 per year and a higher soil ingestion rate of 25 g $year^{-1}$. *RAC* proposed this scenario for consideration at the January 1999 RSALs meeting.
8. The recreational land user is similar to the open space user already described in the current Rocky Flats Cleanup Agreement. The differences are more frequent site visits (100 times per year for 3 hours per visit), a higher annual breathing rate of 750 m^3 per year, and a higher soil ingestion rate of 25 g $year^{-1}$. *RAC* proposed this scenario for consideration at the January 1999 RSALs meeting.
9. The subdivision resident lives in a developed neighborhood, works in a home office on the site, maintains a garden for fresh produce, and uses the site for running or biking for physical exercise. The person is onsite 22.5 hours per day, 350 days per year, or 7900 hours per year. Of that time, the person is outdoors 15% of the time. The annual breathing rate (7400 m^3 per year) and soil ingestion rate (88 g $year^{-1}$) are slightly higher than the residential scenario described in the current Rocky Flats Cleanup Agreement. *RAC* proposed this scenario for consideration at the February 1999 RSALs meeting.
10. The current onsite industrial worker scenario assumes a person works onsite 8½ hours per day, 5 days per week, 50 weeks a year, or 2100 hours per year. It is assumed that 60% of the worker's time is spent outdoors. The potential pathways of exposure for this person include inhalation, direct soil ingestion from outdoor activities, and direct gamma exposure from the soils. The annual breathing rate is 3600 m^3 per year, based on a time-weighted average of breathing rates and activity levels for the time spent onsite. *RAC* proposed this scenario for consideration at the February 1999 RSALs meeting.

Key Parameter Summary for the Rocky Flats Environmental Technology Site Radionuclide Soil Action Levels

	Current DOE/EPA/CDPHE Scenarios			Additional Scenarios for consideration						
Parameter	Residential	Open space	Office worker	Resident rancher	Infant of resident rancher (NB-2 yr)	Child of resident rancher (5-17 yr)	Office worker	Rec. land user	Neighborhoo resident	Current site industrial worker
Time on the site (hr/yr)				23	23.5	16	8	3	22.5	8.5
Time on the site (days per year)				365	365	365	250	100	350	250
Time on the site (hr/yr)	8400	125	2000	8400	8600	5800	2000	300	7900	2100
Time indoors onsite (hr/yr)				4700	7740	5075	1750	300	6700	900
Time indoors onsite (%)	100	100	100	57	90	88	88	100	85	40
Time outdoors onsite (hr/yr)	0	0	0	3700	860	725	250	0	1200	1200
Time outdoors onsite (%)	0	0	0	43	10	12	12	0	15	60
Inhalation Shielding Factor	1	1	1	1	1	1	1	1	1	1
Breathing rate (m^3 per year)	7000	175	1660	10000	1800	4400	2000	750	7400	3600
Breathing rate (liters per year)	7 million	0.18 million	1.7 million	10 million	1.8 million	4.4 million	2 million	0.75 million	7.4 million	3.6 million
Soil ingestion (grams per day)	0.2 for 350 d	0.1/ visit for 25 visits/yr	0.05 for 250 days	0.25 for 365 days	0.04 for 265 days	1 for 365 days	0.1 for 250 days	0.25 / visit for 100 visits	0.25 for 350 days	0.25 for 250 days
Soil ingestion (grams per yr)	70	2.5	12.5	90	15	365	25	25	88	62
Irrigation water source	groundwater	na	na	Woman Creek	Woman Creek	Woman Creek	na	na	groundwater	na
Irrigation Rate (meter/yr)	1	na	na	1	1	1	na	na	1	na
Fraction of contaminated homegrown produce	1	0	0	1	0	1	0	0	1	0

na = not applicable

RSALOP

Radionuclide Soil Action Level Oversight Panel

Public Meeting Reminder

The following display ad ran in the weekly Sentinel/Transcript published on March 4 in seven metro communities. It also ran in the Boulder Daily Camera on February 27 & 28 and March 7 and March 10:

RSALOP

Radionuclide Soil Action Levels Oversight Panel

PUBLIC MEETING

"Planning for Tomorrow. . . .Radionuclide Soil Action Levels at Rocky Flats"

Where: *Westminster City Hall*
4800 W. 92nd Avenue (East of Sheridan Blvd. On 92nd Ave.)
Westminster, CO 80030

When: *Wednesday, March 10, 1999*
6:30 - 7:00 P.M. Open House — 7:00 - 9:00 P.M. Discussion

- **What is a "Radionuclide Soil Action Level"?**
- **What's the Issue?**
- **Why Be Concerned About Plutonium in the Soil at Rocky Flats?**
- **What's Being Done to Protect the Community?**

Get the answers to these questions and more. Your input is needed as we work together to determine the amount of radioactive materials that may remain in the soil. Please join us for this important discussion. For more information, please contact either Carla Sanda, Advanced Integrated Management Services, Inc. (303-277-0753), or Ken Korkia, Rocky Flats Citizens Advisory Board (303-420-7855).

RSALOP TECHNICAL DISCUSSION

RAC representatives will be available from 2:30 - 3:30 p.m. Thursday, March 11, 1999 at the Broomfield City Building - Bal Swan Conference Room for in-depth technical discussions immediately prior to the regularly scheduled meeting.

CHECK OUT THE RSALOP WEB SITE

www.rfcab.org/SALOP.html

P.01

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	02:56 PM	KEN STARR	3'57"	7	SEND	OK	170	
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	03:12 PM	JOHN SHEPHERD	2'38"	7	SEND	OK	170	
	03:15 PM	VICTOR HOLM	5'10"	7	SEND	OK	170	
	03:43 PM	KEN KORKIA RFCAB	**'**"	0	SEND	BUSY	170	
	03:21 PM	TOM MARSHALL	2'57"	7	SEND	OK	170	
	03:24 PM	LEROY MOORE	3'02"	7	SEND	OK	170	
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166

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167

JOSEPH GOLDFIELD
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Environmental Engineering
nergy Conservation

129 Elm Street
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(303) 321-7276

February 2, 1999

AIMSI
5460 Ward Road, Suite 370
Arvada, CO 80002

attn Carla Sanda and /or Anna Corbett

Subject: Enclosed, Breathing Rates of Exposed Individuals

Dear Carla and Anna,

I am enclosing a copy of the subject report. Please make about 30 cpoies for distribution at our next meeting. Thank you very much.

Sincerely,

Joe Goldfield

Joe Goldfield

BREATHING RATES OF EXPOSED PERSONS

Residing on Plutonium Contaminated Soil

for Calculating Health Effects

JOSEPH GOLDFIELD, PE
Denver, CO

January 31, 1999

169

BREATHING RATES FOR CALCULATING HEALTH EFFECTS OF INDIVIDUALS EXPOSED TO PLUTONIUM CONTAMINATED SOIL

SUMMARY

Estimates are made of breathing rates that are applicable to calculations made to determine health effects of residents living on soil contaminated with plutonium. To adequately protect the population so exposed, it is necessary to use breathing rates of individuals defined by the EPA as "the reasonably maximally exposed individual experienced by the 95th percentile of the population at a remedial site". Using that definition, breathing rates determined for other health studies, and an assumed scenario, it is estimated that the RME will inspirate 26,700 cu. m. of air per year. That estimate is about 3.6 times as great as the yearly estimated inspiration of air (7,500 cu. m. per year) used to calculate the health effects of living on soil at Rocky Flats contaminated with plutonium at levels proposed for cleanup.

No attempt has been made (to my knowledge) to determine whether corrections must be made to breathing rates measured at sea level, where the air is 1.25 times as dense as the air at Rocky Flats, to breathing rates estimated for individuals living at Rocky Flats.

INTRODUCTION

An important criterion for calculating health effects of plutonium contaminated soil on residents living on that soil is the breathing rate estimated for those individuals. The breathing rate is one of the factors that determine the quantity of plutonium contaminated soil particles that is drawn into the lungs and may cause disease to develop. The purpose of this report is to discuss the criteria to use in selecting breathing rates to calculate health effects of people living on plutonium contaminated soil and to recommend specific values to use for this parameter. It also includes a discussion of the effects of altitude on the quantity of air that must be inspirated compared to the volumes inspirated at sea level where many of the studies of breathing rates were probably made.

CRITERIA FOR SELECTING BREATHING RATES

The EPA has ruled that the intention of its regulations is to protect the "reasonably maximally exposed individual" (RME) living on a contaminated site. It further defines the RME as the exposure experienced by the 95th percentile of the population at a remedial site (i.e. the upper 5th percentile). Applying these criteria to the selection of breathing rates to be chosen for making health effects caculations requires us to be quite conservative. We cannot select breathing rates that are average rates for a resident population but rather rates that will encompass 95% of the resident population.

The studies of health effects of residents living on soil contaminated with radioinuclides are not the first attempts to evaluate breathing rate selection for similar studies. In January 1969, a publication called "Air Quality Criteria for Particulate Matter" was issued as a comprehensive study of the effect of airborne particulate matter on the exposed population of the United States. This study was headed by the Commissioner of the National Air Pollution Control Administration. He was assisted by a prestigious advisory committee of 14 experts. 43 nationally known experts and reviewers contributed to the report. A liaison group consisting of representatives from 17 agencies also participated in the preparation of the document.

The table below was reproduced from that report. It was chosen as the level of breathing rates to be applied for making calculations of health effects of the particulates in inspirated air.

TABLE 9-1. RESPIRATORY AIRFLOW PATTERNS FOR A GROUP OF HEALTHY YOUNG MEN.[9]

Exercise level	Inspiratory flow rate l/min (Maximum)	Expiratory flow rate l/min (Maximum)
Sedentary	40	32
622 kg-m/min	100	107
1660 kg-m/min	286	322

The study from which this table is extracted was called "Air Flow Measurements on Human Subjects with and without Respiratory Resistance at Several Work Rates." Arch. Ind. Hyg., Vol. 3, pp 461-478, 1951. Five authors led by Professor Leslie Silverman are listed. Dr. Leslie Silverman was for many years a distinguished professor at Harvard. (As I recall in the School of Public Health.)

RECOMMENDED SCENARIO FOR DETERMINING YEARLY BREATHING VOLUMES

Scenarios for determining the yearly volume of air inspirated by an individual living on plutonium contaminated soil are at best educated guesses. Nevertheless, I will make a guess for one particular scenario for a healthy, physically fit young man living and working on the plutonium contaminated soil at Rocky Flats.

I would assume that the young man exercises heavily for 1 hour per day. He does heavy work such as digging or gardening for two hours per day. He walks or works in a shop for four hours per day. He is sedentary--performing no work or exercise for 17 hours per day (includes sleeping).

Using the scenario outlined and the inspirated air volumes from the table on the preceding page, I have prepared the following

YEARLY INSPIRATED AIR BY A HEALTHY YOUNG MAN
LIVING AND WORKING AT ROCKY FLATS

Activity	Time per day (hrs.)	Liters per min.	Total per day (cu.m.)
Exercising	1	100	6
Heavy Work Digging, Gardening	2	100	12
Walking, Light Work	4	60	14.4
Sedentary and Sleeping	17	40	40.8
Total			73.2

The total for a year is 73.2 cu. m. (cubic meters) per day x 365 days per year = 26, 700 cu.m. per year.

Contrast this result with the estimate of 7,500 cu. m. per year--the inspirated air volume used by the DOE, EPA, and the CDPHE for calculating soil cleanup standards to be used for rendering Rocky Flats fit for human occupancy. The estimate calculated above is 3.6 times as great as one used to set the soil cleanup standards.

EFFECT OF ALTITUDE

The altitude at Rocky Flats is 6,000 feet above sea level. Atmospheric pressure at sea level is 30 inches of mercury. The pressure falls about one inch of mercury for each 1,000 feet increase in elevation. Thus the atmospheric pressure at Rocky Flats is about 24 inches of mercury. At sea level, air weighs 0.075 pounds per cubic foot. At 6,000 feet the air density is only 0.060 lbs. per cu. ft.

For a given energy level of activity the body requires the same weight of air per minute at altitude as it does at sea level, not the same air volume. Thus, the inspiration of air must increase by a factor of 1.25 (0.075 ÷ 0.06). I understand there are some mechanisms by which the body can at least partially compensate for this problem. Someone with a knowledge of physiology must be consulted to ensure that corrections are not needed to breathing rates determined at sea level when applying them to rates estimated at altitude.

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176

RSALOP

Radionuclide Soil Action Level Oversight Panel

AGENDA

RSALOP Meeting - March 11, 1999
Broomfield City Building - Zang's Spur Conference Room
4:00 - 7:00 P.M.

4:00 - 4:10	OPENING	Mary Harlow
	• Introductions	
	• Minutes corrections/approval	
	• Sign-In	
	• Agenda Review	Facilitator
	• Group Agreements	Facilitator
4:10 - 4:15	CO-CHAIRS UPDATES	
	• Public Meeting Recap	Mary Harlow
	• Peer Review Team	LeRoy Moore
4:15 - 4:20	RFCA Regulator Report	Steve Gunderson, CDPHE
4:20 - 5:20	Computer Code Strengths/Weaknesses	Dr. John Till, Art Rood, Dr. Helen Grogan, *RAC*
5:20 - 5:25	PUBLIC COMMENT	
5:25 - 5:30	BREAK	
5:30 - 5:40	DISCUSSION OF GOLDFIELD PAPER	Joe Goldfield, RSALOP
5:40 - 6:10	SCENARIO DEVELOPMENT REVIEW	Dr. John Till, Jill Weber, *RAC*
6:10- 6:40	PLUTONIUM SOLUBILITY	Dr. Helen Grogan, *RAC*
6:40 - 6:45	PUBLIC COMMENT	
6:45 - 6:50	ANNOUNCEMENTS	
6:50 - 7:00	OTHER TOPICS/FUTURE AGENDA ITEMS/ ACTION ITEMS	Facilitator

UPCOMING MEETINGS/ACTIVITIES

April 8	RFSALOP Meeting	4-7 P.M. Broomfield City Bldg.*
May 13	RFSALOP Meeting	4-7 P.M. Broomfield City Bldg.*
June 10	RFSALOP Meeting	4-7 P.M. Broomfield City Bldg.*
July 8	RFSALOP Meeting	4-7 P.M. Broomfield City Bldg.*

*Broomfield City Building, One Descombes Dr. - Zang's Spur/Bal Swan Conference Rooms (lower level)

178

This fax includes the Agenda for the monthly RSALOP meeting.
Thursday, March 11, 1999.

Also included is information on Scenario Development from Kathleen Meyer. This will be the topic of the technical discussion to be held from 2:30pm to 3:30pm immediately prior to the regularly scheduled meeting.

We are also enclosing a meeting reminder.

DON'T FORGET TO ATTEND THE PUBLIC MEETING!
See details attached.

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180

Radionuclide Soil Action Level Oversight Panel

MINUTES

Radionuclide Soil Action Levels Oversight Panel
March 11, 1999 - 4:00p.m. - 7:00 p.m.
Broomfield City Building - Zang's Spur/Bal Swan Conference Rooms

NOTE: Minutes are presented in draft form and should not be quoted or distributed until receiving final approval by the Rocky Flats Soil Action Level Oversight Panel at its April 8, 1999 meeting.

Mary Harlow, Co-Chair, convened the regular meeting of the Radionuclide Soil Action Level Oversight Panel (Oversight Panel or Panel) at 4:10 p.m. and opened with the introduction of the following attendees:

Hank Stovall, City of Broomfield
Niels Schonbeck, HAP & MSCD
Russell McCallister, DOE-RFFO
Dave Shelton, Kaiser-Hill
Heather Balser, City of Louisville
Laura Brooks, Kaiser-Hill
Jeremy Karpatkin, DOE-RFFO
Joe Goldfield, CCANW
Todd Margulies, TM Consulting
Jill Weber, *RAC*
Mary Harlow, City of Westminster
Dean Heil, CSU
Laura Till, Facilitator
Victor Holm, RFCAB
Carla Sanda, AIMSI
Edd Kray, CDPHE
Tom Marshall, RMPJC
Kathy Schnoor, City of Broomfield
John Till, *RAC*
Helen Grogan, *RAC*
Carol Lyons, City of Arvada
Tim Rehder, US EPA
Brady Wilson, RFCAB Staff
Ken Korkia, RFCAB
Ken Starr, JEFFCO
Rick Roberts, RMRS
Joel Selbin, CU-Boulder
LeRoy Moore, RMPJC
Art Rood, *RAC*

MINUTES REVIEW/APPROVAL

Minutes of the January 14, 1999 meeting of the Oversight Panel were reviewed and approved with the following correction: Under "Panel Discussion", page 3, the last bulleted item stated that the ".......Working Group has been looking at redesigning the D&D program....". It should have read "".......Working Group has been looking at using the D&D program....".

AGENDA REVIEW

Laura Till reviewed the Agenda as well as the Group Agreements. The agenda was approved as distributed; the meeting was turned back to the Co-Chairs.

CO-CHAIRS UPDATES

Public Meeting - The project's first public meeting was held last night, March 10, 1999 at the Westminster City Hall from 6:30 - 9:00 p.m. Seven storyboards were developed to provide project basics to meeting attendees. The storyboards were placed on easels in the foyer staffed by three panel members to greet those attending the meeting and address any questions or comments they may have regarding the project. The meeting was attended by RSALOP members, site representatives, interested community representatives, several residents, and a contingency of Boy Scouts who were fulfilling requirements for the Scout Communications badge by participating in a community meeting. The meeting opened with a brief overview by Hank Stovall and introduction of panel members by Mary Harlow. John Till then presented a review of the project, which was delivered in concise, non-technical terms to assure clear understanding by all attendees.

Trip to Washington, DC - Ms. Harlow then updated the group on a discussion she had with Mr. Jim Fiore, Deputy Acting Assistant Secretary for Environmental Restoration, U.S. Department of Energy - EM 40 during a recent trip to

Washington, DC. Mr. Fiore indicated that there was a great deal of interest and concern at Headquarters regarding the RSALOP work. He asked for a project update, asked how long the project will take, and expressed his hope that there would be no "surprises" to Headquarters along the way. He asked that they be kept apprised of the project status. In addition, Senator Domenici has received $12M for a study related to the potential effects of exposure to low level radiation.

PEER REVIEW SUBCOMMITTEE REPORT - Discussion Lead: Dr. LeRoy Moore

Dr. Moore reminded the group that as of February 10, 1999 a 5-member peer review team had been assembled (names and affiliations were published in the February 11, 1999 minutes). A conference call was conducted on Monday, March 8, 1999 with four members of the Peer Review Team and the following RSALOP representatives: Hank Stovall, LeRoy Moore, Carla Sanda, Joe Goldfield, Dean Heil, Ken Korkia, and Victor Holm. It was an extremely worthwhile effort. RSALOP representatives were impressed with the keen level of interest displayed by the Peer Review Team, as well as the volume of background information they requested.

The first task for the Peer Review Team is review of the Task 2 draft report. A specific schedule has been provided for receipt of comments to the draft documents. At the request of the peer review team, a decision was made that peer review comments would be provided to *RAC* with no individual names attributed to comments. This is standard practice for peer review efforts.

RFCA REGULATOR REPORT - Discussion Lead: Tim Rehder, EPA

The Agencies have formed a working group to review the interim RSALs and attempt to investigate any information that may have become available subsequent to establishment of the 1996 interim levels. A primary question at this time centers on whether or not the RSALs would be different if the 1997 NRC regulation for cleaning up radioactive sites were used in place of the EPA draft regulations (those used to set the 1996 interim levels). The Group is working to identify potential differences if that had been the case. For example, in the Superfund process -- when selecting parameters, the guidance recommends that parameters be used so that one can arrive at what is known as "reasonable, maximal exposure". There is also some guidance as to how that "reasonable, maximal exposure" is selected. The NRC regulation says that one should use parameters for what is called the "average person in the critical group". The Group is wrestling with exactly what that means and will likely go back to NRC for additional guidance. The Group is also trying to determine whether or not the NRC regulations require an ALARA analysis for what is reasonable and achievable when cleanup standards are set. There is some debate in the Group as to what the regulation actually says regarding that subject. Minutes of the last meeting refer to this issue.

Another question being addressed is whether or not the RSALs would look different if another computer model had been used. A number of modeling efforts are now underway that will use numerous computer programs; i.e., the State will model scenarios using D&D; EPA will use the GENII program; DOE will use the MEPAS program; Kaiser-Hill will use the RESRAD program, and Diane Niedzwiechi, CDPHE toxicologist, will conduct basic slope factor calculations to come up with risks using the same parameters.

Panel Discussion:
Joel Selbin commented that at last night's public meeting, John Till indicated that RAC has looked at these five different programs and decided to eliminate three of these programs from further modeling efforts. In light of that, he asked Mr. Rehder if he anticipates reconsideration of the codes? Mr. Rehder said he does not believe it would be reconsidered; he thinks it may still be useful information to see what information those models will provide in the way of dose assessment. In addition, every effort is being made to maintain the independence of this process, so RAC's decision will likely not alter the course.

Mary Harlow asked if the RFCA group was following the same scope of work as the RSALOP. Mr. Rehder assured Ms. Harlow that this was not the case at all, but rather the Group is trying to learn as much as they can about the process originally used and what new information they can find that may related to future recommendations.

COMPUTER CODE STRENGTHS & WEAKNESSES - Discussion Lead: Dr. John Till, *RAC*, with assistance from Art Rood, *RAC*

This agenda item was structured as a discussion period; no formal presentation materials were developed. Dr. Till began the discussion with a brief comparison of what the regulators are doing versus what *RAC* is doing. One major difference is that *RAC* is taking a stochastic approach using uncertainties, whereas the RFCA regulator group is not. That approach reflects a major difference in both the approach and potentially the outcome. That is one reason, for example, that some codes are not being considered, since major work would be required to apply uncertainty to some of the existing models. Dr. Till pointed out that the RFCA Regulator Group might want to consult ICRP 43 to find a discussion on the "critical group". ICRP is taking a whole new look at this concept of critical group and scenarios. Basically, it is a concept that has been generally applied, and ICRP has recommended it, but it is not very well defined.

Dr. Till briefly reviewed the ***Task 2 Report: Computer Models***. The report provides a discussion of the computer models, describes an approach to the study , and provides a brief recap of topics like validation and verification. ***RAC*** did not go into tremendous depth discussing a code that couldn't be considered -- if, for example, the necessary documentation could not be obtained. This was the case with the D&D program, although some discussion is provided simply because of Panel interest and discussion. However, this code is currently still under development at NRC. Although it is available, it has not been documented. The NRC indicated that additional information is expected in the near future; however, due to the schedule of the study, this program has been eliminated from further evaluation.

Dr. Till then discussed a recent problem: After much work, the ***RAC*** team finally realized that they had been provided an incorrect version of the documentation provided for the RESRAD program. This was a bit of a setback for the team and required substantial additional work; however, correct documentation has now been obtained. The new version calculates resuspension differently from the original calculations, which could have important ramifications. Understanding the resuspension portion of the model has been somewhat difficult as it is written. In fact, ***RAC*** will likely take a different approach by inserting its own resuspension model within RESRAD. The team is considering an approach using empirical, site-specific data to derive a model for the site, which they believe may result in a more defensible approach than using what currently exists in the model.

Art Rood provided a brief summary of their computer model review, as follows:

RESRAD - source codes were obtained for Version 5.82 (the latest copy, which uses a "Windows" interface). The benefit of having the source code is the ability to run the program from a command line and bypass the user interface, since one of the critical parts of the approach is use of the Monte Carlo simulation. Although RESRAD has a built-in Monte Carlo utility, it is currently available only in a Beta release. In addition, it seems to be limited to certain kinds of distributions and how correlation is preserved among parameters when performing a calculation. ***RAC*** representatives prefer to run the program from a command line with the flexibility of writing scripts that can provide input to both execute and extract data from the source code. Overall, RESRAD incorporates standard models for resuspension, plant ingestion, and radionuclide decay and ingrowth, which can be very tedious to deal with. The model parameters and some resuspension details can be changed to fit specific needs. ***RAC*** found the approach used and scripting routine to be acceptable. The only problem was the change in the way resuspension was dealt with (pgs 38-39 of the report, and Figure 4.2.3-1 - which explains the differences between the original RESRAD and revised RESRAD program.) Art briefly reviewed and discussed this section of the report. The graph in the figure explains the differences between the original and new RESRAD factor. As the area increases, the area factor for the original RESRAD approaches 1 -- the concentration in the area is the same as what the resuspension model predicts in the air. As you go to a smaller area, you have the effects of the edge -- in other words, the area is not that big, which results in dilution. The new area factor takes into consideration particle deposition, as well as both lateral and longitudinal particle diffusion with the wind speed, and it is a function of wind speed. As wind speed increases, there is more dilution. (As the wind speed increases, more dilution is observed, and the area factor decreases.) The net effect for a 200 meter area with a 4 meter per second wind speed (~average wind speed for Rocky Flats) would result in about a 10-20% reduction. In other words, the inverse of that would increase the soil action levels by that amount. The approach is to delve into the resuspension issue and try to incorporate site-specific data into the parameters. This is still in the investigative stage at this point. There appears to be a substantial difference, then, between Version 5.61 and the proposed Version 5.82.

MEPAS - ***RAC*** obtained the code and documentation from Pacific Northwest Laboratory. This program has a lot in it, and it will be interesting to see what the EPA benchmark is from running this program. The program has a wind speed - dependent resuspension model. MEPAS requires substantially more data than RESRAD. In general, the model seems to be more complex -- not necessarily better, but more complex. The biggest drawback to MEPAS is the inability to obtain the source code -- without that information it is impossible to script the code to perform Monte Carlo calculations. As a result, MEPAS has been eliminated from further consideration.

GENII - Written by Pacific Northwest Laboratory under the direction of the U.S. Department of Energy, GENII contains all relevant pathways for calculating soil action levels. It treats resuspension much the same as RESRAD. The program also includes modules for groundwater concentrations that will go into the ingestion dose. It also includes off-site exposure models; i.e., an air dispersion model to calculate from the site to some off-site location. GENII was developed under a stringent quality assurance plan and has been peer-reviewed. The food chain model is quite sophisticated. Using RESRAD inputs and conceptual models, ***RAC*** ran some benchmarks using GENII and tried to simulate the

RESRAD soil action levels. The results are described on pg. 46 in Tables 4.4.3-2 and 4.4.3-3. A positive value in these tables would indicate that RESRAD was higher than GENII and a negative value would indicate that GENII was higher than RESRAD. The most striking difference is the external -- in almost every case RESRAD was higher, which was attributed to a very different way of dealing with exposure. GENII calculates it based upon looking at a photon source and actually calculates photon transport; whereas, RESRAD uses a series of exposure rate conversion factors that are then corrected for different densities and source thickness. However, when looking at the total, there isn't a great deal of difference, with the exception of uranium. Some of that is attributed to the ingestion pathway, while some of it is attributed to external pathway. The ingestion pathway is typically more important for those radionuclides that are more readily taken up by the body and plants. Sandia Laboratories has developed a Monte Carlo driver for the GENII code. However, the disadvantage of GENII is that it is tedious to change the different solubility classes of radionuclides; i.e., all radionuclides must be either soluble or insoluble. Therefore, it would be necessary to make multiple runs to change the solubility class.

MM SOILS - This program was downloaded from the Internet. The biggest problem with MM Soils is that it only handles chemicals with first order decay; i.e., one decay product. Actinides have long decay chains; therefore, it would be extremely difficult to adapt this program to the project needs. As a result, this program has been discounted.

D&D - This program was designed as a screening level code by NRC, and was intended to be very conservative. One of the things noted is that it has a user interface as well as a Fortran code. The user interface limits selection of particular values to certain ranges; e.g., soil ingestion only allows a range of values that does not encompass the Rocky Flats soil ingestion rate used in the RSALs set in 1996. Additionally, it is in beta test phase, which means there could still be errors. Difficulties were encountered when attempting to incorporate the Monte Carlo simulation. As a result, this program is not being considered. Some comparisons were made, however, which reflected substantial differences in the soil action levels determined with D&D versus RESRAD, when using what appeared to be the same model. The biggest difference was reflected in the ingestion pathway, as discussed in the report.. Full air mass loading is also handled differently; e.g., RESRAD calculates an air calculation with deposition onto the plant as well as weathering on the plant. D&D instead applies a mass loading parameter in grams of dry soil per gram of dry plant -- so it is actually just a percentage, with a default value of 10%. Therefore, 10% of what is plant matter is contaminated soil, which is very conservative. The program also considers that everything that gets on the plant is incorporated into the plant, which results in a direct pathway for dose. As a result, when the program is run with default values, the results reflect 99% of the dose. Complete figures are included in the Task 2 Report. Although it is possible to change the ASCII file to reflect different default values, it is a difficult process. A major problem with D&D is that none of the code's documentation is in final form. ***RAC*** representatives have contacted NRC, who will forward a final copy of the documentation as soon as it is completed. However, since there is no projection as to when this documentation will be completed, D&D will not be considered.

In summation, there seems to be two viable possibilities: GENII and RESRAD. There is very little difference in the results that would be calculated between these two codes. RESRAD is a bit easier to use. In addition, ***RAC*** representatives received the source code and documentation earlier for RESRAD, which has jump-started their process a bit. As a result, a decision has been made to go forward with RESRAD. It is important to remember that none of these codes is perfect, but that at this point RESRAD seems to be the most applicable.

Panel Discussion

- *Joe Goldfield requested clarification: Is **RAC** saying that for a given soil action level or for a given effect of resuspension one could triple the amount of plutonium. Mr. Rood responded that for a given activity concentration in soil, the concentration is roughly 3 times less in air -- Version 5.82 predicts a concentration that is 3 times less than Version 5.61. Mr. Goldfield responded that this is a tremendous effect -- is RAC asking the Panel to believe that the soil action levels can be tripled? Dr. Till responded that RAC is not asking the Panel to "believe" anything. Rather, he urged Mr. Goldfield to thoroughly read the report and reminded him that RAC has some difficulties with this as well. Dr. Till also said that at this point in the study this is not a fair question. Rather, RAC's findings and concerns have been laid out in the report, and the investigation will continue. Mr. Goldfield added that if the results were as they appear now, there would be at least one very unhappy participant in this effort. Dr. Till said they have not yet presented any final results. Dr. Till further stressed that this is a new version of RESRAD with a new resuspension model, which very likely isn't perfect. He further emphasized that at this point, all they are saying is that if the new RESRAD version were used to recalculate the original soil action levels, the resulting numbers would be higher. RAC is not entirely pleased with the new resuspension models and plans to do explore some different options. LeRoy Moore reflected that at this point, the program is not fixed and RAC can modify the inputs for the resuspension model. Victor Holm questioned the scientific validity of going into a program to change the ASCII codes. Art Rood responded that he didn't see a problem with this as long as it was carefully documented. The main thing to remember is that anything reported should be clear enough to be replicated by the scientific community.*

- *Niels Schonbeck reflected his dismay at the inability of researchers to obtain copies of information; i.e., the source code for MEPAS that is considered "proprietary". After all, this information was developed at taxpayer expense and should be available for research use.*
- *Hank Stovall asked to what extent RESRAD -- either in its prior or current version -- has been peer reviewed? Dr. Till responded that this program has been around for a long period of time, which means that it has been used and reviewed extensively. Most of the mathematical calculations come from peer reviewed literature. Just because it has been around for so long indicates that it has undergone thorough review of both calculations as well as the source code. Art Rood referred the Panel to references in the Report (page 55) that refer to review and analysis of the code.*
- *Dr. Till reminded the Panel that without budget or schedule restraints, RAC would likely not use any of the existing codes but would instead develop one specifically for this task. Needless to say, this is not an option, so a code must be selected that demonstrates the greatest likelihood for completing the task at hand.*
- *Jeremy Karpatkin asked for clarification to a statement made several times by RAC indicating that they are not pleased with the approach RESRAD takes to resuspension. Does the report embody specific concerns regarding resuspension? Dr. Till referred him to Section 3.1.3 of the report, which goes into additional detail on this issue.*
- *Joel Selbin asked if he was correct with the assumption that all of the plutonium at Rocky Flats is considered to be insoluble, while at places like Hanford it is soluble. Is that a correct premise? Dr. Till responded that Dr. Helen Grogan will discuss this further in her presentation this evening -- but there is no simple answer to this question. In addition, Dr. Till also added that it is highly unlikely that the Actinide Migration Studies group will not come up with anything in time to provide substantial assistance to this task. As a result, it will be necessary to make defensible judgements regarding the soluble versus insoluble fraction of plutonium at the site. This can be dealt with in the computer code.*
- *Joel Selbin reflected that he believes that solubility of plutonium may change with time -- there may be chemistry taking place over time that can solubilize plutonium. That may have to be factored into this.*

PUBLIC COMMENT

Has ***RAC*** considered combining the codes to incorporate the strong points of various codes for different pathways and in turn come up with a combined soil action level?

Dr. Till responded that there would only be two that they would consider: GENII and RESRAD. He further indicated that yes, they will consider combining particular elements if it would appear to be better or more feasible. However, they will have to consider whether it would be worth the time to pull particular elements out -- but if they think it will make an important difference they would likely do it.

BREAK

DISCUSSION OF GOLDFIELD PAPER - Discussion Lead; Joe Goldfield, RSALOP

Mr. Goldfield discussed a paper he has written regarding individual breathing rates. Mr. Goldfield reflected that when looking at a problem like how much plutonium in soil gets into a person, there are really only a few parameters involved: concentration of the plutonium in the soil, relationship between the plutonium in the soil and the plutonium in the airborne soil, and the breathing rate of an individual. Dr. Helen Grogan interjected that another important factor is particle size distribution. Mr. Goldfield responded that particle size distribution is automatically taken care of because the wind blowing across the soil automatically provides an allutriation effect that clears out the differences in particle size in the soil so that you've collected the portion that is capable of being drawn into the lung. However, the soil has an enormous range of particle size. Therefore, if there are pebbles in the soil, the wind would not pick that up -- even though it counts within the gram that is calculated when determining how much plutonium is in the soil. The portion that is brought up by the air should concentrate -- and you should have more plutonium per gram in the airborne fraction than there is in the soil. This concentrated fraction is now inhaled, is respirable below 10 microns -- and that is basically all that one needs to know in order to calculate an individual's exposure. Mr. Goldfield stated that he has calculated that over a two-year period, a man living on soil containing 1420 pCi/gram of plutonium, takes in an amount that is over the allowable lifetime limits for an exposed worker in a plutonium plant. The key thing is that the breathing rate is an exceedingly important criterion to use in this calculation and must be correctly determined. Mr. Goldfield also described a study that he conducted while working on development of gas masks to determine the breathing rates of men, At least one of the subjects breathed more than 1 cubic foot per minute. One cubic foot per minute equates to 28.3 liters per minute. Mr. Goldfield indicated his surprise when learning that the DOE calculations use 13.9 liters per minute as a breathing rate for a potential resident. In addition, Mr. Goldfield has a copy of a document entitled ***Air Quality Criteria for Particulate Matter***, which developed to establish the calculations under the Clean Air Act and was used to set the standards for particulate levels in air. Many factors discussed in this study are dealt with in this document. The document also contains a table providing breathing rates. A Committee led by the Head of the National Air Pollution Control Administration developed the document -- comprised of

12 prestigious individuals, with 40 nationally known contributors, 15 governmental agencies. The document doesn't portray the lowest levels -- but what they believed to be the correct levels when trying to determine the health effects of breathing particulates in air. The table says that the breathing rate for men at rest -- sedentary -- was 40 liters per minute. Mr. Goldfield stressed that in his opinion, the study should not be looking for the lowest levels of air intake, but should be looking for the highest levels. He went on to say that an advanced degree is not a license to kill -- when dealing with public safety, all knowledge is supposed to be used to protect people. One should not use a figure that simply represents the "average" -- but rather a figure should be used that is at the high-end level to assure that most of the people breathe less. Otherwise, we are not protective of the population as a whole. That is the rationale behind Mr. Goldfield's recommendation that 40 liters per minute be used. The document also provides figures related to respiration rates for men during exercise. Mr. Goldfield described a scenario representing an individual beginning each day by running and breathing 100 liters per minute, followed by working in the garden for 2 hours and breathing another 100 liters per minute. Walking and light work results in 60 liters per minute. Most of the day the subject is sedentary -- at 40 liters per minute. Overall, Mr. Goldfield came up with a calculation of 73 cubic meters total per day -- which translates to 26,700 cubic meters per year -- 3.8 times as high as the 7,000 liters per minute for people living on the soil at Rocky Flats. Mr. Goldfield stated that another bit of information to consider is that air drops in pressure 1" of mercury per thousand feet. Rocky Flats, at 7000', air pressure instead of being 30" of mercury is 23" of mercury. The partial pressure of oxygen is in that same ratio compared to sea level: 23 over 30. That is about a 20% decrease in the oxygen level. Mr. Goldfield's question then was, since most of the breathing rate experiments were conducted at sea level, should a compensatory breathing rate be used? That may be an important factor to follow up on to determine if the body compensates for changes in altitude. The chemical operations in the body that generate energy are not based on volume, but rather are based on weight. The weight of oxygen taken into the blood causes the reactions that provide the body with the energy it needs to perform work. Mr. Goldfield suggested that this area must be further explored.

Panel Discussion:
Mary Harlow expressed her appreciation to Mr. Goldfield for taking the time to do the research on this issue and presenting his perspective to the panel.

SCENARIO DEVELOPMENT REVIEW - Discussion Lead: Dr. John Till, *Risk Assessment Corporation*

Dr. Till referred the group to page 17 of the report which was a spreadsheet dealing with a total of 9 scenarios: 3 developed for the first calculation of soil action levels, and 6 that have been discussed as part of this study. It is important to develop plausible scenarios -- something that could really occur -- but also something that leans toward the safe, conservative side that may result in a higher dose. The resident rancher scenario seems to fit that criterion. The two most critical parameters appear to be breathing rate and soil ingestion rate. Based upon the Panel's discussion in the technical briefing prior to this meeting, it appears logical to combine some of the scenarios. For example, it is probably not prudent to examine just a 2-year old child or a 5-17 year old child -- these scenarios can be eliminated in favor of one depicting an individual beginning life on the site. In addition, ***RAC*** can allow the resident rancher to be on-site, essentially unrestricted use of the site to make a calculation. A calculation could also be made, however, to include restricted use of the site. That would assure that both calculations would be available for consideration. In reviewing the report, it is important to provide ***RAC*** with feedback on these figures. Obviously, it will be important to spend extensive time on the breathing rate to assure that rates are not extreme -- but are conservative. ***RAC*** has obtained a copy of the data discussed by Joe Goldfield and will carefully review the information to determine its applicability to this study.

RAC will bring information back to the group next month and present some distributions and information with which to make some preliminary decisions. Jill Weber has taken a look at breathing rate distributions described in the literature back to 1951. ***RAC*** can delve into this information, extract values and come up with a distribution of possible breathing rates. Several breathing rate distributions found in the literature were briefly discussed with the group. However, their findings have been significantly less than those discussed by Mr. Goldfield. There must be a difference for this, and ***RAC*** representatives will make every attempt to understand what those are.

✔ ***Action Item: RAC will review data and bring additional information to Panel at April meeting to promote a clearer understanding of things like breathing rate so that the Panel can bring final scenario recommendations to RAC by May 8.***

Panel Discussion
- *Mary Harlow asked why no consideration was given to future use of groundwater or the potential for children playing in streams on the site. Art Rood responded that there is a brief description provided for the groundwater pathway. Generally, the pathway is extremely complex and because of the difficulty in groundwater monitoring, this will not be*

discussed in great detail. However, this cannot be completely dismissed, so it does need to be the subject of a future study. This simply cannot be addressed in any level of detail within this study. There are some examples where the RESRAD model was turned on for the groundwater pathway wherein individuals drink water from surficial aquifers. The action levels did change dramatically for Plutonium 241, Americium 241, and Uranium 234 -- primarily because of the radioactive daughters from those radionuclides that are relatively mobile. That is really the extent of investigation possible within this study. The site has looked at groundwater issues, so additional information may be available from site sources.

- *Jeremy Karpatkin asked for clarification - is RAC saying that they have looked into the assumption that there is enough groundwater for subsistence and that information saying there is not enough for subsistence may be in error? Art Rood responded that this should be re-evaluated in terms of what one is trying to protect. For example, if one wants to argue that it is credible to assume some kind of subsistence conditions, then it might be important to look at that surficial aquifer. These aren't necessarily scientific considerations but are probably more policy considerations. Basically, what they are referring to be that policy decisions may need to be addressed.*

PLUTONIUM SOLUBILITY* - Discussion Lead: Dr. Helen Grogan, *Risk Assessment Corporation*
*Copies of presentation materials may be requested from Anna Corbett, AIMSI, 303-456-0884

Dr. Grogan began her presentation with the question: "Why is there such a fuss about plutonium?" She responded that part of it is the fact that plutonium behaves differently than many other inorganic elements because it can exist simultaneously in multiple oxidation states. To better explain this, Dr. Grogan's presentation reflected four oxidation states -- or valence states -- in which plutonium can be typically be found. This actually tells us that in the hydrolysis reaction there is a lot more going into that insoluble hydroxide state than what is left in solution as the soluble plutonium ion. Hydrolysis and subsequent sorption on to particulates primarily control solubility of plutonium (IV) in soil. Soluble, diffusible Plutonium (IV) usually constitutes less than 0.1% of the total plutonium in soil, but the important thing to remember is that the plutonium in the soil in that solid phase serves as a long-term reservoir.

Solubility is a tricky subject, but the important thing to determine is the bioavailable plutonium within the system; i.e., what can actually move in a solution and perhaps be taken up by plants, animals or humans. In addition to the oxidation reduction reactions, plutonium can react with other ions in the soil to form stable, soluble complexes. Rather than the soluble plutonium hydrolyzing, it can form complexes that in turn stabilize the plutonium and keep it in a more available form. Dr. Grogan discussed laboratory experiments using DTPA, a synthetic ligand that has the ability to form highly stable and soluble plutonium complexes. It has been used to examine the ability of other ligands to compete with soil surfaces and hydroxyl ions for association with the plutonium ion. Generally, two classes of organic compounds are found that can form soluble plutonium complexes in soils: humic substances -- particularly the fulvate fraction (fulvate acids and other similar organics found in the soil), and a group of organic compounds referred to as "relatively low molecular weight nonhumic substances" largely derived from microbial metabolism. In natural systems, the mass of natural complexing ligands is probably very small. Dr. Grogan also discussed several plant uptake studies where differences in uptake were primarily related to differences in soil properties and the presence of natural and synthetic organic ligands that partially stabilize plutonium against hydrolysis in soil. The plant growth rate and biomass production is a secondary factor. Addition of plutonium to soil as an organic complex increases the soil-to-plant concentration ratio by over four orders of magnitude compared to when inorganic plutonium is added to the soil. A 1987 study by Garland et al found no significant difference in the uptake of plutonium (IV) and Plutonium (VI). Only plutonium (VI) was found in the xylem stream. In addition, similar forms of plutonium appear to be presented to the plant root. Another 1987 study by Cline and Schreckhise compared uptake of the oxide and nitrate forms of plutonium. Uptake of the nitrate form was 10-20 times greater than the oxide form and uptake of both forms decreased by an order of magnitude during the three growing seasons. Plutonium concentration in the seeds was consistently less than in the other above-ground parts. Dr. Grogan also touched on several environmental observations which suggest consistency in plutonium profiles for soil samples collected with two to four years of the original deposition from the 903 pad and soil samples collected 20 years later. Plutonium in soils at Rocky Flats is attached to soil particles. Migration by water was not significant. Work will be continuing on this subject, and the Panel will be kept updated.

- *Panel members asked that RAC look carefully at work performed by Iggy Littaor, as well as information coming from the Nevada Test Site regarding movement of plutonium in water.*
- *Dean Heil made the following point regarding trying to test whether or not a chemical had migrated to the soil based on looking at profile concentrations: it has been his experience that you will only be able to distinguish whether or not a chemical has migrated if at least 5% of that chemical has moved. That is because the limitation in measuring element concentrations in soils has at least at 5-10% error rate. So if we are looking for <5-10% of a chemical having moved, we will not be able to distinguish if that has occurred by looking at soil profile distributions.*

- *Mary Harlow asked whether anything was found regarding the anoxic conditions found in ponds during spring and fall -- a lot of heavy metals can be liberated. Would you expect plutonium to act like other heavy metals and be liberated? Dr. Grogan responded that although she found a lot of information looking at plutonium speciation and solubility in natural water systems, she couldn't recall anything specifically that observed an actual release at those times.*
- *Joel Selbin was confused about how cesium tracks plutonium. Dr. Grogan responded that when cesium is in soil, it reacts with the clay minerals and becomes incorporated into the clay lattice.*
- *Joe Goldfield commented that he wanted to caution that the movement of plutonium in soil is highly politically charged and that any conclusions must be looked at with a grain of salt.*

PUBLIC COMMENT

Edd Kray, CDPHE, stated that he recently met with an NRC official who discussed the issue of soluble plutonium and indicated that a potential solution to this question seemed to be extremely simple -- take a sample and send it in for a lung fluid solubility test. He indicated that they don't want to know the solubility in the soil, but rather the solubility in lung fluid. There are many laboratories that perform this test.

ANNOUNCEMENTS

Tim Rehder, EPA, announced that the next meeting for the Actinide Migration Study is April 29 from 1 - 3 p.m. at JEFFCO Airport. A public meeting will be held the same day from 4:30 - 6:30 p.m. at a location TBD.

FUTURE AGENDA ITEMS/ACTION ITEMS

- Bob Kanick requested that a discussion be scheduled regarding comments from the Panel to *RAC*; i.e., what process should be in place to assure that *RAC* clearly knows what comments have been approved by the Panel for them to act on versus comments that were merely discussion points at the meeting
- Carla Sanda will check with John Corsi, Kaiser-Hill, to assure that members of the panel are notified of upcoming Actinide Migration Study meetings.

✓ ***Action Item: KEY DATES FOR PANEL ACTIONS***

Task 1 Report - Comments due to RAC by March 11 (Final report due May 8)

Task 2 Report - Comments due to RAC by May 8 (Final report due July 8)

Scenarios - Recommendations due to RAC by May 13 meeting

MEETING WAS ADJOURNED AT 7:00 P.M.

Upcoming Meetings & Activities

All future meetings will be held from 4 - 7 p.m. at the Broomfield City Building, One Descombes Dr., Broomfield, CO - Zang's Spur/Bal Swan Conference Rooms, on the following dates: April 8, May 13, June 10, July 8, August 12, September 9, October 14, and November 11, 1999.

NOTE: The previously-elected Steering Committee, made up of: Mary Harlow, Hank Stovall, Leroy Moore and Lisa Morzel routinely meets each Monday prior to the regularly scheduled meeting to plan the agenda. Panel members may attend this meeting. To confirm meeting date, time and place, please contact either Mary Harlow or Hank Stovall.

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P	Joe Goldfield	CCANW	303-321-7276	Mail or e-mail
C	Laura Till	Facilitator		303-447-0077

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	06:05 PM	JESSIE ROBERSON DOE	4'19"	12	SEND	OK	209	
	06:10 PM	RUSSELL MCCALLISTER	3'09"	12	SEND	OK	209	
	06:13 PM	TIM REHDER EPA	5'53"	12	SEND	OK	209	
	06:20 PM	KEN STARR	10'16"	12	SEND	OK	209	
	06:31 PM	NANETTE NEELAN	10'15"	12	SEND	OK	209	
	06:41 PM	JOHN CORSI	3'09"	12	SEND	OK	209	
	06:45 PM	DAVE SHELTON	8'21"	12	SEND	OK	209	
	06:53 PM	NIELS SCHONBECK	5'59"	12	SEND	OK	209	
	07:00 PM	JOHN SHEPHERD	7'03"	12	SEND	OK	209	
	07:07 PM	VICTOR HOLM	12'41"	12	SEND	OK	209	
	07:20 PM	KEN KORKIA RFCAB	6'07"	12	SEND	OK	209	
	07:26 PM	TOM MARSHALL	27'24"	12	SEND	OK	209	
	07:54 PM	LEROY MOORE	8'24"	12	SEND	OK	209	
	08:58 PM	DEANNE BUTTERFIELD	18'08"	14	SEND	OK	(02) 209	
	08:04 PM	WILL NEFF	16'06"	12	SEND	OK	209	
	08:21 PM	JOEL SELBIN UCD	5'54"	12	SEND	OK	209	
	09:16 PM	LAURA TILL	16'42"	17	SEND	OK	(02) 209	

TOTAL : 5H 5M 10S PAGES: 458

3/11

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RAC

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Breathing rate distributions

- Created from a number of breathing rate studies, including
  - Silverman, Lee, Plotkin, Sawyers, and Yancey 1951
  - Thompson and Robison 1983
  - Roy and Courtnay 1991
  - Layton 1993
  - EPA 1996

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Breathing rate distributions

- A distribution of breathing rates was created for adults (>18 years), children (5-17 years) and infants (0-4 years) for two activity levels - resting and active
- Each distribution includes the uncertainty introduced by gender, age over the span, and experimental method.

RAC

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Breathing rate distributions

- Distributions were combined by giving equal weight to each study using Monte Carlo techniques
- Each study was sampled from equally and combined with other studies to form the distributions that *RAC* is presenting for RFSALOP use in considering scenario parameters

RAC

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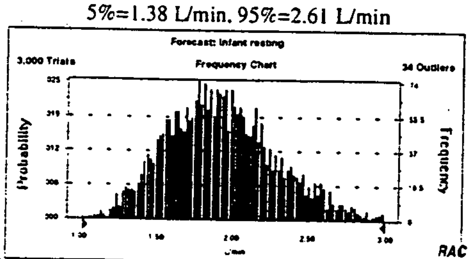
Infant resting

fit to a lognormal distribution with GM = 1.90 L/min and GSD = 1.22, 5%=1.38 L/min, 95%=2.61 L/min



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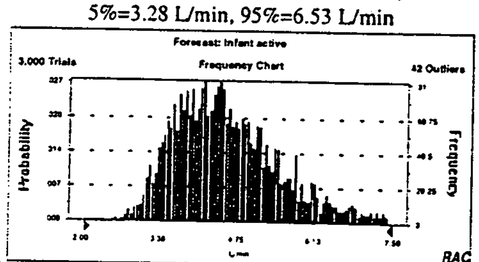
Infant active

fit to a lognormal distribution with GM = 4.51 L/min and GSD = 1.23, 5%=3.28 L/min, 95%=6.53 L/min



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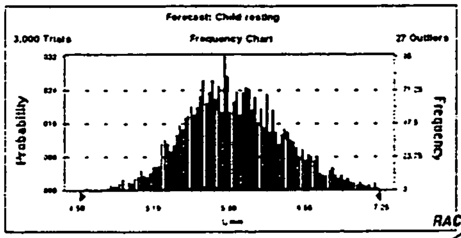
194

Child resting

fit to a lognormal distribution with
GM = 5.92 L/min and GSD = 1.08.
5%=5.22 L/min. 95%=6.76 L/min



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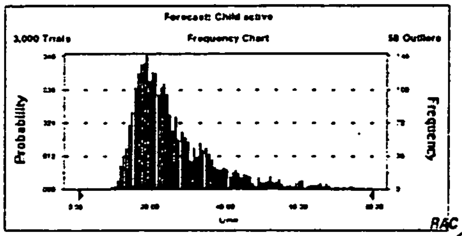
Child active

fit to a lognormal distribution with
GM = 24.91 L/min and GSD = 1.56.
5%=13.87 L/min. 95%=59.44 L/min



RAC

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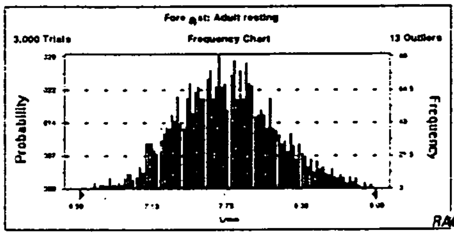
Adult resting

fit to a lognormal distribution with
GM = 7.74 L/min and GSD = 1.06.
5%=7.09 L/min. 95%=8.50 L/min



RAC

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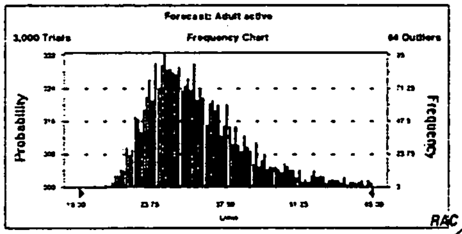
Adult active

fit to a lognormal distribution with
GM = 31.75 L/min and GSD = 1.35.
5%=20.78 L/min. 95%=54.72 L/min



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Soil ingestion distribution

- Created from a number of soil ingestion studies. including
  - Calabrese et al. 1989
  - Thompson and Burmaster 1991
- Also looked at how deterministic studies fit into distribution
  - Kimbrough et al. 1983
  - EPA 1994
  - NCRP 1996
  - Hawley 1985

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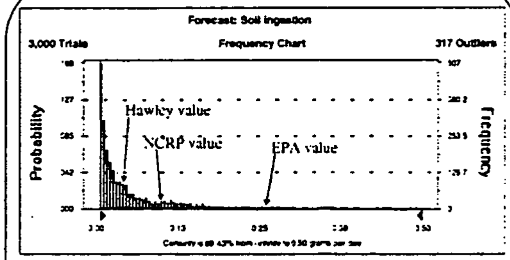

Fit to a lognormal distribution with GM = 0.04 g/day
GSD = 7.89. 5%=0 g/day. 95%=1.08 g/day

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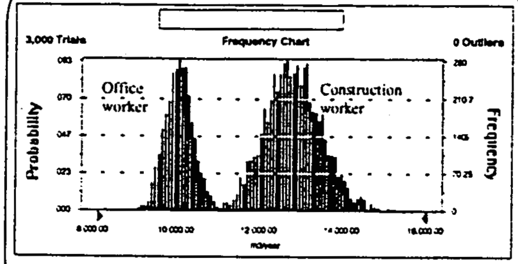
195



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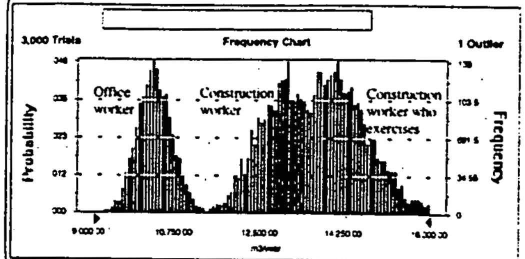

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KEY DATES FOR PANEL COMMENTS TO *RAC*

- Task 1--- Comments due to *RAC* on March 11 (Final report due May 8)
- Task 2 --- Comments due to *RAC* May 8 (Final report due July 8)
- Scenarios --- Recommendations due to *RAC* by May 8 (Draft report on Inputs and assumptions due July 8)

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196

Key Parameter Summary for the Rocky Flats Environmental Technology Site Radionuclide Soil Action Levels

Parameter	Current DOE/EPA/CDPHE Scenarios: Residential	Open space	Office worker	Additional Scenarios for consideration: Resident rancher	Infant of resident rancher (NB-2 yr)	Child of resident rancher (5-17 yr)	Office worker	Rec. land user	Neighborhood resident	Current site industrial worker
Time on the site (hr/day)				23	23.5	16	8	3	22.5	8.5
Time on the site (days per year)				365	365	365	250	100	350	250
Time on the site (hr/yr)	8400	125	2000	8400	8600	5800	2000	300	7900	2100
Time indoors onsite (hr/yr)				4700	7740	5075	1750	300	6700	900
Time indoors onsite (%)	100	100	100	57	90	88	88	100	85	40
Time outdoors onsite (hr/yr)	0	0	0	3700	860	725	250	0	1200	1200
Time outdoors onsite (%)	0	0	0	43	10	12	12	0	15	60
Inhalation Shielding Factor	1	1	1	1	1	1	1	1	1	1
Breathing rate (m^3 per year)	7000	175	1660	10000	1800	4400	2000	750	7400	3600
Breathing rate (liters per year)	7 million	0.18 million	1.7 million	10 million	1.8 million	4.4 million	2 million	0.75 million	7.4 million	3.6 million
Soil ingestion (grams per day)	0.2 for 350 d	0.1/ visit for 25 visits/yr	0.05 for 250 days	0.25 for 365 days	0.04 for 265 days	1 for 365 days	0.1 for 250 days	0.25 / visit for 100 visits	0.25 for 350 days	0.25 for 250 days
Soil ingestion (grams per yr)	70	2.5	12.5	90	15	365	25	25	88	62
Irrigation water source	groundwater	na	na	Woman Creek	Woman Creek	Woman Creek	na	na	groundwater	na
Irrigation Rate (meter/yr)	1	na	na	1	1	1	na	na	1	na
Fraction of contaminated homegrown produce	1	0	0	1	0	1	0	0	1	0

na = not applicable

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Plutonium Solubility in Soils

Helen A. Grogan
Risk Assessment Corporation

Radionuclide Soil Action Levels Oversight Panel,
Broomfield, Colorado
March 11, 1999

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Examples of Pu oxidation states

III	IV	V	VI
Pu^{3+}	Pu^{4+}	PuO_2^{+}	PuO_2^{2+}

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Hydrolysis reaction

$Pu^{4+} + 4H_2O = Pu(OH)_4 + 4H^+$ (K_{sp} ~10^{-56})

Solubility of Pu(IV) in soil is primarily controlled by hydrolysis and subsequent sorption on particulates. Soluble, diffusible Pu(IV) usually constitutes less than 0.1% of the total Pu in soil, but the solid phase serves as a long term reservoir (Wildung et al. 1987).

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Complex dissociation

$2Pu^{4+} + 3DTPA = Pu_2(DTPA)_3$ (K_{sp} ~10^{-18})

DTPA is a synthetic ligand that has the ability to form highly stable and soluble Pu complexes. It has been used in many laboratory experiments to examine the ability of other ligands to compete with soil surfaces and hydroxyl ions for association with the Pu ion.

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Formation of soluble Pu complexes in soils

- two general classes of organic compounds identified
  - humic substances, particularly the fulvate fraction
  - relatively low molecular weight nonhumic substances largely derived from microbial metabolism
- in natural systems the mass of natural complexing ligands is probably small

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Plant uptake studies

- differences in uptake are primarily related to differences in soil properties and the presence of natural and synthetic organic ligands that partially stabilize Pu against hydrolysis in soil
- plant growth rate and biomass production are a secondary factor
- addition of Pu to soil as an organic complex increases the soil-to-plant concentration ratio (CR) by over 4 orders of magnitude compared to when inorganic Pu is added to soil

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Plant uptake studies

- Garland et al. (1987) found no significant difference in the uptake of Pu(IV) and Pu(VI)
- only Pu(IV) found in the xylem stream
- similar forms of Pu appear to be presented to the plant root
- Believe Pu(VI) is reduced to the Pu(IV) valence state (Fe, Mn, S, organic matter, or at root surface)

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Plant uptake studies

- Cline and Schreckhise (1987) compared uptake of the oxide and nitrate forms of Pu
- uptake of the nitrate form was 10-20 times greater than the oxide form
- uptake of both forms decreased by an order of magnitude during the three growing seasons
- Pu concentration in the seeds was consistently less than in the other above ground parts

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Environmental observations

- Consistency in Pu profiles for soil samples collected within 2 to 4 years of the original deposition from the 903, and soil samples collected 20 years later
- Plutonium in soils at Rocky Flats is attached to soil particles
- Higley (1994) found the highest Pu activity associated with colloidal (<0.45 *μm*) and clay (0.45–2 *μm)* particle size fractions
- ~50% total inventory in coarse silt (10–53 *μm)*

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Environmental observations

- Significant migration of clay particles down soil column due to crack formation (bypass flow through macropores), and to a lesser extent frost heaving processes.
- Migration by water was not significant
- Recent results from Hulse et al. (1999) support these observations. Cs-137 shown to be a good tracer for Pu in soils. Both are very strongly sorbed to small soil and clay particles

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SUPPLEMENTARY INFORMATION. Requests should be addressed to the London editorial office of *Nature*.

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Transmission of chromosomal instability after plutonium α-particle irradiation

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WHEN investigating the biological effects of ionizing radiation on the haemopoietic system, a confounding problem lies in possible differences between the biological effects of sparsely ionizing, low linear energy transfer radiation such as X-, β- or γ-rays, and densely ionizing, high linear energy transfer radiation such as α-particles. To address this problem we have developed novel techniques for studying haemopoietic cells irradiated with environmentally relevant doses of α-particles from a plutonium-238 source. Using a clonogenic culture system, cytogenetic aberrations in individual colonies of haemopoietic cells derived from irradiated stem cells have been studied. Exposure to α-particles (but not X-rays) produced a high frequency of non-clonal aberrations in the clonal descendants, compatible with α-emitters inducing lesions in stem cells that result in the transmission of chromosomal instability to their progeny. Such unexpected instability may have important implications for radiation leukaemogenesis.

In mammals, the maintenance of cells in the peripheral blood is achieved by the proliferation and differentiation of precursor cells, all derived from a small, self-maintaining population of multipotential stem cells. Although it is evident that the stem cell compartment is heterogeneous with respect to a number of biological properties[1], the transplantation assay that detects murine spleen colony-forming units (CFU-S) is a useful measure of stem cells[1,2]. We have demonstrated that a clonogenic assay for a cell (CFU-A) that has properties indistinguishable from those of CFU-S, provides a useful quantitative *in vitro* assay for these cells[3]. Having now developed a technique for irradiating haemopoietic cell suspensions in thin layers with Pu-238 α-particles incident as a parallel beam of energy 3.3 MeV and linear energy transfer (LET) 121 keV μm^{-1}, that is, near to the expected maximum biological effectiveness[4], and established a technique for obtaining chromosome preparations from individual colonies, we have been able to do a karyotypic analysis of the effects of α-particle irradiation on murine stem cells.

*To whom correspondence should be addressed.

Preliminary studies indicated that after exposure of normal murine bone marrow cells to 0.25, 0.5 or 1.0 Gray (Gy) Pu-238 α-particle irradiation, the proportions of surviving stem cells assayed as Day 12 CFU-S were roughly 65, 42 or 18% (D_0 = 0.58 Gy) (S.A.L., D.T.G. and E.G.W., manuscript in preparation) and were similar for CFU-A. The particle fluence was 5.15×10^{10} m^{-2} Gy^{-1} so these doses correspond to a mean number of α-particles passing through a 7-μm diameter cell of 0.5, 1.0 or 2.0. Hence, many of the surviving cells were those which, by chance, did not receive a particle. A particular feature of irradiation of tissues by environmentally important α-particle-emitters is that it is entirely concentrated into a small number of separate, densely ionizing tracks of very limited ranges (35–90 μm). At low doses, any individual cell is likely to receive no dose or, if it happens to be in the path of a track, to receive a substantial dose of radiation (~0.5 Gy). For such α-emitters, therefore, the problem of whether low doses might be leukaemogenic reduces essentially to assessing the effectiveness of a single track, or a small number of tracks, in producing appropriate damage in the relevant target cell. Thus, for a stem cell with the properties of CFU-S that has an estimated diameter of 7 μm (ref. 5, 6), the doses we have used are directly relevant to the low-dose problem. Our survival data indicate that the probability of a stem cell (measured as CFU-S) surviving the passage of a single α-particle is only about 10% on the basis of simple biophysical considerations, assuming 7-μm diameter cells (S.A.L. *et al.*, manuscript in preparation). These surviving cells may carry viable genetic damage resulting from insult that is very much greater, at both the cell and chromatin level, than would ever be received from low doses of low-LET radiation[7].

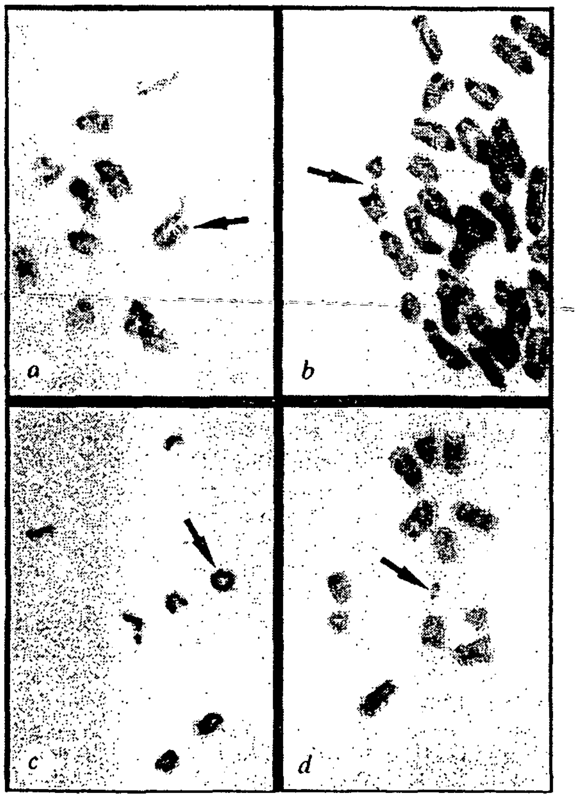

FIG. 1 Representative parts of metaphase spreads in colonies derived from CFU-A in marrow suspensions exposed to α-particle irradiation. *a, b*, Arrows single chromatid aberrations (respectively, a chromatid intrachange and isochromatid deletion). *c, d*, Arrows, single chromosome aberrations (respectively, a ring and a double minute, which may be secondarily derived from previous chromatid changes).

TABLE 1 Cytogenetic aberrations in colonies derived from stem cells in marrow suspensions exposed to α-particle- or X-irradiation

Radiation exposure (Gy)	Colonies with aberrations	Metaphases with aberrations	Aberrations/metaphase 1	2	3	>3	Total aberrations	Number of different aberrations chromosome	chromatid
0	7/59	7/432	7	0	0	0	7	0	7
α Particles									
0.25	2/5	8/29	7	0	1	0	10	3	7
0.50	6/12	19/92	13	3	2	0	25	8	14
1.00	4/10	26/107	14	7	4	1	44	4	34
X-rays									
3.0	2/86	2/409	2	0	0	0	2	0	2
		16/409	2 (clonal)	0	0	0	16	2	0

Bone marrow cells from male CBA/H mice were irradiated with α particles at 0.2–0.8 Gy min^{-1} using a recently constructed variable dose-rate source containing a 20-mm-diameter disc of plutonium-238 (ref. 16). Cells were X-irradiated at 0.75 Gy min^{-1} using a Siemens Stabilipan X-ray machine operating at 250 kV constant potential and 14 mA, giving a half value layer of 1.2 mm of copper. Immediately after irradiation the cells were washed, resuspended and the CFU-A assay[3] was used to obtain colonies of cells derived from members of the haemopoietic stem cell compartment. Cells were plated in 45-mm Petri dishes containing 2 ml modified alpha Eagles medium supplemented with 20% horse serum, 0.3% agar, antibiotics, glutamine and sources of colony-stimulating activities as described previously[3]. For quantitative studies, triplicate cultures were incubated at 37 °C in a fully humidified atmosphere of 10% CO_2, 5% O_2 and 85% N_2 for 11 days. Cytogenetic analyses were done using a previously reported method for karyotyping haemopoietic colonies[17] and in our experiments, only colonies that met the size criterion for being scored as CFU-A-derived[3] were selected for study. Briefly, metaphases in developing day 7 colonies (containing 10^3–10^4 cells, that is, some 10–13 cell divisions from initiation of clonal proliferation) were arrested by adding colcemid to the dishes. Individual colonies were transferred in 10-μl droplets of 0.5% KCl onto poly-L-lysine coated microscope slides and hypotonic treatment of the cells was achieved by inverting the slide to prevent attachment and allowing the cells to swell in a hanging droplet. After 25 min in a humidified incubator at 37 °C, the slide was turned upright and the cells allowed to attach to the coated surface of the slide. Air-dried slides were fixed and G-banded using standard methods[18].

Metaphase preparations of colonies produced by CFU-A surviving α-particle irradiation revealed that 40–60% had karyotypic abnormalities (Table 1) and chromatid aberrations appeared at a greater frequency than chromosome aberrations. In an individual colony, not all cells exhibited abnormalities and up to 50% of scorable metaphases may carry single or multiple, nonidentical aberrations; that is, no aberrations were clonal. Examples of aberrations found in colonies are shown in Figs 1 and 2. The results of experiments in which we exposed the cells to 3 Gy X-rays, a dose that reduced the survival of CFU-A to about 5%, were markedly different to the results of our Pu-238 experiments. Of 86 CFU-A-derived colonies studied in detail, only two had chromosome abnormalities. In both cases they were clonal aberrations; that is, present in all scorable metaphases from the colony. Two cells from different colonies had single chromatid aberrations; an incidence comparable to the background frequency in control colonies.

Our results demonstrate a significant and important difference in the effects of the two types of irradiation. It is evident that the abnormalities observed in the colonies derived from cells surviving α-particle irradiation are present at high frequencies, comparable to those of exchange chromosome aberrations in α-irradiated human blood lymphocytes[8]. But, most strikingly, the nonclonality and variable number of cells in a colony exhibiting chromatid aberrations is consistent with them arising *de novo* in cells derived from a clonogenic cell that survived the passage of one or more radiation tracks before the initiation of clonal proliferation. For most biological endpoints the relative biological effectiveness (RBE) of slow α-particles, relative to low-LET radiations, is 3–50 (refs 4, 9, 10) and the currently recommended weighting factor for radiological protection is 20 (ref. 11). Our experiments provide evidence for a unique effect of α-particles, suggesting an effective RBE approaching infinity as was also suggested for sister chromatid exchanges in resting human lymphocytes[12].

The pattern of Pu-238 α-particle-induced karyotypic abnormalities we have demonstrated suggests that the exposed, surviving stem cells transmit to their daughter cells some chromosomal instability that may result in one or more visible cytogenetic aberrations many cell cycles later. We have no evidence to suggest that particular chromosomes are consistently involved, or that these aberrations arise at 'fragile sites' and it is possible to hypothesize that the instability could, on occasions, disrupt a region of the genome involved in leukaemic transformation. As stem cells have the property of self-renewal, such a change could arise in a daughter stem cell and thus represent an apparent 'initiating lesion'. The actual initiating lesion is, of course, the radiation-induced instability some generations earlier.

There is much concern about clusters of leukaemia

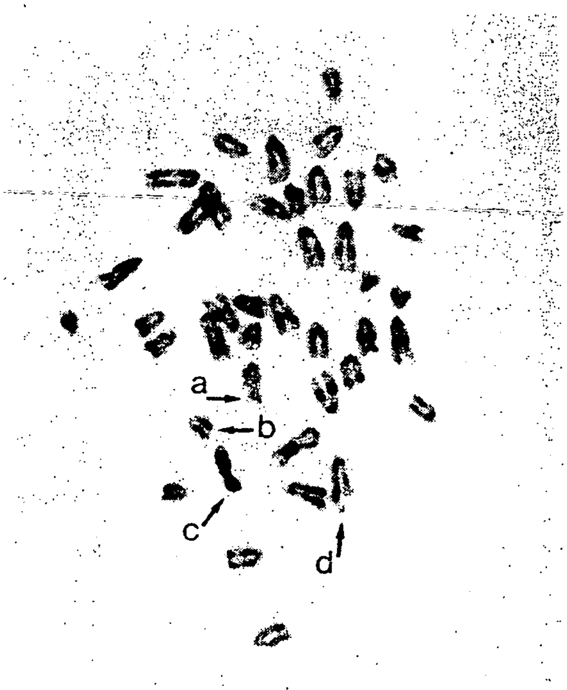

FIG. 2 An example of a metaphase spread exhibiting multiple aberrations in a colony derived from a CFU-A in a marrow suspension exposed to α-particle irradation. Arrowed are: *a*, chromatid break; *b*, acentric chromosome fragment; *c*, possible derivative chromosome with either constriction or median centromere (probably translocation-derived); *d*, single minute chromosome.

epidemiologically linked to nuclear sites[13,14]. Estimates of radiation dose in these cases are based on data from environmental monitoring used in conjunction with complex environmental and biological pathway models. Estimates of leukaemia risk are based conventionally on epidemiological data for low-LET radiations and enhanced effectiveness of high-LET radiations from experimental RBE measurements[15]. These estimates are not consistent with a causal connection between the doses and the leukaemias[13,14]. But if as we believe from theoretical biophysical considerations[7] and some experimental support[12], that there may be classes of unique, initial radiogenic damage induced only by high-LET radiations, then the RBE for such damage would be effectively infinite. Leukaemias arising from such a situation may not have been identified as radiogenic from human epidemiological data (which is based predominantly on considering low-LET radiation) and our findings may then have considerable relevance to the problem of low-dose radiation exposure from artificial or natural α-emitters. Investigating the longer-term consequences of the demonstrated chromosomal instability and identifying the molecular basis of the α-particle-induced lesion are significant challenges for future studies. □

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ACKNOWLEDGEMENTS. We thank R. Wilkinson, P. Adams and D. Badger for technical assistance, and J. Savage and E. Evans for discussion. This work was supported, in part, by the United Kingdom Coordinating Committee for Cancer Research.

Crystal structure of a dUTPase

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THE enzyme dUTPase catalyses the hydrolysis of dUTP[1] and maintains a low intracellular concentration of dUTP so that uracil cannot be incorporated into DNA[2]. dUTPase from *Escherichia coli* is strictly specific for its dUTP substrate,[3] the active site discriminating between nucleotides with respect to the sugar moiety as well as the pyrimidine base. Here we report the three-dimensional structure of *E. coli* dUTPase determined by X-ray crystallography at a resolution of 1.9 Å. The enzyme is a symmetrical trimer, and of the 152 amino acid residues in the subunit, the first 136 are visible in the crystal structure. The tertiary structure resembles a jelly-roll fold and does not show the 'classical' nucleotide-binding domain. In the quaternary structure there is a complex interaction between the subunits that may be important in catalysis. This possibility is supported by the location of conserved elements in the sequence.

The dUTPase enzyme (EC 3.6.1.23) was obtained using an overproducing genetic construct[4]. Crystals were grown at room temperature in a mixture of polyethyleneglycol PEG8000, 50 μM $MgCl_2$, 450 μM pyrophosphate and succinate buffer at pH 4.2 (ref. 5). At this pH, activity measurements are difficult, but dissolved crystals show enzyme activity from pH 5. These crystals diffract X-rays to beyond 1.7 Å resolution. There is one subunit per asymmetric unit (data collection summarized in Table 3). Details of the crystallographic work will be published elsewhere.

dUTPase is packed as a trimer around the threefold axis of the crystal, with large solvent channels between the enzyme molecules. Chromatography confirms that the molecular weight of dUTPase in solution corresponds to a trimer (G.L., manuscript in preparation), rather than to a tetramer as reported earlier[6]. A trimeric subunit arrangement has also been found for a mammalian dUTPase[7]. The trimer has a wedge-shaped appearance when viewed perpendicularly to the 3-fold axis and a triangular face, typical for a trimer, when viewed along the 3-fold axis (Fig. 1*a*). The largest distance across a triangular face is about 60 Å and the length along the axis is ~45 Å. The subunits associate through interactions between twisted β-sheets, thus burying three hydrophobic surfaces about the 3-fold axis. The arrangement of monomers resembles that of the trimeric tumour necrosis factor[8,9], but the details of relative orientation of strands along the axis differ.

Figure 2*a* and *b* shows a topology diagram and a ribbon representation of the subunit which consists of a polypeptide

TABLE 1 X-ray data statistics

	Resolution (Å)	λ (Å)	*R*-merge (%)	Unique reflections	Metal sites per subunit
Native E(Mg-PP_i) data:					
2 crystals	1.9	1.009	6.9	13,640 96% complete	None found
Derivatives:					
Hg, 1 crystal	2.0	0.995	5.9	11,730	1
Pt, 1 crystal	2.1	1.050	5.7	9,910	1

The space group is *R*3 with cell dimensions $a=b=86.6$ Å and $c=62.3$ Å, and the crystals contain one subunit per asymmetric unit. Intensity data were collected using monochromatic synchrotron radiation at the EMBL outstation at DESY, Hamburg. The Hendrix-Lentfer imaging plate scanner, constructed in-house at EMBL, was used as detector. Data were processed with a modified version of the MOSFLM package. *R*-merge is defined as $\sum|I_i-\langle I\rangle|/\sum\langle I\rangle$, where I_i is an individual intensity measurement and $\langle I\rangle$ is the mean intensity for this reflection. Derivative data were collected at wavelengths chosen to maximize the anomalous signal. For the mercury derivative, a native crystal, E(Mg-PP_i), was soaked in 75 μM ethyl mercury phosphate for 4 h. The second platinum derivative was similarly prepared using 1.2 mM K_2PtCl_4 for 7 h. The mercury compound reacted with the only cysteine residue present in the sequence, whereas platinum binds to a methionine side chain. Both isomorphous and anomalous components were used for the phase determination to 2.2 Å resolution, giving an overall figure of merit of 51%, which was increased to 78% by solvent flattening[16]. This gave a high-quality map with clear continuity in the electron density. The model was built using the program FRODO[17] on an Evans and Sutherland PS330 graphics system. The initial model was refined by a cycle of simulated annealing using XPLOR[18], and subsequently by restrained least-squares minimization using PROLSQ[18]. The final *R* factor for 136 residues and 189 water molecules is 14.5% when all reflections between 1.9 and 8.0 Å are used. The geometry of the final model is in good agreement with the target values for the stereochemical parameters: the deviation in bond lengths was 0.010 Å and in torsion angles 2.5°. The average temperature factor for the protein atoms was 20.9 and for the solvent molecules 38.1.

Rocky Mountain Peace and Justice Center
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February 17, 1999

Ms. Carla Sanda
Ms. Anna Corbett
AIMSI
5460 Ward Road #370
Arvada, CO 80002

Dear Carla and Anna:

As followup to the February 11 workshop on risk provided for the RSALOP by Dr. Charles Meinhold I am sending the following two items:

1) A letter with attachments addressed to Dr. Meinhold raising questions about his presentation;

2) A paper entitled "Limitations of the ICRP Recommendations for Worker and Public Protection from Ionizing Radiation" by Canadian radiation specialist Dr. Rosalie Bertell (originally prepared for the European Parliament).

Please make these available to members of the RSALOP.

Thank you,

LeRoy Moore
LeRoy Moore

203

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February 16, 1999

Dr. Charles B. Meinhold, President
National Council on Radiation Protection and Measurements
7910 Woodmont Avenue, Suite 800
Bethesda, MD 20814

Dear Dr. Meinhold:

Thank you for the very informative workshop on radiation health risk you gave in Broomfield, Colorado, on February 11 for the Rocky Flats Radionuclide Soil Action Levels (RSALs) Oversight Panel. During your presentation I raised several questions which I want by means of this letter to pursue further, since we had entirely too little time during the workshop to discuss them adequately.

1) My first line of questioning concerns the relative biological effectiveness (RBE) of alpha emitters, such as plutonium. The RBE specifies how damaging a dose received internally from a given alpha emitter may be by comparison to a dose of the same magnitude received externally from gamma radiation. Typically, internal alpha emitters are much more damaging. Specifying the appropriate RBE is crucial for calculating risk. An incautious calculation can greatly underestimate potential harm. The National Council on Radiation Protection and Measurements (NCRP) and the International Commission on Radiological Protection (ICRP) recommend using an RBE of 20 in calculating risk from plutonium exposure (ICRP Publication 26, 1977; and ICRP Publication 60, 1990). This number was used by DOE, EPA, and the Colorado Department of Public Health and Environment in setting the RSALs for Rocky Flats. The agencies believe that in following the lead of NCRP and ICRP they are on firm footing, but I question whether these bodies themselves are on firm footing in terms of evidence.

As you explained, any given radionuclide has a range of RBEs, depending on the end-points in terms of disease or disability. Thus, one of your overhead projections showed a table (I did not get the reference) that gave a range of RBEs for alpha-emitters of from 1 to 100. That the high end of the scale was only 100 surprised me, since as early as 1979 R. J. DuFrain et al of Oak Ridge in *Health Physics, 37: 279-289*, calculated that the appropriate RBE for alpha-induced cytogenetic (hereditary) damage was 278 -- almost triple the upper end on the table you showed. Moreover, an August 1997 Draft Report called "Assessing Risks of Exposure from Plutonium" (RAC Report No. 5 CDPHE-RFP-1997-Draft), written by Helen A. Grogan, Warren K. Sinclair, and Paul G. Voilleque as part of the Rocky Flats Dose Reconstruction Study, provides much detail on this topic. From their survey of a large body of research they report RBE's for plutonium ranging as high as 110 for lung cancer, 350 for bone sarcomas, 360 for hematopoiesis -- that is, from 5.5 to 12 times as high as ICRP's 20. Regarding ICRP and NCRP they comment: "Differences in RBE between different biological tissues or for plutonium as opposed to any other alpha-emitter have not been considered in detail by these organizations" (p. 6-30). ICRP's 1990 Publication 60 makes the very same RBE proposal as ICRP's 1977 Publication 26. It appears that ICRP and NCRP aren't doing their homework.

204

Staying, however, with the scale you presented, if 100 RBE is the upper end of the scale, why do ICRP and NCRP recommend 20 as the appropriate RBE for all alpha exposures? Does this result from taking an averaging approach, as if harm resulted from average exposure distributed throughout the body rather than from a discrete exposure to a distinct organ for which there would be a specific RBE. If ICRP and NCRP have to recommend a single RBE number for the political expedience of setting radiation standards, wouldn't it be more in keeping with the task of protecting public health to take a mean approach rather than an averaging one? Staying with your numbers, this would result in a recommended RBE for alpha-emitters not of 20 but of 50. There would still be numerous cancers for which the upper range RBE would be above 50. Of course, a most-cautious approach would employ the highest RBE, a more cautious approach at least a number well above the mean. Getting a more realistic number matters. What is at stake is the health of certain people in the population, including people who live near or work at Rocky Flats.

Further to the point of RBE, Eric G. Wright and his colleagues at the Medical Research Council at Harwell, Oxfordshire, conclude from their research that the RBE for alpha-induced chromosomal damage is "effectively infinite" (see their letter to *Nature*, vol. 355, 20 Feb. 1992, pp. 738-740 [enclosed]). An article by Rob Edwards in *New Scientist*, October 11, 1997, pp. 37-40 (also enclosed), discusses the research of Wright and others focused on what Wright calls "radiation-induced genomic instability" -- that is, chromosomal damage that could permanently pollute the human gene pool. Such instability, Wright and his associates say, can result from a dose as low as 0.5 grays of alpha radiation -- "the equivalent of a single alpha particle passing through a cell, the lowest dose the cell could receive." Edwards quotes Jack Little of the Harvard School of Public Health: "Genomic instability changes our way of thinking about how radiation damages cells and produces mutations." Further, according to a report from a 1995 World Health Organization (WHO) conference in Helsinki, genomic instability is also a "plausible mechanism" for explaining illnesses other than cancer. Such illnesses may prove so elusive that epidemiology is "powerless" to detect any relationship between their incidence and exposure to radiation. In the light of findings like these, Edwards, in a remarkable understatement, says, "the regulatory system starts to look inadequate."

From the preceding paragraph I draw two questions: How does NCRP respond to the work of Wright and others on the whole question of radiation-induced genomic instability and its implications for setting standards for permissible exposure to radiation? The response needs to consider the whole body of studies mentioned in Edwards' article, including the unpublished report of the 1995 WHO Helsinki conference on this topic. Second, what about the possibility that radiation-induced genomic instability may contribute to illnesses other than cancer? How is NCRP incorporating this issue into its work?

2) During your presentation you emphasized that NCRP's recommendations regarding risk of exposure to radiation are based on a linear/no threshold approach. NCRP thus assumes that there is no such thing as a safe dose above natural background level, and that harm is commensurate with the dose. I asked at the time why NCRP didn't employ the more cautious supralinear approach proposed by researchers who say they find heightened damage to the organism at very low levels of exposure. In response you said that some quite unhealthy individuals are biologically susceptible to disease from low-

dose exposure, and that adjusting standards for general exposure to these unhealthy persons would mean they might die at age ten rather than eleven. With this answer you really missed the point of my question, for I was asking about the possible harmful effects of very low-dose exposure to otherwise healthy persons within the population in general.

One of the researchers who advocates a supralinear approach is Karl Z. Morgan, long-time head of health physics at DOE's Oak Ridge facility and your predecessor within both NCRP and ICRP. Enclosed is a copy of an interview with Morgan in which he explains why he has concluded that a supralinear approach best fits the data. He says that "down at the very low doses you actually get more cancers per person-rem than you do at the high doses." He doesn't mean that more cancers result from low-dose exposure but that "damage per unit dose is greater at these levels." This is true "in part because the high levels will more often kill cells outright, whereas low levels of exposure tend to injure cells rather than kill them, and it is the surviving, injured cells that are the cause for concern." I'm curious how NCRP responds not simply to these words of Morgan's but to the published papers in which he and others have provided the basis for adopting a supralinear by contrast to a linear approach in calculating risk from very low-dose exposure.

3) This brings me to my final line of questioning. In your talk you said that between 1977 and 1990 NCRP and ICRP upped their understanding of the risk posed by exposure to radiation fivefold. That is, by 1990 these two influential bodies saw radiation as five times more dangerous than they had thought only thirteen years earlier. Radiation hadn't become more dangerous. It was only seen to be. (Oddly, this did not affect ICRP/NCRP recommendations regarding the RBE for alpha emitters.) I asked whether we can expect a similar change in assessment of risk over the next fifteen to twenty years. When you in effect said, "No, because our understanding has more or less stabilized," I felt like I was in church listening to a preacher whose words weren't quite believable.

It seems to me that, while we have learned a great deal about potential harm from radiation exposure, our understanding is still very incomplete. You referred in your own talk to myriad uncertainties. An article by Rudi H. Nüssbaum and Wolfgang Köhnlein in *Environmental Health Perspectives*, vol. 102, No. 8 (August 1994), 656-667, examines a large body of recent research on negative health effects from low-dose exposure that challenge prevailing understandings. The studies they review need to be carefully appraised. In addition, I invite you to consider: What if ICRP and NCRP greatly underestimate the appropriate RBE for alpha emitters? And what if those concerned about radiation-induced genomic instability are correct? Or what if a supralinear approach is not simply safer but also more appropriate for determining risk? Then there's Alice Stewart, the person who four decades ago identified harm to fetuses in utero from x-rays of the mother. She says standards for permissible exposure should be based not on data from Japanese survivors of one-time high-dose events but on exposure to very low doses that may or may not be long-term and continuous. There seems ample reason to suppose that in the near future radiation may be recognized as more dangerous than admitted today by NCRP or ICRP. This is not an idle concern for people who live near a facility like Rocky Flats, or for those of us charged with the task of overseeing a review of the Rocky Flats Radionuclide Soil Action Levels.

I put the foregoing issues before you because the answers you provided to my questions at the time of your workshop were inadequate and not convincing. I realize my questions are not small ones and that answering them will be complicated. If you yourself or others within NCRP can provide answers I will be grateful. I commend you not only on your knowledge of a very complex subject but also on your ability to make it clear to others. Those of us who are concerned about low-dose radiation emissions from a facility like Rocky Flats need to hear from people like you, just as you need to hear from us. Such exchange will lead to science which will be both better in a technical sense and more credible to the affected public.

The BEIR VII study just now being undertaken under the auspices of the National Academy of Sciences will examine the current state of knowledge regarding low-dose exposure with a view to possibly recommending changes in standards for permissible exposure. I therefore am forwarding this letter to the director of the BEIR VII committee, since the issues raised here need to be part of their homework.

In the belief that you could influence the way the BEIR VII work will be carried out, I urge you to insist that this study be done in the most open way possible, from literature search to determination of scope of the study to hearing and responding to concerns of affected populations around nuclear facilities across the country to presenting findings and conclusions in ways that are convincing and thus acceptable to the public. Science of this sort is too important to be conducted behind closed doors. On behalf of your fellow citizens, please weigh in on the side of openness and public participation in every aspect of the BEIR VII study. Lacking this will only perpetuate the current distrust of nuclear science and the nuclear industry -- and, of course, of the government agencies which implement recommendations from bodies like NCRP, ICRP, and the BEIR VII committee.

I will welcome an early response to the questions posed here.

Yours sincerely,

LeRoy Moore

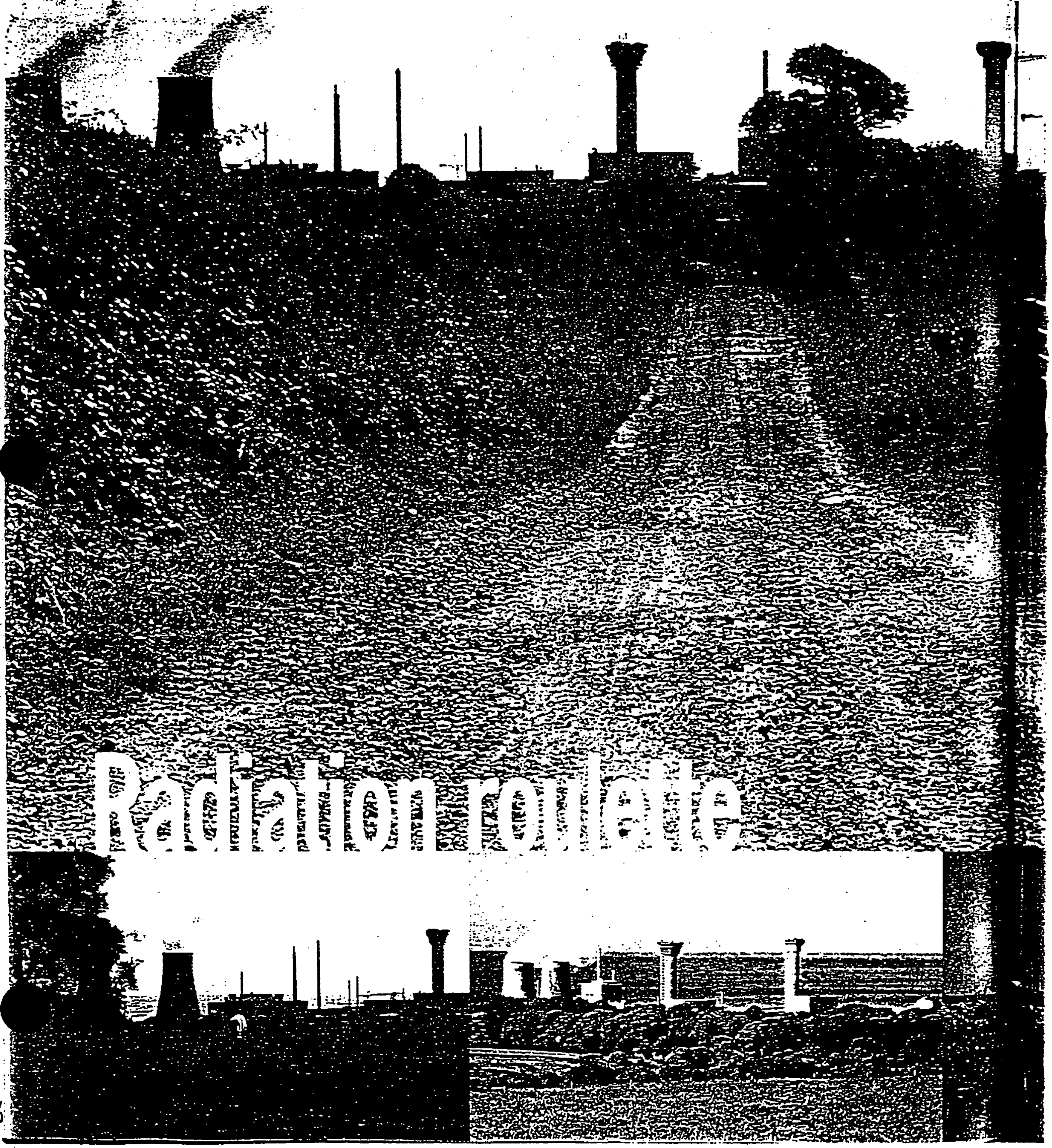
LeRoy Moore, Ph.D.

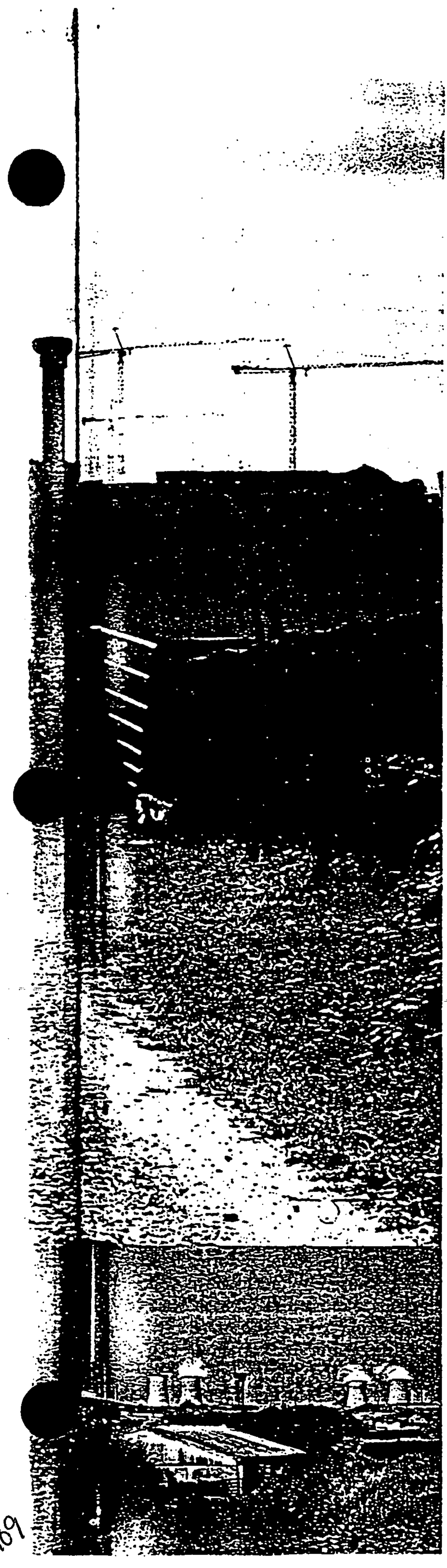
Enclosures:

M. L. Kadhim et al, article from *Nature*
Rob Edwards article from *New Scientist*
Robert Del Tredici interview with Karl Z. Morgan

cc: ✓Rocky Flats Radionuclide Soil Action Levels Oversight Panel
John Till, Risk Assessment Corporation
Rocky Flats Citizens Advisory Board
BEIR VII Committee, c/o Rick Jostes, Study Director, BEIR VII, National Research Council

207


Radiation roulette



Photography: Robert Clifford

The discovery that radiation damages DNA in a new and unexpected way has raised fears that it may cause a far wider range of diseases than previously thought. *Rob Edwards* reports

EAT enough arsenic and you'll die. Death is swift and sure. Radiation, on the other hand, is far less predictable. Expose yourself to even a low dose of radiation and it might or might not kill you some time in the future. This hit-and-miss effect on the body, along with the fact that it's invisible, and so mysterious, is why most people have a profound mistrust of radiation.

Epidemiological studies of survivors from Hiroshima and Nagasaki show that people started dying of leukaemia five years after the bombs were dropped. It took another 15 years for cancers to develop in the lung, breast and urinary tract. Scientists have used these and other studies to reduce emissions from nuclear plants to levels that they predict will keep the likely number of deaths from radiation-induced disease to a vanishingly small figure. At present, it's internationally accepted that a member of the public should not receive more than 1 millisievert a year. Yet, despite these safeguards, mistrust of radiation and the nuclear industry persists.

Now, radiation biologists are concluding that the public may well have been right all along. They have found a previously unknown pathway by which radiation can subvert living cells. Radiation, they say, may cause a much wider range of diseases than epidemiological studies predict. Even levels of exposure below 1 millisievert a year could be harmful, and thousands of people could face early death as a result. Worst of all, the small doses of radiation that millions habitually receive could be poisoning the human gene pool, wreaking damage on future generations. "It is a horrifying concept," says Eric Wright from the Medical Research Council at Harwell in Oxfordshire. "But we now have early indications that it may be happening."

Conventional wisdom says that when ionising radiation hits a living cell there are three possible outcomes. Either the cell is unharmed, or it is killed, or it survives with its DNA damaged (see Diagram on page 26). If the DNA is not mended by the cell's repair enzymes and the cell divides, the damage will be passed on to its daughter cells. Depending on the type of cell and which genes, if any, are damaged, the result could be uncontrolled growth and eventually cancer.

But Wright, who is head of experimental haematology at the MRC's Radiation and Genome Stability Unit, has found a fourth possibility. Radiation can also, he says, inflict damage on cells that at the moment can only be detected after they have divided several times. He calls this radiation-induced genomic instability.

The eventual effects of the instability include broken or misshapen chromosomes and mutated genes, and early cell death. Research from around the world has shown that it can be produced by neutrons, X-rays, gamma rays and alpha radiation. In the laboratory, a dozen cell divisions over a couple of weeks are enough to generate chromosomal defects in up to 30 per cent of an irradiated cell's progeny. "I regard the phenomenon as established," says Wright. "There is no doubt that genomic instability is a real consequence of radiation exposure."

Vulnerable cells

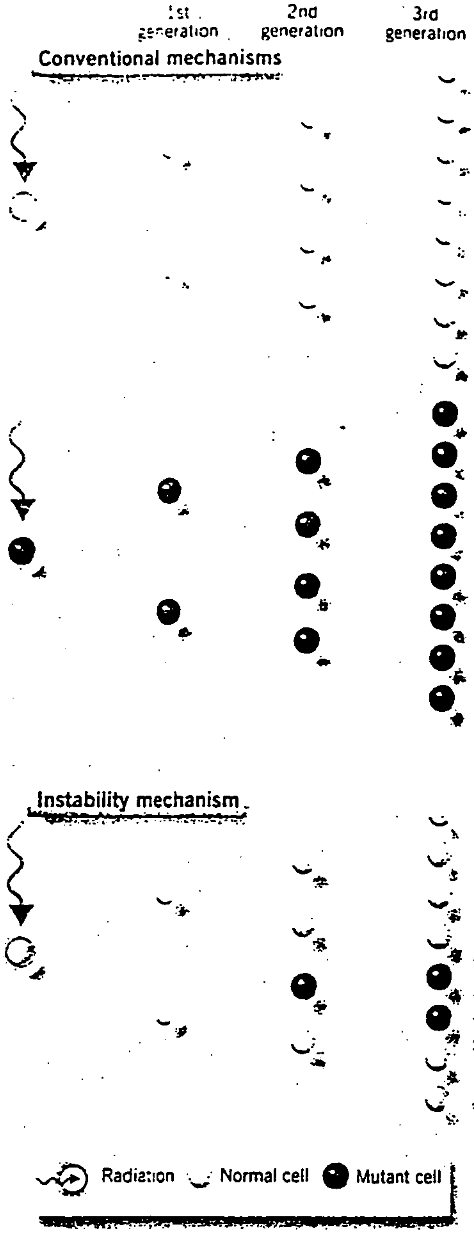
Inside the body, this process could have big implications. In an average lifetime, a human being will experience 10^{16} cell divisions, mostly in the first few years of life and during puberty. But stem cells in the bone marrow, which keep the blood replenished with red and white cells, as well as cells in the gut and skin, continue to divide throughout adult life. Likewise, sperm are constantly produced by cell division in adult males. In these cases, the potential for radiation-induced instability to do its worst appears to be highest.

Wright, Munira Kadhim, and colleagues announced the discovery of genomic instability in 1992. They exposed stem cells from the bone marrow of mice to plutonium-238, giving them a dose of about 0·5 grays of alpha radiation. This is the equivalent of a single alpha particle passing through a cell, the lowest dose the cell could receive.

The cells were kept in Petri dishes for

209

Conventional thinking (top) says that a cell hit by radiation is unharmed, is damaged or is killed (not shown). With instability, damage appears only in later generations

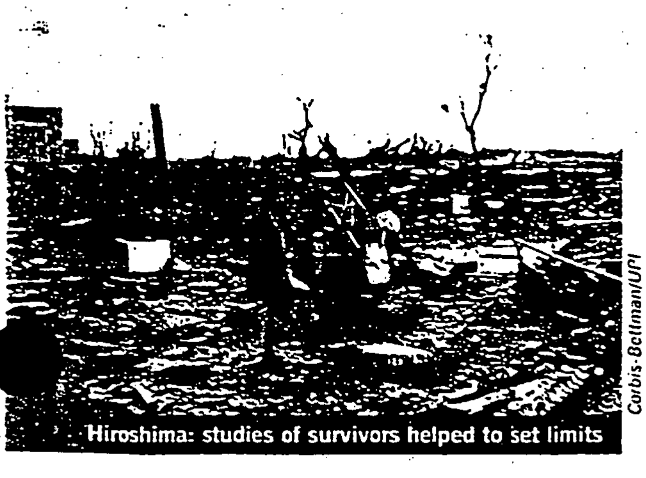


11 days until they had divided between 10 and 13 times, each producing between 10 000 and 100 000 daughter cells. Wright found that the progeny of the irradiated cells contained three and a half times as many chromosome aberrations as the descendants of cells that were not irradiated. In a letter to *Nature*, he concluded that the "relative biological effectiveness"—a measure of how damaging low-level radiation can be in the body—for isotopes that emit alpha particles is "effectively infinite".

In 1994, Wright repeated the experiment with stem cells taken from four people. After between 10 and 15 divisions, up to 25 per cent of the progeny of cells from two of the individuals were riddled with broken and distorted chromosomes. The fact that cells from the other two subjects showed no signs of induced instability may mean that some people carry genes that protect them from this type of damage, Wright argues.

Mounting evidence

At least six other laboratories around the world have now found similar results. Bo Lambert from the Karolinska Institute in Stockholm, for example, showed that X-rays damage the chromosomes of the descendants of irradiated human lymphocytes. Robert Ullrich from the University of Texas in Galveston discovered chromosome aberrations in the offspring of human breast cells caused by neutron and gamma irradiation. Last year, researchers from NASA and the University of Naples in Italy reported that the offspring of skin cells developed chromosome aberrations after exposure to X-rays and alpha particles. They concluded that genomic instability "could determine late genetic effects and should therefore be carefully considered in the evaluation of risk for space missions".



Hiroshima: studies of survivors helped to set limits

These studies all use cells grown in laboratories, and so are open to the criticism that something different might happen in living animals. At least two experiments, however, suggest that radiation also causes genomic instability in vivo. In a previously unnoticed study in 1989, Christian Streffer from the University of Essen in Germany exposed fertilised eggs of mice to X-rays. When skin cells were taken from the growing fetuses, they contained more chromosome aberrations than cells taken from unirradiated fetuses.

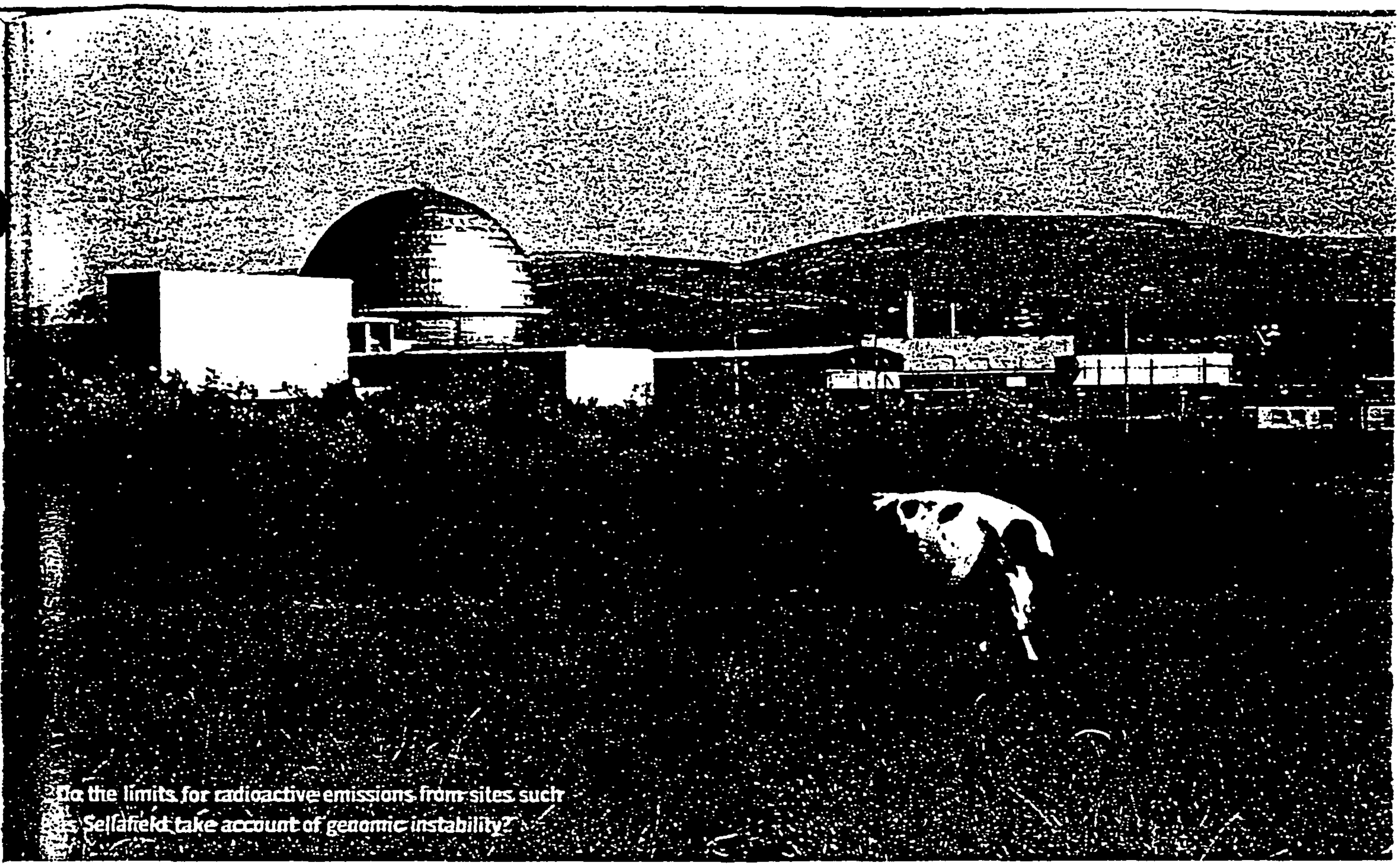
In addition, last year, Wright and his colleagues at the MRC irradiated stem cells from the bone marrow of male mice and transplanted them into female mice. (The transplants and their progeny contained a Y chromosome so could be easily distinguished from the females' cells.) The researchers detected "persisting chromosomal instability" in the male cell line up to a year later.

More recently, in order to test his suspicion that some people carry genes that predispose them to genomic instability, Wright has shown that some strains of mice are more vulnerable to genomic instability than others. In one experiment, he exposed bone marrow cells from three strains to radiation. Daughter cells from two of these strains went on to develop more chromosome aberrations than cells from the other.

Wright and other radiobiologists are now searching for the mechanisms behind genomic instability. In one experiment, Wright found abnormal levels of highly reactive free radicals in cells derived from irradiated cells. There is good evidence that raised levels of free radicals can induce chromosomal damage, and Wright believes that a buildup of these chemicals over several generations could be the root cause of genomic instability.

Keith Baverstock, a senior radiation scientist with the WHO, has a different theory. He believes radiation could damage a gene for one of the DNA repair enzymes. DNA is not a static molecule but changes all the time, and repair enzymes constantly cut out damaged sections and patch them up. If radiation stops one of these enzymes doing its job, a subsequent error may not be properly repaired. When the cell divides, its progeny will inherit this imperfection along with the disabled enzyme, which will carry out further imperfect repairs, and so on, piling up flaws down the generations. "Finally it gets so bad that the whole thing just breaks up and you get instability," argues Baverstock.

At this point, the question becomes the same as that asked for all forms of DNA damage caused by radiation—how does the damage cause disease? Most work on this question has focused on cancer and scientists believe that certain genes may hold the key. If a gene that promotes cell division is damaged, for example, that cell can divide over and over again. Other possible contenders are genes, such as *p53*, that normally suppress the development of cancer. If a person's two copies of *p53*



Do the limits for radioactive emissions from sites such as Sellafield take account of genomic instability?

are damaged, a tumour is likely to grow.

All these suggestions could be different parts of the same complex puzzle. Baverstock compares the difficulties of identifying the biological mechanisms to a long car journey. "You may know that a car started in Glasgow and finished in Cambridge," he says. "But the number of different routes it could have taken in between is immense."

Despite the holes in our understanding of induced genomic instability, Wright feels that we already know enough to start worrying. He believes that in addition to cancers such as leukaemia, it may cause small increases in a wide range of other diseases. These could include developmental defects in fetuses, such as deformed limbs and cleft palates, and brain disorders such as Alzheimer's, Parkinson's and motor neuron diseases. But he stresses that these suspicions are not yet backed up by experimental evidence.

The amount of radioactivity needed to induce instability could be tiny. Wright's director at the MRC unit, Dudley Goodhead, argues that a single alpha particle is enough to injure a cell and increase the risk of disease. Those who swallow just one atom of plutonium are hence marginally more likely to die early. "It's like Russian roulette," says Goodhead.

Wright and Goodhead are not the only ones to be concerned. Two years ago this month, more than 30 radiobiologists and health specialists from around the world gathered in Helsinki for a workshop on the public health aspects of radiation-induced genomic instability. They cite 26 studies which, they say, suggest that the accepted rules about how to calculate the biological impact of radiation should be rewritten. "Genomic instability changes our way of thinking about how radiation damages cells and produces mutations," says Jack Little, professor of radiobiology at the Harvard School of Public Health in Boston, who attended the workshop.

'Wright's main concern is that the human gene pool could be permanently polluted'

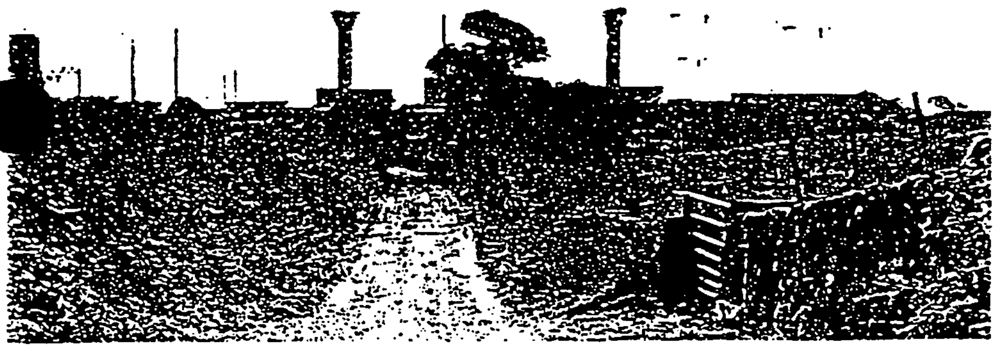
Last year, participants in the workshop produced a report for the WHO and, although it was not published, *New Scientist* has obtained a copy. It suggests that instability is an early, key event in the process that leads to cancer. It points out that people with the inherited disorder Fanconi anaemia develop the same sort of chromosome aberrations seen in radiation-induced instability and about 15 per cent of these contract leukaemia.

Instability is also a "plausible mechanism" for explaining illnesses other than cancer, the report says. "It would seem likely that if genomic instability led to health effects these would not be specific but may include developmental deficiencies in the fetus, cancer, hereditary disease, accelerated aging and such non-specific effects as loss of immune competence." Epidemiology would be "powerless" to detect any relationship between the incidence of such diseases and exposure to radiation, the report says, because the number of people who would suffer any single disease would be too low.

Baverstock, who was the main organiser of the Helsinki workshop, and Wright, believe that the world should be more wary of low-level radiation. If genomic instability is causing unpredicted disease, and if some people are genetically predisposed to it, the regulatory system starts to look inadequate. Existing measures meant to protect people, argue Wright and Baverstock, are less than reassuring.

To check that people do not receive more than 1 millisievert a year, the British Ministry of Agriculture, Fisheries and Food monitors "critical groups" of people who, because of their lifestyle, are likely to receive the highest doses of radioactivity from nuclear plants. The Sellafield complex in Cumbria has been the largest emitter of radiation in Britain, discharging

211



radioactive gas into the air and liquid into the Irish Sea. The critical groups here have included fishermen working the Irish Sea, people who eat seaweed and occupants of houseboats moored on contaminated Cumbrian estuaries.

Scaremongering

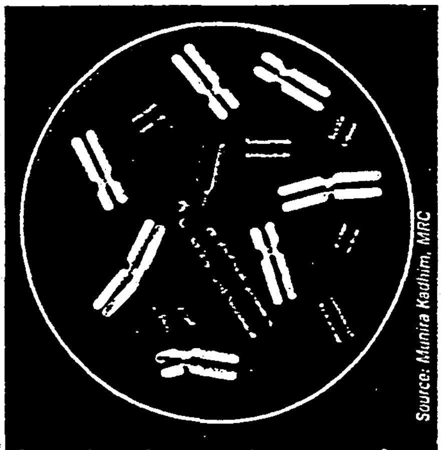
The underlying assumption is that everybody is equally vulnerable to radiation, and that possible health effects depend purely on levels of exposure. But if the critical groups do not contain people who are genetically predisposed to genomic instability, then this system will overestimate the level of radiation deemed "safe". These people could then be exposed to levels of radiation that could harm them. So the number of people to have died or suffered from radiation released from Sellafield, nuclear weapons tests, the Chernobyl accident and from medical X-rays and radon in buildings, could be much greater than anyone has dared to admit.

This is regarded as unscientific scaremongering by Britain's National Radiological Protection Board at Harwell. Roger Cox, head of the radiation effects department at the NRPB, does not dispute that his colleagues across the road at the MRC have found unstable changes in cells descended from irradiated cells. But he disagrees that they are likely to have any impact on health.

"The basic science is not the problem here, it is their interpretation of it," Cox argues. There is no proof that genomic instability leads to cancer or other diseases, no studies that have shown an association between illness and instability and there is no hard evidence of any causal mechanisms. Even if instability causes an increased rate of illness, it would already be taken into account by existing safety limits. "We're quite some way from having serious doubts about the risk estimates we make," he says.

In particular, Cox dismisses the suggestion that genomic instability can cause small increases in a wide range of diseases as "totally speculative". Although he admits that such an effect cannot be ruled out, he argues that if it exists it must be very minor, contained within the statistical noise of epidemiological studies. "There is rigorous medical surveillance of Hiroshima and Nagasaki victims," he says. "It would be a surprise if there was any major effect on any aspect of health that had not been picked up."

Wright concedes that there is no proof that instability causes cancer, but he argues that it is "highly unlikely" to be irrelevant to the process. Cox fails to appreciate, he says, that the scattergun effect of instability—small increases in a wide range of diseases—would by its very nature escape the notice of epidemiologists. Wright also questions the relevance of studies of atom bomb survivors to the understanding of genomic instability. Extrapolating from a group of people exposed to a large, acute dose of radiation to a group receiving small, chronic doses may not be valid. Two different mechanisms may be involved, and it's important to learn if this is the case. Instead, says Wright, the NRPB gets defensive and criticises "anything and everything that does not fit their corner of the world".



Source: Munira Kadhim, MRC

Beyond repair: some chromosomes from cells descended from irradiated cells appear broken and distorted (red)

His biggest concern is that instability could blight future generations. He has collaborated with Brian Lord from the Patterson Institute for Cancer Research at the Christie Hospital in Manchester in a study that is due to be published soon. It gives the first clear experimental evidence that instability can be passed from a mole to his offspring in sperm.

Lord found that the pups of male mice exposed to alpha radiation suffered chromosome aberrations in their bone marrow likely to be associated with genomic instability. The finding lends support to the controversial theory advanced in 1990 by the late Martin Gardner from Southampton University that the children of fathers exposed to radiation at Sellafield run a higher than normal risk of contracting leukaemia.

But Wright and Baverstock fear that the consequences could extend far beyond the leukaemia cases. Millions of people worldwide are exposed to low level radiation. The damage inflicted on their DNA could be passed to their children, and to their children's children. The human gene pool could be permanently polluted.

Furthermore, argue Wright and Baverstock, there is no logical reason why such damage should be confined to ionising radiation. Carmel Mothersill from the Dublin Institute of Technology told meetings in Toulouse and Oxford last month that the offspring of cells exposed to low levels of cadmium and nickel also suffer high rates of cell death—a tell-tale sign of genomic instability. Chemicals in tobacco smoke, air pollution or pesticides might also destabilise the genome.

These ideas are already irritating scientists working in radiation protection, who believe that existing safeguards are adequate. Wright and Baverstock themselves accept that institutional change will be slow and that there is much still to be learnt about the biology of genomic instability. In the meantime, they are minimising their own exposure to radiation. Baverstock refused dental X-rays which were not medically necessary. Wright too avoids medical X-rays unless his dentist or doctor can convince him they are essential. And he does not eat fish from the Irish Sea for fear of contamination by plutonium from Sellafield.

Further Reading: "Genomic instability induced by ionising radiation" by William Morgan and others, *Radiation Research*, vol 146, p 247. A full list of references is on Planet Science

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SUPPLEMENTARY INFORMATION Requests should be addressed to the London editorial office of *Nature*.

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Transmission of chromosomal instability after plutonium α-particle irradiation

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WHEN investigating the biological effects of ionizing radiation on the haemopoietic system, a confounding problem lies in possible differences between the biological effects of sparsely ionizing, low linear energy transfer radiation such as X-, β- or γ-rays, and densely ionizing, high linear energy transfer radiation such as α-particles. To address this problem we have developed novel techniques for studying haemopoietic cells irradiated with environmentally relevant doses of α-particles from a plutonium-238 source. Using a clonogenic culture system, cytogenetic aberrations in individual colonies of haemopoietic cells derived from irradiated stem cells have been studied. Exposure to α-particles (but not X-rays) produced a high frequency of non-clonal aberrations in the clonal descendants, compatible with α-emitters inducing lesions in stem cells that result in the transmission of chromosomal instability to their progeny. Such unexpected instability may have important implications for radiation leukaemogenesis.

In mammals, the maintenance of cells in the peripheral blood is achieved by the proliferation and differentiation of precursor cells, all derived from a small, self-maintaining population of multipotential stem cells. Although it is evident that the stem cell compartment is heterogeneous with respect to a number of biological properties[1], the transplantation assay that detects murine spleen colony-forming units (CFU-S) is a useful measure of stem cells[1,2]. We have demonstrated that a clonogenic assay for a cell (CFU-A) that has properties indistinguishable from those of CFU-S, provides a useful quantitative *in vitro* assay for these cells[3]. Having now developed a technique for irradiating haemopoietic cell suspensions in thin layers with Pu-238 α-particles incident as a parallel beam of energy 3.3 MeV and linear energy transfer (LET) 121 keV μm^{-1}, that is, near to the expected maximum biological effectiveness[4], and established a technique for obtaining chromosome preparations from individual colonies, we have been able to do a karyotypic analysis of the effects of α-particle irradiation on murine stem cells.

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Preliminary studies indicated that after exposure of normal murine bone marrow cells to 0.25, 0.5 or 1.0 Gray (Gy) Pu-238 α-particle irradiation, the proportions of surviving stem cells assayed as Day 12 CFU-S were roughly 65, 42 or 18% (D_0 = 0.58 Gy) (S.A.L., D.T.G. and E.G.W., manuscript in preparation) and were similar for CFU-A. The particle fluence was 5.15×10^{10} m^{-2} Gy^{-1} so these doses correspond to a mean number of α-particles passing through a 7-μm diameter cell of 0.5, 1.0 or 2.0. Hence, many of the surviving cells were those which, by chance, did not receive a particle. A particular feature of irradiation of tissues by environmentally important α-particle-emitters is that it is entirely concentrated into a small number of separate, densely ionizing tracks of very limited ranges (35–90 μm). At low doses, any individual cell is likely to receive no dose or, if it happens to be in the path of a track, to receive a substantial dose of radiation (~0.5 Gy). For such α-emitters, therefore, the problem of whether low doses might be leukaemogenic reduces essentially to assessing the effectiveness of a single track, or a small number of tracks, in producing appropriate damage in the relevant target cell. Thus, for a stem cell with the properties of CFU-S that has an estimated diameter of 7 μm (ref. 5, 6), the doses we have used are directly relevant to the low-dose problem. Our survival data indicate that the probability of a stem cell (measured as CFU-S) surviving the passage of a single α-particle is only about 10% on the basis of simple biophysical considerations, assuming 7-μm diameter cells (S.A.L. *et al.*, manuscript in preparation). These surviving cells may carry viable genetic damage resulting from insult that is very much greater, at both the cell and chromatin level, than would ever be received from low doses of low-LET radiation[7].

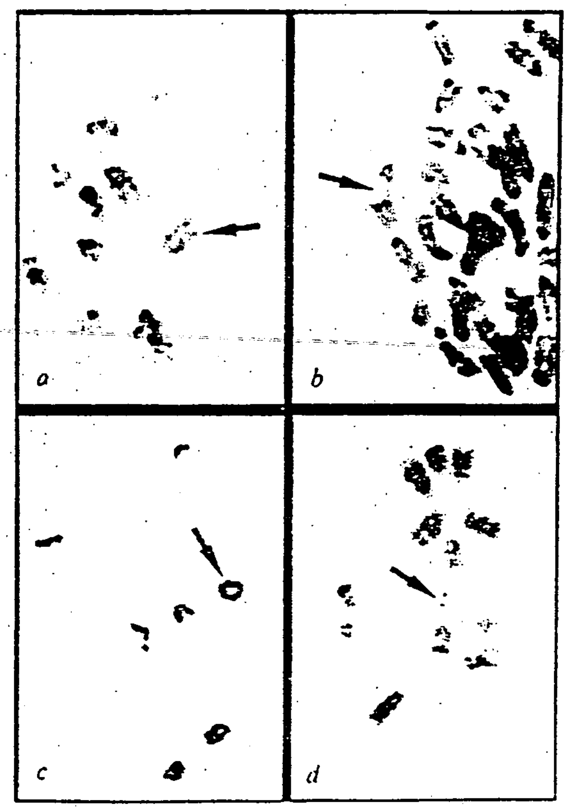

FIG. 1 Representative parts of metaphase spreads in colonies derived from CFU-A in marrow suspensions exposed to α-particle irradiation. *a, b,* Arrows single chromatid aberrations (respectively, a chromatid intrachange and isochromatid deletion). *c, d,* Arrows, single chromosome aberrations (respectively, a ring and a double minute, which may be secondarily derived from previous chromatid changes).

TABLE 1 Cytogenetic aberrations in colonies derived from stem cells in marrow suspensions exposed to α-particle- or X-irradiation

Radiation exposure (Gy)	Colonies with aberrations	Metaphases with aberrations	Aberrations/metaphase 1	2	3	>3	Total aberrations	Number of different aberrations chromosome	chromatid
0	7/59	7/432	7	0	0	0	7	0	7
α Particles									
0.25	2/5	8/29	7	0	1	0	10	3	7
0.50	6/12	19/92	13	3	2	0	25	8	14
1.00	4/10	26/107	14	7	4	1	44	4	34
X-rays									
3.0	2/86	2/409	2	0	0	0	2	0	2
		16/409	2 (clonal)	0	0	0	16	2	0

Bone marrow cells from male CBA/H mice were irradiated with α particles at 0.2–0.8 Gy min^{-1} using a recently constructed variable dose-rate source containing a 20-mm-diameter disc of plutonium-238 (ref. 16). Cells were X-irradiated at 0.75 Gy min^{-1} using a Siemens Stabilipan X-ray machine operating at 250 kV constant potential and 14 mA, giving a half value layer of 1.2 mm of copper. Immediately after irradiation the cells were washed, resuspended and the CFU-A assay[3] was used to obtain colonies of cells derived from members of the haemopoietic stem cell compartment. Cells were plated in 45-mm Petri dishes containing 2 ml modified alpha Eagles medium supplemented with 20% horse serum, 0.3% agar, antibiotics, glutamine and sources of colony-stimulating activities as described previously[3]. For quantitative studies, triplicate cultures were incubated at 37 °C in a fully humidified atmosphere of 10% CO_2, 5% O_2 and 85% N_2 for 11 days. Cytogenetic analyses were done using a previously reported method for karyotyping haemopoietic colonies[17] and in our experiments, only colonies that met the size criterion for being scored as CFU-A-derived[3] were selected for study. Briefly, metaphases in developing day 7 colonies (containing 10^3–10^4 cells, that is, some 10–13 cell divisions from initiation of clonal proliferation) were arrested by adding colcemid to the dishes. Individual colonies were transferred in 10-μl droplets of 0.5% KCl onto poly-L-lysine coated microscope slides and hypotonic treatment of the cells was achieved by inverting the slide to prevent attachment and allowing the cells to swell in a hanging droplet. After 25 min in a humidified incubator at 37 °C, the slide was turned upright and the cells allowed to attach to the coated surface of the slide. Air-dried slides were fixed and G-banded using standard methods[18].

Metaphase preparations of colonies produced by CFU-A surviving α-particle irradiation revealed that 40–60% had karyotypic abnormalities (Table 1) and chromatid aberrations appeared at a greater frequency than chromosome aberrations. In an individual colony, not all cells exhibited abnormalities and up to 50% of scorable metaphases may carry single or multiple, nonidentical aberrations; that is, no aberrations were clonal. Examples of aberrations found in colonies are shown in Figs 1 and 2. The results of experiments in which we exposed the cells to 3 Gy X-rays, a dose that reduced the survival of CFU-A to about 5%, were markedly different to the results of our Pu-238 experiments. Of 86 CFU-A-derived colonies studied in detail, only two had chromosome abnormalities. In both cases they were clonal aberrations; that is, present in all scorable metaphases from the colony. Two cells from different colonies had single chromatid aberrations; an incidence comparable to the background frequency in control colonies.

Our results demonstrate a significant and important difference in the effects of the two types of irradiation. It is evident that the abnormalities observed in the colonies derived from cells surviving α-particle irradiation are present at high frequencies, comparable to those of exchange chromosome aberrations in α-irradiated human blood lymphocytes[8]. But, most strikingly, the nonclonality and variable number of cells in a colony exhibiting chromatid aberrations is consistent with them arising *de novo* in cells derived from a clonogenic cell that survived the passage of one or more radiation tracks before the initiation of clonal proliferation. For most biological endpoints the relative biological effectiveness (RBE) of slow α-particles, relative to low-LET radiations, is 3–50 (refs 4, 9, 10) and the currently recommended weighting factor for radiological protection is 20 (ref. 11). Our experiments provide evidence for a unique effect of α-particles, suggesting an effective RBE approaching infinity as was also suggested for sister chromatid exchanges in resting human lymphocytes[12].

The pattern of Pu-238 α-particle-induced karyotypic abnormalities we have demonstrated suggests that the exposed, surviving stem cells transmit to their daughter cells some chromosomal instability that may result in one or more visible cytogenetic aberrations many cell cycles later. We have no evidence to suggest that particular chromosomes are consistently involved, or that these aberrations arise at 'fragile sites' and it is possible to hypothesize that the instability could, on occasions, disrupt a region of the genome involved in leukaemic transformation. As stem cells have the property of self-renewal, such a change could arise in a daughter stem cell and thus represent an apparent 'initiating lesion'. The actual initiating lesion is, of course, the radiation-induced instability some generations earlier.

There is much concern about clusters of leukaemia

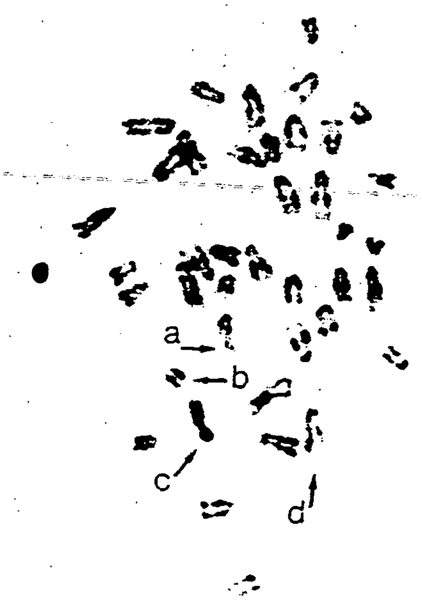

FIG. 2 An example of a metaphase spread exhibiting multiple aberrations in a colony derived from a CFU-A in a marrow suspension exposed to α-particle irradiation. Arrowed are: *a*, chromatid break; *b*, acentric chromosome fragment; *c*, possible derivative chromosome with either constriction or median centromere (probably translocation-derived); *d*, single minute chromosome.

214

epidemiologically linked to nuclear sites[13,14]. Estimates of radiation dose in these cases are based on data from environmental monitoring used in conjunction with complex environmental and biological pathway models. Estimates of leukaemia risk are based conventionally on epidemiological data for low-LET radiations and enhanced effectiveness of high-LET radiations from experimental RBE measurements[15]. These estimates are not consistent with a causal connection between the doses and the leukaemias[13,14]. But if as we believe from theoretical biophysical considerations[7] and some experimental support[12], that there may be classes of unique, initial radiogenic damage induced only by high-LET radiations, then the RBE for such damage would be effectively infinite. Leukaemias arising from such a situation may not have been identified as radiogenic from human epidemiological data (which is based predominantly on considering low-LET radiation) and our findings may then have considerable relevance to the problem of low-dose radiation exposure from artificial or natural α-emitters. Investigating the longer-term consequences of the demonstrated chromosomal instability and identifying the molecular basis of the α-particle-induced lesion are significant challenges for future studies. □

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Crystal structure of a dUTPase

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THE enzyme dUTPase catalyses the hydrolysis of dUTP[1] and maintains a low intracellular concentration of dUTP so that uracil cannot be incorporated into DNA[2]. dUTPase from *Escherichia coli* is strictly specific for its dUTP substrate,[3] the active site discriminating between nucleotides with respect to the sugar moiety as well as the pyrimidine base. Here we report the three-dimensional structure of *E. coli* dUTPase determined by X-ray crystallography at a resolution of 1.9 Å. The enzyme is a symmetrical trimer, and of the 152 amino acid residues in the subunit, the first 136 are visible in the crystal structure. The tertiary structure resembles a jelly-roll fold and does not show the 'classical' nucleotide-binding domain. In the quaternary structure there is a complex interaction between the subunits that may be important in catalysis. This possibility is supported by the location of conserved elements in the sequence.

TABLE 1 X-ray data statistics

	Resolution (Å)	λ (Å)	*R*-merge (%)	Unique reflections	Metal sites per subunit
Native E(Mg-PP$_i$) data:					
2 crystals	1.9	1.009	6.9	13,640 96% complete	None found
Derivatives:					
Hg, 1 crystal	2.0	0.995	5.9	11,730	1
Pt, 1 crystal	2.1	1.050	5.7	9,910	1

The space group is *R*3 with cell dimensions $a = b = 86.6$ Å and $c = 62.3$ Å, and the crystals contain one subunit per asymmetric unit. Intensity data were collected using monochromatic synchrotron radiation at the EMBL outstation at DESY, Hamburg. The Hendrix-Lentfer imaging plate scanner, constructed in-house at EMBL, was used as detector. Data were processed with a modified version of the MOSFLM package. *R*-merge is defined as $\sum|I_i - \langle I\rangle|/\sum\langle I\rangle$, where I_i is an individual intensity measurement and $\langle I\rangle$ is the mean intensity for this reflection. Derivative data were collected at wavelengths chosen to maximize the anomalous signal. For the mercury derivative, a native crystal, E(Mg-PP$_i$), was soaked in 75 μM ethyl mercury phosphate for 4 h. The second platinum derivative was similarly prepared using 1.2 mM K_2PtCl_4 for 7 h. The mercury compound reacted with the only cysteine residue present in the sequence, whereas platinum binds to a methionine side chain. Both isomorphous and anomalous components were used for the phase determination to 2.2 Å resolution, giving an overall figure of merit of 51%, which was increased to 78% by solvent flattening[16]. This gave a high-quality map with clear continuity in the electron density. The model was built using the program FRODO[17] on an Evans and Sutherland PS330 graphics system. The initial model was refined by a cycle of simulated annealing using XPLOR[18], and subsequently by restrained least-squares minimization using PROLSQ[19]. The final *R* factor for 136 residues and 189 water molecules is 14.5% when all reflections between 1.9 and 8.0 Å are used. The geometry of the final model is in good agreement with the target values for the stereochemical parameters: the deviation in bond lengths was 0.010 Å and in torsion angles 2.5°. The average temperature factor for the protein atoms was 20.9 and for the solvent molecules 38.1.

The dUTPase enzyme (EC 3.6.1.23) was obtained using an overproducing genetic construct[4]. Crystals were grown at room temperature in a mixture of polyethyleneglycol PEG8000, 50 μM $MgCl_2$, 450 μM pyrophosphate and succinate buffer at pH 4.2 (ref. 5). At this pH, activity measurements are difficult, but dissolved crystals show enzyme activity from pH 5. These crystals diffract X-rays to beyond 1.7 Å resolution. There is one subunit per asymmetric unit (data collection summarized in Table 1). Details of the crystallographic work will be published elsewhere.

dUTPase is packed as a trimer around the threefold axis of the crystal, with large solvent channels between the enzyme molecules. Chromatography confirms that the molecular weight of dUTPase in solution corresponds to a trimer (G.L., manuscript in preparation), rather than to a tetramer as reported earlier[6]. A trimeric subunit arrangement has also been found for a mammalian dUTPase[7]. The trimer has a wedge-shaped appearance when viewed perpendicularly to the 3-fold axis and a triangular face, typical for a trimer, when viewed along the 3-fold axis (Fig. 1*a*). The largest distance across a triangular face is about 60 Å and the length along the axis is ~45 Å. The subunits associate through interactions between twisted β-sheets, thus burying three hydrophobic surfaces about the 3-fold axis. The arrangement of monomers resembles that of the trimeric tumour necrosis factor[8,9], but the details of relative orientation of strands along the axis differ.

Figure 2*a* and *b* shows a topology diagram and a ribbon representation of the subunit which consists of a polypeptide from Robert Del Tredici, At Work in the Fields of the Bomb (N.Y.: Harper + Row, 1987)

5. Dr. Karl Z. Morgan, the Father of Health Physics

Karl Ziegler Morgan was director of Health Physics at the Oak Ridge National Laboratory for twenty-nine years. Founder and president of the Health Physics Society, he was also the first president of the International Radiation Protection Association. He edited the Health Physics Journal *for twenty-five years and for more than forty years has participated in committees concerned with the measurement and evaluation of radiation doses to humans and animals. He has published several hundred articles on radiation safety and frequently appears in court cases as an expert witness on radiation hazards.*

Dr. Karl Z. Morgan—
Atlanta, Georgia, August 8, 1983

Prior to my becoming a health physicist I was a cosmic ray physicist. I got my doctorate at Duke University and did my dissertation on cosmic rays, which resulted in my making measurements of radiation in caves and coal mines. In this endeavor I worked at Mount Evans one summer at the laboratory of Dr. Arthur Compton of Chicago, the Nobel physicist. One day in early 1943, I received a phone call telling me I must come to Chicago, there was something exciting going on, it was secret, and it was related to my field. Well, I took the train to Chicago, and when I walked into Dr. Compton's office several people greeted me and said, "Karl, you will be in the field of Health Physics."

You mean they already had the name "Health Physics"? I've always heard you were the "father" of Health Physics.

Well, that's the point. I started to turn around for the door. I said, "There's been a bad mistake. I've never heard of Health Physics." And they said, "Hold on, Karl, we've not heard of it either." Then they said they'd already carried through a security clearance on me so they could tell me what was going on, namely, that on December 2, 1942, the first pile of graphite and uranium went critical for the first time. They explained they were intent on making an atomic fission weapon. They felt it might have considerable bearing on our ability to win the war. At that time it appeared to some of us that our chances of winning the war were not very good. Those were very dark days. They told me they were determined to do this work safely—and it would be my job to make certain that it was done safely.

Who made up your team?

Dr. Karl Z. Morgan

H. M. Parker, C. C. Gamusfelder, and Jim Hart were some of the first health physicists with me. In addition there were medical people and radiation biologists. Sometimes it was hard to say which we were—radiation biologists, medical men, or health physicists. We all worked together very closely.

What was it like, being involved in work on the first atomic bombs?

We worked very hard in those days. We knew that Hahn, Strassmann, and Meitner had been the ones to discover fission and they were Germans, and we supposed that they were giving advice to Hitler to go hell-bent in the production of a nuclear bomb. So we worked night and day trying to develop techniques by which this work could be done safely. But we had, all of us, a serious misconception in that we adhered universally at that time to the so-called "threshold hypothesis," meaning that if a dose were low enough, cell repair would take place as fast as the damage would accrue, and there would be no resultant damage. In other words, we believed there was a safe level of radiation.

How long did that remain a misconception?

I would say by the time of the Chalk River Conference in November of 1949 at Chalk River, Canada. It was a tripartite conference of people in this field from the United Kingdom, the U.S., and Canada. By that time I think the majority of us realized that there really wasn't a so-called safe level of exposure.

I'm surprised to hear that. I was under the impression that no early studies existed showing health hazards at extremely low levels of exposure.

That's not correct. In that early period, there were some in the Atomic Energy Commission who recognized the importance of doing basic research, so they set up large laboratories at Oak Ridge, at Hanford, at the Argonne Laboratory in Chicago, at Los Alamos, also at Savannah River and later at Brookhaven. In these laboratories they had large studies of animals, all kinds of animals, as well as plants, to see the effects of all types of ionizing radiation. They investigated the effects of dose rate, the effects of low doses, the effects of high doses, and the production of malignancies. Some of us at the Chalk River Conference had seen the results of those hundreds of early experiments on animals, and we saw no reason—at least I saw no reason—why you wouldn't anticipate the same sort of effects on man as we had found on rats and mice and dogs.

What were some of the things you found? Why is radiation dangerous at low levels?

There isn't a safe level because it's just a matter of chance that a photon or alpha particle or neutron, when it comes through your body, will come close to the nucleus of a cell, damage the cell, and disturb some of the information in the nucleus. In the nucleus of a normal cell are forty-six chromosomes; along these chromosomes we have the genes. In combination, if these genes were like letters in a book, it would take millions of books to record all the information available in every nucleus of every cell in our whole body. So when the radiation goes through, occasionally—very, very, seldom—it damages a cell in such a way that it can survive in its damaged form. These damaged cells can be likened to a library that a madman has broken into and ransacked, randomly ripping pages out of books. The damaged cells no longer have sufficient instructions as to what to do under many adverse circumstances. One of the most serious consequences happens when a cell doesn't know when to stop dividing, or how big to get, or what chemicals to produce; and eventually there are enough of these cells that you can identify as a cancer.

How does this tie in with the "linear hypothesis" about radiation levels and the cancers they can cause?

The linear hypothesis means that you can predict the amount of cancers you will get from a given amount of radiation—and it doesn't matter whether you get the radiation over a short time, in high doses, or over a longer time in smaller doses. The way it is expressed is: you can expect one fatal cancer for every 1,000 person-rems of radiation.

What does "1,000 person-rems" mean?

This refers to the total amount of radiation that can cause one cancer. It's called "person-rems" because it can be spread out among a number of people. According to the linear hypothesis it makes no difference whether 1,000 people receive one rem or whether 500 people get two rems—or whether 10,000 people get a tenth of a rem apiece. All of the standard-setting bodies at the present time assume the linear hypothesis is true, and they say that if you have twice as many person-rems of exposure you'll get twice as many cancers. And, except for the latency period in the appearance of a cancer, it doesn't matter over what period of time you receive the exposures. Radiation-induced leukemia has been known to appear in a time as short as one year, although the average latency period for leukemia is eight to ten years, and in the case of solid tumors like cancer of the breast, brain tumors, bone cancer, and thyroid carcinoma, the latency period is about thirty years.

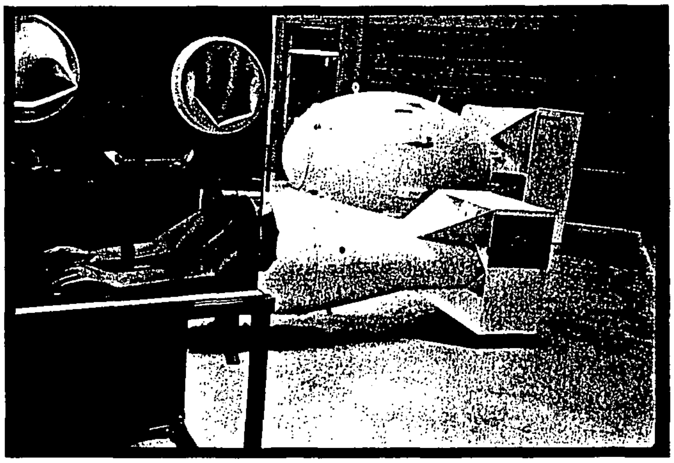
In the past decade some of us have gone further in examining the literature, and we have concluded that instead of the linear hypothesis, there is a "supralinear" hypothesis which fits the data more appropriately. In particular, Drs. Stewart and Kneale in England and myself here, and Mancuso in Pittsburgh, and Sternglass, and maybe fifty or so other people have been publishing papers showing that down at the low doses you actually get more cancers per person-rem than you do at the high doses. Now, I'm not saying that you get more cancers at these low doses than at high doses. I'm saying that damage per unit dose is greater at these low levels. And that's true in part because the high levels will more often kill cells outright, whereas low levels of exposure tend to injure cells rather than kill them and it is the surviving, injured cells that are cause for concern. There are of course other factors involved with high doses, and one of them is that high doses can do serious damage to the body's immune system.

So the supralinear hypothesis says there really is a difference between 500 people who get two rems each and 10,000 people who get half a rem. Will more damage occur among the 10,000 people who got the lower doses?

It looks that way, yes. This is now becoming quite a point of contention. When we first began these discussions many people thought we were crazy, because they believed that even the linear hypothesis was overconservative.

you told the trial judge it was so toxic that it didn't matter how it got into her refrigerator, it still meant negligence on the part of the company. How toxic is plutonium?

For more than a quarter of century I was an active member of the International Commission on Radiological Protection and the National Council on Radiation Protection, and during that time I was chairman of the Internal Dose Committee for both these organizations. I made the earliest calculations on permissible levels of plutonium and all the radionucleides when I was at Oak Ridge. It was my committee that set the levels for all the nucleides, and these same levels are now being used by the Nuclear Regulatory Commission, the Environmental Protection Agency, and others, with essentially no modification. We set the permissible body burden for plutonium-239 as .04 millionths of a curie, that is, .04 microcuries. You never want to permit a worker to exceed that level in his body. If he ever did build up this much it would be serious because



Foreground: glove box for handling plutonium
Background: Hiroshima and Nagasaki duplicate bomb casings
Bradbury Science Museum, Los Alamos, New Mexico

If the supralinear hypothesis is founded on reality, what would that mean for the commercial nuclear power industry and the nuclear weapons complex?

If it can be established that the damage per unit dose at very low levels is greater than at high levels, there's no question that the effects of fallout, the effects of handling radioactive materials, and the effects of even a small medical exposure will be much more severe than had been anticipated. This, I suppose, is one reason why we have received so much flak when we presented our case.

Can you talk a bit about plutonium? I understand you were an expert witness in the Karen Silkwood case, where you testified on the hazards of plutonium, and

this represents an average dose-rate to the skeleton of 30 rems per year for the rest of his life. Essentially it's there forever, and it continues to irradiate you. I've published papers in the *Journal of Industrial Hygiene* showing that this level was in fact far too high and should be reduced by a factor of 240. Those in the nuclear industry found every way they could to try to show flaws in the arguments I used. The typical response from consultants to the Department of Energy is: "Although you observe this effect in a baboon, you have no proof you would observe it in man." So they want to wait until you have human guinea pigs, I guess, to get the proof.

Just yesterday I was visiting the Chem-Nuclear waste disposal site in Barnwell, and I watched workers moving all kinds of *boxes and casks of radioactive materials into huge clay trenches. I brought along my own Geiger counter and as soon as we got close to the edge of the trench, my beeper started reading thirty and forty times higher than background. I asked Jim Purvis, who was showing me around, whether men who worked over the open trenches got any special hazard pay. He told me, "No, they do not receive a hazard pay, because there is no hazard. The radiation they are subjected to is well below the acceptable level."*

This employee gave you the response that you might have expected—namely, that there was no hazard, and no need for special hazard pay. They assume that as long as you don't exceed the maximum permissible exposure level of five rems per year, there's no hazard. They don't appreciate the fact that all the standard-setting bodies in the world today set these standards on the assumption that there is no safe level of radiation exposure. So the question is not: What is a safe level? The question is: How great is the risk? All exposure subjects you to some risk. The more exposure you get to radiation, the greater the risk it will cause a cancer. The cancer may derive from one single small exposure, but on the other hand, it may derive from a series of exposures, one of which sometime in the past happened to be the actual cause. On many occasions I have tried to point this out to my students by saying that when radiation passes through our bodies and comes near a particular cell, there are several things that can happen. The most likely thing is that it will go right by or right through the cell without doing anything. Number two: there's a high probability that if this radiation comes near the nucleus of the cell it will cause its destruction. I don't mean it will be evaporated, I mean it will damage it in such a way that it cannot reproduce itself, so for all purposes in a few months at most it will be dead. Number three: there's a remarkable possibility that this cell will be damaged, yet it will survive, and it will repair itself, and for all intents and purposes it will be quite normal. But number four is what we fear. Fortunately the probability of it is exceedingly low. Number four is: the radiation comes near the nucleus of this cell, it produces damage, and the cell survives, but it survives in its damaged or perturbed form. It divides, it divides again and again, and, on the average, if it's leading to a solid tumor, after thirty years it will be large enough that it will be recognized as a malignancy.

These forms of damage don't show up immediately. With exposure to radiation you don't feel the sense of pain that you do when you burn yourself. But the damage shows up in a very serious and dramatic way some years later when the results are diagnosed as cancer. That is why I think it behooves us to find out more accurately what these risks are.

Karl, there are a number of populations at risk in America from radiation: the nuclear workers at the different sites, people who bury the waste, truck drivers, the atomic veterans. Is the radiation story going to end up looking like the asbestos story when all the data are in? Do you think we should anticipate a rash of diseases related to radiation, and that eventually there will come a unanimous understanding of the real hazard?

I wish I could say yes. I have confidence in the future, provided, of course, we can prevent a nuclear war. But it takes a very long time for man to learn the lesson and for the information to filter down to where it has some effect. Back in the year 1500 it was known that miners in the cobalt mines of Bohemia and Saxony were dying of the so-called miner's disease. And yet it hasn't been long in this country since we've had many miners working underground at levels as high or higher in radium and radon as existed in these mines over 400 years ago. I think we'll be having many sad lessons more before we learn what we should already know by now.

Limitations of the ICRP Recommendations for Worker and Public Protection from Ionizing Radiation

For Presentation at the STOA Workshop
Survey and Evaluation of Criticism of Basic Safety Standards
for the Protections of Workers and the Public against Ionizing Radiation
European Parliament, Brussels, 5 February 1998

ABSTRACT:

The mathematical and biological elegance of the International Commission on Radiological Protection (ICRP) intellectual structure, which has the obvious mark of the physicist, should not be allowed to blind us to its inability to address the full spectrum of worker and public health problems caused by the routine and/or accidental exposures to ionizing radiation inseparable from the operations in the nuclear fuel cycle. I am referring to the very narrow administrative decisions which limit the focus of ICRP concern, and make possible the simplifications designed for administrating its recommendations. For example, the recognized biological endpoints deemed to be of concern for regulatory purposes are limited to: radiation induced fatal cancers and serious genetic diseases in live born offspring.

There are many administrative decisions embedded into the elaborate (artificial) methodology for calculating effective whole body dose and for calculating the expected number of radiation induced fatal cancers. The strengths of the ICRP approach rest primarily on its ability to quickly convert a multidimensional problem, that is, a mixture of radionuclides, having a variety of energies and types of emissions, multiple pathways to humans, and a variety of target human organs, into a linear system amenable to management decisions. This is a recognized mathematical achievement. However, in risk assessments, long term chronic exposure, the aftermath of a disaster, or in worker compensation hearings, these same techniques cloud reality and work effectively against justice for the victims. The elegant mathematics must not be allowed to cover up the injustices.

In terms of its own claims, ICRP does not offer recommendations of exposure limits based on worker and public health criteria. Rather, it offers its own risk/benefit trade off suggestion, containing value judgements with respect to the "acceptability" of risk estimates, and decisions as to what is "acceptable" to the individual and to society, for what it sees as the "benefits" of the activities. Since the thirteen members of the Main Committee of ICRP, the decision makers, are either users of ionizing radiation in their employment, or are government regulators, primarily from countries with nuclear weapon programs, the vested interests are clear. In the entire history of the radiologist association formed in 1928, and ICRP, formed when the physicists were added in 1952, this organization has never taken a public stand on behalf of the public health. It never even protested atmospheric nuclear weapon testing, the deliberate exposure of atomic soldiers, the lack of ventilation in uranium mines, or unnecessary uses of medical X-ray.

This paper will examine the credibility of the Atomic Bomb Studies as a basis for the radiation protection standards, the adequacy of the biological mechanisms and endpoints chosen for standard

219

setting, the adequacy of research on other possible biological mechanisms and endpoints, and the decisions made by ICRP on the "acceptability of the detriment" to the individual and to society, relative to comparable decisions made by health professionals for chemical hazards.

THE ATOMIC BOMB STUDIES:

The atomic bomb studies followed, and did not precede the setting of the radiation protection guidelines recommended by ICRP and followed internationally until 1990. The main recommendations were set in 1952, and the first doses assigned to A-bomb survivors were not available until 1965. Moreover, the research was designed to determine the effects of an atomic bomb, not the health effects of exposure to ionizing radiation. The research was undertaken by military researchers from both the US and Japan familiar with and primarily concerned with military used of atomic, chemical and biological warfare agents. The research has come too late for standard setting needs, it has focused on cancer deaths, is uncorrected for healthy survivor effect, and is not inclusive of all of the radiation exposures of cases and controls (dose calculations omit fallout, residual ground radiation, contamination of the food and water, and individual medical X-ray), and fails to include all relevant biological mechanisms and endpoints of concern.

It is normally claimed that biological basis of the cancer death risk estimates used by ICRP, is the atomic bomb studies. However, these studies are not studies of radiation health effects, but of the effects of an atomic bomb. For example, the radiation dose received by the Hiroshima and Nagasaki survivors from fallout, contamination of food, water and air, has never even been calculated. Only the initial bomb blast, modified by personal shielding, is included in the US Oak Ridge National Laboratory assigned "dose". This methodology is carried to an extreme. For example, one survivor I know lived within the three kilometer radius of the hypocenter, but was just beyond the three kilometre zone, at work, when the bomb dropped. As soon as she could, she returned home after the bombing and found her parents and brother dead. Then she stayed in her family home for the three following days, not knowing where to go and filled with grief. Although she suffered radiation sickness and many subsequent forms of ill health, she is counted as an "unexposed control" in the atomic bomb data base. By using the "not in the city" population which entered after the bombing as "controls", many of cancers attributable to the radiation exposure in both cases and controls are eliminated from the outcomes considered related to the bomb. In contrast, in the United States:

> "Any veteran exposed to a nuclear bomb test or who was part of the first 11 months of occupation of Hiroshima or Nagasaki is provided coverage for radiation exposure and any such veteran is assured priority of hospital treatment ahead of veterans with non-survivor claims. Occupation of Hiroshima or Nagasaki means official military duties within ten miles of either city, between the dates of 6 August 1945 and 1 July 1946." (Ref. 1)

The difference is obvious: the A-bomb studies measure only cancers due to the bomb blast; veterans are compensated for radiation induced cancers.

The basic radiation protection standards, recommended by ICRP and in effect until 1990, were set by the physicists of the Manhattan Project and presented to the International Association of Radiologists in 1952, when they asked to be allowed to join the organization. They set maximum permissible doses per year as 50 mSv for workers and 5 mSv for the public.

The data base for the Hiroshima and Nagasaki Life Span Study, the basis for the mortality estimates, was first identified in the 1950 Japanese Census. The information was not collected and ready for analysis until around 1957, and because it depends on first cause of death information, it was based on only a small percentage of deaths for the first seven years. It was heavily dependent on the accuracy of death certificates. Deaths in the Hiroshima and Nagasaki population between 1945 and 1950 are not included in the study. Even today, the majority of the 1950 identified survivors are still alive. (Ref. 2)

The first research reports were based on distance from the hypocentre. The doses were not assigned to the survivors until the T65D, (which stand for tentative dose estimates, 1965), compiled by John Auxier of Oak Ridge National Laboratory, became available. Atomic Bomb dose/response studies could not have been the basis of recommendations set in 1952 because they did not exist!

Interestingly, the Atomic Bomb Casualty Commission (ABCC) and its successor organization, the Radiation Effects Research Foundation (RERF), has since the beginning collaborated with the Japanese National Institute of Health (JNIH). ABCC was set up be the occupying force in September 1945. Their Japanese partner was responsible for hiring and firing all Japanese scientists who worked on the A-bomb data, although the US assumed singular control of all of the dose assignments once they were available. The JNIH was actually established by the order of the U.S. Forces (Ref. 3), staffed with scientists from the Institute of Infectious Disease (IID) attached to the University of Tokyo, and containing most of the leading medical scientists from the Japanese Biological Warfare (BW) Institutions and the infamous Unit 731, which was responsible for the gross experimentations with humans in Manchuria during World War II. (Ref. 4) The Japanese scientists who engaged in biological warfare experiments on live human beings, allegedly including allied prisoners of war, were granted immunity by the U.S.Army from investigation for war crimes in return for the results of their experiments. Kobayashi Rokuzo, advisor to the IID laboratory was attached to the Japanese Army's Medical College headquarters of the BW network, was Director of JNIH from 5/47 to 3/55. His Vice-Director for the same term was Kojima Saburo, who had intensively cooperated with BW Unit 1644 in the vivisection of humans at Nanking, and with the IID unit during the occupation of China. The Director of the JNIH from 3/55 to 4/58 was Komiya Yoshitaka, who was a member of the Institute of Health in Central China during the occupation, part of the BW network of hospitals run by the Military Police. Yanagisawa Ken, Vice-Director from 10/58 to 3/70, conducted experiments on Chinese youths during the occupation, through BW Unit 731. It was through these human experiments that he developed dried BCG, becoming "eminent" in medical circles. The list is much longer, including Directors and Vice-Directors up until 1990, scientists known to have conducted military experiments on humans.(Ref. 5).

Clearly warfare and the results of the nuclear bomb "experiment" were the main guiding principles of the research at Hiroshima and Nagasaki. American researchers were "safe" with the Japanese who had also conducted research on humans in order to further their war tactics. Consequently, it was not until 1994 that the research on cancer incidence rate after the A-bomb exposure was first published, highlighting their neglect the high incidence rate of breast, thyroid and skin cancers (not always fatal). Incidence rate had been unreported up until then (Ref. 6).

In 1986, we witnessed the release of a complete reassignment of doses to the Hiroshima and Nagasaki survivors, supposedly based both on revised estimates of the neutron component of the dose and new estimates of shielding. According to Dr. Dale Preston, who directed the reassignment of doses, this was not a simple proportional change in all doses, but a true reassignment, often to new categories of exposure. This implies that all of the research based on the earlier assignment of doses is now considered to be wrong.

> "The importance of the new research is that it completely changes the scheme of radiation doses that people are supposed to have received in Japan, particularly in Hiroshima." (Ref. 7)

According to this same article, the dispute over dose estimates had been brewing for four years, since 1977, when the US National Council on Radiation Protection asked John Auxier for supporting information for his assignment of doses to atomic bomb survivors. Auxier stated that when his office was moved in 1972, the record division at Oak Ridge mistakenly shipped his files to the shredder. He never reported the loss of these valuable papers. There was no US Government response until 1981 and it took until 1990 to complete this rearrangement of the Hiroshima and Nagasaki data. All of this manipulation of data took place "in house" by the staff of the US Department of Energy. Such sweeping change in a data base is usually considered manipulation, whether deliberate or not.

There are other reasons to challenge the ICRP reported reliance on the atomic bomb studies for its fatal cancer risk estimates. Not only does this research fail to include dose from residual radiation, fallout and food web sources, but it also fails to include medical X-ray data for each survivor. Radiation "dose" in these studies excludes all ionizing radiation exposures except that from the original flash of the bomb. Many survivors were part of special investigations requiring medical X-rays, the Japanese medical doctors X-ray the survivors at their yearly medical examination, the American researchers X-ray them every second year.

Although the A-bomb scientists have now admitted that more cancers were caused per unit dose of radiation than previously thought, ICRP has now given itself risk reduction factors for slow dose rate and low dose. This introduction of an unsubstantiated "correction factor" gives evidence of the inadequacy of the data base to answer important questions about worker and public exposures, which are almost all at low doses and slow dose rate. It also indicates that the ICRP knows that it is inadequate. There is no supporting human evidence for this reduction of the risk factors, and considerable evidence that it is not warranted. (Ref. 9).

I do not have time to go into all of the myriad details involved in forming my judgement, since I have worked in this field for thirty years, but I would generally recommend the article: "Inconsistencies and Open Questions Regarding Low-Dose Health Effects of Ionizing Radiation", by Rudi H. Nussbaum and Wolfgang Kohnlein, and also the fine research papers published by Dr. Alice Stewart on this subject, and on ABCC failure to correct their data for the Healthy Survivor effect. It is my professional opinion that the slow dose rate - low dose reduction factors used by ICRP (and UNSCEAR) are not justified. It is also my professional opinion that the fatal cancer dose rate for an exposure of one hundred Person Gray should be conservatively set at 20, rather than the current 5 as recommended by ICRP. The direct extrapolation for Atomic Bomb data to low dose exposure would predict 17 fatal cancers per Person Gray exposure. They obtain this estimate in spite of losses through failure of death certificate information and elimination of all deaths prior to 1950. This, in the face of under reporting, is in close agreement with nuclear worker data, and should not be reduced with this Dose-Dose Rate Reduction Factor.

BIOLOGICAL MECHANISMS AND ENDPOINTS:

In the early 1950's, when it was generally recognized that using the erythema dose, the dose which actually burnt the skin, was not adequate as a guide to radiation protection, many different biological endpoints were proposed as guides to regulatory standards: reproductive problems, tumors, congenital malformations, cataracts, blood disorders. Other possible biological endpoints were added later: obesity, hormonal disruptions, auto-immune diseases, developmental disorders, mental and physical retardation. ICRP decided that people should only be concerned about fatal cancers, and the only biological mechanism to be considered would be direct damage to DNA. Most of the other endpoints are dismissed as transient, not consequential, not damaging of the gene pool, or not fatal. This is an administrative, not a scientific decision, with which we may well wish to disagree. Even with respect to fatal cancers, those which were promoted or accelerated by the radiation exposure are not counted, because they are not considered to be "radiation induced"(Ref. 10).

Hiroshima and Nagasaki studies of non-cancer effects of exposure to ionizing radiation are either very poor or non-existent. I remember my frustration when I first looked for data on the relationship between exposure to radiation and adult onset diabetes. Diabetes among Hiroshima males had shown a linear trend with dose for causing death (Ref. 11). Since diabetes is not normally a first cause of death, one could well question the relationship of radiation with incidence rate of diabetes. When I located the research paper from the ABCC, I was astonished to find a bold statement that diabetes shows no relationship with radiation exposure in the early part of the paper. There is no supporting evidence for this statement. The remainder of the paper is devoted to a discussion of diabetes among A-bomb survivors with no further mention of or reporting of their doses. Reference is made to negative findings of atomic bomb research in order to discourage further research into the relationship between diabetes and radiation. Diabetes rates are extremely high in the nuclear fall out areas of the Pacific, downwind of the Nevada Test Site, and in areas of heavy fallout in the Arctic. However, no research has been done into the possible causal links with nuclear fallout.

The US studies of the health affects of nuclear fallout were carried out in the Marshall Islands, not (as noted earlier) in Japan (Ref. 12). They are much less publicized. The US began testing nuclear bombs at Bikini Atoll in the summer of 1946, before the territory had been given to it by the UN as

223

a "Strategic Trust Territory". The world community knew that it was the intention of the US to use this territory for nuclear testing, but chose to look the other way. The Australian Ambassador was the exception, and he chose to resign from the UN over this issue. Other nations could hardly have failed to notice! Australia merely replaced their Ambassador, the US was given its testing site in 1947, and everyone looked the other way as the US and UK conducted nuclear tests in the Pacific and Australia (Ref. 13).

On March 1, 1954, the US exploded a 15 Megaton hydrogen bomb at Bikini, and no one informed the Rongelap People, who lived downwind of the testing site. The Weather men stationed at Rongerik Atoll, slightly further away from Bikini than Rongelap, have publicly testified that they warned the military that the winds were traveling in the direction of inhabited Atolls. The US Navy ship, Gypsy, stationed just off the tip of Rongelap, was ordered to move away from the fallout area, but the Rongelap People were not warned.

About 72 hours after the heavy fallout on Rongelap, which polluted the land, drinking water and food, the Rongelap People were evacuated to the Kwajalein Atoll military base for medical examination and care. Many suffered sever radiation sickness, burns, epilation (hair loss), and depleted blood counts. They were forced to stay on Kwajalein for three years, until the US Military declared their Atoll again "safe for inhabitation". In moving this population of about 87 people back to the Rongelap Atoll, the US chose a population of relatives (Rongelapese who were not on the Atoll at the time of the fallout), matched for age and sex, to return to the Atoll as a "control" group for their research.

Money appropriated by the US Congress for the health of the Rongelap People was given to the Brookhaven National Laboratory for their research program. The Laboratory purchased and outfitted a ship which they used in the summer to travel from Long Island, New York, via the Panama Canal, to the Marshall Island, which is about half way between Hawaii and Japan. Their medical program consisted primarily in conducting blood tests of the Rongelap "cases" and "controls", and examinations for thyroid nodules or other thyroid abnormalities. The medical "care" given to the Marshallese consisted of referral slips to local health professionals noting some medical problem which had been found during the examination and recommending medical diagnosis or treatment (often not available in the substandard facilities in the Trust Territory). If they found a thyroid abnormality, this Brookhaven team would recommend flying the Marshallese to the Cleveland Clinic in the US for a thyroidectomy, calling this preventive surgery (preventing thyroid cancer by removal of the thyroid gland).

In 1978, the US Department of Energy conducted an extensive investigation of the residual radiation on Rongelap Atoll. The Rongelap People after seeing the reports of their still contaminated Atoll and food web, evacuated themselves and began a struggle with the US Congress for cleanup and compensation. Finally in the late 1980's, the Congress agreed that the Island was still uninhabitable, although the experimental population had been living there from 1957 to May 1983, some 26 years. The nuclear scientists working for the US Department of Energy and the US Department of Defense claimed that the Rongelap People were irrationally fearful of the radiation and that their evacuation was uncalled for. Eventually the Congress not only commended the Rongelap People, but they ordered a cleanup of the Atoll to a level guaranteeing that exposures of the people would not exceed 0.25 mSv per year, well below the 5 mSv per year standard used in the US. This same standard for cleanup was used by the US on the Johnston Atoll, another US nuclear test site in the Pacific.

The medical examination of the Rongelap People included many reports of "monster" and molar births. According to the People they actually began to photograph these abnormalities, which at first they had hidden thinking it was their own fault to have such abnormal pregnancies. When the photographs were shown the American researchers, the pictures were seized. They burned them in front of the people saying: "This is what we think of your evidence". We heard this story from many different people on the Atoll.

In a cross sectional study which we undertook in 1988 (Ref. 14), we included 297 children, 134 adult females and 113 adult males, randomly chosen from Rongalapese in the US DOE "exposed" category, i.e. in the actual fallout, "control" category, i.e. relocated on the contaminated Atoll with the exposed group in 1957, and "neither" of the above, and their children. We found the following proportions with serious chronic illness among adult Rongelapese born prior to the 1954 hydrogen bomb detonation:

Category of Exposure:	Males	Females
Exposed	88.5%	88.6%
Controls	63.6%	76.8%
Neither	55.6%	58.1%

Serious congenital disease or malformation in living children (realizing that with the substandard medical facilities many were miscarried, stillbirths or infant deaths):

Category of Parental Exposure for children 15 years or under in 1988 (born since 1973):

Exposed*	15.3% with serious congenital diseases or malformations
Controls	21.0% with serious congenital diseases or malformations
Neither	8.3% with serious congenital diseases or malformations

* This category had a higher rate of miscarriages and still births. There were 59 (1.6 grandchild per adult) offspring in this category, while the other two categories included 81 (4.1 grandchild per adult) and 84 (3.1 grandchild per adult) children respectively.

Category of Parental Exposure for those 16 to 34 years old in 1988 (born between 1954 and 1972)

Exposed**	No children
Controls	2.1% with serious congenital diseases or malformations
Neither	2.0% with serious congenital diseases or malformations

** There were only 13 live children (0.36 per adult) in this survivor group, whereas there were about 50 (48, 2.4 per adult and 51, 1.9 per adult) respectively representing the other two exposure categories.

In the survivor population, those over 35 years of age in 1988, 2.4% were found to have congenital diseases or malformations. Using the three age groups as roughly representing three generations of Rongelapese, those exposed, their offspring and the third generation, we find some startling changes in health parameters:

THYROID RELATED PROBLEMS:

Category:	Exposed	Controls	Neither
Alive in 1954	58.3%	5.0%	18.5%
First Generation Offspring	----	8.3%	11.8%
Second Generation Offspring	1.7%	----	1.2%

It seems that we should have expected the thyroid abnormalities at Chernobyl! However, the world medical community was completely unprepared for the crisis since this Rongelap data was not widely known by the non-US Government scientists.

TUMOURS AND CYSTS:

Category:	Exposed	Controls	Neither
Alive in 1954	25.0%	5.0%	7.4%
First Generation Offspring	15.4%	4.2%	7.8%
Second Generation Offspring	----	2.5%	1.2%

HEART PROBLEMS:

Category:	Exposed	Controls	Neither
Alive in 1954	22.2%	15.0%	7.4%
First Generation Offspring	7.7%	6.3%	3.9%
Second Generation Offspring	5.1%	13.6%	3.6%

MENTAL AND NEUROLOGICAL ABNORMALITIES:

Category:	Exposed	Controls	Neither
Alive in 1954	2.8%	----	3.7%
First Generation Offspring	7.7%	6.3%	2.0%

Second Generation Offspring	1.7%	----	1.2%

These figures likely indicate the teratogenic effects on first generation born on the contaminated Atoll after the relocation there of the exposed and control population in 1957.

REPRODUCTIVE PROBLEMS EXPERIENCED BY WOMEN:

Category:	Exposed	Controls	Neither
Alive in 1954	66.7%	60.0%	46.2%
First Generation Offspring	25.0%	36.4%	22.7%

ADULT ONSET DIABETES:

Category:	Exposed	Controls	Neither
Over 35 years of age	11.5%	7.9%	5.2%

It seems clear that limiting ones concern to fatal cancers may provide neat mathematical simplicity, but it is unrelated to the reality of the suffering of the survivors of radiation exposure.

The Investigation Committee of Atomic Bomb Victims of the Hannan Chuo Hospital, Osaka, Japan, undertook a study of 1,233 atomic bomb survivors (554 males, 678 females, and 1 unknown) living in Osaka (Ref.15). This study was undertaken in 1994, and the average age of the survivors was 59.5 years. The survivors were compared with the data for the same age group of the Standard Japanese Population (Ref 16).

More than 90% of the survivors were under medical service and more than 50% experienced frequent hospitalizations, about 2.5 time higher than in their unexposed peer group. They found the following:

DISEASE	% SURVIVORS WITH DISEASE	RELATIVE MORBIDITY TO THAT OF GENERAL PUBLIC
Lumbago	28.4%	3.6
Hypertension	23.9%	1.7
Ocular Disease	18.0%	5.0
Neuralgia and Myalgia	12.3%	4.7
Leukopenia	12.1%	13.4
Gastritis	9.9%	4.5
Gastroduodenal Ulcer	9.8%	4.7
Ischemic Heart Disease	9.8%	4.7
Liver Disease	9.0%	6.4
Diabetes	8.2%	2.7

Similar findings have been reported at international NGO forums on the damage and its aftermath for atomic bomb survivors in Japan, and documented in the 1986 report of the Association of Victims of Atomic Bombs of Japan. Recently the RERF has acknowledged that in their limited survivor group they have found excess relative risk of cerebro-vascular and cardiac diseases, and gastro - intestinal diseases, especially liver disease, in those who were younger the 40 years at the time of bombing (Ref. 17, 18 and 19). One can only conclude that the official radiation studies were either incompetent to report these disease or uninterested in them.

In the early 1970's, when I was part of the analytical team working on the Tri-State Leukemia Survey, I noticed the remarkable statistical regularity of the increase of non-lymphatic leukemia incidence in the population with increasing age. From age 15, when the incidence rate is at a minimum and childhood cancers have played out, one finds an increased rate of about 5% per year of these leukemias. I found the same compound interest type increase in non-lymphatic leukemias in the general population with increased usage of diagnostic medical X-rays, about 4% for trunk examinations. Therefore, I posed a new research question: What exposure to medical X-rays is comparable to one year of natural aging for increasing the risk of non-lymphatic leukemia? I found that the answer was dependent on the part of the body exposed to the X-ray, which turned out to be the amount of the bone marrow exposed by the particular X-ray procedure (Ref. 20).

With one more important piece of information, namely that medical X-ray is measured by the mR in air at skin entrance (rather than by tissue or bone marrow dose as used by the physicist), I will telescope some ten years of research into a few short conclusions:

- For X-ray of arms or legs, and dental X-ray, it requires an accumulated dose of 4000 mR to increase the risk of non-lymphatic leukemia the same amount as one year of natural aging.
- For chest X-ray, it requires an accumulated dose of 1670 mR at skin entrance to simulate one year's natural aging for increasing non-lymphatic leukemia rate.
- For abdominal X-ray it requires an accumulated dose of 1000 mR in air at skin entrance to simulate one year's natural aging for increasing the non-lymphatic leukemia rate.
- The corresponding bone marrow doses for these three sites and these mR doses are: 0.64, 0.72 and 0.83 mSv.
- This is clearly consistent with measurements of the external annual effective dose equivalent for natural background radiation: 0.65 mSv in UNSCEAR 1982 (for normal parts of the world); 0.81 mSv in Solon et al. 1958 (for 124 US cities); 0.61 mSv in Beck et al. 1966 (for 210 locations in the US).

I called this generalized effect of X-ray on the ability to resist non-lymphatic leukemia an "acceleration of the aging process" (Ref. 21). This is a less sophisticated term than "genome instability", but I think that I was measuring the same phenomenon in humans exposed to diagnostic X-rays.

Another important point of this research is that although medical X-ray is low dose, it is given at a fast dose rate, a matter of seconds, whereas the natural background dose is delivered at a very slow rate, spread over the course of a year. There is obviously not a dose rate difference, contrary to what the ICRP would have us believe.

In other research on the Tri-State Leukemia data, I used the natural aging equivalent of each persons medical X-ray exposure history, and added it to their chronological age to obtain what I called the person's "biological age". This was then used in the standard age adjusted statistical procedures rather than the chronological age. It served to elucidate many problems of apparent inconsistency in the data, and proved to be a valuable tool in understanding the complex relationships between environmental factor influencing leukemia rates in a large population. For this reason, namely, its general nature as a factor requiring control (just as one must control for age in epidemiological research) I believe that the aging effect, or genome instability, has broader consequences than just increasing the rate of non-lymphatic leukemia. Again, this implied a need to expand the biological endpoints and low dose mechanisms of concern when dealing with exposure to ionizing radiation.

In addition to these general affects on the whole organism, there are micro-biological effects and biomarkers of exposure which have been neglected by the ICRP because of their focus on cancer death and only one mechanism, namely, direct damage to the DNA molecule initiating a malignant growth. Professor Michael Vicker, University of Bremen, has documented the acute radiosensitivity of blood to micro-Gray doses of radiation, causing the arachidonic acid cascade (Ref. 22). Rather than trying to extrapolate the DNA damage hypothesis from the high dose exposures to radiation into theoretical happenings in the low dose range, researchers would do better to expand the mechanisms studied to include those which actually occur at the low dose and their sequelae.

With all of the sweeping changes which have occurred in biology and microbiology since the 1952 discovery of DNA by Watson and Crick, radiobiology has stayed focused on cancer and direct damage to DNA. Other branches of biology have expanded to consider the entire cell, systems influencing cellular behavior including functional levels and coupled feedback reactions of networks of inter- and intra- cellular responses regulating cell communication. Without a holistic view of biology and physiology, radiobiology has been consumed with detail and elaborate mathematical picture of the small world which was delimited by the very first administrative decisions of the nuclear bomb era.

In an organism, cells communicate with one another through the exchange of specific information, for example through a hormone, and the translation of this signal into intracellular messages. Paracrine (hormones secreted from tissues other than endocrine glands) and endocrine hormones are unable to pass through cell membranes. Therefore their information (the hormone) requires a cellular receptor on the outside surface of the cell, a transmembrane signaling that is connected to the receptor, called a "second messenger-generating enzyme", and a correct interpretation of the second

229

messenger system. Various second messengers are released into the cell after stimulation of a particular receptor enzyme system, and which systems may be activated depends on the genetically determined receptors possessed by the cell. This communication system between cells in complex systems, can be modified, for example by phosphorylating particular proteins, and two second messengers can interact through feedback and cross talk. Ionizing radiation causes many interferences and disruption in this delicately balanced intercellular communication system. In radiobiology, these problems are dismissed and assume to be either trivial or perfectly repaired. Ionizing radiation induces oxidative stress, something admitted by radiobiology but discussed only in terms of its thermal effects. This same oxidative stress induces measurable inflammation, including a massive cascade of fatty acids in various states of oxidation. These mediate inflammatory reactions in the blood and other tissues, such as blood vessel endothelium, and function as second messengers, even controlling such things as pain and chemiluminescence.

The perturbation of cellular communication, regulation and homeostasis by low doses has major consequences for human health and development. It is irrational, as the physicists are now doing, to count on the failure to observe high dose effects at low doses as "proof" that such doses are "safe". DNA damage is a statistical phenomena, called stochastic by the physicists, while the inflammatory response is non-stochastic, or deterministic as it is now called. Unlike skin burns, these internal inflammatory responses occur at microGray doses. The ICRP assumes that deterministic effects do not occur below 500 mGy doses.

The ionizing radiation stimulations are "illicit" in the sense that there is no equivalent stimulation of the arachidonic pathway after non-radiological physiological stimulation, making it pathogenic in character, difficult for the body to regulate and return to homeostasis. This response activates the monocytes, which kill themselves by the oxidants they produce, often ending up as pus along with their digested cellular victims. They can endanger the host by killing other tissue, for example, transplants or infarcted heart tissue.

Activated monocytes are carcinogenic, provoking hitherto latent oncogenic systems and genomic errors to replicate. This may well be one of the mechanisms by which cancers were increased within the first ten years after the Chernobyl disaster. These cancers were dismissed by the IAEA as not radiation related because the ICRP required latency period of ten years had not been completed. These were radiation promoted or accelerated cancers, not radiation induced cancers. Again, we see ICRP recognizing only radiation induced cancers, whereas the victim will experience both mechanisms as due to the disaster.

HORMESIS:

Recently, in a concerted effort to raise the permissible levels of radiation for workers and the public, members of the Heath Physics Society have been actively promoting their theory of Hormesis, namely, that low dose exposures to radiation induce "beneficial" effects such as longevity, robustness, radio-resistance and increased growth. The use of the term "beneficial" implies a judgement, not a scientific fact. Experiments backing these hypotheses have been difficult to reproduce and definitions of "beneficial" have been controversial and appear very subjective. Claims of low dose hormesis have frequently been based on high dose observations, and the only mechanisms offered for these effects has been speculation on repair overshoot at the cellular and genome level. Cell growth as "hormetic" is the most troubling claim, since illicit growth stimulation signifies catastrophe for biological organisms.

What has been sorely neglected in this public relations battle, is that low dose radiation at the cellular level must necessarily affect a large range of molecules in the cellular communication system in any particular cell type. In order to produce one "good" effect, one must endure many other unwanted "bad" effects which will in the long run claim a physiological price perhaps significant, although they evolve to a clinically observable level more slowly (Ref. 23).

Many of the phenomena which have been attributed to radiation exposure by the victims, and those scientists and physicians who have studied the problem from the victims point of view or simply from the available information, can be explained by the low dose effects on inter- and intra cellular communication. In particular, this includes: the high rate of cardiovascular disease deaths in radiologists (Ref 24); the deaths of infants in the higher fallout areas after the Chernobyl disaster in Germany (Ref. 25); the increased rate of low birth weight infant deaths which I documented in Wisconsin, statistically associated with increases in off gas releases from neighboring nuclear reactors (Ref. 26); and the higher than expected cancer mortality rates for nuclear workers (Ref. 27 and 28).

In therapeutic irradiation to kill cancer cells, there are often unwanted reaction in non-irradiated tissues. Sometime this secondary effect is lethal. Under the dominant theory that the only damage of concern is DNA damage, there is no remedy after the exposure. However, experience in hospitals has shown that corticosteroids, which inhibit one of the second messenger reactions, and aspirin like compounds, which inhibit the inflammatory response, can reduce these secondary effects They have demonstrated that these conditions are treatable.

The internal "sunburn" attributable to low dose ionizing radiation exposure may perturb homeostasis, and aggravate pathological conditions such as allergic or arthritic diseases, heart and circulatory disfunction, and cause death for the embryo, fetus or infant critically dependent on timed signal exchanges between cells for proper development.

It may also be true that in subsistence communities, such as was reported for India, children are more sensitive to the low dose effects. The children in five Indian villages downwind from two nuclear reactors demonstrated four-fold higher rates, statistically significant levels, of congenital malformations than a comparable subsistence control group 50-60 kilometres away. Adults (born before the operation of the nuclear reactors) showed comparable levels of congenital malformations (Ref. 29). There have also been documented reports of teratogenic effects after the Chernobyl disaster (Ref. 30). This has very serious implications for the current push to market this unwanted technology in the economically developing countries.

My own research has pointed out the dramatic reductions of monocytes in ionizing radiation exposed populations in many parts of the world (Ref. 31). It seems to be clearly a biomarker for exposure, similar to the way a sun burn is a biomarker for exposure to visible and ultra violet light. I believe that what I am measuring is both a response to low dose radiation as described by Vickers, and also an effect due to the radiosensitivity of the stem cells in the bone marrow which produce the monocytes. These stem cells, subjected to chronic irradiation by the radionuclide incorporated into bone (strontium 90, plutonium, uranium, radium, lead 210), become depleted, clinically resulting in iron deficient anemia and depression of the cellular immune system.

I hope that I have shown that the very narrow focus of ICRP on one biological mechanism of damage to one type of molecule, namely DNA, and neglect of all other mechanisms and molecular damage from ionizing radiation, is scientifically abhorrent and practically very prejudicial to the victims of radiation. There are now attempts to further restrict this narrow focus to health effects due to doses above 100 mSv, through claims of "hormesis" below this dose. The victims must try to fit their problems into the narrow categories "accepted" by the ICRP. It should be the other way around, namely the ICRP is expected to recognize and protect against all mechanisms, damage to all important molecules, and the serious consequences of such damage for human health subsequent to all doses of radiation.

It should also be noted that studies done in Russia after the Chernobyl disaster, point to doses which are below the stimulation of the cellular repair system. That is, at very low doses of radiation the cellular repair mechanisms are not stimulated and the damage goes unrepaired. This would imply "J" shaped curve for effects at low doses (Ref. 32).

ADEQUACY OF RESEARCH INTO NON-CANCER EFFECTS:

Unfortunately, because of the professional isolation of radio-biologists from their colleagues in microbiology, biology and physiology, they have spent their time in elaborate mathematical modeling of the basic narrow focus determined in 1952: namely reconciling the different types of radiation and energies of the transformation events, relating partial body exposure to whole body exposure, setting tissue weights to reflect the fatal nature of the induced cancers. They have missed the examination of subtle low dose exposure mechanisms, investigations into the reasons for differences in radiation sensitivity between different tissues, different people and the same person at different periods in their life.

The non-cancer effects of radiation have largely been studied outside of the generous funding mechanisms of the nuclear establishment, and these studies often cannot produce accurate dose estimates. For example, the whole field of teratogenic effects of radiation. These effects are well known, and have been demonstrated in medical X-ray case and even more clearly in Kerala, India, and Chernobyl, Ukraine. However, if you have made an administrative decision that there are only two categories of radiation effects worth considering: direct damage to the Standard Man, and damage to the population gene pool, then this damage is of no concern and dose responses are not obtained. Teratogenic damage, embryonic and fetal losses, as well as still births, apparently do not count, because they do not effect the population gene pool and are not an economic cost to society. These damaged offspring never pass on the defect to future generations.

I did a small study on the Tri-State Leukemia data to see if there was a deficit of births in the "irradiated in utero" sub-sample. I found that in the control children, those without leukemia or other life threatening disease, matched to the case children for age, sex and geographical location, there was a deficit of children in every irradiation category (Ref. 33). This is highly significant on a 1% level, that is, it would happen by chance in less than one of a hundred such studies. In all, assuming that the unirradiated children gave the population distribution of pathological factors, and the children with no pathological factors gave the distribution of irradiation categories, 259 children would have been expected in the control population, but there were only 223, a loss of 26 (10%) of the sample. The children with leukemia, on the other hand, were over represented in each of the radiation and pathology categories. There were 151 children, while only 130 were expected, an excess of 21 (14%). Both of these groups of children were controlled for Mother's earlier pregnancy loss and pathologic factors. One can assume that the excess was attributable to diagnostic X-ray at doses below 1 mSv. Usually prenatal X-ray examinations are assumed to give a dose of 0.5 mSv to the fetus. This is one half of the yearly dose to the public permitted by ICRP. Investigation into the mechanisms behind this reproductive loss has been minimal or non-existent.

Research into the genetic effects of exposure to ionizing radiation has also been unsatisfactory, even though this is on the ICRP administrative list of detriment concern. For example, as early as 1957, the World Health Organiztion identified the population exposed to high background radiation in Kerala, India, as the best population in the world for studying the genetic effects of radiation (Ref. 34). This was never followed up with action until a group of independent researchers with a small grant from the World Council of Churches undertook a study in 1988. This data has now been collected but needs more input of money for main frame computer analyses, and publication of the findings. We do know that on the high background monozite sands, with chronic exposures between 3 and 30 mSv per year, there is four times the rate of Down's Syndrome, twice the rate of other mental retardation, epilepsy, congenital blindness and deafness, deformities of the long bones and infertility, than is found in the matching control group on normal background (Ref. 35).

It is scientifically outrageous to keep stating that the RERF research found no genetic effects of radiation! Atomic bomb researchers were aware of the fact that their data base was inappropriate. Their research is clearly poorly designed because of their odd matching of cases and controls, their failure to correct for healthy survivor effect and the shortness of time since exposure, which can mask intergenerational effects. Yet the ICRP has failed to call for support for the research which is universally agreed upon as most likely to show the effects of chronic intergenerational exposures.

Meanwhile, the genetic problems has been reduced by ICRP administrative decision not to deal with recessive genetic damage, or diseases with genetic components, but rather to limit consideration of genetic damage to the most obvious autosomal dominant and X-linked defects, and chromosomal diseases. The risk estimates being used for genetic damage are derived from rat studies. Sometimes the genetic effects "of concern" are limited to the first generation offspring under the pretext the damage to subsequent generations does not cause sorrow to the individual exposed during their life time!

Current urgent research needs in the area of radiation health and safety includes:

- Funding of serious analysis of the Kerala data, with full involvement and credit given to those who have carefully collected this data without proper financial support from either governments or the nuclear industry.

- Research into the dose response estimates appropriate for teratogenic effects of radiation and inclusion of these effects in the administrative category of "detriments".

- Research into dose response relationships between radiation exposure and the occurrence of: cysts; blood abnormalities; autoimmune diseases; hormonal disruptions; reduced fertility; skin cancer (including non-melanoma), and the so-called "transient" effects of exposure which disrupt homeostasis.

One would expect that such research, seriously undertaken, would lead to the use of genetic and teratogenic damage as the basis of radiation protection standards.

In the current application of radiation protection standards, for example at nuclear reactors, it is important to change the focus from maximally exposed individuals (usually the Standard Man who works out of doors near the facility) to maximally susceptible individuals (the embryo, fetus and baby being fed with contaminated milk), in order to truly protect against the most severe detriments. Standards should be protecting the public against the harmful effects of radiation exposure both to the individual (including those unborn) and to the gene pool.

The elegance of the mathematical theory should not take precedence over common sense protection of the most vulnerable.

NEED FOR RADIATION PROTECTION STANDARDS:

I would not like my remarks to be construed to mean that regulation of radiation exposure should not take place. It is of course necessary that standards be set. I believe that the standard setting should be recommended by a professionally established open body, with credentials in occupational and public health. The ICRP is profoundly undemocratic and unprofessionally constituted. It is self-appointed and self-perpetuated. Certainly a recommending body could be composed of individuals elected from professional societies such as international associations of professionals trained in occupational health, epidemiology, public health, neonatology, pediatrics, oncology, etc. Some members could be recommended by the WHO and the ILO.

An organization of users of radiation, such as ICRP, being asked to set standards is like inviting the tobacco industry to regulate tobacco! ICRP is organized by its By-Laws to include only users and national regulators (usually coming from the ranks of users) of radiation.

If it is decided that fatal cancer incidence rate should be the biological endpoint on which the regulations are based, and I do not accept this as the best indicators of problems, then the radiation industry needs to conform to the same standards of injury as is used for regulating the chemical industry.

The State of Minnesota, in the USA, decided that a nuclear waste dump should not be able to cause more than one cancer (fatal of non-fatal) over the life-time (70 years) of an exposed person. This is the standard which the State used for chemical polluters. Based on this, a criteria of no exposure of the public above 0.0005 mSv per year was derived by the State Department of Health. This Standard is being enforced in that State, although it is ten thousand times lower than the current permissible dose to the public per year under US Federal Law, namely 5 mSv per year.

In Ontario, the Advisory Committee on Environmental Standards (ACES) expressed astonishment that the nuclear industry was permitting itself to pollute the drinking water with up to 40,000 Bq of tritium per Litre, under the 5 mSv per year federal radiation dose limit for members of the public. When the ICRP reduced the recommendation to 1 mSv per year, the industry agreed to lower the permissible level of tritium in water to 7,000 Bq per Litre. When the ACES used the industry risk estimates for calculating the expected number of fatal cancers considered to be "permissible" under this Standard, they called for an immediate reduction in permissible levels to 100 Bq per Litre, with a further reduction to 20 Bq per Litre within five years. This was based of the standard setting used for toxic chemicals. This means the radiation protection guide line allows 350 times more fatal cancers than chemical standards would allow.

While I understand mathematically why the nuclear industry, dealing with a mixture of radionuclides sets such unreasonably high permissible values, I see also that these high values are used for public relations reasons to assure the trusting public when there is a spill or abnormal incident at a reactor. Stating that the exposure was less than 10% of the permissible dose, sounds reassuring! Yet if one knew that the permissible dose was 350 times too high based on cancer deaths caused, 10% would be seen as 35 times too high. It is in the interest of the nuclear industry, hiding behind ICRP, to carry on the subterfuge that "permissible" implies "no harm".

The ICRP assume no responsibility for the consequences attributable to a country following its recommendations. They stress that the Regulations are made and adopted by each National Regulatory Agency, and it merely recommends. However, on the National level, governments say they cannot afford to do the research to set radiation regulations, therefore they accept the ICRP recommendations. In the real world, this make no one responsible for the deaths and disabilities caused!

In ordinary public health practice, an industry can be called "safe", if it causes the death of less than one person per million exposed to it per year. Using the nuclear industry's own estimate of risk of fatal cancer, and the 1990 ICRP recommendation to keep exposures of the general public below 1 mSv per year, there is an expectation of 50 cancer deaths per year per million exposed. I believe that the risk estimate used by ICRP is too low by a factor of four, based on research done at the low dose and slow dose rate exposure level. This means the number of deaths per year may be as high as 200. These 200 deaths are likely to be predominantly deaths of women and children, and many of the cancers will be expressed clinically after the local reactor is decommissioned. Women have more cancers per unit exposure than do men because of their high risk breast and uterine tissue, and also because they are more susceptible to radiogenic thyroid cancer than are males. Children pick up more radionuclides from the water and food web, incorporating more in bone because they are growing. Children have less mature immune systems, and have a longer life expectancy during which the cancers of longer latency period can develop. It is the men over 50 years who have the smallest risk!

It would certainly be worthwhile for the Parliament to appoint a serious study of radiation protection standards, considering the current death estimates together with the potential breadth of biological endpoints which are truly of concern to the general public. Mental retardation, epilepsy, blindness and deafness are tragedies as well as social expenses never assumed by this industry. Infertility is spawning expensive in vitro fertilization clinics throughout the world. The economic costs externalized by this industry are very large.

I would personally be opposed to leaving the regulation of radiation completely to each national government, with an international recommendation. The nuclear industry has been trying for several years to have the regulations relaxed even further, and I understand that the next released report from the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) will be devoted to the "belief" in hormesis, the "benefit" of exposure to low level radiation. As a plenary member of the Health Physics Society, I have watch this movement within the industry expand over the past few years. The rallying cry is: "Put your mouth were your money is". Health physicists are trying to keep this industry alive in any way they can. Making radiation more acceptable to the public is part of that plan. In the face of such organized opposition to regulation, it will be necessary to establish an honest, prestigious organization which speaks to health - both of humans and of the ecosystem. It should be independent of the vested interest of users of radiation who make their living from this use. It should not attempt risk-benefit trade-offs, but only clarify and quantify the risks.

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239

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240

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February 24, 1999

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Re: Responses to letter from Mr. Jeremy Karpatkin of the DOE Field Office to Mary Harlow, Co-chair of the RSALs Oversight Panel

Dear Mr. Korkia:

Attached to this letter are our responses to the letter from Mr. Jeremy Karpatkin of February 8, 1999. Please forward these responses to the Oversight Panel for their use in preparing a response to the Department of Energy.

Although we did provide an oral response to the questions at the February 1999 meeting, this written response should be considered official, and includes additional consideration from *RAC* regarding the questions posed.

Sincerely,

Kathleeen R. Meyer, Ph.D.
For John E. Till

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241

Responses from *RISK ASSESSMENT CORPORATION (RAC)* to technical questions on *RAC* presentation of 1/14/99 received by fax on 2/10/99 from Jeremy Karpatkin of the DOE Field Office to Mary Harlow, Co-Chair of the RSAL's Oversight Panel, dated February 8, 1999

Questions asked in the letter are repeated below, followed by a response from RAC.

1. The agencies in formulating the RSALs relied on the land use assumptions of the Rocky Flats Cleanup Agreement: the onsite office worker and open space user. These in turn were based on consensus community recommendations contained in the Future Site Use Working Group report and in CAB recommendations. As a basis for comparison, the agencies compared these scenarios to one of the institutional control breakdown, defined as a residential scenario. At the January 15 RSALOP meeting, the RAC briefed the RSAL OP on some potential exposure scenarios that RAC will analyze in the coming months. While realizing that these are not necessarily the final scenarios that will be chosen by RAC, the initial scenarios do raise some questions. Please explain the methodology for choosing the use of the residential rancher, infant of resident rancher and child of resident rancher exposure scenarios. Why was a resident rancher chosen for assessment given the urban nature of the areas encroaching on Rocky Flats? Are these scenarios intended to be scenarios of institutional control breakdown or of reasonably anticipated future land uses? Does RAC believe that these scenarios more accurately capture institutional control failure than the scenarios analyzed by the agencies? If so, why? Does RAC believe the agencies erred in their determination of the reasonably anticipated future land use? Or does the RAC believe that clean up standards should not be based on reasonably anticipated land uses? If it is the latter, please explain what the basis for clean up should be other than reasonably anticipated land uses?

Response: It is correct that the scenarios described at the January 14 meeting are not the final scenarios. It is important to show the process we are using in developing the scenarios, and to involve the panel at each step. Regarding the resident rancher scenario, *RAC* believes that this is a potential scenario to propose because the Rocky Flats site is still an open area. Also, ranching has historically been a part of the surrounding area so it is not unreasonable to suggest that as a possible scenario for the panel's consideration. When looking into the future it seems reasonable to assume that this scenario could represent anticipated future land use or a reasonable scenario if institutional control is lost. *RAC*'s intention was to demonstrate the procedure for establishing scenarios and to provide the panel with a broader range of scenarios for evaluation. We will consider a number of likely scenarios before we decide on the final scenarios for the project.

Our role in this project is to independently assess soil action levels for the Rocky Flats Environmental Technology Site with specific reference to computer programs that might be useful in the calculation. A part of the scope of this project is to review the Department of Energy calculations of soil action levels with the RESRAD program. We will fully document our review of the RESRAD code and our independent assessment of the scenarios analyzed by the agencies.

242

2. RAC has developed exposure parameter (i.e., breathing rate, soil ingestion rate, etc.) values to be used with their chosen exposure scenarios. RAC presented graphs on potential ranges for the breathing rate exposure parameter based on three studies. Given the range of studies available on this topic, including the studies surveyed on a 1997 EPA Handbook (see below) why did RAC choose these three studies? How did RAC choose a specific breathing rate from the range of values given in these three studies? What methodology was used to decide that these breathing rates were most appropriate to use at Rocky Flats? EPA's OSWER Directive 9285.6-03, "Human Health Evaluation Manual, Supplemental Guidance: 'Standard Default Exposure Factors', dated 3/25/91, and in EPA's Exposure Factors handbook (EPA/600/P-95/002F), dated August 1997, are considered by the Site to be authoritative studies in these areas. Can RAC explain why it chose not to reference these studies in developing exposure parameters?

Response: *RAC* believes strongly that it is important to describe the process behind the development of scenarios. In January, we used several breathing rate studies as examples of the kinds of data that will be used to develop uncertainty distributions for key parameters like breathing rates. This presentation described the step-wise process to show how breathing rates can be selected based on activity levels and age, and how these values are summed over a specified time period (e.g. hour, day or year) to yield an annual breathing rate. This demonstration was important for the panel and others to understand that an annual breathing rate is not based on an average value but rather on carefully estimating the time spent in different activities and at indoor or outdoor locations throughout the day. As you recall at the end of the meeting we provided a work sheet for the panel to provide input to *RAC* for the scenarios.

RAC is aware of the EPA reports cited in the question and has copies of them. Actually some of the reports referenced in the January presentation on breathing rates are studies that EPA used in formulating recommendations. Selecting appropriate parameters for the scenarios depends upon a thorough review of the scientific literature, and fully considering the uncertainty distributions of the relevant parameters. *RAC* believes that it is important to go back to the original studies when possible to evaluate the data for use in developing uncertainty distributions. Subsequently, we can generate a distribution of values using Monte Carlo techniques. These distributions can be characterized with a central value such as the median and some measure of the spread of the distribution, such as the 5th and 95th percentiles of the distribution. From these uncertainty distributions, we will select appropriate parameter values for the scenarios. In developing a particular scenario, we can use a high (or low) percentile of the distribution as needed to extend protection to people who might come into contact with the site in the near or distance future. Once a parameter value is selected from our distribution of values for use in a scenario, the scenario is considered fixed just as standards are fixed. At the February 1999 meeting, other studies were cited, including the EPA reports, and preliminary uncertainty distributions of breathing rates were presented.

March 9, 1999

Jeremy Karpatkin, Director
Office of Communications
U. S. Department of Energy - Rocky Flats Field Office
PO Box 928
Golden, CO 80402

RE: YOUR FEBRUARY 8, 1999 LETTER #99-DOE-07780

Dear Jeremy:

Thank you for your letter dated February 8, 1999 transmitting questions regarding scenario selection and inhalation rates that were presented by *Risk Assessment Corporation (RAC)* at the January 14 Radionuclide Soil Action Levels Panel (RSALOP) meeting.

Dr. Kathleen Meyer provided a brief response to these questions at the February 11, 1999 meeting; however, we are enclosing a detailed written response for distribution to DOE-RFFO and Kaiser Hill technical staff. We will provide copies of the enclosure at the RSALOP meeting scheduled for March 11 to assure that all Panel members have an opportunity to review your concerns and the follow-up provided by *RAC* representatives. We trust that this information sufficiently addresses the queries; however, if you should require additional detail, please let us know.

The study continues to move along as scheduled, and we are rapidly approaching an important milestone: the first of three planned public meetings. We cordially invite you to attend the meeting scheduled from 6:30 - 9:00 p.m. Wednesday, March 10, at the Westminster City Hall. The meeting will open with a 30-minute open house to provide attendees an opportunity to visit with Panel members and review and discuss a series of storyboards designed to explain the basics of the project. We are enclosing an agenda and hope to see you there.

As usual, we appreciate your input and participation in our meetings; we look forward to working with you throughout the ongoing study.

Sincerely,

Original Signed By
Hank Stovall, Co-Chair
Steering Committee
RF Soil Action Level Oversight Panel
(303) 466-5986

Original Signed By
Mary Harlow, Co-Chair
Steering Committee
RF Soil Action Level Oversight Panel
(303) 430-2400 - Ext. 2174

cc:
U.S. Department of Energy
Jessie Roberson

RSALOP Members

244

February 25, 1999

Dear :

Thank you for your willingness to serve on the Radionuclide Soil Action Levels Oversight Panel Peer Review Team.

Enclosed is the final Letter of Agreement that will be discussed in our upcoming conference call. You will note that review dates have changed for the tasks since our original mailing. We sincerely hope this will not adversely impact your schedule.

To provide you with additional background information on the project, we are also enclosing the following:

- Section IV - Project Description and Scope – an excerpt from the original Request for Proposals that was issued on the project to prospective technical contractors.
- Proposal of Work - an excerpt from the winning proposal from Risk Assessment Corporation on the project
- Fact sheet entitled *"Planning for Tomorrow...Radionuclide Soil Action Levels at Rocky Flats"*

We look forward to talking with each of you at the conference call scheduled for: Monday, March 8, 1999 at 9:30 a.m. (Mountain Standard Time). You may connect to the call by dialing ***1-800-403-2004***. When asked for the "participant code", please enter ***392779***. Thank you again for your willingness to take on this important task. If you have any questions prior to the conference call, please feel free to contact either of us. Mary Harlow may be reached at (303) 430-2400 ext. 2174, while Hank Stovall can be reached at (303) 466-5986.

Sincerely,

Hank Stovall
Hank Stovall, Co-Chair

Mary Harlow
Mary Harlow, Co-Chair

Enclosures:
As Stated

Cc: Jesse Roberson, DOE-RFFO
RSALOP Members

245

Letter of Agreement

The Rocky Flats Citizens Advisory Board (RFCAB) serves as the funds manager for the Radionuclide Soil Action Levels Oversight Panel project and related peer review process. This letter outlines the agreement between the RFCAB and Dr. X (hereafter referred to as the reviewer) towards the conduct of peer review for the Radionuclide Soil Action Levels Oversight Panel (RSALOP). The RSALOP will deliver to the reviewer four draft reports prepared by the contractor, *Risk Assessment Corporation*, as part of its work in conducting an independent assessment of the radionuclide soil action levels developed for the cleanup of the Rocky Flats Environmental Technology Site. The reviewer will assess these draft reports and prepare a written analysis for submission to the RSALOP. For timely completion of the written analyses, the RSALOP, through RFCAB, will award an honorarium, plus reimbursement for costs (e.g., phone calls, faxes, delivery services) associated with the conduct of the review. The reviewer understands that full award of the honorarium is dependent upon completion and delivery of his or her written analysis within the prescribed deadlines as outlined below:

Task 2 Report:	**Computer Models**
March 12:	Draft report transmitted to reviewer
April 2:	Reviewer's written analysis delivery deadline to RSALOP
Task 6 Report:	**Soil Sampling Protocols**
May 14:	Draft report transmitted to reviewer
June 4:	Reviewer's written analysis delivery deadline to RSALOP
Task 3 Report:	**Inputs and Assumptions**
July 9:	Draft report transmitted to reviewer
July 30:	Reviewer's written analysis delivery deadline to RSALOP
Task 5 Report:	**Independent Calculation**
September 10:	Draft reports transmitted to reviewer
October 1:	Reviewer's written analysis delivery deadline to RSALOP

As stated above, the RSALOP has established an honorarium for timely completion of the written analyses. RSALOP, through RFCAB, will award a maximum $2,000 honorarium as follows:

A full honorarium amount of $500 for each report will be awarded if the written analysis is delivered by the deadlines outlined above. Written analyses received up to seven days past the delivery deadline will result in a decreased award of $400 per report. Analyses received eight to fourteen days past the delivery deadline will result in a decreased award of $250 per report. No honorarium will be awarded for analyses received more than fourteen days past the delivery deadline.

By the signatures below, the parties acknowledge concurrence with this agreement.

__________________________ Date: ____________________

James A. Kinsinger
Chair

__________________________ Date: ____________________

246

NEWS RELEASE

For Immediate Release

Contact: Carla Sanda, AIMSI
(303) 277-0753

HOW MUCH IS "*TOO MUCH*" PLUTONIUM IN ROCKY FLATS SOILS?

WESTMINSTER, Colo., March 5, 1999 --National attention is focusing on a study currently underway regarding soil cleanup levels for Rocky Flats, the former nuclear weapons production plant located in Jefferson County. A public meeting is scheduled from 6:30 - 9:00 p.m. on Thursday, March 10 at the Westminster City Hall, 4800 W. 92nd Ave., Westminster, CO. The evening will begin with a 30-minute open house designed to provide background information, followed by briefings regarding the progress to date and future goals for the study.

As Rocky Flats moves closer to final remediation goals, one of the primary challenges facing site officials and residents is determination of the amount of radionuclides, such as plutonium, that may legally remain in the soil following remediation. These levels are known as "radionuclide soil action levels" because remediation is triggered when the amount of radioactive material in the soil exceeds established levels. A cleanup agreement negotiated in 1996 between site officials and its regulators set interim levels for plutonium and other contaminants that could remain in the soil at the site. Some members of the community, however, believed that those interim levels were too high. As a result, the Department of Energy agreed to fund a citizen-directed, independent review of the calculation of the soil action levels. To provide oversight of the study, the Radionuclide Soil Action Levels Oversight Panel (Panel) - comprised of scientists, local government representatives and citizens - was formed in 1998. After a formal bidding process, the Panel selected *Risk Assessment Corporation (RAC)* to conduct the technical review. Work has been proceeding since last fall and is scheduled for completion in November 1999.

This public meeting is the first of three to be scheduled throughout the course of the project. Briefings will explain why the community should be concerned about plutonium in the soil at Rocky Flats, why the study is being done, what has been learned so far, and what is planned for the future. Panel members and RAC representatives will be on-hand to answer questions and further explain the ongoing work. There will also be time for public comments and questions. For additional information regarding the meeting or the study, please contact Carla Sanda, Advanced Integrated Management Services, Inc., at 303-277-0753.

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247

February 1999

To: Rocky Flats Soil Action Level Panel

From: Kathleen R. Meyer

Topic: Summary of Scenarios from the Rocky Flats Cleanup Agreement and Proposed by RAC

Scenarios describe the characteristics and behaviors of hypothetical individuals who might have some contact with the radionuclides in the soil at the site. The people described by the scenarios live, work, or use the Rocky Flats site for recreational purposes. For the soil action level assessment, a succession of hypothetical individuals over time (for example, 1000 years) is considered. A goal for designing the scenarios in this study is that if the hypothetical individuals are protected by specified dose limits, then it is reasonable to assume that others will be protected. The reference scenarios are standards against which the soil action levels can be measured.

Selecting appropriate parameters for the scenarios depends upon a thorough review of the scientific literature, and fully considering the range of reported values for the relevant parameters. *RAC* believes that it is important to go back to the original studies when possible to evaluate the data for use in developing the possible range of values for the scenario parameters. After compiling data on the parameters, we generate a distribution of values using Monte Carlo techniques. These distributions can be characterized with a central value such as the median and some measure of the spread of the distribution, such as the 5th and 95th percentiles of the distribution. From these uncertainty distributions, we select appropriate parameter values for the scenarios. In developing a particular scenario, we can use a high (or low) percentile of the distribution as needed to extend protection to people who might come into contact with the site in the near or distance future. Once a parameter value is selected from our distribution of values for use in a scenario, the scenario is considered fixed just as standards are fixed.

RAC is evaluating the three scenarios described in the final report, *Action Levels for Radionuclides in Soils for the Rocky Flats Cleanup Agreement*, dated October 31, 1996, along with seven additional scenarios that we have proposed and described at the monthly RSALs meetings. We believe that it is important to provide the panel with a broad range of scenarios for evaluation and to consider a number of likely scenarios before we decide on the final scenarios for the project. The following table summarizes key parameters for those scenarios. We present short descriptions of each scenario below, beginning with the current RF Cleanup Agreements scenarios.

1. The future residential exposure scenario assumes that an individual resides onsite all year and grows and consumes homegrown produce. This person would be exposed to radioactive materials in soils by directly ingesting the soils, by inhaling resuspended soils, by external gamma exposure from contaminated soil and by ingesting produce grown in contaminated soil. This scenario is from the current Rocky Flats Cleanup Agreement.
2. The open space exposure scenario assumes the person visits the site 25 times per year, spending 5 hours per visit at the site. The person would be exposed to radioactive materials in the soil by directly ingesting the soils, by inhalation of resuspended soils, and by external gamma exposure from the soils. This scenario is from the current Rocky Flats Cleanup Agreement.
3. The office worker exposure scenario represents an individual who works a 40-hour per week, 50-week per year job indoors in a building complex at the site. It is assumed that this person

would be exposed to radioactive material in soils by directly ingesting the soils, by inhaling resuspended soils, and by external gamma exposure from soils. This scenario is from the current Rocky Flats Cleanup Agreement.

4. The resident rancher scenario assumes loss of institutional control where the rancher is raising a family. The rancher maintains a garden and leads an active life at the site, spending 23 hours per day, 365 days per year or 8400 hours at the site. Of that time, over 40% is spent out of doors. The potential pathways of exposure for this person include inhalation; eating produce from garden irrigated with some water from site stream, direct soil ingestion from outdoor activities, and direct gamma exposure from the soils. The annual breathing rate is 10,000 m^3 per year, based on a time-weighted average of breathing rates and activity levels as described during the monthly RSALs meetings. *RAC* proposed this scenario for consideration at the January 1999 RSALs meeting.
5. Infant in rancher family is 0 to 2 years of age, and onsite 23.5 hours per day, 365 days per year, or 8600 hr/year. The infant's potential pathways of exposure include inhalation, some ingestion of produce from family garden, some direct soil ingestion from outdoor activities, and direct gamma exposure from soils. *RAC* proposed this scenario for consideration at the January 1999 RSALs meeting.
6. The child of the rancher family is assumed to be 5 to 17 years of age, and onsite 16 hours per day, 365 days per year, or 5800 hr/year. The potential pathways of exposure include inhalation, eating produce from garden irrigated with site stream water, direct soil ingestion, and gamma exposure from soils. *RAC* proposed this scenario for consideration at the January 1999 RSALs meeting.
7. The office worker scenario is quite similar to the office worker scenario already described in the current Rocky Flats Cleanup Agreement. The differences are a higher breathing rate of 200 m^3 per year and a higher soil ingestion rate of 25 g $year^{-1}$. *RAC* proposed this scenario for consideration at the January 1999 RSALs meeting.
8. The recreational land user is similar to the open space user already described in the current Rocky Flats Cleanup Agreement. The differences are more frequent site visits (100 times per year for 3 hours per visit), a higher annual breathing rate of 750 m^3 per year, and a higher soil ingestion rate of 25 g $year^{-1}$. *RAC* proposed this scenario for consideration at the January 1999 RSALs meeting.
9. The subdivision resident lives in a developed neighborhood, works in a home office on the site, maintains a garden for fresh produce, and uses the site for running or biking for physical exercise. The person is onsite 22.5 hours per day, 350 days per year, or 7900 hours per year. Of that time, the person is outdoors 15% of the time. The annual breathing rate (7400 m^3 per year) and soil ingestion rate (88 g $year^{-1}$) are slightly higher than the residential scenario described in the current Rocky Flats Cleanup Agreement. *RAC* proposed this scenario for consideration at the February 1999 RSALs meeting.
10. The current onsite industrial worker scenario assumes a person works onsite 8½ hours per day, 5 days per week, 50 weeks a year, or 2100 hours per year. It is assumed that 60% of the worker's time is spent outdoors. The potential pathways of exposure for this person include inhalation, direct soil ingestion from outdoor activities, and direct gamma exposure from the soils. The annual breathing rate is 3600 m^3 per year, based on a time-weighted average of breathing rates and activity levels for the time spent onsite. *RAC* proposed this scenario for consideration at the February 1999 RSALs meeting.

Key Parameter Summary for the Rocky Flats Environmental Technology Site Radionuclide Soil Action Levels

	Current DOE/EPA/CDPHE Scenarios			Additional Scenarios for consideration						
Parameter	**Residential**	**Open space**	**Office worker**	**Resident rancher**	**Infant of resident rancher (NB-2 yr)**	**Child of resident rancher (5-17 yr)**	**Office worker**	**Rec. land user**	**Neighborhoo resident**	**Current site industrial worker**
Time on the site (hr/yr)				23	23.5	16	8	3	22.5	8.5
Time on the site (days per year)				365	365	365	250	100	350	250
Time on the site (hr/yr)	8400	125	2000	8400	8600	5800	2000	300	7900	2100
Time indoors onsite (hr/yr)				4700	7740	5075	1750	300	6700	900
Time indoors onsite (%)	100	100	100	57	90	88	88	100	85	40
Time outdoors onsite (hr/yr)	0	0	0	3700	860	725	250	0	1200	1200
Time outdoors onsite (%)	0	0	0	43	10	12	12	0	15	60
Inhalation Shielding Factor	1	1	1	1	1	1	1	1	1	1
Breathing rate (m^3 per year)	7000	175	1660	10000	1800	4400	2000	750	7400	3600
Breathing rate (liters per year)	7 million	0.18 million	1.7 million	10 million	1.8 million	4.4 million	2 million	0.75 million	7.4 million	3.6 million
Soil ingestion (grams per day)	0.2 for 350 d	0.1/ visit for 25 visits/yr	0.05 for 250 days	0.25 for 365 days	0.04 for 265 days	1 for 365 days	0.1 for 250 days	0.25 / visit for 100 visits	0.25 for 350 days	0.25 for 250 days
Soil ingestion (grams per yr)	70	2.5	12.5	90	15	365	25	25	88	62
Irrigation water source	groundwater	na	na	Woman Creek	Woman Creek	Woman Creek	na	na	groundwater	na
Irrigation Rate (meter/yr)	1	na	na	1	1	1	na	na	1	na
Fraction of contaminated homegrown produce	1	0	0	1	0	1	0	0	1	0

na = not applicable

U.S. Department of Energy
Office of Southwestern Area Programs
Environmental Management
EM-45

Fax No.: 301-903-3887

Telephone No.: 301-903-1828, 301-903-3896

Date: 2-25-99

Total Pages: 1 excluding cover sheet

To:	Organization	Telephone No.	Fax No.
ANNA CORBETT OR CARLA SANDA	RFSALOP	303-456-0884	303-456-0858

From:	Telephone No.:
AUTAR RAMPERTAAP	301-903-8191 FAX 301-903-3877

Message: Anna, Please put me on your mailing List to get copies of RSAL materials in the future.
① Copies of Presentation material (from 2/11/99 and future materials)
② RAC project deliverable to RFCAB on RSAL Task 1 to 9.

MAIL ADDRESS:
AUTAR RAMPERTAAP
RE ENVIRONMENTAL RESTORATION TEAM LEADER
U.S. DEPT OF ENERGY
19901 GERMANTOWN RD
CLF BUILDING ROOM 2154, EM-45
GERMANTOWN MD 20874

Mailed 3/1/99 KKC

Faxed 3/5/99 KKC

C. PROPOSAL OF WORK

The Scope of Work (SOW) for this RFP requires seven tasks be performed that go beyond a simple review of the proposed soil action levels document. Each task is presented below as it appears in the RFP. With each task, we restate the actions required in the RFP, provide a summary of our proposed actions for performing the task, and then provide a justification and discussion of our approach. Project deliverables are identified at the end this section. Personnel assigned to each task and their level of effort are described in Section D.

Task 1. Cleanup Levels at Other Sites

Actions:

- *Identify and evaluate cleanup levels and/or action levels (i.e., RSALS) which exist or are projected for use at other radionuclide contaminated sites (particularly with plutonium and americium) and the processes/models used to determine them as to their applicability in setting cleanup levels at RFETS.*
- *Identify any processes/models that were or are being used to determine offsite impacts to communities from onsite cleanup levels.*
- *Provide a summary of this evaluation itemizing the reasons why such levels or processes/models are or are not applicable for use in assessing cleanup levels for RFETS.*

Considerations:

- *This study should concentrate on examples of soil similarly contaminated with transuranic elements and, in particular, plutonium and americium. Of particular interest is the reasoning that went into the setting of these cleanup levels and the subsequent history of the site, including any cleanup. The study should compare the cleanup and/or action levels within the context of site-specific conditions, projected land use, and the then-existing risk assessments and dose standards. This portion of the study will be used to place the calculated RFETS values in context.*

***RAC* Proposed Actions for Task 1**

1. Evaluate all available soil cleanup and/or action level studies performed for either specific or generic sites.
2. Compare these cleanup levels at other sites with those proposed for RFETS.
3. Discuss the methods, assumptions, and relative merits of each study and its applicability to RFETS environment.
4. Identify the models and methods used in these studies that may be applicable to the RFETS environment.
5. Document findings in a report.

Discussion and Justification of Approach

This task is important in putting the RFETS action levels into perspective and helping interested individuals understand how soil action levels are determined. Preliminary comparisons made by a concerned citizen (Joe Goldfield) have alerted us to the possibly high action levels for plutonium proposed for RFETS compared with plutonium action levels defined for other sites. The soil action level is defined as the soil concentration that results in a dose that does not exceed regulatory standards for annual radiation dose. In the case of Rocky Flats, a dose of 15 mrem y^{-1} for a restricted release scenario and 75 mrem y^{-1} for an unrestricted release scenario was stipulated.

The evaluation and summary of cleanup and/or action levels at other sites will (a) provide a description and history of the site for which action levels were defined, (b) indicate which radionuclides are present, (c) summarize pathways and exposure scenarios considered, (d) describe models and methodologies used to determine action levels, annual dose limits, and/or standards adhered to, and (e) list the final action levels established at the sites. Information gathered in this task may be summarized in tabular form. Emphasis will be placed on those sites having transuranic contamination, particularly plutonium and americium. Attention will be drawn to action levels that considered offsite impacts to surrounding communities. Models and methodologies used to calculate offsite impacts will be identified and reviewed for possible application to the RFETS environment.

In order to highlight the differences that methodology, site-specific conditions, and input parameter values have on action levels, we propose normalizing action levels to their annual dose limits. The normalized soil action level is the annual dose limit divided by the soil concentration (annual dose per unit activity concentration in soil). Normalized action levels focus attention on the methodology and input parameter differences by factoring out differences due to different dose standards. Results will be presented by exposure scenario in table format. These tables will assist in making valid comparisons between different action levels. Pathways will be listed in order of relative importance.

Task 1: Cleanup Levels at Other Sites — Deliverables and Schedule
After project initiation:
- *Monthly:* Meet with Oversight Panel and present latest findings, address concerns, and discuss future direction.
- *3 Months:* Submit draft report to Oversight Panel and send out for peer review.
- *6 Months:* Incorporate the peer review comments and present final report to Oversight Panel.

2. Computer Models

Actions:
- *Identify and evaluate all relevant available or emergent models which can be used to calculate radionuclide contamination levels in soils based on a given dose rate.*
- *Evaluate the models to determine which are most applicable and best suited to model the site-specific conditions at RFETS.*
- *Provide a description of these models, a summary of the strengths and weaknesses of each, and a recommendation for the most appropriate model(s).*

Considerations:
- *Models that are inappropriate to RFETS site conditions, obsolete, or which cannot be readily validated should not be included. The RESRAD model must be included due to its use in determining the current RSALs. A comparison of the different models using RFETS site-specific data would be useful. The contractor is encouraged to find computer codes capable of modeling both onsite and offsite dose rates. If no models exist for this determination, the contractor will review offsite migration/impacts over time/distance for various cleanup levels. It is possible that no one model will prove satisfactory for determining both, but that a*

combination of models may be necessary. The contractor will be expected to recommend the most appropriate model(s) for RFETS site-specific conditions and to justify this recommendation. Whichever model or models are recommended should be thoroughly validated. It is not necessary that the contractor perform this validation; peer reviewed, published studies will suffice. In the event that RESRAD is not recommended, RESRAD should be run in parallel with the recommended model(s) as a comparison.

***RAC* Proposed Actions for Task 2**

1. *RAC* will search for existing or developmental computer programs that estimate radiation dose rate to an individual as a function of that individual's exposure to soils contaminated with radionuclides.
2. The programs will be evaluated for suitability for site-specific use at RFETS, and RESRAD will be included in the evaluation.
3. A summary report will describe the programs and recommend a program or prescribed use of a combination of programs for analyzing and establishing soil action levels for RFETS.
4. The search will include some general environmental assessment programs, which would have the capability of considering offsite migrations of radioactivity.
5. Recommendations will include the problem of extending validation of models and programs for RFETS applicability.

Discussion and Justification of Approach

RAC will search for existing or developmental computer programs that estimate radiation dose rate to an individual as a function of that individual's exposure to soils contaminated with radionuclides. Such programs should be able to relate levels of radionuclides in soils on and near the RFETS to the dose rate over time to an individual who spends time both on and off the site and should be adaptable to scenarios of future exposure to a decommissioned site. The programs will be evaluated for site-specific applicability at RFETS. The criteria for rating computer programs will include

(1) The validity of mathematical models implemented by a program: acceptance among scientists, logical correspondence with the features of the site, treatment of exposure pathways, and consistency with the available site data
(2) Amount and quality of validation of a program that has been carried out and documented, and the program's suitability for local validation
(3) Program documentation (including user manuals) and availability of source code
(4) The platform (i.e., computer and operating system under which the program runs) and programming language, assuming the source code is available
(5) Flexibility of operational features, including the option of controlling the program from the operating system's command line, with input data in an electronic file, rather than being required to communicate with the program exclusively through a graphic user interface (pointing and clicking with a mouse).

It is useful to distinguish between the terms "model" and "computer program." A model is a conceptual construct that draws on scientific knowledge to describe part of a real system in a quantitative way. A computer program implements one or (usually) more models, using the equations that describe them to perform calculations that simulates movement of contaminants through environmental media (such as air, soils, water, and food) and estimates doses to people exposed to those media. A program usually has elaborate input/output and reporting capabilities.

Validation seeks to test computer programs by comparing their predictions with measurements made under field conditions similar to those simulated by the programs. All such validation exercises are restricted to specific places and conditions, and even extensive validation of a program does not ensure correct results if the program is applied uncritically to a particular location and problem. *RAC* has usually found it necessary to perform validation calculations based on site-specific data.

The possibility of local validation of any selected programs is of fundamental importance, and it is not a routine procedure. It requires careful study of available site data and formulation of tests using the candidate program with appropriate assumptions and input data to permit comparison of outputs with site-specific measurements. The results often indicate an unacceptable correspondence, and if so, it is necessary to reexamine the assumptions. Sometimes calibration of the model to site data is required. This means that by an analysis of the relationship between the local input data and the corresponding predictions, a factor or formula is arrived at by which the predictions of the program will be adjusted for local use. Although the adjustment is necessarily based on limited data, it is expected that a general degree of improvement of local predictions will result. For example, in both the Fernald and the Rocky Flats dose reconstruction studies, *RAC* found that generic atmospheric transport models did not acceptably reproduce air concentrations measured at those sites without some calibration to measurements made over limited periods of time.

Analysis of propagated uncertainties is essential to the establishment of credible soil action levels, and such analysis requires substantial use of Monte Carlo computer simulation methods. In some circumstances, the inclusion of Monte Carlo instructions in the reviewed program could be useful, but the kind of flexibility described in item 5 (above) is preferred so that the Monte Carlo analyses could be scripted and carried out at the operating system's command level, with the program being executed repeatedly with input files generated from sampled input values. In this way, the analysis is not restricted by the particular uncertainty design that the developers built into the program's logic; this hardwired design may not be best for the applications at hand.

Source code usually is not available if a program is a commercial product. Although we would not automatically reject a program for which the source code is proprietary, one must consider that an examination of source code can often resolve the inevitable questions about the models and how they are implemented that are not answered in the documentation. And it frequently happens that one needs certain outputs that the program's developers did not anticipate but that can be provided by inserting a print statement into the source code and recompiling; this remedy is not possible without the source code. *RAC* is *not* proposing to perform an extensive review of the source code of any candidate program; rather, *RAC* considers the availability of the source code an assurance that whatever checking and probing that it deems appropriate can be done.

The platform is of concern only if it imposes obstacles to examining and working with a candidate program. Programs for which source code in one of the languages FORTRAN, C, or C++ is available should present no serious problem. Programs that have been developed to operate under Windows 95 or Windows NT should also be manageable. Programs without source code that are distributed as binaries native to non-Intel workstations would require special arrangements.

The RESRAD program will be included in this evaluation, as required by the RFCAB. *RAC* will ask the RFCAB to make every effort to help persuade DOE to make available the RESRAD source code for purposes of the evaluation and subsequent application of the program. To the best of our knowledge, this source code has never been made public.

Software quality assurance issues are addressed in the *RAC* Software Quality Assurance Plan. In brief, the *RAC* plan requires that off-the-shelf software include ample documentation to verify that the code operates correctly and performs the calculations that it claims. Software developed by *RAC* will include documentation that will state (a) the purpose of the software, (b) the mathematical equations imbedded in the code, (c) solution techniques, and (d) sample applications.

Task 2. Computer Models — Deliverables and Schedule
After project initiation:

- *Monthly*. Meet with Oversight Panel and present latest findings, address concerns, and discuss future direction.
- *4 Months*. Submit draft report to Oversight Panel and send out for peer review.
- *7 Months*. Incorporate the peer review comments and submit final report to Oversight Panel.

3. Inputs and Assumptions

Actions:

Evaluate the input parameters, inputs, default inputs, and assumptions for the current analysis (RESRAD) used to set the RSALs at RFETS. At a minimum, this evaluation must satisfy the following:

(a) Are the input parameters, inputs, default inputs, and assumptions adequate, accurate, and credible in simulating the conditions at RFETS, given the future land use scenarios envisioned in RFCA, and the subsequent conversion to dose rate/contamination levels?

(b) For each of the input parameters, what is the sensitivity of the input values in terms of resulting contamination levels?

(c) For each of the input parameters, what is the distribution of possible input values? Identify each of these based on the sensitivities determined in (b) above from least conservative to most conservative, with conservative meaning that which results in lower contamination levels given a certain dose limit. Quantify the uncertainties of the inputs or input distributions.

(d) For each of the input distributions in (c) above, identify an input value which can be considered "reasonable" or "best estimate." Provide the reasoning for these choices.

Considerations:

All of the input parameters to the model need to be examined. Parameters that are easily confirmed, non site-specific parameters, or those which are specified by the EPA or other regulatory agencies, should be noted as such. If the investigation indicates that such values are not appropriate, alternatives should be recommended. Parameters for which there are site-specific input data for RFETS should be identified and a thorough study of the distribution of possible values should be performed.

***RAC* Proposed Actions for Task 3**

1. Evaluate input parameters, default inputs, and assumptions for adequacy, accuracy, and creditability concerning current and future land use scenarios and conversion to dose rate/contamination levels. This includes evaluating exposure scenarios defined for soil action levels in terms of their creditability for addressing doses for future land use scenarios.
2. Perform a sensitivity analysis of one parameter at a time with RESRAD using the cases developed for the proposed soil action levels. Determine which parameters are *unlikely* to contribute substantially to the overall uncertainty in the soil action levels. Consideration will be given to the sensitivity of the individual parameter and how that parameter is used in the underlying RESRAD equations.
3. Develop uncertainty distributions for parameters that are not selected in (1) from site-specific data if available. Literature will be reviewed if site-specific data does not exist.
4. Write a computer interface for RESRAD that performs Monte Carlo calculations on the parameters not selected in (1) and stores output.
5. Perform Monte Carlo simulations using the distributions developed in (2) for the exposure scenarios defined for the proposed soil action levels and any alternate scenarios the Panel wishes to include.
6. Extract from the Monte Carlo output, the sensitivity of the soil action levels to each input parameter, and the uncertainty in the overall action levels. Report results by exposure scenario.
7. Document and interpret results in a report.

Discussion and Justification of Approach

This phase of the SOW essentially requests that a quantitative sensitivity/uncertainty analysis be performed on the RESRAD simulations used to generate the proposed soil action levels. In addition, input parameters and exposure scenario assumptions are to be reviewed and evaluated in terms of their credibility for assessing doses considering the future land use scenarios.

For the evaluation of the suitability of input parameters for establishing RSALs at RFETS, *RAC* can draw on its experience in evaluating and applying environmental monitoring data collected at the RFETS and vicinity. This includes data that characterizes environmental conditions such as meteorology, soil characteristics, and hydrology. Exposure scenarios will also be reviewed and alternative scenarios suggested.

In this task, *RAC* also proposes to do a Monte Carlo sensitivity/uncertainty analysis on the proposed soil action levels. The current version of the RESRAD model contains features for performing sensitivity analysis. However, the methods used by the code are only designed to evaluate sensitivity for one parameter at a time and do not consider interaction and correlation between parameters. A sensitivity analysis that considers interaction and correlation between parameters requires random sampling from distributions and is typically more involved than an approach that treats one parameter at a time. The latter kind of approach may be useful at the onset of a sensitivity analysis, but a thorough understanding of the sensitivity of the output variable to changes in the input requires a random sampling approach. For example, the output variable's sensitivity to parameter *X* may change as another parameter *Y* is varied. A meaningful sensitivity analysis requires that distributions of input parameters (at least in preliminary form) be developed first. Then, using Monte Carlo sampling techniques, the sensitivity of the output variable to each input parameter can be determined. This approach has the added benefit of providing a quantitative uncertainty analysis of the RESRAD derived soil action levels. The uncertainty analysis results can be used to make valid comparisons to soil action levels determined using other models and codes as stipulated in Task 5.

A beta test version of the RESRAD program that includes routines to perform Monte Carlo sampling and uncertainty analysis is available. However, the program has not been thoroughly tested, verified, and validated at this time. It is unknown when the final version of this program will be released. As an alternative to using the beta test version of RESRAD, we propose writing our own Monte Carlo sampling routines using verified and validated sampling routines available in the public domain. The interface with RESRAD will require knowledge about how RESRAD reads and writes model data. *RAC* has researched this option with the RERAD software developers.[b] Our research has indicated that our approach is both feasible and attainable in the allotted time. Communication between the computational portion of RESRAD and its graphical-user interface (GUI) is routed through several ASCII files. Our custom interface will (a) randomly sample from the distributions derived in Subtask 2, (b) write the necessary RESRAD input files, (c) run the RESRAD code, and (d) extract and store the results from the RESRAD output. Ideally, we would like to obtain a copy of the source code and an effort will be made to do this. However, the success of this approach is not contingent upon receipt of the source code. The interface will be written in a standard programming language (C++ or FORTRAN). We will not modify any of the computational parts of the RESRAD program, and we will check code output using our interface with output generated using the GUI to assure our interface is operating properly. The interface source code will be available to the Oversight Panel for independent review.

Parameter distributions will be defined in terms of standard distributions (i.e. normal, lognormal, uniform, triangular) or, if required, a custom distribution will be constructed. Typically, statistics like the mean and standard deviation are used to describe the distribution, but for nonsymmetric distributions, three or more standard percentiles (such as the 5th, 50th, and 95th) are sometimes better indicators. Attention will focus on those parameters that determine concentrations of radionuclides in environmental media (soil, air, and water). Parameters that define the exposure scenario and physical attributes of the receptor will be addressed separately by defining alternative exposure scenarios and computing action levels for each of these scenarios. Parameter distributions will be developed from site-specific data if available. If site-specific data are lacking, the available literature will be reviewed for appropriate values.

Monte Carlo calculations will then be performed on all scenarios including the original scenario used to establish the proposed soil action levels. Results may be summarized in tabular form showing the percentile values of the output distribution. However, other statistics describing the distribution may be reported as well.

This approach has a number of advantages in that both uncertainty and sensitivity are quantified for soil action levels. Proper interpretation of results is critical to understanding the meaning of the output in the context of the assessment question. As part of our documentation, we will include a detailed section (with examples) on how a layperson may interpret results of the sensitivity and uncertainty analysis, pointing out the implications in terms of soil action levels.

[b] Oral communication with David LaPore, Argonne National Laboratory, July 1. 1998.

RAC personnel have over 50 years combined experience in scientific software development and computing and are qualified for this task, having written many custom software applications employing Monte Carlo sampling for the Fernald and Rocky Flats Dose Reconstruction Projects.

Task 3. Inputs and Assumptions — Deliverables and Schedule
After project initiation:
- *Monthly*. Meet with Oversight Panel and present latest findings, address concerns, and discuss future direction.
- *8 Months*. Submit report to Oversight Panel and send out for peer review.
- *11 Months*. Incorporate the peer review comments and submit final report to Oversight Panel.

4. Methodology

Actions:
- *Identify and evaluate the methodologies which can be used to select or combine the necessary inputs/outputs for a given computer model in determining contamination levels for a given dose limit.*
- *Within one (1) month of the start of the contract, present to the Oversight Panel and stakeholders a summary of these methodologies along with a recommendation and justification as to the best suited for such an analysis.*
- *Compare or contrast this recommended methodology with that used in the existing RESRAD analysis.*

Considerations:
- *It is understood that there are several methodologies (e.g., bounding, best estimate, conservative, probabilistic risk assessment, etc.) which can be used to shape the inputs for such an analysis. The question as to "how conservative is conservative?" makes this a subjective rather than simply a scientific issue, because the affected communities must accept the risks involved. Therefore, the Oversight Panel wishes to fully understand the nature and implications of each of the potential methodologies to ensure that the methodology chosen can best produce credible and defensible results from this independent review which will be acceptable to the broadest range of stakeholders.*

***RAC* Proposed Actions**
1. *RAC* will review the approaches to interpretation of data and results in simulation ("methodologies") and develop a discussion of these approaches.
2. No later than one month after the beginning of the contract, *RAC* will present the discussion of item 1 to the Oversight Panel and stakeholders.
3. *RAC* will recommend to the Oversight Panel an approach, based on state-of-the-art methods of uncertainty analysis, to relate concentrations in soil to annual radiation doses to individuals represented in specific exposure scenarios.

Discussion and Justification of Approach

In our experience, terms like "best estimate," "conservative," and "probabilistic risk assessment" sometimes have different meanings for different people. Instead of discussing the representation of inputs (parameters) and predicted values in terms that might be misconstrued, we believe it would be useful to summarize *RAC's* recommended approach to the treatment of quantitative information that is subject to uncertainty. This includes initial values, parameters, and calculated quantities.

If we consider the scenario definitions and dose limits fixed, then all uncertainty is associated with the calculated soil action levels. One view of our goal is to estimate a probability *P* that the annual dose limit will not be exceeded if the soil contamination equals any specified level (including the soil action level), given the exposure scenario. The probability *P* should be interpreted as a measure of confidence based primarily on the uncertainties in parameters and data; it does *not* represent the fraction of an exposed population for which the annual dose does not exceed the limiting value. Thus, *P* does not represent the probability that an individual would be exposed; all individuals described by the scenarios are exposed by definition. What we would estimate is a level of confidence that the exposure would produce an annual dose that does not exceed a set limit, given contamination at the soil action level. From another point of view, our goal would be to start with the exposure scenario and its fixed annual dose limit and to calculate the corresponding soil action level as an uncertain quantity. This latter interpretation entails some additional complications, but the underlying mechanisms of computation are the same.

We would not ordinarily interpret the exposure scenarios themselves as uncertain, although some gray areas exist. It generally is less confusing to take the scenario definitions as given and confine the uncertainty to environmental measurements and transport simulations (uncertainties in environmental transport often dominate any uncertainties hypothesized for the scenarios). When questions arise concerning scenario features, it usually is preferable to address them by considering alternative scenarios that change only the features in question.

In performing uncertainty analysis, *RAC* emphasizes the following principles:

A. Uncertainties are represented by distributions of probability. The distributions may apply to single (scalar) numeric variables (the most commonly discussed case) or jointly to multiple variables that may be either stochastically independent or dependent, depending on the interpretation. The distributions can be communicated and explained by various quantitative and graphic devices, such as giving certain percentiles (5th, 50th, 95th) and by showing plotted scatter charts and histograms. Such devices need to be chosen and presented with the background of the audience in mind.

B. *RAC* generally recommends that calculations *not* be deliberately biased high to compensate for lack of knowledge. Rather, analysts should do their best to keep their procedures free of bias. Conservatism, when warranted, should be expressed by increasing the variance of a quantity's uncertainty distribution while keeping its "center" (e.g., 50th percentile) fixed. (The variance is a measure of a distribution's spread or dispersion. The variance is inversely related to the precision with which the quantity is known: if the variance is large, the quantity is known with low precision.) An exception to this general principle occurs in dealing with quantities that are unlikely to affect the outcome of a calculation to a significant degree, in which case the quantities in question may be judiciously biased high.

C. Uncertainties for input variables may be estimated from sample distributions of data, from analytic considerations (e.g., physical arguments that establish bounds for the quantity), by analogy with similar or related quantities, or by seeking consensus of experts. Sometimes nonrigorous arguments based on weight of evidence are persuasive, but when they are offered, they must be acknowledged as such. In doubtful cases, the sensitivity of the outcome to the questioned parameter should be examined; if there is little effect, excessive concern may be unjustified. If there is significant effect, the variance of the uncertainty distribution of the parameter should be increased to a point where there can be little doubt that the distribution includes all values. If such a point cannot be agreed upon, or if the affect on the outcome is so great as to render it virtually meaningless, then further research must be undertaken or alternative simulation strategies must be sought.

D. Results usually should not be presented as point estimates (i.e., single "hard" numbers, such as 2.7 pCi g^{-1}). The desired estimate of the quantity is a distribution, and unambiguous and sufficient information about it should be disclosed (e.g., 5th, 50th, and 95th percentiles; less desirable for nonsymmetric distributions are mean and standard deviation).

E. Explanations should be framed to avoid misunderstandings about the interpretation of statements involving probability.

RAC has substantial experience in applying these principles to real environmental assessments that present difficulties and complications never encountered in textbook discussions. With the statement of these principles, *RAC* discloses its position with regard to the approach to preparation of input quantities and interpretation of results in the proposed estimation of soil action levels. We agree with the Oversight Panel that the imposition of limits on conservatism introduces subjectivity into the process, and we are prepared to assist the Oversight Panel in contrasting this approach with other options. In particular, the approach we advocate focuses the issue of conservatism on the probability P that the annual dose limit of the scenario will not be exceeded if the soil radionuclide level equals the soil action level. Accordingly, we will develop a presentation for the Oversight Panel and stakeholders, to be given at the end of the first month of the contract, in which these options and their implications are examined as thoroughly and as clearly as this very brief preparation time permits.

Task 4. Methodology — Deliverables and Schedule

After project initiation:

- *1 Month.* Meet with Oversight Panel and present methodology approaches for interpretation of data and results.
- *Ongoing.* Incorporate discussion items into the methodology used in the independent calculation of soil action levels. Incorporate findings in appendix of final report.

5. Independent Calculation

Actions:

- *Using the methodology recommended in 4. above, select/combine the inputs identified in 3. above, as well as any new inputs required by the model recommended in 2. above in that model to calculate contamination levels for the dose limits set for each of the RFCA land use scenarios assumed in the original analysis. This includes a residential scenario.*
- *As part of the calculations, include a statement of the assumptions and level of uncertainty involved in the specific approach utilized. State the dose limits in terms of risk.*

RAC Proposed Actions for Task 5

1. The computer programs identified in Task 2 will be used to calculate soil action levels, using the methodology identified in Task 4.
2. Programs will be set up to carry out Monte Carlo uncertainty analysis with the calculations. We will estimate probability distributions for soil action levels, interpret the distributions, and provide a statement of confidence in the results.
3. Soil action levels will be derived for each of the land use scenarios assumed in the original analysis and for the alternative scenarios identified in Task 3 if this is requested by the Oversight Panel.
4. Carcinogenic incidence risk will be estimated for each annual dose limit.

Discussion and Justification of Approach

This task will be built on what has been learned in carrying out Tasks 2–4 and will provide what we expect to be defensible soil action levels. The soil action levels will be presented in terms of uncertainty distributions, and we will provide a report that discusses these distributions in their proper context.

Each scenario presents a prescribed annual dose limit that constrains the levels of radionuclides in the soil within and contiguous with the RFETS. The calculation gives the radionuclide level in the soil as a function of the annual dose, and the uncertainty analysis provides a probability distribution for the radionuclide level in the soil. This probability distribution is based on the uncertainties specified for the model input parameters. This distribution represents the soil action level when the annual dose has its limiting value. *RAC* will compute soil action levels for each of the exposure scenarios (including the alternative scenarios from Task 2 if requested to do so) and provide the uncertainty analysis and interpretation that is an integral part of the process.

Some complications occur because of multiple radionuclides. If the sum of ratios method is followed, the distribution of soil action level is determined for each radionuclide separately. When measurements of the radionuclides in soil are made, the method consists of summing the ratios of the measured values divided by the corresponding soil action levels. If the sum exceeds 1, the combined action level is exceeded. When uncertainty distributions are involved, however, the distribution of the sum of ratios must be estimated from the distributions of the individual ratios and from estimates of sampling error. The probability Q that the sum of ratios exceeds 1 is calculated from the distribution of the sum, and the criterion for action is based on the magnitude of Q. Because of correlations within the calculation, it is preferable when possible to perform the calculations with all radionuclides present at once to avoid distortion of the distribution of the action criterion. We will clarify these correlation effects in the report and develop ways, with input from the Oversight Panel, of dealing with them.

RAC will perform these calculations based on the recommended programs, models, and methods and compare the results with the RESRAD approach. It should be emphasized that the credibility of the results has more to do with analysis, assumptions, data, definitions of scenarios, handling of uncertainty, and clear explanations of the methods used than on the formalistic execution of any specific computer programs.

The connection between annual dose to exposed individuals in a scenario and risk of cancer incidence is itself subject to uncertainty. *RAC* will provide estimates of this risk for each of the prescribed annual dose limits based on contemporary estimates of the uncertainties for the radionuclides and exposure modes that are relevant to this work.

Task 5. Independent Calculation — Deliverables and Schedule
After project initiation:
- *Monthly*. Meet with Oversight Panel and present latest findings, address concerns, and discuss future direction.
- *9 Months*. Submit draft report to Oversight Panel and send out for peer review.
- *12 Months*. Incorporate the peer review comments and submit final report to Oversight Panel.

6. Protocols

Actions:
- *As an integral part of the recommendations about the RSALS, recommend specific soil sampling procedures to be followed as an appropriate method of monitoring actinide concentrations in soil before and after remediation.*

Considerations:
- *It is necessary to find a scientifically credible method for guaranteeing that the cleanup levels will actually be met in terms of what contamination levels are ultimately measured at the site. This study should clearly delineate such parameters as sample spacing, depth of samples, sampling methods, and all associated quality assurance which ensures that the methods used for measuring contamination before and after any remediation are directly applicable to the parameters used for setting the cleanup levels. The technical literature on valid statistical approaches should be reviewed to verify sampling methods and recommend approaches that are appropriate for the cleanup at RFETS.*

***RAC* Proposed Actions for Task 6**
1. Review and evaluate established soil sampling methodologies for application to RFETS.
2. Recommend a soil sampling protocol that addresses characterization sampling to determine the nature and extent of contamination before remedial efforts and verification sampling to assess remaining residual contamination after remediation.
3. Provide a review of the current methods of sampling and analysis at RFETS.
4. A literature review of soil sampling design based on statistical considerations and incorporate the information into the recommended sampling design.
5. Address quality assurance issues regarding data quality objectives, documentation, chain-of-custody, laboratory requirements, and data validation.

Discussion and Justification of Approach

A recommended specific soil sampling protocol will be developed to accompany the proposed RSALs. The protocol is necessary to provide a mechanism to evaluate the ability to attain RSALs in the environs of RFETS. The soil sampling protocol will allow decision making regarding site remediation by providing methods that statistically compare the RSALs with field data in a scientifically defensible manner that allows for consideration of uncertainty.

The sampling protocol will address two aspects of soil sampling: (1) characterization sampling to determine the nature and extent of contamination before remedial efforts and (2) verification sampling to assess the remaining residual contamination after remediation. Characterization sampling is necessary to ensure that adequate remedial measures are taken to ascertain attainment of the RSALs. Verification sampling is required for "proof" of acceptable remediation efforts and that the RSALs have indeed been attained.

The soil sampling protocol will provide RFETS with recommended methodologies for the determination of sample spacing, sampling depth, sampling methods, and quality assurance. The acceptance and implementation, through the development of policy and procedures, will be the responsibility of RFETS.

Current methods of sampling and analysis at the RFETS will be reviewed. This review will include pertinent procedures, sampling methods, packaging, chain-of-custody requirements, analytical methods, and quality assurance requirements. The review of current RFETS sampling methods will provide the basis for comparison to other industry standards and methods and the determination of the adequacy of existing RFETS methods.

The soil sampling protocol will include recommendations for sample spacing, depth of samples, sampling methods, and quality assurance. Each of these key areas of the soil sampling protocol will be addressed as described below.

The determination of sample spacing will be based upon statistical techniques. Currently, several methods have been proposed and others have been embraced by regulatory agencies for determining appropriate sampling strategies. Historically, this problem has been addressed at the Nevada Test Site. Recently, the "Multi-Agency Radiation Survey and Site Investigation Manual" (MARSSIM) was developed through cooperation of the U.S. Environmental Protection Agency, DOE, U.S. Nuclear Regulatory Commission, and U.S. Department of Defense. In addition, several investigators such as R.O. Gilbert, D.A. Singer, D.F. Parkhurst, have developed methods for statistical sampling based upon hot spot detection, geometrical grid patterns, and statistical significance testing. A review of the available techniques, potential applications at RFETS and an evaluation of implementation requirements will be conducted and recommendations provided in the final report.

The main factor for consideration in any of the available sample spacing, or conversely the number of samples, involves the specification of Type I (false positive) and II (false negative) errors. Variation in sampling and laboratory analyses will introduce uncertainty into the decision regarding the attainment of RSALs at RFETS. As a result of these uncertainties, the site may be judged to meet the RSALs, when in fact, it may not, resulting in a false positive decision, or Type I error. Conversely, the site may be judged to require additional remediation to attain the RSALs, when in fact, it may require no additional remediation, resulting in a false negative decision, or Type II error. The key to determining the appropriate spacing for soil samples lies in the ability to appropriately define acceptable Type I and II error levels in terms of both health protection and consideration of sampling costs. Acceptable Type I and II error levels will be evaluated considering health protection but balanced with sampling costs.

Soil sampling depths will be determined based upon the derivation of the RSALs, applicable parameters, and transport/exposure pathways. Depth of sampling is highly dependent upon the nature of the contamination in terms of mobility, depth distribution, and availability to potential receptors by various transport pathways. Recommendations will be provided in the sampling protocol for the depth of soil samples and other relevant issues including sample compositing, biased sampling, and sample stratification.

Sampling methods will be evaluated and proposed in the soil sampling protocol. Methods for collection of the soil samples in the field, including equipment, decontamination of sampling instruments, sample packaging, labeling, and documentation will be addressed.

Quality assurance issues will be addressed in the soil sampling protocol. Quality assurance issues will include recommended data quality objectives, documentation, chain-of-custody, laboratory requirements, and data validation. The assessment of data quality indicators (including precision, bias, representativeness, comparability, and completeness) will be completed and recommendations provided for determining sample and laboratory data usability.

Task 6. Sampling Protocols — Deliverables and Schedule
After project initiation:
- *Monthly.* Meet with Oversight Panel and present latest findings, address concerns, and discuss future direction.
- *5 Months.* Submit draft report to Oversight Panel and send out for peer review.
- *8 Months.* Incorporate the peer review comments and submit final report to Oversight Panel.

7. Actinide Migration

Actions:
- *Meet with the Actinide Migration Panel to share information in order to ascertain the applicability of any results from the actinide migration studies on the inputs to the modeling for this analysis.*
- *Study these results and any other relevant data and make a preliminary determination of what impact these will have on the results such as obtained in 5. above.*

Considerations:
- *Ultimately, cleanup levels must be protective of offsite residents. Calculations for the existing RSALs only considered onsite exposure scenarios. Since offsite air and water quality standards are more restrictive, it is possible these standards will control the cleanup. How can the issue of plutonium migration be incorporated into an evaluation of the RSALS? An Actinide Migration Study is currently underway. The final results of this study will not be ready in time to be used in this study. Some preliminary results will, however, be available. It is understood that any conclusions that can be based on this are tentative pending the completion of the Actinide Migration Study. The contractor should, however, identify the data needs of this study as early as possible in order to facilitate the collection and analysis of additional data needed.*

***RAC* Proposed Actions**
1. Meet with the Actinide Migration Panel early in the project to review their current understanding and evidence of actinide migration at RFETS.
2. Based on the findings in (1), consider what other pathways may be relevant for evaluation of offsite exposures.
3. Evaluate what potential impact actinide migration will have on the soil action levels, given offsite dose limits and water quality standards for offsite exposure may be more restrictive.
4. Identify data gaps that will impact future hydrologic studies of actinide migration from the RFETS.

Discussion and Justification of Approach

The potential for offsite migration of actinides deserves attention at the outset of the study. Information gathered in this task should be integrated with the model selection task (Task 2) so that all relevant pathways of exposure to receptors both onsite and offsite are included. Special emphasis will be placed on aqueous phase transport because drinking water contamination has the potential to affect hundreds of thousands people in the surrounding communities. However, other pathways of migration will also be given due attention including resuspension and atmospheric transport. If necessary, simple bounding-level calculations will be used to estimate the relative importance of these migration mechanisms.

If it appears that surface and drinking water pathways have the potential to affect the soil action levels significantly then the capability to address them will be considered an essential part of any recommended suite of environmental models to be used to develop soil action levels. Potential pathways of concern include atmospheric, groundwater, and surface water. While we can select models that include the groundwater and surface water pathways, it is unlikely these models would have the level of detail required for an in-depth evaluation of these pathways. Models that are typically used to estimate groundwater and surface water contaminant movement require specialized expertise and data requirements. While some *RAC* personnel have expertise in using these models, the time and resources required to run them far exceed the time constraints of this study. Moreover, the final results of the actinide migration study need to be finalized before detailed hydrologic modeling can proceed. Therefore, any attempt to address this pathway will be semiquantitative in nature and the results should be interpreted as such. More importantly, the data needs of a future hydrologic investigation can be identified at this time.

Task 7. Actinide Migration — Deliverables and Schedule

After project initiation:

- *Monthly*: Meet with Oversight Panel and present latest findings, address concerns, and discuss future direction.
- *Quarterly or as needed*: Meet with Actinide Migration Panel; summarize meeting in letter report to Oversight Panel.
- *Ongoing*. Incorporate findings into final reports.

Project Deliverables

A comprehensive report will be generated at the end of this project. The main body of the report will be directed to the level of the educated public and will summarize our findings and recommendations. Four appendices will provide the technical details of our work. The appendices will cover the following technical topics

Appendix A	Cleanup Levels at Other Sites
Appendix B	Computer Models, Methodology, Input Assumptions, and Independent Calculation
Appendix C	Sampling Protocol
Appendix D	Summary of Meetings with the Actinide Migration Panel

Each appendix will be written to be a stand-alone report, thereby, facilitating peer review of individual pieces of the overall project. Appendix B includes the material for four of the tasks

(Tasks 2–5). Each task will be provided in a separate section in the appendix to allow peer review as the draft documents are produced.

RAC will provide assistance to the Oversight Panel in preparing a separate summary report directed to members of the general public who are unfamiliar with the current proposed Residual Soil Action Levels (RSAL). It is *RAC's* understanding that the responsibility of producing the summary report for the public resides with the Oversight Panel. *RAC* has had considerable experience assisting other oversight panels in preparing newsletters and fact sheets for distribution to the public.

D. WORK AND FISCAL MANAGEMENT

This section explains how the Review of Soil Action Levels Project will be organized. staffed, and managed by *RAC* and how the management and coordination of consultants will be accomplished. A profile of *RAC* is provided first, followed by detailed estimate of the number of hours anticipated to complete each task and personnel involved. Cost control and budget variance procedures are described last.

Company Profile.

RAC was founded in 1977 by Dr. John Till. *RAC* is a of a team of independent consultants who have demonstrated their ability to work together to complete complex technical tasks in a timely and efficient manner. Dr. John Till, the president of *RAC*, provides team leadership and is the overall principle investigator of the team. Although *RAC* Team members are independent, these professionals share a commitment to teamwork and mutual support. *RAC* has taken advantage of advances in telecommunications equipment during recent years that makes communication between team members easy and efficient. All team members have state-of-the-art Pentium II computers equipped with high-speed modem and fax capabilities and telephone message systems. In addition, *RAC* Team members have electronic mail capabilities and access to a dedicated bulletin board system and file-transfer-protocol site.

Dr. Till assigns day-to-day management of a project's details to technical project leaders. Tracking of the project status is done by these leaders and also by Leeann Denham, who tracks milestones and project budgets for all *RAC* projects. While *RAC* Team members live and work in locations throughout the United States, Dr. Till regularly meets with individuals or small groups of *RAC* professionals whenever opportunities arise. Key team members will also meet in conjunction with the monthly Oversight Panel meetings. More formal *RAC* Team meetings are held several times a year, at least quarterly. At these intensive sessions, each current project is given a thorough review, schedules and anticipated deliverables are carefully examined, and technical details of specific segments of the work are examined by the group.

Hour Estimates

Table 2 lists the proposed hours *RAC* anticipates to complete the project in the one-year time frame as stipulated in the RFP. Hours are itemized by persons performing the work and by task. We have separated the project into the seven tasks identified in the Proposal of Work and added an additional task (Task 8) for Oversight Panel interface and other responsibilities. Interface with the Oversight Panel is described in Section E.

Procedures for Cost and Schedule Control

The RFP states that procedures should include methods to identify budget variances at the earliest possible time, as well as maintain the schedule. Efficient cost control measures are necessary to insure that the project is cost-effective. A fundamental element of *RAC's* cost management process is the integration of resource planning (completed before project initiation relying heavily on past experience and expert judgment); cost estimating (closely coordinated with resource planning); cost budgeting (resource planning and cost estimating result in a cost baseline budget that will is used to measure and monitor cost performance); and cost controlling (monitoring cost performance. ensuring all changes are accounted for in baseline budget and informing the RFCAB of the changes). In addition to closely monitoring spending and forecasting potential budget issues, *RAC* is also concerned about the impact of budget decisions on all project stakeholders, specifically, the RFCAB. The project baseline budget will be compared with the actual spending at least monthly to forecast any effects of cost changes. Tools used to track the interaction of these various aspects include both spreadsheets and project management software. Whenever possible, causes of budget variances are documented so that they become part of *RAC's* historical database for future cost management planning. It is the project manager's responsibility to ensure that the task is on schedule and within budget. The *RAC* tracking manager issues monthly budget reports to the project manager.

Table 2. Hourly Breakdown of Staff Level of Effort by Task

Task	J. Till	H. Grogan	G. Killough	K. Meyer	R. Meyer	J. Mohler	A. Rood	S. Sharp	W. Sinclair	D. Thorne	P. Voillequé	J. Weber	P. Boelter,	L. Denham	S. Francis	Total Hours
Task 1: Cleanup Levels at Other Sites	40	8	32	16	16	16	44	16	0	32	16	24	20	20	20	320
Task 2: Computer Models	36	48	160	24	24	0	120	40	0	120	40	64	20	44	20	760
Task 3: Inputs and Assumptions	60	48	184	48	48	28	216	28	0	176	48	48	20	60	20	1032
Task 4: Methodology	16	0	24	8	8	0	32	8	8	24	8	16	8	8	0	168
Task 5: Independent Calculation	56	24	144	28	28	32	144	32	120	128	40	64	20	48	20	928
Task 6: Protocols	48	52	128	56	24	20	128	40	0	152	56	48	20	44	20	836
Task 7: Actinide Migration	72	0	24	56	56	0	40	16	0	8	48	0	12	20	12	364
Task 8. Interfacing and Responsibilities[a]	48	8	32	8	16	8	48	60	24	40	8	16	48	24	24	412
Total hours	376	188	728	244	220	104	772	240	152	680	264	280	168	268	136	4820
	JT	HG	GK	KM	RM	JM	AR	SS	WS	DT	PV	JW	PB	LD	SF	

a. Task 8 includes all interfaces with the Oversight Panel and public.

E. INTERFACE WITH THE OVERSIGHT PANEL

The success of this project depends on establishing a good working relationship between the Oversight Panel and *RAC*. Information, ideas, concerns, and suggestions must flow freely between *RAC* and the Oversight Panel for the relationship to work. In addition, professional respect between the Oversight Panel and *RAC* must be established. *RAC* has had considerable experience working with Oversight Panels during performance of three dose reconstruction projects. For example, over the past three years, *RAC* scientists have spent a considerable amount of time and effort beyond the contract specifications in addressing concerns of the Health Advisory Panel and the public for the Historical Public Exposures Studies at Rocky Flats.

During the course of this project, key *RAC* personnel will meet with the Oversight Panel at their regularly scheduled monthly meetings. At each meeting, *RAC* personnel will inform the panel of their latest findings, seek advice from the panel on future directions, recommend alternative approaches, and respond to concerns and requests made by panel members. *RAC* will provide copies of their presentations and draft reports for review by the Oversight Panel. Outside of the monthly meetings, *RAC* personnel will be available via telephone, e-mail, fax or if necessary, a personal visit.

F. PEER REVIEW

The credibility of any scientific endeavor is gained through peer review. *RAC* is committed to this general principle in all of its work and believes peer review to be essential to the credibility of any scientific investigation. In past projects, *RAC* has solicited advice from oversight panels and concerned citizens to identify potential peer reviewers. *RAC* has also been open to peer review by individuals representing all sides of a scientific issue. We are open to reviews by scientific panels such as the National Academy of Sciences and The Natural Resources Defense Council. We are committed to an open review policy for all our work.

RAC will suggest peer reviewers based on (a) their overall reputation and credibility in the scientific community, (b) their expertise in the particular area of work to be reviewed and (c) the absence of conflict of interest issues. *RAC* will also solicit suggestions from panel members and concerned members of the public. Reviewers that are currently outside the DOE system are preferable; however, *RAC* recognizes that a significant portion of the expertise in this field resides in the national laboratory system, and the individuals who possess this expertise cannot be ignored. A list of potential reviewers will be provided to the Oversight Panel two months into the project. Panel members will have a month to review the list and provide suggested changes to *RAC*. Upon agreement between *RAC* and the Oversight Panel concerning the list of potential reviewers, reviewers will be contacted and their availability assured. Individuals who are unable to participate will be removed from the list and new ones suggested. After all reviewers are confirmed, a timetable for review will be presented to the Oversight Panel.

Our experience has shown that peer review typically takes longer than expected. Therefore in most cases, we have allowed two to three months for review and incorporation of comments into the final documents.

RFCA RSAL Working Group Meeting Minutes
January 27, 1999

Mission Reminder
The Rocky Flats Cleanup Agreement (RFCA) Radionuclide Soil Action Level (RSAL) Working Group (RWG) is tasked with evaluating new information and determining its impact to the RSALs. (See, RFCA paragraph 5 and the Responsiveness Summary for Soil Action Levels released on November 6, 1996.) This includes developing an understanding of how the information impacts the RSALs. The RWG will evaluate the pluses and minuses of different approaches to developing RSALs.

Attendance
The RWG convened on January 27, 1999 at EPA. In attendance for DOE was Russell McCallister; attendees for EPA were Tim Rehder and Mark Aguilar; attendees for CDPHE were Steve Gunderson, Diane Niedzwiecki, Edd Kray, Tom Pentecost, and Carl Spreng; attendees for the Kaiser Hill Team were Laura Brooks, Bob Nininger, and Rick Roberts. Also in attendance were the following members of the public: Will Neff and Brady Wilson.

Agenda
Update on RWG Meeting Minutes-12/16/98
Update of actions
Report from the NRC Workshop held January 21 through 22, 1999
Continuation of RWG Action 1, Conduct a Regulatory Analysis
Other Items
Path Forward

Update on RWG Meeting Minutes-12/16/98
Additional comments from RWG members were being added to the meeting minutes for the RWG Working Group Meeting on 12/16/98. In addition, the following language will be added to the top of the meeting minutes "**NOTE:** During the working group review of these meeting minutes, some members of the RRWG felt that some areas of the minutes contained insufficient detail to describe the discussion that occurred during the actual working group meeting. Rather than attempt to revise the meeting minutes, the RRWG members agreed to addend comments from RRWG members to the meeting minutes. The addendum is not subsidiary to the original minutes, but is added to further clarify points made during the original discussion."

Meeting minutes from the January 19, 1999 meeting are still being prepared.

Update of actions
All non-ongoing, outstanding, actions have been completed.

Report from the NRC Workshop held January 21 through 22, 1999
Edd Kray and Rick Roberts attended the public workshop on the Nuclear Regulatory Commission's (NRC) License Termination Criteria (LTC) held on 1/21 and 1/22 in Rockville, MD. The workshop is the second of six workshops being hosted by the NRC on the LTC. Approximately 50 individuals attended the workshop. The major points from this workshop were:

1. The presenters at the workshop discussed the radiation dose model DandD on the first day of the workshop. The presenters during the second day of the workshop covered 10CRF20.1403 which involves restricted use issues. There was a presentation on the radiation dose modeling being performed at Portland General Electric Company. This presentation included an assessment of building rubble in an offsite landfill. The NRC verbally stated that this assessment needed to be performed since the dose from radioactive material needs to be assessed for 1,000 years. This is significant since it is the first time the NRC has stated that the radiation dose from building rubble needed to be assessed in a landfill. The exposure scenario(s) required to assess the radiation dose from radioactive material in a landfill have not been defined by the NRC. This is significant for RFETS since it may be necessary to assess a landfill exposure to disposition building rubble.

271

2. The NRC states in verbal comments that engineered barriers such as a cap would be considered an institutional control. The NRC stated that the protection afforded by a cap could not be taken into account when assessing loss of institutional controls in the future.

3. EPRI (Electric Power Research Institute) is currently assessing the RESRAD codes versus the DandD code. The results of this assessment will be out by the end of the year. A draft report dated October 15, 1998, is available on the NRC web-page and may be downloaded and printed.

4. NRC is developing a probabilistic version of the DandD code which will use a set of default parameters developed based on Monte Carlo analysis of the physical inputs values. They anticipate completion of this project within approximately 6 months.

5. NRC is looking at the default values used for the indoor resuspension factor in the current DandD code. It appears that the current value may be over-conservative. The proposal is to base the new factor on total rather than removable contamination levels. This may change outputs for surface contamination limits on some radionuclides.

6. NRC approaches being developed for modeling of subsurface contamination appear to be more conservative than RESRAD by a ratio of about 4:1.

7. NRC is developing a standard review plan for dose modeling calculations. This may be useful to the WG's efforts once published.

8. EPRI has been working with the DandD code and found some issues in regard to DCGL values for a number of nuclides, particularly Cesium-137, Strontium-90 and alpha emitters. NRC is working to correct this. Interestingly, their calculations for 25 mrem DCGL's for plutonium 239 or 240 still come to 1.86 pCi/g for soils in a residential farming scenario, 0.212 pCi/g for farming on a landfill and a 27.7 dpm/100cm2 surface contamination limit for a building renovation scenario.

9. NRC discussed "restricted release" scenarios. They stated that the rule requires a licensee to justify any inability to meet the 25 mrem free-release criteria before considering alternate criteria for license termination based on land-use restrictions. An application must prove that free-release is prohibitively expensive or results in net public or environmental harm before looking to land-use restrictions to meet the 25 mrem criteria.

Continuation of RWG Action 1, Conduct a Regulatory Analysis/Discussion on application of NRC rule and ALARA to RFCA and the Rocky Flats Vision

Based on previous discussions, the RWG members agreed to review two main issues with regards to the regulatory analysis of the NRC rule. First, do NRC numbers (25/100 mrem) alter our approach? Second, does the NRC rule alter how we look at land use restrictions and modeling under RFCA?

Future Land Use Scenarios: NRC Approach Compared to the EPA/CERCLA/RFCA Approach
The RWG discussed the RFCA framework described in the RFCA preamble, RFCA Attachment 5, The Action Levels and Standards Framework for Surface Water, Ground Water, and Soils, and the Rocky Flats Vision. This framework provides that the industrial area will be managed and cleaned as necessary to allow restricted open space or industrial uses in the existing Industrial Area and that the buffer zone will be managed and cleaned as necessary to accommodate open space uses in the Buffer Zone. The RWG discussed whether the RWG was bound to this framework or whether the framework could be expanded. In 1996, RSALs for a residential land use scenario were calculated so the RFCA framework has been expanded in the past. RSALs for a residential land use scenario were calculated to provide a value to the RFCA Parties, below which, future land use restriction may not be required. The RWG agreed that the RFCA framework does not prevent the RWG from evaluating future land use scenarios outside of the framework. The NRC emphasizes unrestricted release after cleanup; it may be to the site's advantage to evaluate unrestricted release in addition to industrial use, restricted open space, or open space.

272

At the November 24, 1998, working group meeting, the RWG had discussed preparing an analysis for scenarios in accordance with the RFCA framework as well as for an unrestricted use. The RWG had also agreed to evaluate the annual dose limits described in RFCA as well as the annual dose limits described in the NRC rule (15/25/85/100 mrem/year). See, Summary Table within the November 24, 1998 meeting minutes. The RWG still believes this complete evaluation should be completed.

The RWG discussed that if soils are remediated to a 25 mrem/year unrestricted use level, then the NRC rule does not require an ALARA analysis; however, if soils are remediated to a 25 mrem/year restricted use level, then an ALARA analysis is required by the NRC.

The RWG spent time discussing the different approaches taken by the NRC and EPA regarding future land use. The NRC's first priority is to cleanup a site to unrestricted future land use. If a licensee is not able to clean up to a unrestricted future land use then the licensee must demonstrate (justify) to the NRC achieving unrestricted release is either prohibitively expensive or would result in net public or environmental harm. Some members of the RWG believe that RFCA gives away this first priority by not requiring cleanup to an unrestricted land use. Some members of the RWG believe that RFCA is consistent with the CERCLA process; RFETS is a CERCLA site and not a NRC site. Under CERCLA, EPA's first priority is to cleanup up to unrestricted use; however, cleanup may also be based on future land use restrictions. EPA looks to the current land use of the site and of the surrounding community, as well as what the reasonable anticipated future land uses are for the area when determining clean up requirements for a site. The RWG acknowledges that the demonstration requirements to the NRC may be different than to EPA.

The RWG acknowledged that the issue of the different approaches regarding future land uses would not be decided by this working group. The RWG decided to identify this issue (discrepancy) for now, set it aside, and continue to move forward with the mission of this group.

Water Pathway Analysis and Protection of Surface Water under RFCA

During the meeting, it was pointed out that under the NRC rule, the water pathway is assessed along with all other exposure pathways to comply with the 25 mrem radiation dose limit. This is different than how the original RSALs assessed exposure pathways to comply with the 15/85 mrem radiation dose limits. The original RSALs included an assessment of all soil pathways to comply with the 15/85 mrem radiation dose limit; the water pathway was not included in the original assessment. Under ALF, all water leaving the site must meet the 0.15 pCi/L standard for Pu. The 0.15 pCi/L standard is based on a 10^{-6} residential risk limit. If the 25 mrem radiation dose limit is applied to RFETS with an all pathways analysis, the current surface water limit may be too stringent since the risk limit of 10^{-6} is a factor of 100 less than the acceptable risk limit. Some members of the RWG question whether there is sufficient surface water at RFETS to fully support a resident. The RWG may want to further analyze this point further in the future.

The RWG discussed that the real driver for radionuclide soil remediation at RFETS may be the protection of surface water rather than the RSAL level. RSALs were designed to protect a person using the land; RSALs were not designed to meet the surface water standard. Cleanup at RFETS must be protective of surface water. Currently, all waters leaving the site must meet the 0.15 pCi/L standard for Pu. After the period of active remediation, all waters on site must meet this standard. The RWG acknowledged that no one has calculated a concentration in soil that would protect surface water to 0.15 pCi/L for Pu. Currently, there is insufficient information regarding the migration of actinides in the environment. When this information is available, the RSALs may be recalculated. For now, when evaluating a potential remediation project, the project team must always consider how the project may impact surface water quality. This may require some sites to be cleaned up to lower levels than the RSALs, i.e., different cleanup levels could be used a different sites. The key point is that during remediation, both the stream standard and the RSAL must be considered when estimating how clean is clean.

NRC/EPA/RFCA Annual Dose Limits and the CERCLA Risk Range

The RWG discussed the differences between the NRC rule, which evaluates 25 mrem/year, the EPA OSWER Directive and RFCA, which both evaluate 15 mrem/year. The EPA OSWER Directive states that if a site uses the NRC dose limits, in general, the risk from radionuclides will be outside the acceptable CERCLA risk range. However, Tim Rehder pointed out to the RWG that the risk level of 3×10^{-4}

273

mentioned in the OSWER Directive represents the average of approximately 60 radionuclides. It is incorrect to associate the risk level of 3 x 10^{-4} with the dose level of 15 mrem/year for a particular radionuclide. When assessed independently, alpha emitters are generally within the CERCLA risk range, e.g., Pu at 15 mrem/year is within the CERCLA risk range. Not all members of the RWG understood this distinction and not all RWG members had the reference document (EPA: The Relationship Between Radiation Dose and Risk and Its Implications in Developing the Radiation Site Cleanup Standard, Fourth Draft, December 12, 1995) that explains the source of the values. The state took the action to make sure that all state RWG members have a copy of the reference document that explains the relationship of the risk number to the dose limits. The other RWG members have copies of the document. If the RWG needs to further discuss the reference document, then it will be discussed at a future RWG meeting.

There are two ways to convert dose to risk:

1) use a radionuclide specific slope factor
2) use the ICRP factor for risk per unit dose for Total Effective Dose Equivalents (TEDE).

The first method employs the methodology from EPA's HEAST (Health Effects Assessment Summary Tables) report. In the HEAST, EPA gives a risk coefficient that is the risk per unit intake (e.g., 10^{-08} per pCi inhaled). To use this method, one would multiply the total activity inhaled or ingested by the risk coefficient to get the risk. The second method employs the methodology from the ICRP. ICRP gives a risk coefficient that is the risk per unit of radiation dose (e.g., 10^{-4} per rem). To use this method, one would multiply the annual effective dose equivalent by the risk coefficient to get the risk. The RWG identified this difference between the NRC and EPA/CERCLA and has agreed to set it aside, and continue to move forward with the mission of this group.

20.1403 Criteria for license termination under restricted conditions.
A site will be considered acceptable for license termination under restricted conditions if:

(a) The licensee can demonstrate that further reductions in residual radioactivity necessary to comply with the provisions of section 20.1402 would result in net public or environmental harm or were not being made because the residual levels associated with restricted conditions are ALARA. Determination of the levels which are ALARA must take into account consideration of any detriments, such as traffic accidents, expected to potentially result from decontamination and waste disposal;

The RWG spent a considerable amount of time discussing cleanup to restricted land uses v. unrestricted land uses. (See above discussion on Future Land Use Scenarios: NRC Approach Compared to the EPA/CERCLA/RFCA Approach.) The RWG acknowledged that this working group would not decide the issue of the different approaches regarding future land uses. The RWG decided to identify this issue (discrepancy) for now, set it aside, and continue to move forward with the mission of this group. In order to keep moving forward, an analysis will be completed for scenarios in accordance with the RFCA framework as well as for unrestricted. The RWG had also agreed to evaluate the annual dose limits described in RFCA as well as the annual dose limits described in the NRC rule (15/25/85/100 mrem/year). See, Summary Table in November 24, 1998 meeting minutes.

This requirement is not applicable to RFETS since RFETS is not a licensed NRC facility; however, the requirement is relevant and may or may not be appropriate because media and substances covered by the regulation are of concern at RFETS. Under CERCLA, restricted land use scenarios may be evaluated as part of the CERCLA process; however, CERLCA may not require a demonstration that further cleanup would result in net public or environmental harm. The CERLCA process considers surrounding land use.

An outstanding question that remains is how will it be demonstrated that residual levels are ALARA.

(b) The licensee has made provisions for legally enforceable institutional controls that provide reasonable assurance that the TEDE from residual radioactivity distinguishable from background to the average member of the critical group will not exceed 25 mrem per year;

While RFCA and the RFETS Vision discuss future land use, it does not provide any legal requirements that restrict the land use. Under the CERCLA process, if a site is not cleaned up to unrestricted release, then

274

legally enforceable institutional controls are required. Some members of the RWG believe that legally enforceable institutional controls will be addressed in the final CAD/ROD(s). Some RWG members believe that this requirement is not applicable and that while relevant, it is not appropriate because CERCLA addresses the same issue. Therefore, there is no requirement to go beyond the CERLCA process. Other RWG members believe that this requirement is not applicable, but the requirement is both relevant and appropriate because the level of assurance of legally enforceable institutional controls required by the NRC is important to help assure longevity of the institutional controls.

It is believed that there are separate working groups looking into the issue of long-term institutional controls for RFETS, as well as the DOE complex. The RWG acknowledged that this working group would not decide the issue of legally enforceable institutional controls. The RWG agreed to identify the issue for now, set it aside, and continue to move forward with the mission of the RWG.

(c) The licensee has provided sufficient financial assurance to enable an independent third party, including a government custodian of a site, to assume and carry out responsibilities for any necessary control and maintenance of the site. The rule then proceeds to outline four acceptable financial assurance mechanisms.

The RWG is concerned that if ongoing monitoring and maintenance, including institutional controls, of RFETS is required beyond cleanup of the site, there needs to be financial assurance that the requirements may be met. EPA has required funds to be established at private CERCLA sites, e.g., Shattuck.

Some RWG members believe that under the CERCLA process, if a site is not cleaned up to unrestricted release, then financial assurances for ongoing monitoring and maintenance are required. Under CERCLA, financial assurance would be addressed as part of the final CAD/ROD(s) process. Some RWG members believe that the NRC requirement is not applicable and that while relevant, it is not appropriate because CERCLA addresses the same issue. Therefore, there is no requirement to go beyond the CERLCA process. Other RWG members believe that the NRC requirement is not applicable, but the requirement is both relevant and appropriate because the level of financial assurance required by the NRC is important to help assure longevity of the institutional controls, monitoring, and maintenance.

The RWG acknowledged that this working group would not decide the issue of financial assurance. The RWG agreed to identify the issue for now, set it aside, and continue to move forward with the mission of the RWG.

(d) The licensee has submitted a decommissioning plan or License Termination Plan (LTP) to the Commission indicating the licensee's intent to decommission . . . The licensee shall document in the LTP or decommissioning plan how the advice of individuals and institutions in the community who may be affected by the decommissioning has been sought and incorporated, as appropriate, following analysis of that advice. The rule lists specific matters that the licensee must seek the advice from affected parties.

The RWG acknowledges that the agencies continually seek public involvement in activities at RFETS, including the Rocky Flats Vision, RFCA, specific projects, and long-term questions; however, the RWG is concerned that the agencies may not have involved the public on the specific matters required by the NRC rule when an NRC facility is seeking restricted release. The RWG agreed to identify the issue for now, set it aside, and continue to move forward with the mission of the RWG. At some point, the parties may need to seek additional public involvement on this issue. For further discussions on the CERCLA/RFCA public involvement process, see section 20.1405 Public notification and public participation, below.

(e) Residual radioactivity at the site has been reduced so that if the institutional controls were no longer in effect, there is reasonable assurance that the TEDE from residual radioactivity distinguishable from background to the average member of the critical group is ALARA and would not exceed either (1) 100 mrem per year; or (2) 500 mrem per year provided the licensee demonstrates . . .

In general, the RWG believes that this section is not applicable, but is relevant and may be appropriate. The 100 mrem/year requirement is similar to the RFCA requirement for 85 mrem/year. In addition, subsection (iii) of this section requires periodic rechecks of the site no less frequently than 5 years to assure that the institutional controls remain in place as necessary to meet the criteria of section 20.1403(b) and to assume and carry out responsibilities for any necessary control and maintenance of those controls. This is similar to the CERCLA requirement found in NCP section 40 CFR 300.430.

20.1404 Alternate criteria for license termination.
In general, this section states that the Commission may terminate a license using alternate criteria greater than the dose criterion of sections 20.1402, 20.1403(b), and 20.1403(d)(1)(i)(A), [i.e., unrestricted use, 25 mrem/year plus institutional controls, public involvement for restricted use] if the licensee provides assurance that public health and safety would continue to be protected and that it is unlikely that the dose from all man-made sources would be more that 100 mrem/year limit. The section provides detailed requirements that a licensee would need to meet if seeking to invoke this provision.

At this time the RWG believes that this requirement is relevant, but is not currently appropriate to RFETS. RFCA states that Tier I action levels for radionuclides will be the more conservative of a) an annual radiation dose of 15 mrem for the appropriate land use receptor, or b) an annual radiation dose of 85 mrem for a hypothetical future resident assuming failure of passive control measures. For Tier II, action levels are based on an annual radiation dose of 15 mrem to a hypothetical future resident. For both Tiers I and II, the total dose from multiple radionuclides will be accounted for by applying the sum-of-ratios method.

20.1405 Public notification and public participation.
Upon the receipt of an LTP or decommissioning plan from the licensee, or a proposal by the licensee for release of a site pursuant to sections 20.1403 or 20.1404, or whenever the commission deems such notice to be in the public interest, the Commission shall:
(a) Notify and solicit comments from:
(1) local and State governments in the vicinity of the site . . . ; and
(2) the EPA for cases where the licensee proposes to release a site pursuant to section 20.1404.
(b) Publish a notice in the Federal Register and in a forum, such as local newspapers, letters to the State or local organizations, or other appropriate forum, that is readily accessible to individuals in the vicinity of the site, and solicit comments from affected parties.

Under CERCLA, public notification and public participation are addressed as part of the CERCLA process. For example, NCP section 300.155, Public Information and Community Relations, states that section 300.415 contains community relations requirements for removal actions; 300.430 contains community relations requirements for remedial actions; and 300.435 contains community relations requirements for enforcement actions. These requirements are intended to promote active communications between communities affected by discharges or releases and the lead agency responsible for response actions. Community Relations Plans are required by EPA for certain response actions. Since, actions prior to the final CAD/ROD(s) are being done as accelerated action actions, section 300.415 apply. In addition, RFCA Part 27, Participation by Local Elected Officials and the Public, contains public participation requirements. Some RWG members believe that the NRC requirement is not applicable and that while relevant, it is not appropriate because CERCLA addresses the same issue. Therefore, there is no requirement to go beyond the CERLCA process. Other RWG members believe that the NRC requirement is not applicable, but the requirement is both relevant and appropriate because the level of public involvement required by the NRC may go beyond the CERLCA/RFCA requirements.

20.1406 Minimization of contamination.
This section applies to applicants for licenses, other than renewals, after August 20, 1997. Since RFETS is not a NRC licensed facility and it is not anticipated that DOE will seek a NRC license in the future, this section is not applicable, relevant, or appropriate.

New Actions
All RWG members must review the NRC Guidance 4006 and be prepared to discuss any issues identified during the review.

All RWG members must review the EPRI model comparison that is available off the NRC web-site.

All RWG members should review the EPA Paper on "The Relationship Between Radiation Dose and Risk and Its Implications in Developing the Radiation Site Cleanup Standard, Fourth Draft, December 12, 1995."

Laura Brooks has the action to start preparing a table that compares the NRC requirements with EPA/CERCLA/RFCA requirements. The goal of the table will be to document the differences between the regulations and identify issues that the RWG has set aside in order to keep moving forward.

Laura Brooks has the action to find out information on the National Waste Policy Act.

Other Information
The next RFSALOP meeting is scheduled for February 11, 1999, from 4:00 to 7:00 at the Broomfield City Hall. Prior to the RFSALOP meeting, there will be a risk workshop from 12:00 to 3:30 at the Broomfield City Hall.

The next RWG meeting is scheduled for February 17, 1999, at 9:00 at CDPHE in room B2G.

The proposed agenda for the next meeting is:
Review of 1/19/99 and 1/27/99 Meeting Minutes – 10 minutes
Update on Actions – 5 minutes
Complete RWG Action 1, Conduct a Regulatory Analysis – 45 minutes
Start RWG Action 2, Model Evaluation, by discussing the EPRI model evaluation – 1 hour, 45 minutes
Other Items – 5 minutes
Path Forward – 5 minutes

277

RFCA RSAL Working Group Meeting Minutes
January 19, 1999

Mission Reminder

The Rocky Flats Cleanup Agreement (RFCA) Radionuclide Soil Action Level (RSAL) Working Group (RWG) is tasked with evaluating new information and determining its impact to the RSALs. (See, RFCA paragraph 5 and the Responsiveness Summary for Soil Action Levels released on November 6, 1996.) This includes developing an understanding of how the information impacts the RSALs. The RWG will evaluate the pluses and minuses of different approaches to developing RSALs.

Attendance

The RWG convened on January 19, 1999 at RFETS. In attendance for DOE was Russell McCallister; in attendance for EPA was Tim Rehder; attendees for CDPHE were Steve Gunderson, Diane Niedzwiecki, Edd Kray, Tom Pentecost, Dick Fox, and Carl Spreng; attendees for the Kaiser Hill Team were Laura Brooks and Rick Roberts. Also in attendance were the following members of the public: Brady Wilson, Victor Holm, Hank Stovall, and Mary Harlow.

Agenda

Review of 12/16/98 Meeting Minutes
Update on Actions
Completion of RWG Action 1, Conduct a Regulatory Analysis
Discussion on application of NRC rule and ALARA to RFCA and the Rocky Flats Vision (This is a continuation of the detailed review of the NRC rule started on December 16, 1998.)
Other Items
Path Forward

Review/Approval of RWG Meeting Minutes – 12/16/98

The RWG spent approximately one hour reviewing the meeting minutes from the December 12, 1998, meeting. Some members of the RWG believe that more detail needs to be included in the meeting minutes. Some RWG members believe that background information is important to include in meeting minutes, especially if the background information is shared (e.g., handouts passed out) at the meeting, but is not available electronically. Most RWG members agree that the key point of meeting minutes is to document where there is consensus and/or disagreement between the members of the RWG. Meeting minutes are not intended to be a minute-by-minute description of the RWG discussions. Where the RWG members have disconnects, there will be an opportunity in the future to document the disconnects and to seek guidance or direction from the RFCA Parties using the RFCA process.

The RWG agreed not to revise the meeting minutes, but to add any comments from RWG members as an addendum to the meeting minutes. The addendum is not subsidiary to the original minutes, but is added to further clarify points made during the original discussion. In the future, RWG members are to forward key points from the meeting that they want included in the meeting minutes to Laura Brooks.

Additional Key Points RWG Members wanted made from the 12/16/98 meeting minute discussion

A recommendation was made that the WG advise the Principals as soon as possible that the draft EPA rule (40 CFR 196), which formed the regulatory basis for the current Soil Action Levels, has been eliminated.

The RWG discussed the NRC rule and the EPA OSWER Directive regarding the NRC rule. There is some language in the OSWER Directive that is confusing to RWG members e.g., the discussion on whether EPA views the NRC rule as protective and whether the dose limits in the NRC rule are within the CERCLA acceptable risk-range. The RWG agreed not to associate the risk level of 3 x 10-4 with the dose level of 15mRem/yr. Representatives from EPA and the State pointed out that 3 x 10-4 is a number that represents that average of approximately 60 radionuclides.

There are two ways to convert dose to risk:

1) use a radionuclide specific slope factor
2) use the ICRP factor for risk per unit dose for Total Effective Dose Equivalents (TEDE).

278

The RWG agreed to have further discussions on this topic.

Update on Actions

Bio-availability of plutonium:
The RWG discussed the bio-availability of plutonium. Information on this subject was distributed by RAC at the January 14, 1999, RFSALOP meeting. Additional information is available on several web-sites, e.g., REACTS. The form of plutonium is important when predicting the impacts to the body if it is ingested or inhaled. The oxide form (insoluble form) of plutonium is less bio-available than other forms (soluble forms) of plutonium. Further analysis needs to be done on whether plutonium is soluble in the environment or in the body. The Actinide Migration Study team is evaluating the form of plutonium in the environment at RFETS in 1999. RAC is attending the AMS meetings. RAC stated in the last technical review session that the oxide form of plutonium was used in the dose reconstruction studies. EPA believes that plutonium is a prime candidate for a swine study. ICRP 48 may have included a swine study on the uptake of plutonium. Rehder will get the ICRP 48 information to the EPA toxicologist for review. Diane Niedzwiecki will also review the material.

Another potential key point regarding the form of plutonium in the environment is how mobile the actinide may be in relationship to its form. There was a recent article in Nature, (1999, Volume 397, pgs. 56-59), "Migration of plutonium in ground water at the Nevada Test Site." The CAB has a copy of this article and will fax a copy to Laura Brooks. Laura Brooks will fax to the RWG.

The RWG will continue looking into this issue.

Definitions of a "Reasonable Maximally Exposed (RME) individual" and "Average Member of the Critical Group" (AMCG):

The differences between RME and AMCG were discussed at length. AMCG is defined in NUREG 1549. Some members of the RWG believe that the AMCG concept is not clearly defined. RME is defined in OSWER. Some members of the RWG believe that the RME concept is more clearly defined. It is unclear to some that there is a significant difference. Some RWG members expressed the belief that there would not be a significant difference if appropriate land use scenarios were used for AMCG vs RME. Other RWG members believe that land use is a critical difference. CERCLA doesn't look far into the future (1000 years). A member of the public noted that the NRC critical group is conservative (residential) and under NRC it is inappropriate to look at short-term uses such as open space. It was noted that under CERCLA we look at 30 years vs 1000 years under NRC. Both CERCLA and the NRC require 5-year reviews where the site is released under a restricted scenario.

The RWG reviewed the February 26, 1992 EPA memorandum, Guidance on Risk Characterization for Risk Managers and Risk Assessors. It was noted that the guidance document requires the use of near maximum values for the most sensitive modeling parameters. Since the mass loading parameter is one of the most sensitive for the modeling of Pu exposures, a maximum or near maximum value should be used rather than site averages.

The actual language from the guidance document states that "If only limited information on the distribution of the exposure or dose factors is available, the assessor should approach estimating the high end by identifying the most sensitive parameters and using maximum or near-maximum values for one or a few of these variables, leaving others at their mean values."

The RWG will continue looking into this issue.

Average annual PM-10 values:
The group discussed mass loading inputs to the models. The State presented data on State measured PM-10 values. Most values were in the 20-30 range as used in the RSAL modeling. Few, if any, measured values were representative of a rural residential scenario. The CPDHE Air Division representative thought that using average values was inappropriate. Some RWG members noted that an extreme annual average

279

during worst case meteorology was appropriate for comparison to the 1000 year standard. Many RWG members agreed that as a most sensitive input parameter, the value used should be conservative. Edd Kray explained that a liberal value should not be used for this very sensitive parameter. Some RESRAD and DandD modelers use defaults of 100 or 200. CSU reviewers recommended using a value of 90 or 100. Other RWG members question whether using an extreme annual average during worst case meteorology is appropriate. A person cannot breath an entire years worth of dust at the peak time. An annual average value may be more representative. Other points discussed included how to account for high wind days and could 1930's dust bowl conditions re-occur. It was agreed that this issue would be re-evaluated and resolved when the RWG gets into later discussions on recalculating cleanup levels.

Completion of RWG Action 1, Conduct a Regulatory Analysis
Discussion on application of NRC rule and ALARA to RFCA and the Rocky Flats Vision (This is a continuation of the detailed review of the NRC rule started on December 16, 1998.)

There was no time to get back to regulatory analysis of the NRC rule. It will be the topic for the next meeting. To better organize the RWG discussion, the RWG agreed to focus on two main issues: 1) Do NRC numbers (25/100 mrem) alter our approach and 2) Does the NRC rule alter how we look at land use restrictions and modeling under RFCA .

There is an Attorney General's (AG's) memorandum on the NRC rule as an ARAR. According to Edd Kray, the memo states that the NRC rule is relevant and appropriate for application to RFETS. It also states that the more conservative of either the 15 mrem or the 1 x 10-4 should be used as an action level. During the 1996 RSAL development, a comparison was made between the 15 mrem and the 1 x 10-4 values. At that time the mrem values were more conservative and were proposed as the action levels. The State will evaluate whether the AG's memo may be shared with the RWG.

Other Information

The next RFSALOP Meeting is scheduled for February 11, 1999, from 4:00 to 7:00 at the Broomfield City Hall.

The next RWG meeting is scheduled for January 27, 1999, at 9:00 at the EPA Conference Center.

The proposed agenda for the next meeting is:
Review of 12/16/98 Meeting Minutes
Status of 1/19/99 Meeting Minutes
Update on NRC Workshop held January 21 through 22, 1999.
Completion of RWG Action 1, Conduct a Regulatory Analysis
Discussion on application of NRC rule and ALARA to RFCA and the Rocky Flats Vision (This is a continuation of the detailed review of the NRC rule started on December 16, 1998.)
Other Items
Path Forward.

280

DRAFT

Soil Sampling Quality Assurance

This intermediate deliverable will be incorporated into
Appendix C
Soil Sampling Protocol

This document provides an overview of the Quality Assurance/Quality Control elements to be considered in a Soil Sampling Protocol.

Risk Assessment Corporation
"Setting the standard in environmental health"

281

Table of Contents

282

LIST OF TABLES

LIST OF FIGURES

Soil Sampling Quality Assurance

1.0 Introduction

Quality assurance is defined as the system of activities required to provide a quality product, whereas quality control is the system of activities required to provide information as to whether the quality assurance system is performing adequately. An adequate quality assurance/quality control (QA/QC) program requires the identification and quantification of all sources of error associated with each step of a soil sampling program so that the resulting data will be of known quality. The components of error, or variance, include those associated with sampling, sample preparation, extraction, analysis, and residual error.

The goal of quality assurance (QA) and quality control (QC) is to identify and implement sampling and analytical methodologies that will limit the introduction of error into analytical data. The required QA/QC program elements are typically developed and documented in Quality Assurance Project Plans (QAPPs) or in similar documents including, but not limited to, decommissioning plans, sampling and analysis plans, and field sampling plans.

The development of a QAPP for soil sampling is beyond the scope of this report. Typically, the development of a soil sampling program and associated QA/QC requirements is an iterative process that the Panel and RFETS will need to discuss during the development of such programs and designs.

In general, the following progression of events leads to the development of a QA/QC program for soil sampling programs:

1. Statement of the study objectives.
2. Evaluation of the impact of mistakes.
3. Definition the data quality objectives (DQOs).
4. Design of the soil sampling study to achieve DQOs.
5. Design of the QA/QC program to confirm achievements of DQOs.

Present guidance for the development of DQOs identifies the following factors for consideration in the sampling program design (NRC 1997):

- Precision
- Accuracy
- Bias
- Completeness
- Representativeness, and
- Comparibility

Other factors of importance include:

- Detection limit of the measurement method used
- Acceptable probability of a Type I error (judging a clean area to be dirty),
- Acceptable probability of a Type II error (judging a dirty area to be clean).

No valid decision can be made about the data or the site under investigation without some knowledge of the magnitude and sources of error in the data. This aspect becomes very important when concentrations of pollutants in a survey area approach an action level. Concentrations that exceed the action level by orders of magnitude require only limited QA as do those areas that contain no pollutant. The area where sampling intensity and increased QA becomes important are those areas where it is not possible to make a clear decision as to the need for and extent of action.

In this report, *RAC* outlines the available QA/QC guidance for soil sampling programs and suggested elements for consideration by the Panel. Elements of a QA/QC program for soil sampling include: data quality objectives (DQOs), documentation, chain-of-custody, laboratory requirements, data validation and the assessment of data quality indicators (DQIs).

It must be noted that RFETS may elect a combination of survey methods to determine that the site meets the RSALS in addition to soil sampling. For example, a combination of survey methods using radiation detection instruments, such as in-situ gamma spectroscopy and Fidler radiation detection equipment. These methods may be used in concert with soil sampling to reduce the cost of the overall survey program. *RAC*'s focus in this task is to consider the use of soil sampling in relation to the development of the RSALs and the use of soil sampling to determine whether the RSALs are attained in a given survey unit.

2.0 Regulatory and Guidance Information

A *quality system* is a management system that describes the elements necessary to plan, implement, and assess the effectiveness of QA/QC activities. These systems are typically called Quality Assurance Programs. Several quality systems requirements and guidance documents have been applied to environmental programs. Some of these requirements include DOE Order 5700.6c (DOE 1991); EPA QA/R-2 (EPA 1994); and MIL-Q-9858A (DOD 1963). In addition there are several consensus standards for QA/QC, including ASME NQA-1 (ASME 1989), and ISO 9000/ASQC A9000 series (ISO 1987). ANSI/ASQC E4-1994 (ASQC 1995) provides national consensus quality standards for environmental programs. It addresses both quality systems and the collection and evaluation of environmental data.

The primary definition of DOE policy concerning quality assurance (QA) is found in DOE Order 5700.6B (DOE 1991). The Order sets forth principles and assigns responsibilities for establishing, implementing, and maintaining programs of plans and actions to provide quality achievement in DOE programs. It is applicable to all DOE programs; however, it does not specifically refer to environmental sampling activities. It specifies that QA activities be identified through the judicious and selective application of appropriate, recognized standards. It also identifies ASME NQA-1 (ASQC 1995) as the preferred standard for nuclear activities.

MARSSIM (NRC 1997) tends to emphasize the use of ANSI/ASQC E4-1994 (ASQC 1995), which provides the minimum set of quality elements required to conduct programs involving environmental data collection and evaluation.

3.0 Data Quality Objectives (DQOs)

The process of planning the soil sampling program for comparison to the RSALs, implementing the sampling plan, and assessing the sampling results prior to making a decision is called the Data Life Cycle. Soil sample survey planning uses the Data Quality (DQO) Process to ensure that the sampling results are of sufficient quality and quantity to support the final decision. Quality Assurance and Quality Control procedures are performed during implementation of the soil sampling plan to collect information necessary to evaluate the results.

MARSSIM (NRC 1997) uses the term Quality Assurance Project Plan (QAPP) to describe a single document that incorporates all of the elements of the survey design (EPA 1994b, 1997). However, typically most DOE sites develop similar documents such as Sampling and Analysis Plans or Field Sampling Plans to describe and document the QA/QC elements of a specific project.

The DQO process is described in detail by EPA (1994a) and in the MARSIM guidance (NRC 1997). The DQO process consists of seven steps as shown in Figure 3-1.

Although the DQO process shown in Figure 3-1, indicates a linear process, the actual process is likely to be iterative. During certain discussion and decisions in the process, DQOs in previous steps may need to be reconsidered or redefined. In addition, the DQO process is a flexible planning tool that can be used more or less intensively as the situation requires. For instance, a preliminary survey of the site may require less intensive DQOs than the final status survey of the site

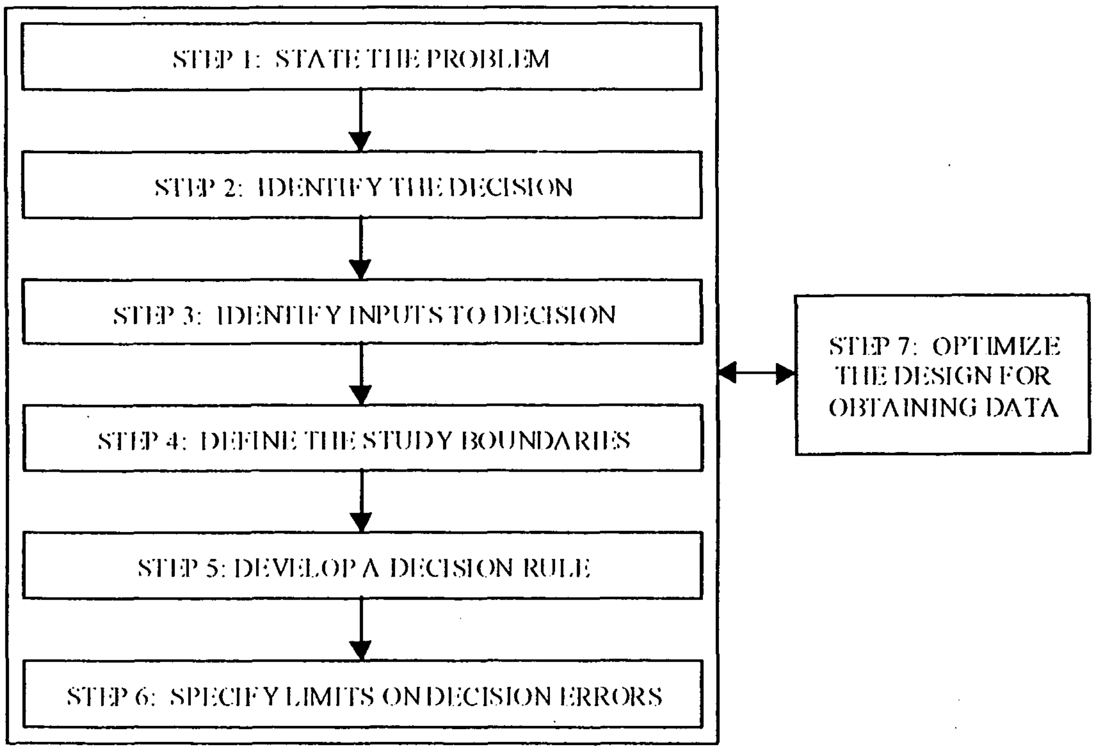

Figure 3-1. The Data Quality Objectives Process (From NRC 1997).

286

The DQO process is provided to the Panel as a recommended strategy for their involvement in the final status survey of the RFETS. The DQO process provides a framework for the concerned public, in the form of the Panel, to be involved in the development of the final strategy for the release of the RFETS. The involvement of the Panel in the discussions and development of the DQOs for the RFETS would provide the mechanism of understanding between the DOE and the Panel as to the methods and decisions to be made for the release of the site. The DQO process will be used by *RAC* in the development of the Soil Sampling Protocol for the RSALs. However, it should be noted that RFETS may elect to modify the soil sampling protocol based on the DQO process due to sampling cost, use of other methods, or a combination of survey detection equipment and sampling (i.e., double sampling (Gilbert 1987))

This report specifically targets the QA/QC aspects (i.e., DQOs) of the soil sampling program and the methodology for identifying potential errors from the point of sample collection to the final analytical result. Data Quality Objectives (DQOs) are qualitative and quantitative statements developed by data users to specify the quality of data needed from a particular data collection activity (EPA 1987). DQOs must address five data quality indicators (DQIs): precision, accuracy, representativeness, completeness, and comparability. The determination of bias is also considered by the MARSSIM methodology manual (NRC 1997). Another data characteristic, level of detection, should also be addressed since it is closely related to the other elements.

3.1 Data Quality Indicators

Data Quality Indicators (DQIs) are measurable attributes of the attainment of the necessary quality for a particular decision. The use of data quality indicators in the QA sampling program allows the determination of data usability. Data quality indicators include precision, bias, accuracy, representativeness, comparability, and completeness.

The DQIs are not all quantitative (numerical) measurements , some DQIs are subject to qualitative (relative) analysis. Of the six principal DQIs, precision and bias are quantitative measures, representativeness and comparability are qualitative, completeness is a combination of both qualitative and quantitative measures, and accuracy is a combination of precision and bias.

Each of the DQIs is described below.

3.1.1 Precision

Precision is a quantitative measure of agreement among replicate measurements of the same property under prescribed similar conditions (ASQC 1995). There are several types of replicate analyses available to determine the level of precision, and these replicates are typically distinguished by the point in the sample collection and analysis process where the sample is divided. The types of QA samples that may be used for the determination of precision include:

1. *Collocated Samples*. Samples collected adjacent to the routine field sample to determine local variability of the radionuclide concentration. Analytical results from collocated samples can be used to assess site variation, but only in the immediate sampling area, and are not recommended for assessing error (EPA 1991a).

2. *Field Replicates*. Samples obtained from one location, homogenized, divided into separate containers and treated as separate samples throughout the remaining handling and analytical process. These samples are used to assess error associated

387

with sample heterogeneity, sample methodology and analytical procedures. Field replicates are used when determining total error for critical samples with contamination concentrations near the action level. For statistical analysis to be valid in such a case, a minimum of eight replicate samples would be required (EPA 1991a).

3. *Analytical Laboratory Replicate.* Subsample of a routine sample that is homogenized, divided into separate containers, and analyzed using the same analytical method. It is used to determine method precision, but because it is a non-blind sample (i.e., known to the analyst) it can only be used by the analyst as an internal control tool and not as an unbiased estimate of analytical precision (EPA 1990).

4. *Laboratory Instrument Replicate.* Repeated measurement of a sample that has been prepared for counting (i.e., laboratory sample preparation and radiochemical procedures have been completed). It is used to determine precision for the instrument (repeated measurements using same instrument) and the instrument calibration (repeated measurements using different instruments, such as two different germanium detectors with multichannel analyzers). A laboratory instrument replicate is generally performed as part of the laboratory QC program and is a non-blind sample. It is typically used as an internal control tool and not as an unbiased estimate of the analytical precision.

When collocated measurements are performed, an estimate of total precision is obtained. When collocated samples are not available for laboratory analysis, a sample subdivided in the field and preserved separately can be used to assess the variability of sample handling, preservation, and storage along with the variability in the analytical process, but variability in sample acquisition is not included. When only variability in the analytical process is desired, a sample can be subdivided in the laboratory prior to analysis. Table 3-1 presents the minimum considerations, impacts if the considerations are not met, and corrective actions for precision.

3.1.2 Bias

Bias is the systematic or persistent distortion of a measurement process that causes errors in one direction (ASQC 1995). Bias is determined quantitatively based on the analysis of samples with a known concentration. There are several types of samples with known concentrations:

1. *Reference Material.* A material or substance, one or more of whose property values are sufficiently homogeneous and well established to be used for the calibration of an apparatus, the assessment of a measurement method, or for assigning values to materials (ISO 1993). A certified reference material is reference material for which each certified values is accompanied by an uncertainty at a stated level of confidence. When appropriate reference materials are available (i.e., proper matrix, proper radionuclide, proper concentration range), they are recommended for use in determining the overall bias for a measurement system.

Table 3-1. Minimum Considerations for Precision, Impact if not Met, and Corrective Action (NRC 1997).

Minimum Considerations for Precision	Impacts When Minimum Considerations Are Not Met	Corrective Action
Confidence level as specified in DQOs. Power as specified in DQOs. Minimum detectable relative differences specified in the survey design and modified after analysis of background measurements if necessary. One set of field duplicates or more as specified in the survey design. Analytical duplicates and splits as specified in the survey design. Measurement error specified.	Errors in decision to act or not to act based on analytical data. Unacceptable level of uncertainty. Increased variability of quantitative results. Potential for incorrectly deciding a survey unit does meet the release criterion for measurements near the detection limits (Type I decision error).	*For Surveying and Sampling:* Add survey or sample locations based on information from available data that are known to be representative. Adjust performance objectives. *For Analysis:* Analysis of new duplicate samples. Use precision measurements to determine confidence limits for the effects on the data. The investigator can use the maximum measurement results to set an upper bound on the uncertainty if there is too much variability in the analyses.

2. *Performance Evaluation (PE) Samples.* PE samples are samples that evaluate the overall bias of an analytical laboratory and detect any error in the analytical method used. These samples are usually prepared by a third party, using a quantity of radionuclides which is known to the preparer but unknown to the laboratory, and always undergo certification analysis. Laboratory procedural error is evaluated by the percentage of the radionuclide identified in the PE sample (EPA 1991a).

3. *Matrix Spike Samples.* Matrix spike samples are environmental samples that are spiked in the laboratory with a known concentration of a target radionuclide to verify percent recoveries. They are primarily used to check sample matrix interferences but can also be used to monitor laboratory performance. However, a data set of at least three or more results is necessary to distinguish between laboratory performance and matrix interference (EPA 1991a).

There are also several type of QA/QC samples used to detect bias caused by contamination these include:

- *Field Blanks.* Field blanks are samples prepared in the field using certified clean sand or soil and then submitted to the laboratory for analysis (EPA 1991a). A field blank is used to evaluate contamination error associated with sampling methodology and laboratory procedures. It also provides information about contaminants that may be introduced during sample collection, storage, and transport (NRC 1997).

- *Method Blanks.* A method blank is an analytical control sample used to demonstrate that reported analytical results are not the result of laboratory contamination (ATSDR 1992). It contains distilled or deionized water and reagents, and is carried through the entire analytical process (laboratory sample preparation, digestion, and analysis). The method blank is also referred to as a reagent blank. The method blank is generally used as an internal control tool by the laboratory because it is a non-blind sample (NRC 1997).

Table 3-2 presents the minimum considerations, impacts if the considerations are not met, and corrective actions for bias.

3.1.3 Accuracy

Accuracy is a measure of the closeness of an individual measurement or the average of a number of measurements to the true value (EPA 1997). Accuracy includes a combination of random error (precision) and systematic error (bias) components that result from performing measurements.

Accuracy is determined by analyzing a reference material of known concentration or by reanalyzing material to which a known concentration of contaminant has been added. To be accurate, data must be both precise and unbiased. As an example consider a target, to be accurate the shots at the target must land close together and, on average, at the spot where they are aimed. In other words, the shots must all land near the bull's eye. This analogy is shown in Figure 3-2.

Table 3-2. Minimum Considerations for Bias, Impact if not Met, and Corrective Actions (NRC 1997).

Minimum Considerations for Bias	Impacts When Minimum Considerations Are Not Met	Corrective Action
Matrix spikes to assess bias of non-detects and positive sample results if specified in the survey design. Analytical spikes as specified in the survey design. Use analytical methods that specify expected or required recovery ranges using spikes or other QC measures. No radionuclides of potential concern detected in the blanks.	Potential for incorrectly deciding a survey unit does meet the release criterion (Type I decision error): if spike recovery is low, it is probable that the method or analysis is biased low for that radionuclide and values of all related samples may underestimate the actual concentration. Potential for incorrectly deciding a survey unit does not meet the release criterion (Type II decision error): if spike recovery exceeds 100%, interferences may be present, and it is probable that the method or analysis is biased high. Analytical results overestimate the true concentration of the spiked radionuclide.	Consider resampling at affected areas. If recoveries are extremely low or extremely high, the investigator should consult with a radiochemist or heath physicist to identify a more appropriate method for reanalysis of the samples.

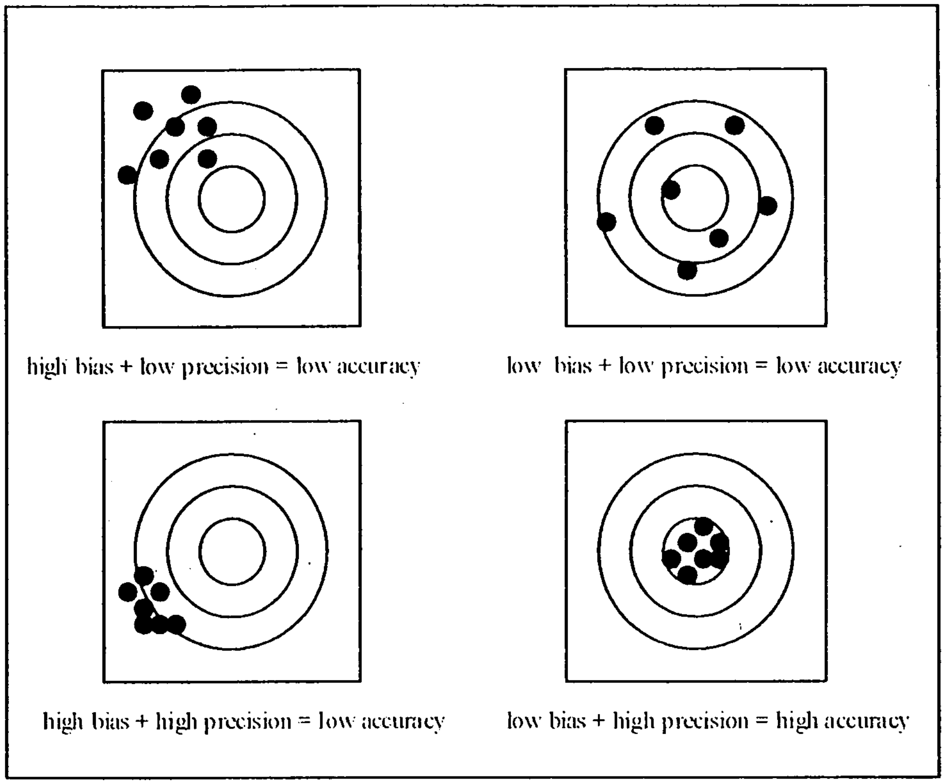

Figure 3-2. Measurement Bias and Random Measurement Uncertainty (NRC 1997).

Accuracy is usually expressed either as a percent recovery or as a percent bias. Determination of accuracy always includes the effects of variability (precision); therefore, accuracy is used as a combination of bias and precision.

3.1.4 Representativeness

Representativeness is a measure of the degree to which data accurately and precisely represent a characteristic of a population parameter at a sampling point (ASQC 1995).. Representativeness is a qualitative term that should be evaluated to determine whether physical samples were collected in such a manner that the resulting data appropriately reflect the media and contamination measured.

When soil sampling is required as part of a survey design, it is critical that the sample collection procedures consider representativeness. Sample collection procedures also need to consider development of the RSALs when determining the representativeness of the samples.

Representativeness is primarily a planning concern. The solution to enhancing representativeness is in the design of the sampling plan. Analytical data quality also affects representativeness since data of low quality may be rejected for use in the analysis. Table 3-3 presents the minimum considerations, impacts if the considerations are not met, and corrective actions for representativeness.

Table 3-3. Minimum Considerations for Representativeness, Impact if Not Met, and Corrective Actions (NRC 1997).

Minimum Considerations for Representativeness	Impacts When Minimum Considerations Are Not Met	Corrective Action
Sampling data representative of survey unit. Documented sample preparation procedures. Documented analytical data as specified in the sampling plan.	Bias high or low in estimate of extent and quantity of contaminated material. Potential for incorrectly deciding a survey unit does meet the RSALs (Type I decision error). Inaccurate identification or estimate of radionuclide concentration. Remaining data may no longer sufficiently represent the site if a large portion of the data are rejected, or if all data from samples at a specific location are rejected.	Additional sampling. Examination of effects of sample preparation procedures. Reanalysis of samples, or resampling of the affected site areas. If resampling or reanalysis cannot be performed, document what areas of the site are not represented due to poor quality of analytical data.

3.1.5 Comparability

Comparability is a qualitative term that expresses the confidence that two data sets can contribute to a common analysis and interpolation. Generally, comprability is provided by using the same measurement system for all analyses of a specific radionuclide. Comparability is usually not an issue except in cases where historical data have been collected and are being compared to current analysis results, or when multiple laboratories are used to provide results as part of a single sampling design (NRC 1997).

The comparability objective provides the needed control over the total measurement process to insure that different studies can be compared. Comparability provides a basis for comparing trends over time or space, for evaluating the relationship between sampling programs, or for insuring that phased sampling efforts produce data of a consistent quality.

When sampling is to occur over an extended period of time or when the investigator desires to compare several sites, it is necessary to insure that the samples be collected in a comparable manner, from comparable fraction of the soil mass, and with comparable methods. For example, one should not attempt to compare samples collected by coring with bucket auger samples. Table 3-4 presents the minimum considerations, impacts if they are not met, and corrective actions for comparability.

Table 3-4. Minimum Considerations for Comparability, Impact if not Met, and Corrective Actions (NRC 1997).

Minimum Considerations for Comparability	Impacts When Minimum Considerations Are Not Met	Corrective Action
Unbiased sampling design or documented reasons for selecting another sampling design. The analytical methods used should have common analytical parameters. Same units of measure used in reporting. Similar detection limits. Equivalent sample preparation techniques. Analytical equipment with similar efficiencies should be factored into results.	Non-additivity of sampling results. Reduced confidence, power, and ability to detect differences, given the number of measurements available. Increased overall error.	Preferentially use those data that provide the most definitive identification and quantitation of the radionuclides of potential concern. For quantitation, examine the precision and accuracy data along with the reported detection limits. Reanalysis using comparable methods.

3.1.6 Completeness

Completeness is a measure of the amount of valid data obtained from the measurement system, expressed as a percentage of the number of valid measurements to that which were collected.

Completeness for measurements is calculated by the following formula (NRC 1997):

$$\%\ Completeness = \frac{(Number\ of\ Valid\ Measurements)\ x\ 100}{Total\ Number\ of\ Measurements\ Planned}$$

If a sufficient amount of sample was originally collected, the analysis can be repeated using archived sample material. Samples collected on a grid to locate areas of elevated activity are also a concern for completeness. If one sample analysis is not valid, the entire sample design for locating areas of elevated activity may be invalidated.

Completeness is not intended to be a measure of representativeness: that is, it does not describe how closely the measured results reflect the actual concentration or distribution of the contaminant in the media being measured. A project could produce 100% data completeness, but the results may not be representative of the actual contaminant concentration. Alternatively, there could be only 70% data completeness (30% lost or found invalid), but due to the nature of the sample design, the results could still be representative of the target population and yield valid results.

For most final status surveys, the issue of completeness only arises when the survey unit demonstrates compliance with the release criterion and less than 100% of the measurements are determined to be acceptable. The question then becomes whether the number of measurements is sufficient to support the decision to release the survey unit.

An alternative method to ensure completeness is to take an additional number of samples in additional to those determined appropriate for the sample design. The planning stages of any study must take into consideration the fact that not all samples will make it intact through the entire measurement process. Sample containers will be broken, instruments will fall out of control, data will be lost, sample tags will be lost, etc. There are many factors that can lead to a sample result being invalidated. This can be compensated for by oversampling or by using a phased sampling effort that allows areas where samples were lost to be resampled in subsequent phases. This latter approach insures that the desired number of samples will be collected. For example, if 20% more measurements were taken in a survey design than required, then a sampling project with 80% completeness may still have sufficient power to support a decision to release the survey unit.

The design of a particular sampling effort provides a minimum number of samples that is needed to yield a desired level of precision for the final results. The probabilities of false positive and false negative answers are specified at the outset. Obviously any loss from the required number of samples will impact the final results. The U.S. Department of Energy has set a completeness objective for the Environmental Survey Program at 90% for both field sampling and laboratory analyses (DOE 1987). Table 3-5 presents the minimum considerations, impacts if they are not met, and corrective actions for completeness.

3.1.7 Detection Limits

The selection of analytical methods based on detection limits is an important process. The detection limit of the method directly affects the usability of the data because results near the detection limit have increased measurement uncertainty.

Table 3-5. Minimum Considerations for Completeness, Impact if not Met, and Corrective Actions (NRC 1997).

Minimum Considerations for Completeness	Impacts When Minimum Considerations Are Not Met	Corrective Action
Percentage of measurement completeness determined during planning to meet specific performance measures.	Higher potential for incorrectly deciding a survey unit does not meet the release criterion (Type II decision error). Reduction in power. A reduction in the number of measurements reduces site coverage and may affect representativeness. Reduced ability to differentiate site levels from background. Impact of incompleteness generally decreases as the number of measurements increases.	Resampling or reanalysis to fill data gaps. Additional analysis of samples already in the laboratory. Determine whether the missing data are crucial to the survey.

4.0 Data Validation

Validation of the analytical data is the process by which the quality of the data is assessed through the use of the specified DQIs and QA/QC sample results. Analytical data validation, including field and laboratory data review, is defined as the systematic process, performed external from the data generator, which applies a defined set of performance-based criteria to a body of data which may result in qualification of the data. Data validation provides a level of assurance, based on a technical evaluation, that an analyte is present or absent, and if present, the level of uncertainty associated with the measurement. Data validation must occur prior to drawing a conclusion from the data.

Analytical data validation for radiochemistry includes a technical review of the laboratory data package covering the evaluation of data quality indicator (DQI) samples, the identification and quantitation of analytes, and the effect of deficiencies in quality control on analytical sample data. Although EPA has developed numerous guidance documents relating to data validation of organic and inorganic constituents, no national standard currently covers data validation of radiochemistry concepts adequately, and the need for a document of this type has been recognized by most of the DOE complex. There is reference in MARSIMM to the development of such guidance, the "*Multi-Agency Radiation Laboratory Analytical Protocols (MARLAP) manual* (NRC 1997), however, at the present time no such document exists. Due to the lack of specific guidance, currently each DOE site has developed site-specific data validation procedures for radiochemistry data.

During data validation, the reviewer examines the data, documentation, and reports to determine if the sampling program was conducted within the limits specified by the DQO process.

4.1 Documentation

Three types of documentation are available for review during the data validation process: (1) field operation records; (2) laboratory records; and (3) data handling records (EPA 1997).

- **Field Operation Records**

  The information contained in these records documents the field operations and consists of the following:

  > *Field measurement records.* These records provide documentation that the proper measurement protocol was performed during the sampling project. This documentation includes the names of the persons conducting the sampling, sample location and identification, maps and diagrams, equipment and SOP used during sampling, and unusual observations. Bound field notebooks are generally used to record raw data, however, data recording forms may also be used for this documentation.
  >
  > *Sample tracking records.* Sample tracking records, also referred to as chain-of-custody records, document the progression of samples as they travel from the original sampling location to the laboratory and finally to disposal.

295

General field procedures. General field procedures, also referred to as SOPs, record the procedures used in the field for the collection of soil samples.

- **Laboratory Records**

The following list describes some of the laboratory-specific records that should be reviewed if available and appropriate:

Laboratory measurement results and sample data. These records contain information on the sample analysis used to verify the analytical methods that were followed. The overall number of samples, sample identification, sample measurement results, any deviations from the SOPs, time of day, and date should be included. Sample location information may also be provided.

Sample management records. Sample management records should document sample receipt, handling and storage, and scheduling of analyses. The records will verify that sample tracking requirements were maintained, reflect any anomolies in the samples such as receipt of damaged samples, and note proper log-in of samples into the laboratory.

QC measurement records. These include the general QC records, such as initial demonstration of capability, instrument calibration, routine monitoring of analytical performance, calibration verification, etc. Project-specific information from the QC checks such as blanks, spikes, calibration check samples, replicates, and splits, should be included in these reports to facilitate data quality analysis.

- **Data Handling Records**

Data handling records document protocols used in data reduction, verification, and validation. Data reduction addresses data transformation operations such as converting raw data into reportable quantities and units, using significant figures, calculating measurement uncertainties, etc. The records document procedures for handling data corrections.

4.2 Data Validation Qualifiers

Data validation begins with an assessment of the quality of analytical results and is performed by a professional with knowledge of the analytical process. Depending on the survey objectives, the level and depth of review varies. The level and depth of the data validation may be determined during the planning process and should include an examination of laboratory and method performance for the measurements and radionuclides involved. This review includes:

- Evaluation of data completeness
- Verification of instrument calibration
- Measurement of precision using duplicates, replicates, or split samples
- Measurement of bias using reference material or spikes
- Examination of blanks for contamination

- Assessment of adherence to method specifications and QC limits
- Evaluation of method performance in sample matrix
- Applicability and validation of analytical procedures or site-specific measurements
- Assessment of external QC measurement results and QA assessments

The result of the data validation process is the assignment of data validation qualifiers. The data validator conducting the data review assigns coded qualifiers to the data when quality control requirements or other evaluation criteria are not met. An explanation of the data qualifiers should be included in the data validation report, along with a summary of the quality of the data package.

5.0 References

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297

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Rocky Flats Soil Action Level Project

Milestone Report 2

Risk Assessment Corporation

March 1999

The main deliverable for the Soil Action Levels Project between the Rocky Flats Citizen Advisory Board and *Risk Assessment Corporation* (*RAC*) will be a comprehensive report issued at the end of the project (November 1999). The main body of the report will be written for the public and will summarize *RAC*'s findings and recommendations. Appendices will provide the technical details of the work. The seven milestone reports will outline *RAC*'s progress in completing the Work Tasks and Deliverables, and the compensation requested according to the schedule provided in the contract. The purpose of this milestone report is to describe the activities that *RAC* has accomplished to date.

Milestone 2 (3/8/99) – 8 milestone items

- Results of a preliminary uncertainty analysis using the RESRAD computer code and the parameters used in the current SAL calculations will be provided (part of Appendix B).
- *RAC* will provide a table summarizing soil action levels at other sites (part of Appendix A).
- Draft report of a review of soil action levels at other sites (Appendix A) will submitted to the panel.
- Sampling protocol based on statistical methods will be provided (part of Appendix C).
- A table of proposed exposure scenarios will be provided.
- *RAC* will provide a review of available computer models that may be used to calculate soil action levels (part of Appendix B).
- Draft report documenting the acquisition, testing, and analysis of computer programs (part of Appendix B) will be submitted (For Task 2).
- Testing and analysis of candidate computer programs will be completed and a brief technical memorandum documenting findings will be provided (Part of Task 2 draft report).

The first milestone item was met at the January 1999 meeting when *RAC* reviewed and described a preliminary uncertainty analysis using the RESRAD code and the parameters currently used in the Rocky Flats soil action level calculation. The next two milestone items were completed at the February 1999 meeting when *RAC* distributed the draft report, *Task 1: Cleanup Levels at Other Sites*, and discussed the approach used to evaluate cleanup standards and levels at other sites. The fourth milestone was met with the distribution of an overview of the Quality Assurance/Quality Control elements to be considered in a Soil Sampling Protocol at the March 1999 meeting. This intermediate deliverable will be incorporated into Appendix C of the final report. For the fifth milestone item, *RAC* provided a summary table and short descriptions of proposed exposure scenarios to the panel in early March. This summary followed presentations about the design and rationale for scenario development at three monthly meetings. The last three milestones have been met with the completion and distribution of the draft Task 2 report, *Computer Models*, to the panel at the March 1999 meeting.

- ***Results of a preliminary uncertainty analysis using the RESRAD computer code and the parameters used in the current SAL calculations will be provided (part of Appendix B).***

At the January 1999 RSAL meeting, Jill Weber, *RAC*, presented a preliminary uncertainty analysis using the RESRAD code and the parameters used in the current Rocky Flats Cleanup Agreement soil action level calculation. This uncertainty analysis focused on the 85 mrem hypothetical resident scenario and the 1429 pCi g^{-1} soil action level for ^{239}Pu. A number of parameters in the RESRAD code were explored, and the sensitivity of the code to changes in these parameters was assessed. The assumption was made that the pathways defined in the original RFETS analysis were appropriate for the Rocky Flats site. This meant that only the pathways used in the Rocky Flats Cleanup agreement calculation were explored, and that surface water and ground water pathways were excluded from this sensitivity analysis.

The importance of the two aspects of sensitivity was emphasized: the mathematical relationship of the parameter of interest to other parameters, and the range of possible values for the parameter. The mathematical relationship of the parameter in the equation might indicate that it would be a significant parameter, but the limit on the range of possible acts to limit its sensitivity. A good example of this is the breathing rate parameter. Although breathing rate is a straight multiplier in the inhalation dose calculation, the limit on its possible range makes it less important in terms of the total sensitivity of the calculation. The mass loading factor and the dose conversion factor emerged as the primary parameters of importance. The mass loading factor reflects the amount of soil that can be resuspended into the air and made available for breathing. This is a very important parameter for the inhalation pathway. Mass loading and related factors have been measured at Rocky Flats and found to vary over several orders of magnitude. The sensitivity analysis made us aware of the importance of this parameter, and we will be reviewing possible values for *Task 3: Inputs and Assumptions.*

Dose conversion factor is the value that converts the intake of radionuclide activity into an effective dose equivalent. This parameter varies with the solubility class of plutonium. The dose conversion factors for insoluble forms of plutonium are 0.308 mrem pCi^{-1} for inhalation and 0.000052 mrem pCi^{-1} for ingestion. These contrast with dose conversion factors for soluble forms of plutonium, which are 0.429 mrem pCi^{-1} for inhalation and 0.0035 mrem pCi^{-1} for ingestion. For soluble plutonium, the ingestion dose conversion factor is nearly two orders of magnitude greater than that for insoluble plutonium, increasing the dose per unit intake and making ingestion an important pathway. This would correspondingly decrease the soil action level for a unit dose. It will be important to review all available documentation on plutonium in soil at Rocky Flats to determine the solubility class of plutonium.

- ***RAC will provide a table summarizing soil action levels at other sites (part of Appendix A).***
- ***Draft report of a review of soil action levels at other sites (Appendix A) will submitted to the panel.***

These two milestones were completed when the Task 1 report, *Cleanup Levels at Other Sites*, was delivered to panel members via Federal Express on Monday, February 8, 1999. This report discusses our work comparing cleanup levels at other sites to those at Rocky Flats, and identifying any information from other facilities that will be helpful to us in conducting the independent analysis at Rocky Flats. In order to provide an equitable comparison, soil action levels were normalized to effective dose by dividing the action level by the dose to create a ratio. In the text of the report, this is referred to as the soil action level to dose ratio. We discovered during this analysis that, in general, the parameters identified in the sensitivity analysis dominate the difference between soil action levels at the different facilities. The table below summarizes the results of this report, and appears as a summary table in the report. For more details on Task 1, please refer to the Task 1 report.

Summary of Comparisons between Rocky Flats Environmental Technology Site Calculations and Those for Other Facilities

Location	Parameter change	Soil action limit to dose ratio ([pCi g^{-1}] $mrem^{-1}$)	Dose to soil action limit ratio (mrem [pCi g^{-1}]$^{-1}$)
Rocky Flats	Original calculation	17	0.06
Hanford	Original calculation	2.3	0.44
	Remove meat, milk, fish, and drinking water pathways and change to RFETS dose conversion factor and mass loading	34	0.03
Rocky Flats	Original calculation	17	0.06
	Change to NTS dose conversion factor	2.8	0.36
Nevada Test Site	Original calculation	4.1	0.24
Rocky Flats	Original calculation	17	0.06
	Change to NRC mass loading	4.6	0.22
NRC DandD Code	Original calculation	7.1	0.14
Rocky Flats	Original calculation	17	0.06
Johnston Atoll	Original calculation	0.85	1.2
	Change to RFETS mass loading, enrichment factor, and calculate air concentration using RFETS dose conversion factor and breathing rate	17.8	0.056
Rocky Flats	Original calculation	17	0.06
Maralinga	Original calculation	0.56	1.8
	Change to RFETS mass loading, breathing rate, dose conversion factor	17.8	0.056
Rocky Flats	Original calculation	17	0.06
Semipalatinsk Nuclear Range	Original measurement	8.8	0.11
Rocky Flats	Original calculation	17	0.06
	Change to Palomares breathing rate	14.1	0.07
Palomares	Original calculation	12.3	0.08

- *Sampling protocol based on statistical methods will be provided (part of Appendix C).*

RAC described the Soil Sampling Quality Assurance guidance (that will be part of the Soil Sampling Protocol in Appendix C) in a draft report to the Panel at the March 1999 RSAL meeting. The report outlines the available QA/QC guidance for soil sampling programs and suggested elements for consideration by the Panel. Elements of a QA/QC program for soil sampling include data quality objectives, documentation, chain-of-custody, laboratory requirements, data validation and the assessment of data quality indicators. The goal of quality assurance (QA) and quality control (QC) is to identify and implement sampling and analytical methodologies that will limit the introduction of error into analytical data. No valid decision can be made about the data or the site under investigation without some knowledge of the magnitude and sources of error in the data. This aspect becomes very important when concentrations of pollutants in a survey area approach an action level. Concentrations that exceed the action level by orders of magnitude require only limited QA as do those areas that contain no pollutant. The area where sampling intensity and increased QA becomes important are those areas where it is not possible to make a clear decision as to the need for and extent of action.

- *A table of proposed exposure scenarios will be provided.*

RAC distributed a summary and descriptions of the proposed scenarios to the panel in early March 1999 for their consideration and review. *RAC* is evaluating the three scenarios described in the final report. *Action Levels for Radionuclides in Soils for the Rocky Flats Cleanup Agreement*, dated October 31, 1996, along with seven additional scenarios that we have proposed and described at the RSALs meetings in January and February 1999. It is important to provide a broad range of scenarios for evaluation and to consider a number of likely scenarios before we decide on the final ones for the project. Selecting appropriate parameters for the scenarios depends upon a thorough review of the scientific literature, and full consideration of the range of reported values for the relevant parameters. After compiling data on the parameters, a distribution of values using Monte Carlo techniques can be generated. From these uncertainty distributions, appropriate parameter values for the scenarios are selected. In developing a particular scenario, we can use a high (or low) percentile of the distribution as needed to extend protection to people who might come into contact with the site in the near or distant future. Once a parameter value is selected from our distribution of values for use in a scenario, the scenario is considered fixed just as standards are fixed.

- ***RAC will provide a review of available computer models that may be used to calculate soil action levels (part of Appendix B).***
- ***Draft report documenting the acquisition, testing, and analysis of computer programs (part of Appendix B) will be submitted (For Task 2).***
- ***Testing and analysis of candidate computer programs will be completed and a brief technical memorandum documenting findings will be provided (Part of Task 2 draft report).***

These three milestone items were met with the distribution of the draft *Task 2: Computer Models* at the March 1999 panel meeting. This report considers soil action levels for the Rocky Flats Environmental Technology Site (RFETS): their purpose, formulation, and models and

302

methods for calculating them, with specific reference to computer programs that might be useful in the calculation. A part of the scope of this project is to review the calculations for choice of the parameters that were used in RESRAD, which is a DOE product developed specifically for implementing the agency's approach to residual radionuclides in soil. The goal of this report is a discussion and comparison of environmental assessment programs that might be used for developing soil action levels for RFETS; as required by the contract, the comparison includes RESRAD. This report summarizes and compares five prominent computer programs that are configured for environmental assessment: RESRAD, MEPAS, GENII, MMSOILS, and DandD.

RSALOP

Radionuclide Soil Action Level Oversight Panel

March 2, 1999

Jessie M. Roberson, Manager
U. S. Department of Energy - Rocky Flats Field Office
PO Box 928
Golden, CO 80402

Dear Jessie:

Work is progressing well on the technical review of the radionuclide soil action levels. *Risk Assessment Corporation* has submitted the Task 1 Report - *Cleanup Levels at Other Sites* for Panel review and comments. The Task 2 Report - *Computer Models* is forthcoming and will be transmitted to our newly formed Peer Review Team on March 12. Overall, the project is right on schedule but with considerable work remaining.

We would like to invite you to our first public meeting scheduled for Wednesday, March 10, 1999 from 6:30 - 9:00 p.m. at the Westminster City Hall. Enclosed is a copy of the agenda for your review. We look forward to introducing the project to the community at large and inviting their participation as we work through the remainder of the technical study. Informational materials have been developed to provide a brief project background to meeting attendees, including the enclosed fact sheet entitled *Planning for Tomorrow...Radionuclide Soil Action Levels at Rocky Flats.*

Panel members appreciate your support of their work on this project and hope that you can join us next week. We look forward to seeing you then!

Sincerely,

Hank Stovall, Co-Chair
Steering Committee
RF Soil Action Level Oversight Panel
(303) 466-5986

Mary Harlow, Co-Chair
Steering Committee
RF Soil Action Level Oversight Panel
(303) 430-2400 - Ext. 2174

Enclosures:
As Stated

cc:
RSALOP Members

4/8/99
Session

305

RADIONUCLIDE SOIL ACTI[illegible] LEVEL OVERSIGHT PANEL
MEETING [illegible]TTENDEES
April 8, 1999

NAME	ORGANIZATION	
✓ CARLA SANDA	AIMSI	[redacted]
✓ Joe Goldfield	RSALOP	
✓ BOB KANICK	CITIZEN - BOULDER	
✓ Tim Rehder	U.S. EPA	
✓ HEATHER BALSER	CITY OF LOUISVILLE	
✓ TODD MARGULIES	TM CONSULTING	
✓ Dean Heil	CSU	
✓ Steve Gunderson	CDPHE	
✓ VICTOR Holm	RFCAB	
✓ KEN STARR	CITIZEN/CONSULTANT (BOOZ·ALLEN+H	
✓ HANK STOVALL	CITY OF BROOMFIELD	
✓ Kathleen Meyer	RAC	
✓ Jill Weber	RAC	

307

RADIONUCLIDE SOIL ACTION LEVEL OVERSIGHT PANEL
MEETING ATTENDEES
April 8, 1999

NAME	ORGANIZATION	[redacted]		
✓ Laura Till	Facilitator			
✓ Ken Korkia	RFCAB Staff			
✓ Brady Wilson	CAB staff			
✓ Kara Dinhoffer	city of Boulder			
✓ Dave Shelton	Kaiser-Hill			
✓ John Corsi	Kaiser-Hill			
✓ Carol Lyons	Arvada			
✓ Russell McCallister	DOE/RFFO			
✓ Laura Brooks	Kaiser-Hill			
✓ Carl Spreng	CDPHE			
✓ DIANE NIEDZWIECKI	CDPHE			
✓ KATHY SCHNOOR	CITY OF BROOMFIELD			
Jeremy Karpatkin	DOE-RFFO			

308

of 3

RADIONUCLIDE SOIL ACTION LEVEL OVERSIGHT PANEL
MEETING ATTENDEES
April 8, 1999

NAME	ORGANIZATION	PHONE	FAX	E-MAIL
Rick Roberts	RMRS			

AGENDA

RSALOP Meeting - April 8, 1999
Broomfield City Building - Zang's Spur Conference Room
4:00 - 7:00 P.M.

4:00 - 4:15	OPENING	Hank Stovall
	• Introductions	
	• Minutes corrections/approval	
	• Sign-In	
	• Agenda Review	Facilitator
	• Group Agreements	Facilitator
4:15 - 4:25	CO-CHAIRS UPDATES	
	• DOE-RFFO Ex-Officio]	
	• Info follow-up to public meeting]	Hank Stovall
	• Task 2 Peer Review Comments	
4:25 - 4:30	RFCA Regulator Report	Tim Rehder, US EPA
4:30 - 5:15	WRAP-UP: SCENARIO DEVELOPMENT	Dr. Kathleen Meyer, Jill Weber, *RAC*
5:15 - 5:20	PUBLIC COMMENT	
5:20 - 5:30	BREAK	
5:30 - 6:40	PROJECT STATUS/PROCESS	Facilitator
6:40 - 6:45	PUBLIC COMMENT	
6:45 - 6:50	ANNOUNCEMENTS	
6:50 - 7:00	OTHER TOPICS/FUTURE AGENDA ITEMS/ ACTION ITEMS	Facilitator

UPCOMING MEETINGS/ACTIVITIES

- **PANEL MEETINGS: May 13, June 10, July 8, August 12, September 9, October 14, and November 11, 1999. Broomfield City Building, One Descombes Dr. - Zang's Spur/Bal Swan Conference Rooms (lower level) 4-7 p.m.**
- **Task 2 Report - Panel Comments due to *RAC* by May 8 (Final report due July 8)**
- **Scenarios - Recommendations due to *RAC* by May 13 meeting**

309

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	Carl Spreng	CDPHE	303-692-3358	303-759-5355
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C	Kathleen Meyer	RAC	970-229-0828	970-229-0829
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	Jessie Roberson	DOE/RFFO	303-966-2025	303-966-6054
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	Nanette Neelan	Jefferson County		303-271-8941
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C	Laura Till	Facilitator		303-447-0077

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310

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P	Carol Lyons	City of Arvada	303-421-2550x3292	303-431-3911
A	Lydia Stinemeyer	City of Arvada	303-421-2550	303-431-3969
SP	Lisa Morzel	City of Boulder	[redacted]	303-441-4478
A	John Tayer	City of Boulder	303-441-3005	303-441-4478
A	Benita Duran	City of Boulder	303-441-4205	303-441-4478
A	Kathy Schnoor	City of Broomfield	303-438-6363	303-438-6234
SP	Hank Stovall	City of Broomfield	303-466-5986	303-438-6296
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DATE	START	RECEIVER	TX TIME	PAGES	TYPE	NOTE	M#	DP
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	03:35 PM	JIM MCCARTHY	46"	2	SEND	OK	219	
	02:51 PM	CAROL LYONS	46"	2	SEND	OK	219	
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	02:54 PM	LISA MORZEL	25"	2	SEND	OK	219	
	02:54 PM	JOHN TAYER	26"	2	SEND	OK	219	
	02:55 PM	BENITA DURAN	25"	2	SEND	OK	219	
	02:56 PM	KATHY SCHNOOR	1'02"	2	SEND	OK	219	
	02:57 PM	HANK STOVALL	45"	2	SEND	OK	219	
	02:58 PM	TOM DAVIDSON	45"	2	SEND	OK	219	
	03:36 PM	HEATHER BALSER	44"	2	SEND	OK	219	
	03:00 PM	SAM DIXION	1'20"	2	SEND	OK	219	
	03:02 PM	MARY HARLOW	50"	2	SEND	OK	219	
	03:03 PM	DR NORMA MORIN	48"	2	SEND	OK	219	
	03:04 PM	S GUNDERSON CDPHE	45"	2	SEND	OK	219	
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	03:07 PM	DEAN HEIL CSU	1'04"	2	SEND	OK	219	
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	03:09 PM	KATHLEEN MEYER	1'19"	2	SEND	OK	219	
	03:11 PM	AUTAR RAMPERTAAP DOE	45"	2	SEND	OK	219	
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	03:13 PM	JESSIE ROBERSON DOE	24"	2	SEND	OK	219	
	03:14 PM	RUSSELL MCCALLISTER	25"	2	SEND	OK	219	
	03:14 PM	TIM REHDER EPA	42"	2	SEND	OK	219	
	03:16 PM	KEN STARR	1'11"	2	SEND	OK	219	
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	03:18 PM	JOHN CORSI	24"	2	SEND	OK	219	
	03:19 PM	DAVE SHELTON	55"	2	SEND	OK	219	
	03:20 PM	NIELS SCHONBECK	44"	2	SEND	OK	219	
	03:21 PM	JOHN SHEPHERD	51"	2	SEND	OK	219	
	03:22 PM	VICTOR HOLM	1'39"	2	SEND	OK	219	
	03:24 PM	KEN KORKIA RFCAB	47"	2	SEND	OK	219	
	03:25 PM	TOM MARSHALL	56"	2	SEND	OK	219	
	03:27 PM	LEROY MOORE	56"	2	SEND	OK	219	
	03:28 PM	DEANNE BUTTERFIELD	56"	2	SEND	OK	219	
	03:51 PM	WILL NEFF	5'23"	6	SEND	OK	219	
	03:30 PM	JOEL SELBIN UCD	44"	2	SEND	OK	219	
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314

P. 02

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[illegible]	[illegible]	CDPHE	303-692-[illegible]	303-759-[illegible]

915

RSALOP

Radionuclide Soil Action Level Oversight Panel

MINUTES

Radionuclide Soil Action Levels Oversight Panel
April 8, 1999 - 4:00p.m. - 7:00 p.m.
Broomfield City Building - Zang's Spur/Bal Swan Conference Rooms

NOTE: Minutes are presented in draft form and should not be quoted or distributed until receiving final approval by the Rocky Flats Soil Action Level Oversight Panel at its May 13, 1999 meeting.

Hank Stovall, Co-Chair, convened the regular meeting of the Radionuclide Soil Action Level Oversight Panel (Oversight Panel or Panel) at 4:10 p.m. and opened with the introduction of the following attendees:

Hank Stovall, City of Broomfield
Tim Rehder, US EPA
Russell McCallister, DOE-RFFO
Dave Shelton, Kaiser-Hill
Heather Balser, City of Louisville
Laura Brooks, Kaiser-Hill
Jeremy Karpatkin, DOE-RFFO
Todd Margulies, TM Consulting
Diane Niedzwiecki, CDPHE
Carol Lyons, City of Arvada
Steve Gunderson, CDPHE
Laura Till, Facilitator
Victor Holm, RFCAB
Carla Sanda, AIMSI
Rick Roberts, RMRS
Joe Goldfield, CCANW
Carl Spreng, CDPHE
Jill Weber, *RAC*
Dean Heil, CSU
John Corsi, Kaiser-Hill
Brady Wilson, RFCAB Staff
Ken Korkia, RFCAB Staff
Ken Starr, JEFFCO Resident
Robert Kanick, Boulder Resident
Kathy Schnoor, City of Broomfield
Kara Dinhoffer, City of Boulder
Kathleen Meyer, *RAC*

MINUTES REVIEW/APPROVAL

Minutes of the March 11, 1999 meeting of the Oversight Panel were reviewed and approved with the following modifications: Correction: On Page 4, within the Section entitled D&D, a sentence on line 8 begins with the words "Full air mass loading". It is corrected to read: "Foliar mass loading".

On Page 7, within the Panel Discussion section of the Plutonium Solubility section, the following is added: In response to a question from Tim Rehder, EPA regarding the bioavailability of Pu4 to humans, Dr. Grogan responded: Pu4 has very low solubility; i.e., it is essentially insoluble. Therefore, its bioavailability is also extremely low for transfer across the gut wall.

AGENDA REVIEW

Laura Till reviewed the Agenda as well as the Group Agreements. The agenda was modified slightly: The Co-Chair update relating to Task 2 Peer Review Comments was moved to become a separate discussion item following the RFCA Regulator Report. In addition, it was agreed that within the time allotted for Project Status/Process, the Panel would attempt to reach consensus on several of the scenario development issues.

CO-CHAIRS UPDATES - Discussion Lead: Hank Stovall

Public Meeting Follow-Up - Since the public meeting held on March 11, information has been provided to numerous entities. Letters along with press packets were sent to the following:

DOE-HQ

- T. J. Glauthier, Deputy Secretary Designate
- Gary King, Policy Advisor to the Assistant Secretary
- Jim Fiore, Dep. Acting Asst. Secty. for ER
- Mr. David Thomassen

COMMUNITY MEMBERS:

- Information packet to Paula Elofson Gardine
- Task 2 Report to Mr. Greg Murray, a local consultant

MEDIA

- The Co-Chairs met with Bernie Morson, Rocky Mountain News to provide in-depth information on the project. This may lead to a future story in the News.

NATIONAL ENTITY

- Sent letter and press packet to E. J. Bentz & Associates -- the group who is conducting a similar study at the Nevada Test Site

STORYBOARDS

- The large storyboards used for the public meeting are available for checkout from the AIMSI office for use by Panel members at presentations or briefings.

RFCA REGULATOR REPORT - Discussion Lead: Tim Rehder, EPA

At the recent meeting, the group discussed designing a chart that will compare the NRC requirements with EPA/CERCLA/RFCA requirements. A draft version will be prepared and will be distributed to the RSALOP when completed.

The group also discussed a report prepared by the Electric Power Research Institute (EPRI) on the comparison of models that may be used for dose assessment.

The group also discussed RAC's plans regarding use of a different model for the air resuspension than the current mathematical model within RESRAD. Each of the parties was tasked to discuss that approach with air modeling experts within their respective agencies. EPA has touched base with representatives at their Office of Radiation and Indoor Air and will provide some information to the modelers, who will in turn provide their opinion on the approach. Representatives plan to review this information in May 1999.

TASK 2 PEER REVIEW FEEDBACK - Discussion Lead: Hank Stovall, Co-Chair

The Peer Review Team has provided its review and written comments on the Task 2 Report to RAC. The Panel must now decide how it would like to use this material; i.e., would Panel members like to obtain the information before or after writing their own comments to the Task 2 Report. It is interesting to note that during a conference call with the Peer Review Team, members were unanimous in their decision not to share comments or information with each other prior to completing individual review and comments. The Team felt it was important that each member formulate his or her own thoughts and recommendations with no potential influence from other reviewers. As a result, each Peer Review Team member submitted individual comments with no name attached, and copies of the entire packet will now be distributed to the Team as a whole. Mr. Stovall invited input from RAC and the Panel as to how the RSALOP should handle input from the Peer Review Team.

Dr. Meyer indicated that it is her preference when serving as a peer reviewer to provide her own reviews of material without being biased with input from other reviewers. Dr. Meyer added that RAC plans to respond to the comments by May 8, which is prior to the due date for RSALOP comments. The point being made is that RAC may have already responded to issues addressed by the peer reviewers that may be subsequently addressed by the Panel.

Panel Discussion

- *Joe Goldfield indicated that it would be very helpful to have this input to review prior to formulating his comments, particularly since he is not extremely familiar with the components of some of the modeling programs.*
- *Bob Kanick stated that it would be helpful to have the benefit of input from technical experts with more experience in particular areas.*
- *Todd Margulies agreed somewhat with Dr. Meyer in that he prefers to "go it alone" when reviewing materials. Mr. Margulies asked whether or not there was a contractual agreement with the Peer Review Team regarding dissemination of the review materials.*

  Hank Stovall responded that there was no contractual agreement with the Peer Review Team regarding how they would be treated, and he reminded the Panel that each reviewer's comments were anonymous.

- *Dean Heil indicated that he saw no conflict with assuring that comments from the Panel remained independent in that the Panel is not serving the same purpose as the Peer Review Team. Dr. Heil also indicated his belief that it is imperative that the Panel review input from the Peer Review Team at some point in this process. In addition, if Panel members do not see those comments until after RAC has responded and after the Panel members have submitted their input, this may raise additional comments or concerns that could impede progress. Therefore, it may be helpful to review comments prior to providing input.*

PANEL VOTE:
By a show of hands, the Panel voted to distribute the Peer Review Team comments to the RSALOP and interested parties requesting copies.

Dr. Meyer then went on to briefly discuss comments received from the Peer Review Team. The comments were quite extensive and should be helpful. *RAC* is pleased with the level of effort. Obviously the reviews vary somewhat from one reviewer to another. As a note, for those members of the RSALOP who haven't experienced a peer review, it's good to remember that it is quite normal for comments to range everywhere from very supportive, to irrelevant, and some that may appear quite negative. An author responds to the comments and either revises the original work or explains why it may be irrelevant to the work. This set of reviews really encompasses that whole spectrum, with some very supportive input, some irrelevant, some editorial, as well as some that are quite negative. *RAC* has had extensive experience with peer review efforts, including several large studies reviewed by the National Academy of Science. Overall, the comments seem to support the work. At this time, *RAC* has divided the comments into three categories. Although *RAC* does want to respond to the input, the project schedule and budget must be considered when structuring responses. As a result, *RAC* proposes addressing the comments by grouping them into the following three categories:

1. Relevant, supportive comments - *RAC* will make changes to the report without direct comment.
2. Irrelevant comments - Comments will be written down with a notation that they are not relevant to the task, with little or no additional detail provided by *RAC*.
3. Legitimate technical concerns/clarifications - *RAC* may not agree with some, so it is important to provide some level of detail why they will not accept their input.

Given the resources at hand, it is likely not possible to write a detailed paragraph on every comment received. *RAC* believes that the categories that really deserve detailed explanation are those legitimate, technical concerns that *RAC* may not agree with. It is important that the reviewers and Panel members understand why these comments are not being incorporated. Dr. Meyer asked for feedback from the Panel as to this approach to comments.

Panel Discussion

- *Todd Margulies concurred with this approach. However, with the Category 3 input, what happens if Panel members believe that legitimate technical concerns should be looked at, when RAC has responded that they will not be incorporated?*
  Dr. Meyer responded that comments are due to them by May, with the final report due in July. That will provide an opportunity to clarify these types of issues or areas of concerns.
- *Bob Kanick asked for confirmation from Hank Stovall that in the event of an issue as described by Todd Margulies, the issue would be resolved by the Panel as a whole as opposed to individual members.*
  Mr. Stovall confirmed that this would be the case and reiterated that later in the agenda the Panel will be discussing Panel process and decision-making.
- *Ken Starr asked for clarification on the responses; i.e., will a brief explanation be provided for those comments that RAC believes are either irrelevant or that they don't agree with.*
  Dr. Meyer indicated that RAC will try to provide some clarification wherever possible and wherever it may be helpful for Panel understanding.
- *Hank Stovall reflected on in his experience as a member of the Health Advisory Panel: its work has been criticized for sending experts off to gather more and more information, which adversely impacted budget and schedule. Since it is essential that this study be completed within the allotted budget and schedule, the Panel must carefully consider what is asked of the technical contractor. Mr. Stovall suggested that we adopt the recommended approach to this first report, and if it needs modification, the Panel will consider changes for the next report.*

PANEL VOTE:
By a show of hands, the Panel approved *RAC*'s approach to grouping and responding to comments within the above 3 categories.

✔ ***Action Items:***

- ***AIMSI will transmit copies of the Peer Review Team comments to the RSALOP and interested parties.***

- ***Panel comments are due to Carla Sanda, AIMSI, by close of business May 7, 1999. Those comments will be compiled and delivered to RAC representatives at the May 13 meeting.***

WRAP-UP: SCENARIO DEVELOPMENT* - Discussion Lead: Dr. Kathleen Meyer, RAC
*Copies of the presentation are available by calling Anna Corbett, AIMSI, 303-456-0884.

Dr. Meyer provided some updates -- at the last meeting RAC received comments to the Task 1 Report, including some from DOE-RFFO. Written copies of responses were distributed at the meeting.

The Task 1 Report has been revised as a Draft Final. The report is currently undergoing an internal review and is due May 8, 1999. It is likely that the report will be available prior to this date. By the May meeting, the Task 6 Report: Soil Sampling will be available as a draft. David Thorne, a member of the RAC team who attended an earlier meeting, will be at the May meeting to discuss this report.

Dr. Meyer moved on to finalization of scenario development with a focus on wrap-up of issues dealing with breathing rates, followed by additional discussion regarding RAC's recommendation of final project scenarios, with the goal of achieving consensus on final project scenarios. Actual write-up of the scenarios and associated parameters will be included in the Task 3 Report, which is due in July.

Dr. Meyer began the discussion by stressing that breathing rate is a key parameter of any scenario and has been an intense discussion topic. Joe Goldfield has proposed a scenario with particular breathing rates. In fact, as a follow-up to information presented by Mr.Goldfield, Dr. Meyer met with him and obtained copies of a report that was referenced in several discussions. RAC representatives carefully reviewed information in the referenced-document and compared it to data that has been previous discussed.

Dr. Meyer reflected that it is extremely important that the studies reviewed in the open literature and the values taken from those studies are correct and interpreted correctly. As a result, she contacted Dr. Loren Cordain, a nationally known physiologist at Colorado State University, with more than twenty years' experience in the area of breathing rates. Dr. Meyer met with Dr. Cordain and reviewed RAC's findings, including uncertainty distributions and interpretation methods. After careful analysis and discussion, Dr. Cordain concurred both with RAC's approach to this issue and how the information was being interpreted and used for this project. A copy of a memorandum from Dr. Cordain was distributed that provided specific information on pulmonary function. The memo also summarized breathing rates that Dr. Cordain has observed in his research and noted in literature. These breathing rates range from resting rates for adult men and women to values for maximal exercise in very healthy individuals. Dr. Cordain stressed that the rates recorded during maximal effort would only be seen in very healthy, relatively large individuals and that those rates could only be sustained for very brief periods of time -- typically 1-3 minutes. This discussion was very helpful and served to reinforce Dr. Meyer's confidence in the overall approach to this issue.

As an added note, Dr. Meyer reported that Dr. Cordain is well known in his field and has been widely published, including the New York Times. A crew from ***Dateline NBC*** was recently at CSU to film Dr. Cordain and highlight some of his work for an upcoming episode.

RAC has developed recommended breathing rate distributions that are included in several recommended scenarios. In all cases, RAC will consider the three scenarios identified in the Rocky Flats Cleanup Agreement (RFCA); i.e., Residential, Open Space, and Office Worker. RAC is now proposing seven additional scenarios:

- Three scenarios within a "restrictive" classification: current onsite worker, office worker, and recreational land user
- Four scenarios within a "Nonrestrictive" classification: rancher, infant of rancher, child of rancher, neighborhood resident.

Restrictive indicates that the time on site is limited -- an individual may be on-site only part of the time, whereas non-restrictive indicates that the referenced individuals could have unlimited time on the site. For this project, RAC is most interested in a non-restrictive scenario. It is important that the critical scenarios represent a conservative, yet plausible exposure. Because this is a prospective study (looking into the future), with the goal of protecting future individuals from radiation exposure, it is appropriate to bias some parameters towards the "high side", but still remain within the range of possibility. The bottom line is that if this critical scenario is protected, it can be assumed that all others individuals will be protected.

After reviewing the literature and other technical information, and discussing and considering Panel comments, RAC is recommending that the following 3 scenarios be dropped from the study: office worker, recreational land user, and neighborhood resident. These scenarios are very similar to the 3 scenarios already included within the RFCA effort. The next recommendation is that for some of the key parameters -- particularly breathing rates - the 95% percentile of the distribution of breathing rates be used. The remaining scenarios, then, would consist of Residential, Open Space, Office Worker, Current Onsite Worker, Rancher, Infant of Rancher, and Child of Rancher.

One of the first discussions on scenarios included a spreadsheet that broke down an individual's day by activity level and duration. Breathing rates were assigned to the individual based upon real values in the literature. In other words, if a person were sleeping, breathing rates were established as 8-10 liters/minute. Values were also inserted for light and heavy activity, to come up with a fairly realistic individual. From that point, the information and scenario was used to generate Monte Carlo simulations for the distributions. Based upon existing breathing rate studies, RAC created distributions of breathing rates for active and sedentary adults, children and infants. Dr. Meyer then reviewed a graph showing probability distributions for three of the full-time scenarios -- the adult, child, and infant scenarios. In developing this type of graph, one looks at the probability that a certain breathing rate will occur, which results in a distribution of values, as shown on the graph. The criteria called for selection of the 95th percentile of this distribution. The graph represented annual breathing volumes in the 95th percentile, as follows: Adult: 10,800 m^3/year, Child: 8,600 m^3/year, and Infant: 1,900 m^3/year. One point of clarification was provided: these figures do not represent figures for all adults, children, or infants, but rather reflect breathing rates for selective scenarios based upon relatively active individuals. These figures also represent 24-hour residency for 365 days. This is very conservative, but represents what RAC feels is a safe way to approach this effort based upon the unknown factors in the future.

Dr. Meyer reminded the Panel that Joe Goldfield discussed and proposed a scenario at the last meeting based upon a breathing rate of <u>26,700 m^3</u>, whereas this scale ranges from <u>1,000 - 12,000 m^3</u>. Based upon information gathered to date and conversations with experts in this field, RAC representatives are not recommending Mr. Goldfield's scenario for consideration.

Dr. Meyer then reviewed a graph depicting the part-time or restrictive scenario breathing rates, again within the 95th percentile. Based upon being on site 35% of the time, the scenario's breathing rate for an on-site worker is calculated at 3,660 m^3/year.

Dr. Meyer also reviewed a table that compared key scenario parameters, including breathing rates, for the seven recommended scenarios. The table also included figures for soil ingestion, use of an irrigation water source, and ingestion of surface water. A summary of the seven recommended scenarios was distributed.

Panel Discussion
Dean Heil asked Dr. Meyer to convert the 10,800 m^3 to liters per minute.
Dr. Meyer responded that this represents ~20 liters/minute.

Jeremy Karpatkin requested clarification as to how much time the part-time on-site worker would be engaged in heavy labor.
Dr. Meyer responded that the assumption that the person was an outdoor worker, involved in 4 hours/day for heavy work. She went on to clarify that when looking at activity studies for construction workers, actual time spent in heavy labor is relatively small -- roughly 4 hours/day.

Joe Goldfield expressed difficulty in understanding the distribution diagrams in that RAC seems to indicate that the figures were not based on actual data but rather on calculations. Mr. Goldfield did not understand how calculations could reflect distribution in breathing rates of a population. It seems that the kind of data that should be examined is the distribution of breathing rates at one particular activity level for a large number of adults. For example, if one is trying to determine what the breathing rate should be at rest, Mr. Goldfield would like to see a chart that indicates the breathing rates for large numbers of individuals along with the distribution of those rates. People are very different from one another, and when large peaks are observed, it indicates that the data does not represent human beings. Breathing rates for human beings don't vary within very narrow bands, but likely vary from low to high by a factor of three. In order to make a decision as to what breathing rate to use for people at rest, Mr. Goldfield would like to see breathing rates for several hundred men at rest. That curve would then allow selection of a breathing rate for men at rest. Similarly, another distribution would be at some reasonable work levels.
Dr. Meyer responded that she would agree -- these graphs simply reflect the results of much in-depth evaluation. RAC has looked at numerous breathing rate studies (in fact, a packet of referenced articles was distributed to the Panel at an earlier meeting). These graphs reflect results gathered from numerous studies involving many different types of individuals. Literature values were used to set up individual scenarios and breakdown of time for each activity. A person at rest has a breathing rate of 8-10 liters/minute, for example. From that, they took the additional step of looking at the distribution of the scenarios -- the breathing rates from the scenarios. The graphs do not reflect a distribution of all the breathing rates throughout the population, but rather is a synopsis of in-

depth, detailed analysis. Dr. Meyer stated that RAC has a curve of distributions for breathing rates for adult men at rest and would provide that information to Mr. Goldfield.

Mr. Goldfield continued to reflect skepticism stating that human beings do not breathe within that narrow range.

Dr. Meyer responded that contrary to Mr. Goldfield's opinion, according to both the literature and Dr. Cordain, this is in fact the correct breathing rate for at- rest individuals. Dr. Cordain further stressed that it is virtually impossible to see a resting breathing rate of 40 liters per minute. Many different parameters are measured when looking at lung function. The 1951 study referenced and discussed by Mr. Goldfield reflected valid parameters, but simply measured different things. The one thing RAC is interested in is the "minute volume", which is what RAC calls the breathing rate -- the parameter needed here. It is really just a matter of knowing the correct parameter to use. The range of 8-10 liters per minute is within normal range.

Victor Holm asked if Dr. Meyer would agree that soil ingestion for a child is also correlated with age -- but negatively correlated? Dr. Meyer agreed. Mr. Holm went on to ask if we aren't also then looking at a combination of the two as almost mutually exclusive: a breathing rate of 8600 m^3/year for a 15-17 year old and a 1 gram per day for a 5-year old.

Dr. Meyer agreed. Jill Weber indicated that another option would be to divide the child into 2 scenarios. Children between the ages of 5-10 breathe at a lower volume (less lung capacity) than is seen when they reach the 15-17 year age.

Victor added that it becomes even more complicated, since the child's dose conversion factor would also vary with age. In other words, a 17-year old begins to have the same conversion factor as an adult. Mr. Holm's concern stemmed from the fact that we may be setting a scenario for a child that will be the critical scenario. If that is correct, fine -- but is it indeed the critical scenario?

Dr. Meyer responded that she would refer back to ICRP to see if they have conversion factors for children broken down by age. She indicated, however, that this is a very new area of research, with a lot of unknowns. An additional issue to consider is the incidence of geophagy (eating of dirt) in children. When that subpopulation is incorporated, it results in a high 95th percentile value. The concern exists that while we want something that is conservative, we don't want something that is implausible. One thing to look at is generation of a distribution without that subgroup of geophagy, which will look at a more normal population that ingests dirt in more typical ways. That would result in a drop in the 95th percentile value.

Robert Kanick's concern still centers on if you are selecting 95th percentile entities, or setting other factors in the scenarios discreetly, based upon some judgement -- you are, in effect, doing something deterministically. For example, suppose we had distributions for everything and then wanted to choose the 95th percentile for all of them, We virtually now have a deterministic study. So even setting some of these parameters as 95th percentile, you are going into a deterministic realm as opposed to a probabilistic realm. For something as sensitive as breathing rate, this is serious. Mr. Kanick reiterated that this is why he has been pushing for this to be a distribution of the probabilistic side of the analysis and not a discrete entity in the scenario side. Although he has received a reply from Art Rood, he will try to write a letter to better explain his thoughts. Another example is Victor's concern regarding the child. Again, the 95th percentile has been set on one end on breathing rate and on the other end -- soil ingestion -- they are at odds with each other; whereas, if they were incorporated into the study as distributions they could handle it probabilistically with no problem. Mr. Kanick asked that this issue be dealt with. This is a major concern, because ultimately if it is not handled probabilistically, you will likely have people arguing where that discrete value should have been set.

Dr. Meyer provided the following clarification: RAC did not select the 95th percentile breathing rate in the original breakdown in activities and time. So, for example, if the person is sleeping, RAC did not take a very high value, but rather took a reasonable mid-range that was not a 95th percentile value. RAC tried to do that in all cases when designing the scenarios. The thing that has been generated here is this: if one assumes that the individual scenario exists -- if the distribution is run 3,000 times and one selects from that, the result is this distribution. RAC is selecting the 95th percentile of that distribution for the scenario and hasn't just selected high values across the board. Jill Weber concurred and said that the program has some subjectivity built into the existence of the distribution for a rancher in that we are defining that a rancher is doing "x" thing for "x" hours each day and "y" thing for "y" hours each day. So there is already a bit of subjectivity within the building of the scenario. The production of those distributions is difficult in the first place. Using those distributions to represent something else is even more difficult. That's why RAC believes that selection of the 95th percentile value is a valid approach. The implication of choosing scenarios and selecting standards is that a single, standardized value is used.

Dean Heil said that in choosing these scenarios, it appears that certain pathways for exposure have been eliminated. For example, things like eating fish from a pond or groundwater scenarios are no longer part of the consideration. Will RAC provide an explanation and rationale for elimination of certain scenarios and exposure pathways in any documentation?

Dr. Meyer responded affirmatively that this type of information would be provided in the Task 3 Report: Inputs and Assumptions. This document in general will focus on the parameters that are most important, but other *parameters will also be addressed that could be considered, as well as the rationale for why they were not being considered.*

Ken Starr said that an earlier discussion indicated that using the 95th percentile value might be contrary to NRC and CERCLA guidance. Is RAC confident that the methodology selected is defensible?

Dr. Meyer said that the RAC team does feel it is defensible -- it's a process that was set up beforehand followed by calculations. This, too, will be documented.

Jeremy Karpatkin said that he assumes that in the next step RAC will look for and correct if any of the 95th percentile assumptions turn out to be mutually inconsistent for any actual existing individual. Mr. Karpatkin reflected that just from listening to the conversation, it might be possible to encounter a situation where the 95th percentile on one parameter makes it physically impossible to coexist with the 95th percentile on another parameter. He asked if RAC will be looking for that and correct for it.

Dr. Meyer stated that she feels confident with what they have and believe that the soil ingestion levels need to be looked at carefully to assure that they don't get into a situation where they are coming up with something that is just implausible.

Mr. Karpatkin went on to say that he was actually speaking to whether two conservatisms for any actual individual may be inconsistent.

Jill Weber replied that this concern goes right to the heart of the discussion: does the Panel believe that RAC needs to use a 7 year old child in terms of breathing rates to establish some consistency with soil ingestion? Dr. Meyer went on to say that based upon their experience, they would tend to break the ages of the child down into perhaps 0-1 and 2-6 and so on. On the other hand, the Panel and RAC must make some decisions and come to agreement as to numbers of scenario. Another possibility would be to separate the scenario into age groups and look at adult soil ingestion as well as children -- and perhaps look at more normal children rather than extreme cases.

Mr. Karpatkin added that in addition to omitting certain pathways, there are also certain pathways where RAC's scenarios come to different conclusions and presumptions than the Agencies; i.e., surface water ingestion and irrigation water sources. When the report is developed, will you explain why these differences exist?

Dr. Meyer indicated that surface water and groundwater issues are very complex. When originally designing this process, the scenarios were built apart from anything that had already been done because they felt that was the right approach. They continue to bump up against regulations and standards. If it is assumed that there is a rancher living with children, even though Woman Creek is usually dry, it is reasonable to assume that there may be some water present at certain times of the year. It is also reasonable, then, to assume that a child will play in the water or perhaps ingest some of the water. As a result, that is part of the scenario. RAC will try to clarify those differences.

Joe Goldfield asked if RAC plans to explain why they eliminated the 40 liters per minute provided in the1951 study as a breathing rate for young men at rest, since this number was part of the data in the well-known national document that used as a basis for the Clean Air Act? Has that simply been eliminated? Is there something wrong with that study?

Dr. Meyer indicated that the study was very good, and Dr. Cordain also reviewed its contents. The 1951 study measured breathing rate. In its extensive tables of data, the breathing rate is reported as minute volume. Those values that were reported correspond very well with other literature values. Those values represent a resting breathing rate of ~10 liters/minute. When referring to that table, it is important to note that the values are "flow rates". Dr. Cordain explained that there are many different parameters measured when evaluating lung function. One parameter is air going in and out -- especially with the masks used at the time. Studies done today use different equipment. Dr. Cordain went on to say that there is air going in, but there is just air flow out, which accounts for the high levels. Those levels are not the same as "breathing rate". The later study that refers to the 1951 study looks more at air flow in and air flow out. They really are not reporting "breathing rates". They report both inspiratory air flow and expiratory air flow, which is more of a flow rate, as opposed to a "breathing rate" -- i.e., the volume of air that we take in each minute. Dr. Cordain reiterated that he has never seen a resting breathing rate of 40 liters per minute.

PUBLIC COMMENT

Dave Shelton had two questions: He understands that RAC will run the scenarios that were part of the RFCA. Will they be run with the same values as were used in the original evaluation?

RAC is running those values just as they were reported in that study. Jill Weber clarified that here we are only talking about scenario parameters. However, with respect to the other input parameters to RESRAD; e.g., mass loading or other parameters, it is likely that those scenarios will be run with some additional parameters having stochastic distributions associated with them.

Mr. Shelton went on to reflect that RAC has said several times that the purpose of many of the things they have been doing is to select the conservative value. Can RAC quantify the level of conservatism it is trying to achieve?

Dr. Meyer responded that they want to be sure that the critical scenario is protective of people's health -- RAC has defined a conservative approach for breathing rate by looking at standard observed breathing rates seen in the population for different at different times, generating a distribution, and then selecting the 95% percentile. In a sense, that is probably their estimate for conservatism.

Mr. Shelton added that it seems that RAC is adding conservatism to conservatism with each of the parameters selected, so in the end you have some sort of added conservatism factor. What does RAC estimate that factor to be?

Jill Weber responded that there is some subjective conservatism here, but there is also some that is qualitative rather than quantitative, simply by definition of a scenario. RAC is not able at this moment to state what the quantitative level of conservatism is -- there may be some point in the future when that is possible -- but not at this point in the project.

Hanks Stovall recommended that RAC consider using any modifications that the agencies may propose as they continue to evaluate original recommendations.

BREAK

CONTINUATION OF WRAP-UP: SCENARIO DEVELOPMENT

Panel Discussion

Bob Kanick - Mr. Kanick stated that he likes the scenarios and the thought processes behind those scenarios -- and he thinks the Panel can say that a certain scenario is reasonable. But after all the parameters of a scenario is established, the fact remains that you have created these distributions -- or volumes -- representative of those choices. Rather than choosing the 95th percentile, you would eliminate all these questions regarding the discrete and subjective nature of choices if you would simply take them and put them into a stochastic analysis. He then asked Dr. Meyer if she would agree.

Dr. Meyer responded that we must remember that a scenario only represents an individual -- not a population, so a population's distribution of breathing rates for an individual cannot be put in. What RAC did is: if breathing rate were measured for a year, the result would be a distribution of the individual breathing rate, which would be narrower or more discrete than the total population's distribution. A scenario really only represents an individual

Mr. Kanick disagreed -- everything we have done so far has been based on a range. The scenario is in principle an individual represented in ranges -- a rancher is a range of all the possible things that could occur to a rancher. You make reasonable statements regarding his time and activities on the site, and then you develop a distribution. He went on to say that although he understands Art Rood's concern regarding this, he still doesn't see why those ranges cannot be incorporated into the stochastic analysis as much as possible using ranges. This approach would eliminate everyone's concern regarding the clashing of the 95th percentiles, the choosing of discrete numbers -- because that is the whole purpose of performing a stochastic analysis: elimination of subjectivity. Mr. Kanick raised this as an issue and requested comments from either Art Rood or George Killough.

Dr. Meyer responded that this has been addressed in several meetings. The distribution of breathing rates in a population cannot be evaluated in a way that will say for certain what the distribution of breathing rates is. By using a total population distribution we are not getting down to a specific scenario. The bottom line is that we do not know what the future will bring -- we are not trying to represent the future populations that may live there. We are simply selecting a few individuals -- we call them "scenarios" -- and set those up as standards against which to measure the soil action levels. We want to try to find an individual that will be protective of other people's health. We are not trying to look at the whole total future population -- we don't know what that may be. It's like establishing a standard -- there is subjectivity in every branch of science -- in DOE standards, in EPA standards, in every standard. Those are based on literature values, and somebody then makes a good, scientifically educated guess. There is subjectivity in using distributions. Dr. Meyer emphasized that scenarios are like standards -- we are not trying to duplicate a population, but rather choose individual scenarios that represent a possible exposure in the future. We simply assign certain characteristics to that individual.

Joe Goldfield - Mr. Goldfield stated that his concern is quite different from others. He's not interested in the statistical nature of the process or the so-called science of the process. To him, the problem is very simple -- if there are 5,000 people living on the cleaned up soil after running through our soil action levels at Rocky Flats -- when the soil action level *is set, how many of that 5,000 will be included in our protected population? Mr. Goldfield strongly stated that he is not concerned about somebody's worry that the 95th percentile may be too restrictive -- if we truly represent health for 95% of those people, we will have protected something like 4,500 of the 5,000. In other words, we still will have allowed 500 people to be over-exposed to plutonium at levels higher than we think is safe. The ideal thing would be to set a standard where all 5,000 people are ensured of no health problems, so that the discussion of a percentage is a "red herring". Mr. Goldfield went on to say that he has no desire to see 50% of the people protected and the other 50% over-exposed. In setting the breathing rate, he still doesn't' have the feeling that 4,500 of the 5,000 people are included within the level of breathing rate that will be protective of people being overexposed to plutonium. The other stuff is just a bunch of nonsense and double talk. He added that he does not have the feeling that we know that we have a number that will give us that but rather has a feeling that we haven't because the number being used is 20 liters per minute.*

Dr. Meyer indicated that this concern is one that the Panel probably needs to handle. She has expressed RAC's views on these issues and has collaborated with a recognized expert. This needs some resolution from the Panel.

PANEL VOTE:

Although there were still issues to resolve in specific details, by a show of hands, the Panel approved the scenarios recommended by RAC.

The Facilitator then moved to some of the concerns within specific scenarios:

The first one posed for discussion was the broad range of the child (aged 5-17). The facilitator asked Victor Holm to voice his concerns with that component. Mr. Holm responded that one solution would be to describe the infant as being 0-4 or perhaps determine the age of the 314 outliers, then put that into the infant. It may then be prudent to remove some of the outliers from the child, with the breathing rate remaining the same. This may result in something more reasonable.

Several other recommendations and/or questions were posed:

From the literature, what is the age span for people with geophagy -- and do they every outgrow it?

Dr. Meyer responded that she would have to review the literature for specific information.

Keep the ages of 0 - 2 and look at a more discrete age range for a child -- and then move into the adult scenario. That may focus things a bit better. Perhaps the child could range from 7 - 10.

Jill Weber mentioned that another idea might be to look at the geophagy age for children and then choose that age for the child.

Given the concerns with the age breakdown of infants vs. children vs. adults, Hank Stovall requested that the Panel come to some agreement this evening with the first 5 scenarios and perhaps decide on the last 2 (those dealing with infant and children) at a later time when more information is available.

Specific direction for RAC would be: Determine typical age for occurrence of geophagy and then create a scenario for either the infant or child, depending upon where it occurs.

Bob Kanick: One of the sources of the dilemma is that in the distribution of breathing rates for a child from 5-17 years old -- if rather than choosing the 95th percentile, you would simply put that distribution into the stochastic part of an analysis, would not this problem go away?

Dr. Meyer responded that it's really how one defines scenarios. In this whole process of setting up soil action levels, the exposure scenario acts as the standard, so you have a standard out there and now you are going to look at the soil concentrations and soil action levels and measure it against that standard. If the standard is varying, as with the soil concentration, what is the outcome? It's like having a standard that changes, and that is not a standard.

Jill Weber added that this would amount to inputting subjective uncertainty into a calculation that could be entirely quantitatively uncertain. Because the scenario is subjective, if a distribution of breathing rates for a scenario is input it introduces subjective uncertainty into a calculation. The analysis would provide very little quantitative information about that calculation.

Dr. Meyer said then that instead of the rancher scenario having a breathing rate of 10,000 cubic meters per year, the next run may be 5,000 or 15,000 -- in the meantime one is trying to compare that scenario against the soil action level, so every time this is run it would be very difficult. There would be no standard of comparison.

Bob Kanick went on to emphasize that the standard should be the criteria with which you set up the distribution--not the numbers themselves. There are standards out there, but one of the purposes of this study -- which is trying to break the mold of the way things are done -- is to say let the standard be the criteria with which the individual in the scenario is lefined, and then based on those standard concepts (like 2 hours of difficult work in the day) develop the range in the analysis.

Dr. Meyer responded that is basically what they have done -- they have developed uncertainty analysis on all of the data out there -- so they have used uncertainty distributions to select these parameters.

Victor Holm then said that he believes he has been mistaken in his perception of the scenarios: he originally thought the scenarios were a "fishing expedition" to find the most critical receptor -- but now he sees that's not what they really are. The reason he was mistaken is if we were looking at a site where we weren't looking a 1,000 years but only 100 years, we could come up with a scenario that would fit the most likely use of that land. The problem here is that we are looking at such a long period of time that we are not able to pick just one scenario. What is the real purpose of the scenarios?

Dr. Meyer responded that we have multiple scenarios because we really don't know what the critical scenario will be. Although we have to "guessestimate", we want to be sure we have covered the most possible and logical areas of concern. Also, we must remember that scenarios do not represent "real people". We don't know this rancher -- it is not a real person, so we can't use population statistics that will say anything about this individual. This is a person that is being fabricated who may exist in the future, and so to say that this person's breathing rate is going to vary stochastically really goes against how we're defining the scenarios.

Hank Stovall asked what portion of the population is prone to geophagy?

Dr. Meyer responded that it is a very, very small percentage.

Mr. Stovall went on to recommend that RAC check out the statistics surrounding geophagy, but does not believe the overall study should be designed to accommodate a very small part of the population that would in turn skew the outcome of the project.

Joe Goldfield then reiterated that he doesn't believe higher mathematics is required to set a breathing rate that would represent a very large portion of the population. He added that he hasn't seen a lot of data that would help to determine the breathing rate that may be needed to protect a large proportion of the population and to him, that is the key question. Mr. Goldfield corrected an earlier statement he made when discussing the 95th percentile: he should have said it rotected 4,750 people out of 5,000 instead of 4,500.

Carol Lyons supported Hank Stovall's query regarding what percentage of the population actually has geophagy and how that should affect the scenarios.

Jeremy Karpatkin brought up a concern -- and indicated that he believed that he is speaking for Jesse Roberson. There is an expectation from the Department of Energy that RAC will indeed critically analyze the three scenarios in the RFCA, take a look at the parameters, "kick the tires", and tell the agencies if the numbers are, in fact, correct. Mr. Karpatkin urged the Panel that if this is not the expectation, a discussion should be scheduled to decide that affirmatively. If there is any confusion on this issue, a conversation should take place between the Panel and RAC.

Dr. Meyer responded that they have talked about this. RAC is not going to analyze what EPA or DOE has done -- that is not part of the effort. RAC has developed scenarios very similar to those three, so it is RAC's recommendation to use those three scenarios as opposed to developing and using three scenarios that are similar to those used in the RFCA. RAC is six months into this project and is making great strides. Dr. Meyer stated that she believes we need to put this into perspective. RAC is certainly going to continue to investigate these scenarios, but the scenarios are a very small part of the overall study.

Jeremy Karpatkin indicated that there are numbers associated with those three scenarios. He went on to say that what he thought RAC said was that they were not going to assess whether or not they were the correct numbers but were simply going to assume they were the right numbers but plug in your own values for your own scenarios. I believe it is the Agency's expectation that RAC will indeed take a look at the values associated with those numbers, and if RAC believes the numbers the Agencies used were not correct, then RAC would use its numbers. For example, you are going to come up with a breathing rate that may be different from what was originally used. I would assume that you would use those numbers. Again, I am not in a position to direct your work, but am simply flagging a concern for the Agency.

PANEL VOTE:

he Facilitator again checked in with the panel and asked for a show of thumbs regarding approving the first five cenarios as they currently stand. The Panel approved that approach.

The Facilitator then suggested that the Panel begin discussing the issue of breathing rate -- in particular the concerns and discussions surrounding the 95% percentile approach. Is the 95th percentile acceptable? The Facilitator then asked for a show of thumbs to either approve or disapprove simply going with the 95% percentile approach and associated numbers. The vote did not result in support; therefore, the Facilitator opened the meeting to further discussion of these areas.

Dean Heil said that after hearing Mr. Kanick's suggestion, it seems to him as well that it should be possible to perform a statistical distribution of each of these parameters, while staying within a certain scenario. For example, with a rancher scenario you would have an expected distribution of breathing rates for that adult rancher and an expected distribution of time spent on the site, and so on. It is not clear to Mr. Heil why it is not possible to run multiple simulations within a given scenario. With all the computer analysis designed to handle these types of calculation, why not run 1,000 simulations for the rancher scenario and for each one of those simulations, randomly select a value for breathing rate, exposure time, etc. for the distributions. Each one of those 1,000 simulations would then represent an individual rancher. Why not do that, because it seems that you would then have some distribution out of those 1,000 simulations that could be worked with. You may be able to then get some idea of how far out the determination is -- or how "representative" that final determination is. What we want in the end is some idea of the distribution of that final calculated number. Again, if we pick the 95th percentile and add those together, does that really represent the 95th percentile, or if not, what does it represent?

Dr. Meyer responded that they would have to consult with other team members. Because he is aware of these concerns, Dr. Killough is performing some calculations that will look at the distribution of breathing rates within an entire population and going through that whole process to calculate soil action levels. One of the things that will come out is that, of course, the soil action level increases since you are now looking at a distribution within a population -- you are not looking at this conservatively. When you look at it conservatively, you may arrive at a lower soil action level. When you look at the total distribution in this way, everything will be shifted up to a higher soil action level. There are many different things to consider with the scenarios, with one being that you run the risk of losing your standard. We can do multiple runs within a scenario. In fact, Jill Weber performed 3,000 runs on the breathing rate distribution for the rancher, so it is not as though RAC is not doing this probability distribution in establishing these scenarios. All RAC is saying is that once we have done that, and we arrive at a value, then we consider them to be fixed and continue with the process. So we're not simply picking breathing rates at random -- thousands of simulations have been run to come up with the parameters. But once we make the decision on the numbers, we will consider it to be a fixed standard to compare against soil action levels.

Jill Weber added that an important thing to remember is that although the breathing rate may be represented as the 95th percentile, it is still a subjective distribution since RAC selected a rancher, then entered times for residence, work, etc. So although we are calling it a 95th percentile and are representing it as a distribution, it is a subjective distribution. You run into trouble when combining a subjective distribution with other very quantitatively established distributions like the ones we will likely use for parameters such as mass loading.

The Facilitator then asked RAC representatives if they are saying that this approach really doesn't work scientifically.

Ms. Weber responded that they would rather not do it and cannot agree to it without further discussion with the rest of the RAC team.

The Facilitator then asked the Panel's suggestions as to what are the specific things that RAC should work on so that the Panel can reach consensus at the next meeting.

Panel Discussion

Joe Goldfield - Mr. Goldfield said that from his perspective the thing that is missing in trying to make a decision is that we are trying to mix too many things in one curve. What we need are several distributions that are not artificially arrived at, but developed from available data of things like: a curve of the adult male population and its breathing rate at rest. Mr. Goldfield would like to see a distribution curve of the breathing rate of adult males at rest. Mr. Goldfield added that he would like to see a couple of work levels -- light activity, heavy activity, with a second curve and third curve that provides a distribution of adult males with their breathing rate. That type of information would make it possible to easily make decisions.

The Facilitator indicated that RAC representatives have that information and will provide it to Mr. Goldfield.

Hank Stovall - Mr. Stovall stated that the 95th percentile certainty is a terminology being used that indicates to the public that we are about 95% certain of all of the components that went into that distribution. He added that from his standpoint as a public official, he will not settle for one percent less than the 95th percentile.

Ken Starr - Reflected that it is extremely important that all the players be at the table. For optimal effectiveness, there are some questions that can't be answered. It looks like we may need to defer some decisions until the next meeting when RAC has the key staff available to address questions and concerns.

Dr. Meyer responded that RAC representatives have been here to discuss these issues, and she is not certain that it is effective use of contract dollars and time to bring people back again and again since it has already been discussed at numerous meetings.

Victor Holm - Reaffirmed what Hank Stovall said in that these are probability distributions, so you can't take 5,000 people and assume that 4,700 are protected while the remaining 250 are not protected. These are probabilities and are not real histograms of actual people.

- ✔ ***Action Item: RAC will bring data to next month's meeting regarding geophagy***
- ✔ ***Action Item: RAC asked that the Panel record their concerns and transmit to RAC to be addressed at the next meeting. Concerns should be forwarded to Carla Sanda, AIMSI, by close of business on Thursday, April 19, 1999.***

PROJECT STATUS/PROCESS - Discussion Lead: Hank Stovall, RSALOP Co-Chair

There has been some concern reflected by Panel members regarding the process by which the Panel makes decisions. Mr. Stovall then asked for input and clarification from the Panel.

Facilitator - Laura Till clarified that the Panel had agreed earlier to make decisions by consensus, or if the Panel agreed that it was in a deadlock surrounding a decision, they had agreed to move to a majority decision. She went on to explain that the concern she had heard was that RAC may hear someone's individual concern, and perceive that concern to be one reflected by the Panel as a whole and would then move to apply considerable effort and resources to deal with it. After talking to RAC earlier this evening, they agreed that if they were confused about whether a concern reflected an individual or Panel concern, they would ask the Panel for clarification and direction to assure that there was no confusion.

Panel Discussion

Bob Kanick - Proposed that two areas be brought before the Panel: 1) Individual concerns regarding any of the task items; e.g., regarding Task 1 RAC had addressed two individual's comments. These were individual comments versus "Panel" comments. Because in general this should be a Panel-wide approach, he believes that we need to generate a process for comments to be agreed upon by the Panel as a whole. For example, with the issues being raised this evening: individual Panel members will transmit individual concerns, followed by a response from RAC. The comments and responses would then be discussed and agreed upon as a Panel. All comments should come before the Panel, who would then determine whether or not they should be addressed by RAC -- particularly time-consuming efforts -- before being incorporated into final documents or decisions.

Jill Weber indicated that it would be more expeditious for the Panel to review comments prior to sending them to RAC to determine whether or not RAC should focus time and effort on those issues.

Todd Margulies said that the current process in place does not support that approach. If comments are sent directly to AIMSI for distribution to RAC, the Panel has no opportunity to determine whether or not RAC should spend time on those comments.

Hank Stovall said that there are probably two categories of comments: brief comments that can be quickly addressed by RAC with little extra effort and ones that should be settled by the Panel as a whole who may in turn ask RAC to react. The real challenge is how do we address comments and concerns as a Panel to assure timely delivery to RAC?

Victor Holm - suggested that any Panel member could send unsolicited comments to RAC via AIMSI, but that RAC can spend as much time as the comment is worth.

Bob Kanick said that John Till briefly discussed this at the last meeting -- in general RAC representatives can evaluate how much time will be required for a comment and will discuss those items with the Panel that will require a substantial effort. The question remains, however: let's say that a Panel member sends comments to RAC. RAC does not respond to the comment. The originator is not satisfied with RAC's action. Then it becomes the Panel's responsibility to determine the final outcome. So it is only issues that Panel members feel are significant and have not been addressed. Mr. Kanick proposed that Panel members send comments/concerns to RAC, who will decide how they will be addressed. The only *time the Panel would need to be involved is if the originator does not feel that his or her concern was adequately addressed. In that case, the Panel as a whole could place the subject on the agenda for discussion and resolution.*

Facilitator - The resolution to be decided upon regarding process is: Panel members will continue to submit written comments/questions/concerns on reports to RAC through AIMSI. When reviewing the next version of the report, if the originator does not feel that their comments have been adequately addressed, the issue can be placed on the agenda for Panel resolution. The Panel was in agreement with this approach with one modification:

Todd Margulies - Reflected that there has been a "paper trail" established for DOE and Agency comments, and peer review comments, but no paper trail has been established for comments received from Panel members. (RAC has indicated that they have not responded in writing to Panel comments but have simply incorporated those comments into the report.) Mr. Margulies recommended that RAC make an effort to develop a "paper trail" for comments received from the Panel to provide a record for Panel comments and resolution. Responses don't have to be detailed, but at least some feedback should be provided to the Panel. RAC agreed that any written comments received from the Panel would be provided with written responses.

✔ **RAC will provide written responses to the comments received from Panel members on Task 1.**

PUBLIC COMMENT

None

FUTURE AGENDA ITEMS/ACTION ITEMS

David Thorne will be at the next meeting to discuss the Soil Sampling Report.

✔ *Action Item: KEY DATES FOR PANEL ACTIONS*

Task 1 Report - Comments due to RAC by March 11 (Final report due May 8)

Task 2 Report - Comments due to RAC by May 8 (Final report due July 8)

Scenarios - Recommendations due to RAC by May 13 meeting

MEETING WAS ADJOURNED AT 7:00 P.M.

Upcoming Meetings & Activities

All regular meetings will be held from 4 - 7 p.m. at the Broomfield City Building, One Descombes Dr., Broomfield, CO - Zang's Spur/Bal Swan Conference Rooms, on the following dates: May 13, June 10, July 8, August 12, September 9, October 14, and November 11, 1999.

NOTE: The previously-elected Steering Committee, made up of: Mary Harlow, Hank Stovall, Leroy Moore and Lisa Morzel routinely meets each Monday prior to the regularly scheduled meeting to plan the agenda. Panel members may attend this meeting. To confirm meeting date, time and place, please contact either Mary Harlow or Hank Stovall.

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RE: RSALOP MEETING MINUTES 4/8/99

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A	John Tayer	City of Boulder	303-441-3005	303-441-4478
A	Benita Duran	City of Boulder	303-441-4205	303-441-4478
A	Kathy Schnoor	City of Broomfield	303-438-6363	303-438-6234
SP	Hank Stovall	City of Broomfield	303-466-5986	303-438-6296
P	Tom Davidson	City of Louisville	303-666-6565	303-673-9043
A	Heather Balser	City of Louisville	303-666-6565	303-673-9043
A	Sam Dixion	City of Westminster	303-426-1202	303-429-5113
SP	Mary Harlow	City of Westminster	303-430-2400x 2174	303-650-1643
	John Student	City & County of Denver	303-285-4067	303-285-5621
	Dr. Norma Morin	CDPHE	303-692-2645	303-782-0188
E	Steve Gunderson	CDPHE	303-692-3367	303-759-5355
	Carl Spreng	CDPHE	303-692-3358	303-759-5355
P	Dean Heil	CSU	970-491-6516	970-491-0564
C	John Till	RAC	803-536-4883	803-534-1995
C	Kathleen Meyer	RAC	970-229-0828	970-229-0829
	Autar Rampertaap	DOE HQ	301-903-8191	301-903-3877
E	Jeremy Karpatkin	DOE	303-966-2080	303-966-6633
	Jessie Roberson	DOE/RFFO	303-966-2025	303-966-6054
	David Thomassen	DOE		Mail
	Russell McCallister	DOE	303-966-9692	303-966-3710
E	Tim Rehder	EPA	303-312-6293	303-312-6067
	Tim Lutes			Mail
P	Ken Starr	Citizen	303-694-4159	303-694 7367
	Nanette Neelan	Jefferson County		303-271-8941
	John Corsi	Kaiser Hill	303-966-6526	303-966-6153
	Dave Shelton	Kaiser Hill	303-966-9877	303-966-6214
P	Niels Schonbeck	Metro State	303-556-8327	303-556-5399
A	John Shepherd	Physician/Soc Resp	303-650-4460	303-650-4403
A	Victor Holm	RFCAB	303-989-9086	303-980-9076
SP	Bob Kanick	Citizen of Boulder	303-444-0049	508-546-2452 call
E	Ken Korkia	RFCAB	303-420-7855	303-420-7579
A	Tom Marshall	RFCAB	303-444-6981	303-444-6523
SP	LeRoy Moore	RMPJC	303-444-6981	303-444-6523
	Deanne Butterfield	RFLII	303-940-6090	303-940-6088
	Will Neff	RFLII	303-940-6090	303-940-6088
P	Joel Selbin	UCD Chem Dept	3[redacted]	303-492-5894
P	Todd Margulies	TM Consulting	303-279-6699	Mail or e-mail
P	Joe Goldfield	CCANW	303-321-7276	Mail
C	Laura Till	Facilitator		303-447-0077

(SP=Steering Committee Panel Member, P=Panel Member, A=Alternate, E=Ex-Officio, C=Contractor), List Revised 5/4/99

5460 WARD ROAD, SUITE 370, ARVADA, COLORADO 80002, 303-456-0884, FAX: 303-456-0858

329

- REMINDER -

All comments regarding the Task-2 Report

are due to either

Anna Corbett or Carla Sanda

by COB Friday, May 7, 1999.

Thanks.

330

332

Rocky Flats Soil Action Level Oversight Panel Meeting

Kathleen R. Meyer
Jill M. Weber

April 8, 1999

Risk Assessment Corporation

Topics

- Responses to DOE comments
- Coming up :
  - Task 1 report-draft final by May
  - Task 6 draft report on Soil Sampling Protocols in May
- Peer review comments on Task 2
- Finalizing the scenarios

233

Finalizing the scenarios

- We obtained input from a well-known physiologist on our breathing rate distributions
- We have developed our recommended breathing rate distributions
- We are providing our recommended scenarios
- We need your decision on our recommended scenarios

hεε -

Colorado State University

Exercise and Sport Science
Fort Collins, Colorado 80523-1582
(970) 491-5081
FAX: (970) 491-0445
http://www.colostate.edu/depts/ess

MEMORANDUM

DATE: April 6, 1999

TO: Kathleen Meyer

FROM: Loren Cordain, Ph.D., Professor and Exercise Physiologist Loren Cordain

SUBJECT: Pulmonary function

REMARKS:

During rest, normal values for minute ventilation (V_E) for adult males would be 10-15 liters per minute. Minute ventilation (V_E) is corrected to body temperature and pressure saturated (BTPS) conditions in which ambient (room) volumes are corrected by the BTPS factor (usually about 1.10). For adult women, (V_E) is slightly lower than for adult men and can range from 8-12 liters per minute. Minute ventilation (V_E) is a function of tidal volume (TV) and breathing frequency (f); such that (V_E) = TV x f. During rest, "f" is about 12 breaths per minute, and at maximal exercise, it can reach 30 to 40 breaths per minute. Tidal volume is dependent upon a persons height and thoracic cavity size and can range from about 200 to 500 ml. During maximal exercise (V_E) in large, athletic males can reach values as high as 200 liters per minute with average values ranging from about 130-150 liters per minute. In females (V_E) during maximal exercise typically ranges from about 90 to 140 liters per minute. Maximal exercise (V_E) rates can be sustained for only brief periods of time, typically 1-3 minutes.

References

1. West JB. Respiratory Physiology. Williams & Wilkins, Baltimore, 1985

2. McArdle WD, Katch FI, Katch VL. Exercise Physiology. Williams & Wilkins, Baltimore, 1996

335

Grouping the Scenarios

DOE/EPA/CDPHE	RAC Scenarios	
	Restrictive (Part-time)	Nonrestrictive (Full-time)
1. Residential	1. Current onsite worker	1. Rancher
2. Open space	2. Office worker	2. Infant of rancher
3. Office worker	3. Rec. land user	3. Child of rancher
		4. Neighborhood resident

- The nonrestrictive scenario is the most important for the RSALs
- The critical scenario represents a conservative, but plausible exposure
- If this critical scenario is protected, then we assume that all other individuals would be protected as well

Scenario Recommendations

- We recommend that *RAC*'s office worker, recreational land user, and neighborhood resident scenarios be dropped because they are very similar to the current DOE/EPA/CDPHE scenarios
- For key parameters like breathing rate, we recommend that the 95th percentile of the distribution of breathing rates be used

337

Recommended Scenarios

DOE/EPA/CDPHE	RAC Scenarios: Restrictive (Part-time)	RAC Scenarios: Nonrestrictive (Full-time)
1. Residential	1. Current onsite worker	1. Rancher
2. Open space		2. Infant of rancher
3. Office worker		3. Child of rancher

Scenario Breathing Rates

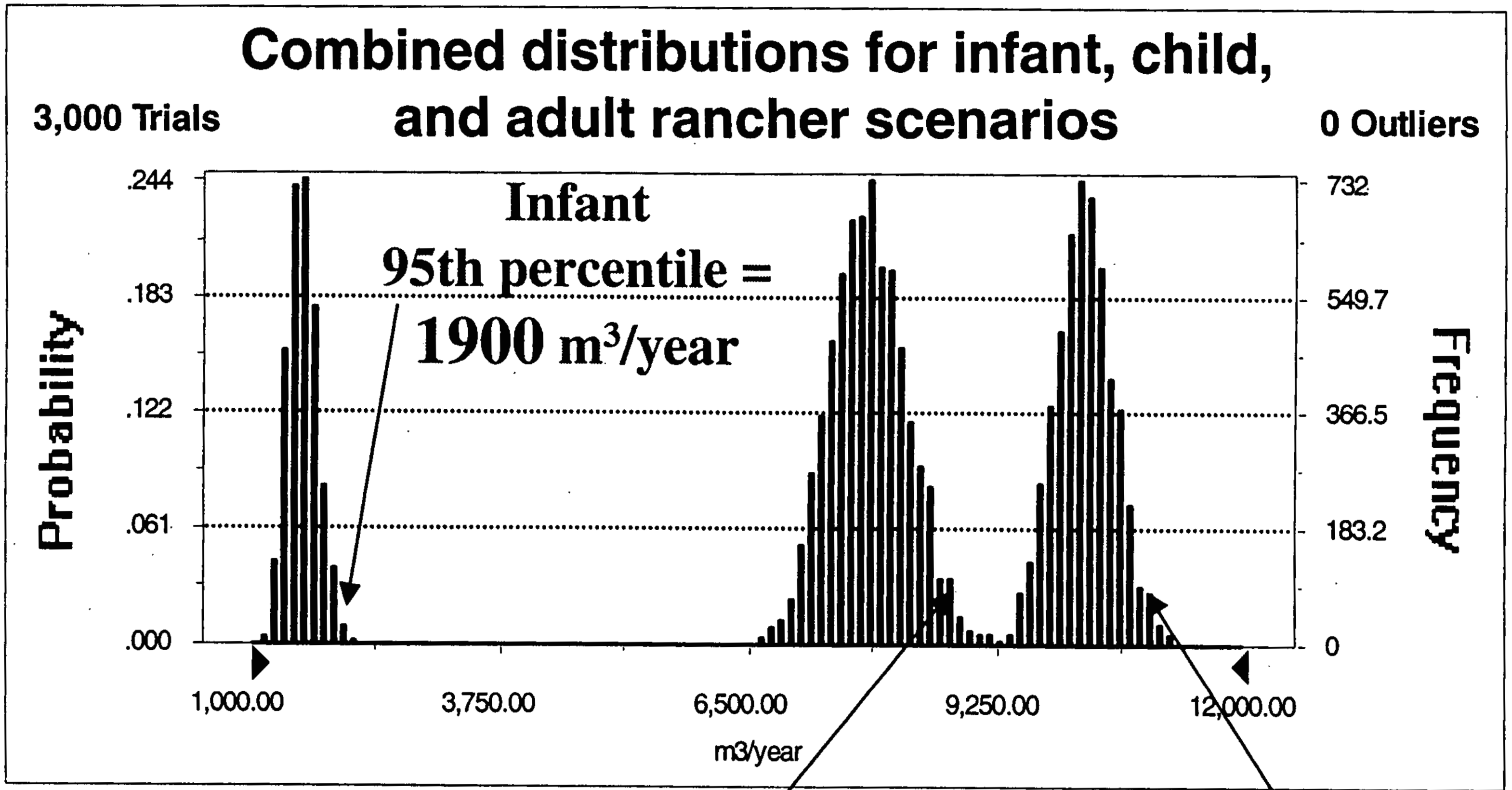
- Based on existing breathing rates studies, *RAC* created distributions of breathing rates for
  - > adults, active and sedentary
  - > children, active and sedentary
  - > infants, active and sedentary

339

Scenario Breathing Rates

- Using these distributions and the recommended breakdowns of daily activity, we created distributions of scenario breathing rates
- *RAC* suggests using the 95th percentile value from these distributions for the scenario breathing rate

RAC full-time scenarios suggested breathing rates



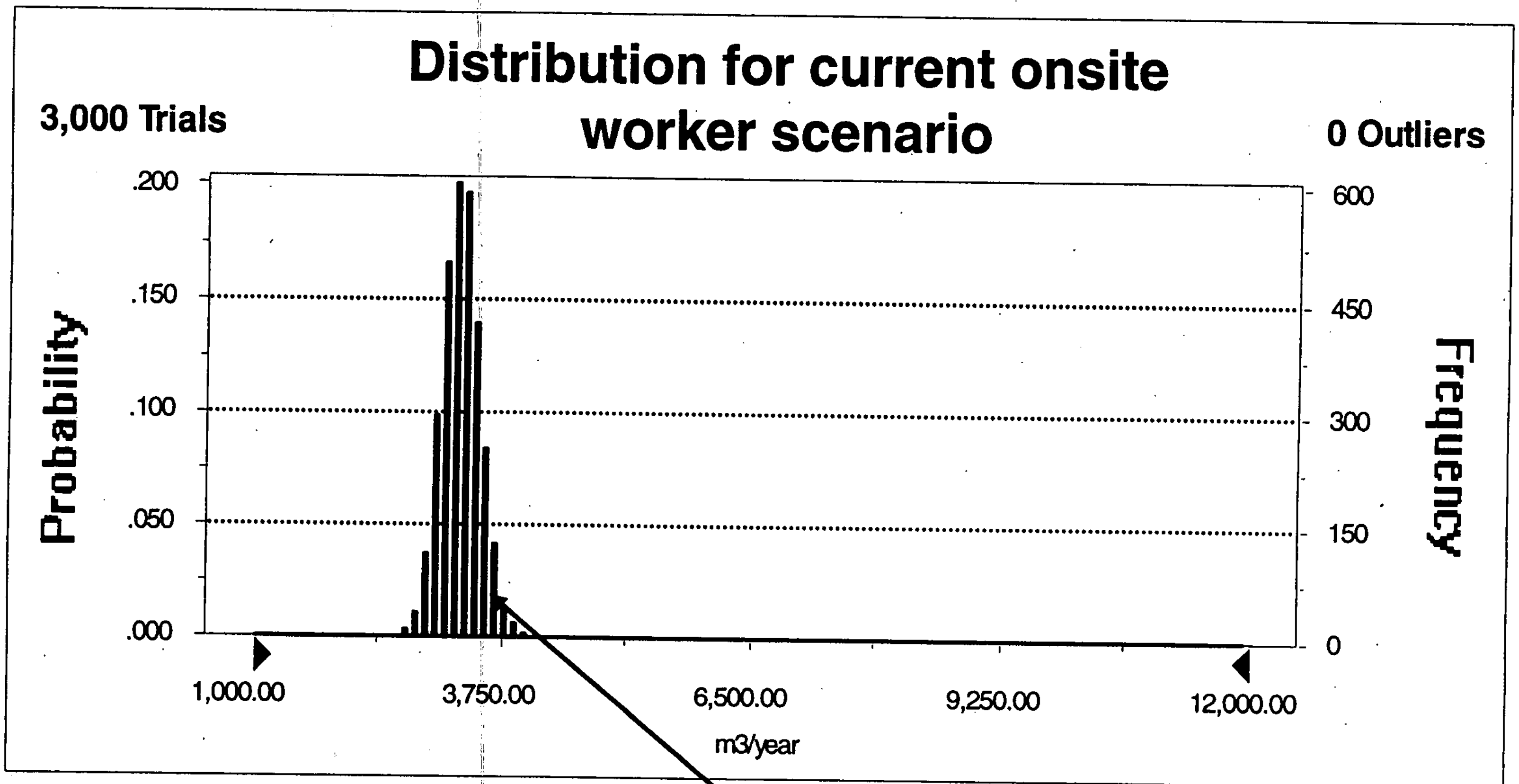
Child
95th percentile = **8600** m³/year

Adult
95th percentile = **10,800** m³/year

340

341

RAC part-time scenario suggested breathing rates



Current onsite worker
95th percentile = 3660 m³/year

Comparison of Key Scenario Parameters

Parameter	Current DOE/EPA/CDPHE Scenarios: Residential	Open space	Office worker	RAC Recommended scenarios — Restrictive: Current site outdoor worker	Nonrestrictive: Resident rancher	Infant of resident rancher (NB-2 yr)	Child of resident rancher (5-17 yr)
Time on the site (hr/yr)	8400	125	2000	2100	8760	8760	8760
Breathing rate (m^3 per year)	7000	175	1660	3660	10800	1900	8600
Soil ingestion (grams per yr)	70	2.5	12.5	60	90	15	365
Irrigation water source	na	na	na	na	Woman Creek	Woman Creek	Woman Creek
Surface water ingestion	no	no	no	no	yes	no	yes

RAC recommends that four of the seven additional scenarios that we have proposed and described be included. In all cases, *RAC* will evaluate the three scenarios described in the final report, *Action Levels for Radionuclides in Soils for the Rocky Flats Cleanup Agreement*, dated October 31, 1996.

DOE/EPA/CDPHE Scenarios:

1. The future residential exposure scenario assumes that an individual resides onsite all year and grows and consumes homegrown produce. This person would be exposed to radioactive materials in soils by directly ingesting the soils, by inhaling resuspended soils, by external gamma exposure from contaminated soil and by ingesting produce grown in contaminated soil.
2. The open space exposure scenario assumes the person visits the site 25 times per year, spending 5 hours per visit at the site. The person would be exposed to radioactive materials in the soil by directly ingesting the soils, by inhalation of resuspended soils, and by external gamma exposure from soils.
3. The office worker exposure scenario represents an individual who works a 40-hour per week, 50-week per year job indoors in a building complex at the site. It is assumed that this person would be exposed to radioactive material in soils by directly ingesting the soils, by inhaling resuspended soils, and by external gamma exposure from soils.

RAC Restrictive Scenario:

4. The current onsite industrial outdoor worker scenario assumes a person works onsite 8½ hours per day, 5 days per week, 50 weeks a year, or 2100 hours per year. It is assumed that the worker is involved in outdoor activities for the majority of time. The potential pathways of exposure include inhalation, direct soil ingestion from outdoor activities, and direct gamma exposure from the soils. The annual breathing rate is 3660 m^3 per year, based on a time-weighted average of breathing rates and activity levels for the time spent onsite.

RAC Nonrestrictive Scenarios:

5. The resident rancher scenario assumes loss of institutional control where the rancher is raising a family. The rancher maintains a garden and leads an active life at the site, spending 24 hours per day, 365 days per year or 8760 hours at the site. The potential pathways of exposure for this person include inhalation; eating produce from garden irrigated with some water from site stream; direct soil ingestion from outdoor activities, and direct gamma exposure from the soils. The annual breathing rate is 10,800 m^3 per year, based on a time-weighted average of breathing rates and activity levels.
6. Infant in rancher family is 0 to 2 years of age, and onsite 24 hours per day, 365 days per year. The infant's potential pathways of exposure include inhalation, some ingestion of produce from family garden, some direct ingestion of water from site stream, some direct soil ingestion from outdoor activities, and direct gamma exposure from soils. The annual breathing rate is 1900 m^3 per year.
7. The child of the rancher family is assumed to be 5 to 17 years of age, and onsite 24 hours per day, or 8760 hr/year. The potential pathways of exposure include inhalation, eating produce from garden irrigated with site stream water, direct soil ingestion, some ingestion of stream water, and gamma exposure from soils. The annual breathing rate is 8600 m^3 per year, based on a time-weighted average of breathing rates and activity levels.

RFCA RSAL Working Group Meeting Minutes
February 17, 1999

Mission Reminder
The Rocky Flats Cleanup Agreement (RFCA) Radionuclide Soil Action Level (RSAL) Working Group (RWG) is tasked with evaluating new information and determining its impact to the RSALs. (See, RFCA paragraph 5 and the Responsiveness Summary for Soil Action Levels released on November 6, 1996.) This includes developing an understanding of how the information impacts the RSALs. The RWG will evaluate the pluses and minuses of different approaches to developing RSALs.

Attendance
The RWG convened on February 17, 1999 at CDPHE. In attendance for DOE was Russell McCallister; attendees for EPA were Tim Rehder and Mark Aguilar; attendees for CDPHE were Steve Gunderson, Diane Niedzwiecki, Edd Kray, Tom Pentecost, and Carl Spreng; attendees for the Kaiser Hill Team were Laura Brooks, John Corsi, and Rick Roberts. Also in attendance were the following members of the public: Brady Wilson.

Agenda
Update on RWG Meeting Minutes-1/19/99 and 1/27/99
Update of actions
Completion of RWG Action 1, Conduct a Regulatory Analysis
Begin RWG Action 2, Model Evaluation
Other Items
Path Forward

Update on RWG Meeting Minutes-1/19/99 and 1/27/99
Draft meeting minutes from the RWG meetings held on 1/19/99 and 1/27/99 were submitted electronically to the RWG on 2/16/99. RWG members should review the draft meeting minutes and provide any comments to Laura Brooks by COB 2/19/99. Any RWG member comments received will be added to the appropriate meeting minutes.

Update of actions
Laura Brooks had the action to start preparing a table that compares the NRC requirements with EPA/CERCLA/RFCA requirements. A draft table will be prepared and shared electronically with the RWG prior to the next meeting.

Laura Brooks had the action to find out information regarding the National Waste Policy Act. A Kaiser-Hill staff member is researching the Act. Any information on the Act will be shared with the RWG at the next meeting.

All other actions will be discussed under the appropriate agenda item.

Continuation of RWG Action 1: Conduct a Regulatory Analysis/Discussion on application of NRC rule and ALARA to RFCA and the Rocky Flats Vision

The RWG agreed to review NRC Draft Regulatory Guide DG-4006, Demonstrating Compliance with the Radiological Criteria for License Termination, to determine if there were key points that add to the regulatory analysis on the NRC rule, Subpart E, Radiological Criteria for License Termination" of 10 CFR Part 20.

Regulatory guides are issued to describe to the public methods acceptable to the NRC staff for implementing specific parts of the NRC's regulations, to explain techniques used by the staff in evaluating specific problems or postulated accidents, and to provide guidance to applicants. Regulatory guides are not substitutes for regulations, and compliance with regulatory guides is not required.

344

Key Points:

Section 1: Dose Modeling

NUREG-1549 and volume 1 of NUREG/CR-5512 provide the rationale for applicability of the generic scenarios, critical groups, and pathways at a site, the rationale and assumptions for scenarios and pathways included (and excluded), the conceptual modeling approaches, and the bases for revising parameters and pathways based on site-specific information.

Site-specific scenarios to calculate doses from residual radioactivity in soil should describe the reasonable land uses and human activities for the future, following license termination. It is reasonable to assume that current land uses in the area will be continued for the period of the dose assessment (1000 years). (See, Section 1.3, Use of Site-Specific Information.)

Some RWG members take strong exception to the above statement regarding the assumption that current land uses will continue for the period of the dose assessment. Some members believe that additional, national discussion is needed regarding future land use assumptions. One possible alternative is to select a future land use scenario that reflects a worst case land use scenario. Other RWG members believe that it is reasonable to assume current land use trends for the future. Some RWG members believe that the original RSALs reflect a worst case scenario since there is an RSAL calculated to be protective to a person living on site if institutional controls fail.

Guidance is not set in stone; guidance is a tool to make review of licensee documents easier for the NRC. If an approach is taken outside of the recommended guidance, then the licensee would have to justify to the NRC why the approach is acceptable.

The NRC released the Draft Regulatory Guide DG-4006 (August 1998) in a draft form to involve the public in the early stages of the development of a regulatory position in this area. It is anticipated that the NRC will finalize this, or similar, guidance within two years.

The RWG discussed whether their work efforts would need to be reviewed by the NRC, e.g., is the approach taken for RSALs at RFETS consistent with what NRC would expect or require; does the NRC have any comments on the approach taken at RFETS. Since Colorado is an agreement state, there may not be a need to go to the NRC; however, the State personnel with authority over NRC licensees may review the work product from the RGW. (One member of the RWG represents the State with authority over NRC licensees.)

Section 1.4, Use of Computer Models, implies a NRC preference for using the DandD computer model. At the last RFSALOP meeting, RAC implied that they did not want to use the DandD computer model. One reason RAC may not prefer the DandD model is because the DandD model may not contain sufficient provisions to conduct an uncertainty analysis that has been important to RAC staff on other projects. The RWG will wait to see the final recommendations from RAC; however, the RWG will continue to evaluate the DandD model.

Section 2: Methods for Conducting a Final Status Survey

The section provides information on how to verify compliance for the Final Status Survey. This discussion is not necessary for the calculation of DCGLs.

Section 2.1, Classification of Areas by Residual Radioactivity Levels, includes a discussion on determining whether there is a substantial amount of subsurface residual radioactivity (deeper than 15 centimeters). This determination should not require a complex set of characterization measurements. The RWG discussed that if the final status survey plan includes subsurface contamination then the RWG may need to model differently to address the subsurface contamination than for modeling to address surface contamination, i.e., the contamination may need to be assumed to be brought up to the surface and dispersed. It was pointed out that the original RSALs do not benefit from any cover. At the time the original RSALs were calculated, there was insufficient information to accurately model radionuclide transport in the subsurface soils. To address this concern, the RFCA Parties agreed to apply the surface soil RSALs to the subsurface soil so that if the subsurface soil reached the surface, it would be protective to a

345

person over the area. In addition, the RFCA Parties agreed that if an accurate subsurface soil leaching model is developed for RFETS in the future, then this application may need to be updated. If subsurface soils are disturbed by remediation activities, both RESRAD and DandD have the capability to model the remediated area.

Section 2.2, Selection and Size of Survey Units, Table 2.1, contains a suggested survey unit area for contaminated land up to 2000 m3. Some RWG members believe this survey unit area is inconsistent, e.g., may be too large, and may not be applicable to RFETS future land use scenarios. Such a large land area may be appropriate for a farming or open space scenarios, but may not be appropriate for a future resident (if consider the residential areas near RFETS). A potential issue with using such a large survey unit area size is that the assessor runs the risk of diluting out data. On the other hand if the survey unit area is decreased substantially, the computer model may fractionate radiation dose due to a limited exposure area. This may be a potential issue for the final dose assessment for RFETS to support the final CAD/ROD.

Section 2.7.2, Determination of Acceptable Decision Errors, states that "any value of beta is acceptable to the NRC." Some RWG members believe that this is inconsistent with CERCLA where normally the Type II error is important and not just any value of beta is acceptable. If the NRC is taking the approach that any value of beta is acceptable, then the RWG may need to evaluate MARSSIM closely (the believed foundation for the NRC statement) and compare the NRC approach to approaches taken at CERCLA sites.

Section 3: Analyses

This section provides the steps that are required for an ALARA analysis. An ALARA analysis is required after the development of the DCGLs, i.e., the discussion on ALARA is not necessary for the calculation of DCGLs.

Section 3.1, ALARA analyses, includes the following key points: "The ALARA requirement is met by performing the remediation action where appropriate, not by reducing the concentration to below a specified value." "If the licensee has already decided to perform a remediation action, there is no need to analyze whether the action was necessary to meet the ALARA requirement. The analysis described in this section is needed only to justify not taking a remediation action. For example, if a licensee plans to wash room surfaces (either to meet the dose limit or as a good practice procedure), there is no need to analyze whether the remediation action of washing is necessary to meet the ALARA requirement."

Section 3.1.5, When Mathematical Analyses are not Necessary, includes the following key point: "In certain circumstances, the results of an ALARA analysis are known on a generic basis and analysis is not necessary. For residual radioactivity in soil at sites that will have unrestricted release, generic analyses show that shipping soil to a low-level waste disposal facility is unlikely to be cost effective for unrestricted release, largely because of the high costs of waste disposal. Therefore, shipping soil to a low-level waste disposal facility generally does not have to be evaluated for unrestricted release."

Some RWG members believe that if remediation can meet 25 mrem for an unrestricted release, than an ALARA analysis is not required.

Section 4:License Termination Under Restricted Conditions

Section 4 contains the following key point: "The restricted conditions should be limited to the smallest portion of the site that is appropriate. However, all areas that will be subject to restricted conditions should be contained within one or occasionally two area. Complicated checkerboard patterns of areas with restricted conditions should be avoided."

Section 4.1, Legally Enforceable Institutional Controls, contains information on types of institutional controls that may be acceptable to the NRC. This information may be useful to other working groups that are evaluating institutional controls and long-term stewardship issues.

Section 4.1.2, Proprietary Institutional Controls on Government-Owned Lands, includes the following subsection on Funds for Enforcement of Controls: Government ownership of land, unless physical barriers are used, would not normally require establishing financial assurance. This may be important if fences or caps are used as part of the final remedy for RFETS.

Has DOE calculated the cost of cleaning up to unrestricted release v. the cost of maintaining institutional controls? Some RWG members believe that there are personnel doing this type of evaluation.

The original RSALs included a calculation to unrestricted release, Tier II. It was believed that these values would allow unrestricted access to an on-site user; however, the protection of surface water still needs to be considered in making final remediation decisions.

General Discussion on Regulatory Analysis

RAC is not conducting a regulatory analysis as part of its work this year. A proposal has been made to the RFSALOP that the RFSALOP consider conducting a regulatory analysis or have someone prepare one for the oversight panel.

The RWG reviewed the issue of whether the RWG needed to make a recommendation to the RFCA Parties on a dose limit for calculating an RSAL or on a regulatory foundation for the calculation of an RSAL, and if so, when should the recommendation be made. This question also concerns what regulatory rule to apply and what methods to follow. Some RWG members believe that one rule/method should be applied to the calculation of an RSAL. Other members of the RWG believe that the CERCLA process should be followed. Some RWG members believe that the RFCA Parties need this information now; other members believe it will be better to wait until the RWG review is complete, the RFSALOP makes a recommendation to the RFCA Parties and the RWG has reviewed the RFSALOP recommendation.

The RWG believes that it will be interesting to see the results of the derivation of RSALs using RESRAD, DandD, other computer models, and what the RAC recommends. Some RWG members think that if similar input parameters are selected, then similar RSALs may be derived.

Some RWG members believe that a benchmark needs to be established prior to beginning the process of calculating an RSAL. The conceptual differences between the rules may be more of a problem than which model to use or which parameters to select. If one rule is selected, then the methodologies that would apply to that rule could be evaluated.

Another question is how to apply one rule to the site, when more than one federal law applies to the site. This is part of the challenge to cleaning up a federal site under CERCLA.

The RWG agreed to add, and evaluate, the CERCLA risk-range to the table that the RWG previously made at the November 24, 1998 meeting.

The RWG agreed to that now may not be the appropriate time to make a recommendation to the RFCA Parties. The RWG will continue to review this issue on a regular basis. The RWG will evaluate various scenarios so that the mission of the RWG can be completed. One possible RWG result is that some type of "hybrid" between RFCA, CERCLA and the NRC rule may be developed and recommended by the RWG to the RFCA Parties. Differences in concepts will be further discussed during the parameter selection.

RWG Action 2: Model Evaluation

Copies of various papers comparing computer models were distributed to the RWG, including a copy of the EPRI model comparison.

The RWG agreed to review the review the material; however, the RWG would not conduct its own in-depth review of the available computer models nor does the RWG plan on documenting it's understanding of the similarities and differences between the available computer models that could be used to calculate a RSAL outside of the already available material.

The following RWG members were assigned the following computer codes:

Tom Pentecost	DandD
Mark Aguilar	GENII
Russell McCallister	MEPAS
Rick Roberts	RESRAD (Both versions 5.61 and 5.82)
Diane Niedzwiecki	Risk Calculation

The RWG agreed to start focusing on these various models and to start developing in-put parameters for the residential scenario. The RWG agreed to review the following information: (1) input parameters that were selected for the original RSALS; (2) default parameters associated with each computer model; (3) recommendations from the 1998 PPRG Annual Review where recommendations were made to scenarios by the PPRG Working Group; and (4) approaches recommended by guidance associated with the computer model.

Input parameter recommendations and selections must be documented.

The revised RWG goal is to develop a general familiarity with the various codes, start the input parameter discussions, start modeling, and conduct sensitivity analyses. Once the RWG has a good understanding of these items, then a national conference among the other DOE sites undergoing a similar process would be beneficial. If such a meeting could be held, it would be useful if actual computer model experts were present to help the various site personnel or working groups understand why there may be differences between the codes, approaches, etc.

Old Actions
Prepare draft table that compares the NRC requirements with EPA/CERCLA/RFCA requirements.

Provide status on information regarding the National Waste Policy Act.

New Actions
Review distributed material on computer model evaluations and comparisons.

Prepare recommendations for input parameters for the residential scenario.

Other Information
The next RFSALOP meeting is scheduled for March 11, 1999, from 4:00 to 7:00 at the Broomfield City Hall. Prior to the RFSALOP meeting, there will be a technical session from 2:30at the Broomfield City Hall.

The next RWG meeting is scheduled for March 17, 1999, at 9:00 at RFETS, Building 460, room 122.

The proposed agenda for the next meeting is:
Review of 2/17/99 Meeting Minutes – 5 minutes
Update on Actions – 5 minutes
Review Draft Comparison Table – 30 minutes
Discussion on Model Evaluation Information - 15 minutes
Start RWG Action 3, Input Parameter – Residential Scenario – 2 hours
Other Items – 5 minutes
Path Forward – 5 minutes

348

RAC responses to DOE comments from February 11, 1999 presentation

1. During the 1998 Rocky Flats Cleanup Agreement (RFCA) Annual Review of the Radionuclide Soil Action Levels, an agency working group reviewed radionuclide soil cleanup levels developed for Hanford and the Nevada Test Site and compared those soil cleanup levels and the methodologies use for the calculations to the RSALs developed for Rocky Flats. The working group reviewed the same documents used by *RAC* for Task1: Cleanup Levels at Other Sites, for the Nevada Test Site and Hanford, but in more detail than presented in the Draft Report for Task 1: Cleanup Levels at Other Sites. The Department of Energy (DOE) has attached to this letter a copy of the working group's summary of the comparison for your information. There may be information in this report useful to *RAC* as it completes Task 1.

    RAC appreciates DOE's inclusion of their working group report for our review. Our analysis of action levels at other sites included a direct comparison of action levels and doses for which these levels were calculated, while the RWG report includes a listing of parameters input into each calculation. Initially, we compared the input values for only a few significant parameters to determine the source of the disparity between Hanford and Rocky Flats and Nevada Test Site and Rocky Flats soil action level values. The final version of the Task 1 report will also include comparisons of industrial worker scenarios where appropriate and available, as well as a comparison of action levels for ^{241}Am.

2. The Draft Report claimed "the hypothetical future resident 85 mrem/year action level is the DOE recommended action level below which no remediation would be required..." This is not an accurate statement regarding action levels used at the RFETS. It is more accurate to state that an action level based on a 15 mrem/year dose level to a hypothetical future resident is the recommended contamination level below which no remediation would be required, assuming there is no impact to surface water. Further, the 85 mrem/year residential scenario was NOT used in RFCA to support a residential use scenario. The 85 mrem/year residential scenario was used to support an Open Space use scenario. This is because the draft EPA rule on which the RFCA Parties relied directly comparing 15 mrem/year for the anticipated use to 85 mrem/year for residential use and choosing the more conservative of the two scenarios. In this case, 85 mrem/year residential was more conservative than 15 mrem/year open space. While we recognize that this explanation does not change the arithmetic conclusion of the draft report, we did wish to make this clarification.

    RAC is grateful for the information and clarification provided by DOE.

3. The Draft Report states that "two parameters at RFETS emerged from the sensitivity analysis as most important and most sensitive to change: mass loading factor and the dose conversion factor." DOE agrees that these are two sensitive parameters; however, DOE also believes that there are other parameters that are sensitive and could significantly impact the final derivation of RSALs. The *RAC* may not have identified or considered these additional parameters. In order for DOE to evaluate the sensitivity analysis conducted by *RAC*, DOE requests that *RAC* provide a more detailed summary of the sensitivity analysis, including the methods and results of the sensitivity analysis, conducted by *RAC*.

When *RAC* completed and reported the sensitivity analysis, we completed it within the boundaries of our contract with the RFCAB. That is, at the January 14, 1999 RSAL meeting, we presented the results of a single-parameter sensitivity analysis of the existing Rocky Flats calculation. For comparison, we chose a single calculation to evaluate the sensitivity. Our selection was the 85 mrem/year hypothetical resident scenario. To comply with our contract and the definition of a single-parameter analysis, we took the hypothetical resident scenario and changed one parameter at a time, reporting to the panel only the most significant results of that analysis by way of the presentation given by Jill Weber in January 1999. In practice, *RAC* analyzed all of the parameters currently in use and reported the change in soil action level for 239Pu and the total dose during the first year of exposure, although all the radionuclide doses and soil action levels were reviewed.

This analysis was by no means the end of *RAC*'s parameter evaluation. As the goal of Task 3, *RAC* will review all of the parameters required as input to the computer model chosen in the Task 2 analysis and will select values appropriate to the Rocky Flats facility and potential residents.

4. The Rocky Flats Vision (part of the Rocky Flats Clean Up Agreement) states that Rocky Flats will be cleaned up to allow open space uses in the Buffer Zone, restricted open space or industrial use for most of the Industrial Area, and other appropriate uses. As of the February 11, 1999 Rocky Flats Soil Action Levels Oversight Panel meeting, *RAC* is currently considering a residential scenario and a current onsite worker scenario. Do the *RAC* and the Oversight Panel also plan to evaluate land uses consistent with the assumptions of the RFCA?

   RAC firmly believes that to meet the goals and requirements of our contract with RFCAB, we need to evaluate not only scenarios and land uses proposed in the original soil action level document, but to provide additional scenarios, consistent with the Rocky Flats facility and possible uses in the future, for review by the panel. We will continue to work with the panel at future meetings to arrive at scenarios for analysis in the independent review by the time of the May 1999 Oversight Panel meeting.

April 8, 1999

COMMENTS ON "Examples of Soil Action Levels at Other Sites"

In a slide presented at the public meeting ("Examples of Soil Action Levels at Other Sites") several clean up standards are presented that seem questionable.

Nevada Test Site--A proposed cleanup level of 326 pCi of Pu per gram of soil is shown to produce a dose of 78.3 mrem. I have the document "Radiological Dose Assessment for Residual Radioactive Material in Soil at the Clean Slaye Sites 1, 2, and 3, Tonopah Test Range" issued by the DOE Nevada Operaations Office, June 1997. The thrust of that document seems to be that a clean up level of 200 pCi of plutonium per gram of soil will allow a dose of 100 mrem.

Maralinga--A clean up level of 280 pCi of Pu per gram of soil will produce a dose of 500 mrem. A document "The Maralinga Rehabilitation Project 1996-1999" has the following conclusion--"The clean-up criteria . . . included the possibility of an Aboriginal group living for a whole year on the edge of the non-residential area in regions of the highest activity permitted outside it (~20-35 kBq/m^2 of ^{239}Pu depending on the site). This could lead to annual dose of 5mSv."

Translating the units--kBq is thousands of becquerel and m^2 is square meters. If we convert to becquerel and to cm^2 (square centimeters), we must multiply by 1000 and divide by 10,000--the net result is 2-3.5 Bq/cm^2. Since a becquerel is equal to 27.3 picocuries, if we multiply by 27.3 we arrive at 55 to 96 piCu per square centimeter. Assuming the sample is 1/8 inch thick and the specific gravity of the soil 1.8, the result is that soil concentration is 55 to 96 pCi per gram of soil. (If we assume the sample is about one centimeter thick--one-quarter inch-- and the specific gravity is 1.8, the concentration per gram of soil will reduce by 50%.) 5mSv is equal to 500 mrem.

Thus the final translation is that a soil concentration of 55 to 96 pCu of Pu per gram of soil will give an annual dose of 500 mrem. to residents

351

living on that soil. Not the figure of 280 piCu per gram given in the RAC table.

Palomares--The RAC table shows that a concentration of 1230 piCu/g will provide a dose of 100 mrem.

"History of Cleanup Standards/Criteria at Nuclear Test and Accident Sites" by Bruce W. Church shows that where the soil concentration was 1800 pCu/g, it was removed to a depth of 10 centimeters. Where the soil had been cleaned to 180 pCu/g it was plowed (and mixed) down an additional 30 cms.

My reading of that is that were attempting to dilute the level down to 6 pCu/g by mixing with uncontaminated soil.

5/13/99
Session

353

354

RADIONUCLIDE SOIL ACTION LEVEL OVERSIGHT PANEL
MEETING ATTENDEES
May 13, 1999

NAME	ORGANIZATION	PHONE	FAX	E-MAIL
HANK STOVALL	CITY OF BROOMFIELD	[redacted]		
Mary Harlow	City of Westminster	[redacted]		
Steve Gunderson	CDPHE	[redacted]		
Laura Till	Facilitator	[redacted]		
Ken Korkia	RFCAB Staff	[redacted]		
Brady Wilson	CAB staff	[redacted]		
Laura Brooks	Kaiser-Hill Company, L.L.C.	[redacted]		
Rick Roberts	Rocky Mountain Remediation Services	[redacted]		
Russell McCallister	DOE/RFFO	[redacted]		
Diane Niedzwiecki	CDPHE	[redacted]		
Carl Spreng	"	[redacted]		

355

RADIONUCLIDE SOIL ACTION LEVEL OVERSIGHT PANEL
MEETING ATTENDEES
May 13, 1999

NAME	ORGANIZATION	PHONE	FAX	E-MAIL
CARLA SANDA	AIMSI	[redacted]		
JOE GOLDFIELD	CCANW	[redacted]		
DAVID THORNE	RAC	[redacted]		
JOHN TILL	RAC	[redacted]		
Kathleen Meyer	RAC	[redacted]		
Niels Schonbeck	Metro State Col.	[redacted]		
TODD MARGULIES	TM CONSULTING	[redacted]		
Carol Lyons		[redacted]		
VICTOR Holm	RFCAB	[redacted]		
BOB KANICK	CITIZEN BOULDER	[redacted]		
KEN STARR	CITIZEN / ENV CONSULTANT	[redacted]		
HEATHER BALSER	CITY OF LOUISVILLE.	[redacted]		
LeRoy Moore	RMPJC	[redacted]		

AGENDA

RSALOP Meeting – May 13, 1999
Broomfield City Building - Zang's Spur Conference Room
4:00 - 7:00 P.M.

4:00 - 4:10	OPENING • Introductions • Minutes corrections/approval • Sign-In • Agenda Review • Group Agreements	Mary Harlow Facilitator Facilitator
4:10 - 4:15	CO-CHAIRS UPDATES • Letter to Jessie Roberson • Status of Administrative Contract Budget Request • Distribution/Identification of Materials for Distribution	Mary Harlow
4:15 - 4:20	RFCA Regulator Report	Tim Rehder, EPA
4:20 - 5:00	PROJECT UPDATE • Peer Review Team Comments	Dr. John Till, *RAC*
5:00 - 5:05	PUBLIC COMMENT	
5:05 – 6:00	SOIL INGESTION INFO UPDATE • Consensus on Scenarios	Dr. Kathleen Meyer, *RAC*
6:00 – 6:10	BREAK	
6:10 – 6:45	REPORT ON TASK 6: SOIL SAMPLING PROTOCOLS	David Thorne, *RAC*
6:45 – 6:50	PUBLIC COMMENT	
6:50 - 7:00	OTHER TOPICS/FUTURE AGENDA ITEMS/ ACTION ITEMS	Facilitator

UPCOMING PANEL MEETINGS

June 10, July 8, August 12, September 9, October 7, November 11:
4-7 P.M. Broomfield City Bldg., One Descombes Dr. - Zang's Spur/Bal Swan Conference Rooms (lower level)

RSALOP TECHNICAL DISCUSSION

RAC representatives will be available from 2:30 - 3:30 p.m. Thursday, May 13, 1999 at the Broomfield City Building - Bal Swan Conference Room for in-depth technical discussions immediately prior to the regularly scheduled meeting.

CHECK OUT THE RSALOP WEB SITE: www.rfcab.org/SALOP.html

356

Attached is the agenda for the RSALOP meeting scheduled for Thursday, May 11, 1999 from 4-7 p.m. at the Broomfield City Center.

RSALOP TECHNICAL DISCUSSION

RAC representatives will be available from 2:30 - 3:30 p.m. Thursday, March 11, 1999 at the Broomfield City Building - Bal Swan Conference Room for in-depth technical discussions immediately prior to the regularly scheduled meeting.

ADVANCED INTEGRATED MANAGEMENT SERVICES, INC.

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	John Student	City & County of Denver	303-285-4067	303-285-5621
	Dr. Norma Morin	CDPHE	303-692-2645	303-782-0188
E	Steve Gunderson	CDPHE	303-692-3367	303-759-5355
	Carl Spreng	CDPHE	303-692-3358	303-759-5355
P	Dean Heil	CSU	970-491-6516	970-491-0564
C	John Till	RAC	803-536-4883	803-534-1995
C	Kathleen Meyer	RAC	970-229-0828	970-229-0829
	Autar Rampertaap	DOE HQ	301-903-8191	301-903-3877
E	Jeremy Karpatkin	DOE	303-966-2080	303-966-6633
	Jessie Roberson	DOE/RFFO	303-966-2025	303-966-6054
	David Thomassen	DOE		Mail
	Russell McCallister	DOE	303-966-9692	303-966-3710
E	Tim Rehder	EPA	303-312-6293	303-312-6067
	Tim Lutes			Mail
P	Ken Starr	Citizen	303-694-4159	303-694 7367
	Nanette Neelan	Jefferson County		303-271-8941
	John Corsi	Kaiser Hill	303-966-6526	303-966-6153
	Dave Shelton	Kaiser Hill	303-966-9877	303-966-6214
P	Niels Schonbeck	Metro State	303-556-8327	303-556-5399
A	John Shepherd	Physician/Soc Resp	303-650-4460	303-650-4403
A	Victor Holm	RFCAB	303-989-9086	303-980-9076
SP	Bob Kanick	Citizen of Boulder	303-444-0049	508-546-2452 call
E	Ken Korkia	RFCAB	303-420-7855	303-420-7579
A	Tom Marshall	RFCAB	303-444-6981	303-444-6523
SP	LeRoy Moore	RMPJC	303-444-6981	303-444-6523
	~~Deanne Butterfield~~	~~RFLII~~ RFC LOG	303-940-6090	303-940-6088
	Will Neff	~~RFLII~~ RFC LOG	303-940-6090	303-940-6088
P	Joel Selbin	UCD Chem Dept	[redacted]	303-492-5894
P	Todd Margulies	TM Consulting	303-279-6699	Mail or e-mail
P	Joe Goldfield	CCANW	303-321-7276	Mail
C	Laura Till	Facilitator		303-447-0077

(SP=Steering Committee Panel Member, P=Panel Member, A=Alternate, E=Ex-Officio, C=Contractor), List Revised 5/4/99

David 358

5460 WARD ROAD, SUITE 370, ARVADA, COLORADO 80002, 303-456-0884, FAX: 303-456-0858

MINUTES

Radionuclide Soil Action Levels Oversight Panel
May 13, 1999 - 4:00p.m. - 7:00 p.m.
Broomfield City Building - Zang's Spur/Bal Swan Conference Rooms

NOTE: Minutes are presented in draft form and should not be quoted or distributed until receiving final approval by the Radionuclide Soil Action Level Oversight Panel at its June 10, 1999 meeting.

Mary Harlow, Co-Chair, convened the regular meeting of the Radionuclide Soil Action Level Oversight Panel (Oversight Panel or Panel) at 4:00 p.m. and opened with the introduction of the following attendees:

Hank Stovall, City of Broomfield
Niels Schonbeck, HAP & MSCD
Brady Wilson, RFCAB Staff
Carla Sanda, AIMSI
Rick Roberts, RMRS
Steve Gunderson, CDPHE
Diane Niedzwiechi, CDPHE
David Thorne, *RAC*
Mary Harlow, City of Westminster
Russell McCallister, DOE-RFFO
Victor Holm, RFCAB
Ken Starr, Citizen
Carl Spreng, CDPHE
Ken Korkia, RFCAB
Todd Margulies, TM Consulting
John Till, *RAC*
Carol Lyons, City of Arvada
Laura Till, Facilitator
Heather Balser, City of Louisville
Laura Brooks, Kaiser-Hill
Kathleen Meyer, *RAC*
Joe Goldfield, CCANW
LeRoy Moore, RMPJC
Bob Kanick, Citizen

MINUTES REVIEW/APPROVAL

Minutes of the April 8, 1999 Panel meeting were reviewed and approved as printed.

AGENDA REVIEW

Laura Till reviewed the Agenda as well as the Group Agreements. The agenda was approved with a minor change to provide additional time for discussion of the Task 6 Report. The meeting was turned back to the Co-Chairs.

CO-CHAIRS UPDATES

Letter to Jessie Roberson: Copies of a letter dated April 27, 1999 from Panel Co-Chairs to Jessie Roberson, Manager, DOE-RFFO, were available on the information table. The letter provided an update to Ms. Roberson on the Panel's work and again reinforced the hope that DOE and site technical representatives will make an effort to attend the technical briefing scheduled prior to each meeting. It is hoped that by attending the pre-meeting, most questions can be directly addressed. This should in turn minimize the need for written questions to *RAC* representatives, which takes a considerable amount of time to read, review and formulate a written response.

Administrative Support Funding Update: Ms. Harlow asked Ken Korkia, RFCAB, to provide an update on the status of extension of the administrative contract which provides funding for meeting facilitation (Laura Till), administrative, and public involvement support (AIMSI). Mr. Korkia stated that a grant amendment in the amount of ~$18,000 had been submitted to DOE for the additional six months of support from Laura Till and AIMSI representatives. Additional funds were required since the original contract was written from June 1998 – June 1999; however, due to the delay in contract award, the contract now requires extension to support the remainder of the Panel's work. The most recent feedback from DOE representatives indicated that additional funding for AIMSI representatives is being considered. However, funding for facilitation support may not be considered, since DOE believes that members of the Panel could provide that support. Mr. Korkia responded that it would not be acceptable to rotate that duty among Panel members, but he has heard nothing further. Hank Stovall reminded Ken Korkia that the Panel is willing to assist in this effort. Mr. Korkia responded that he will keep the Co-Chairs informed of his progress and advise if any additional support is needed.

Identification of Materials for Distribution: Carla Sanda reminded the Panel and meeting attendees that any materials intended for distribution at the meeting should be identified; i.e., the name and affiliation of the individual or group providing the materials and purpose for distribution. Since meeting minutes and distributed materials are routinely mailed to stakeholders and DOE officials in Washington, it is important to identify the purpose and source of materials so that readers can distinguish between project materials distributed by the Panel or its contractors and materials that may be provided by others as a matter of interest.

✔ ***Action Item:*** *John Till, RAC, has requested that Panel comments to draft task reports have the same submittal deadline as that established for the Peer Review Team. This will expedite review and response to all comments and should expedite formulation of written responses to all comments received. Comments on the Task 6: Sampling Protocol report that distributed this evening are due to Carla Sanda, AIMSI, by close of business June 4, 1999. Dr. Till also requested that whenever possible comments should be forwarded to RAC electronically to expedite processing. Panel comments can be forwarded via email to Carla at:* candftrvl@msn.com. *If this isn't possible, please submit written comments, and AIMSI representatives will in turn transmit an electronic version to RAC representatives.*

<u>RFCA REGULATOR UPDATE</u> – Discussion Lead: Steve Gunderson, CDPHE

Mr. Gunderson reported on meetings conducted on April 13 and May 5.

The April meeting focused on a comparison of RESRAD Version 5.61 with RESRAD Version 5.75 and later. Discussions included agency technical representatives as well as a conference call with Dr. Charlie Yu, Argonne National Laboratory, the principal RESRAD code developer. It appears that the key difference between older and newer versions of RESRAD is the air resuspension component. Earlier versions, including Version 5.61, used an "area factor" based on a simple box model, where the calculation only took into account the size of an area of contamination. This meant that if a contaminated area was greater than 3 meters in size, the program basically assumed that all particles resuspended in air would be contaminated. Argonne representatives believed that element represented an over-conservative approach. The newer version is based on a Gaussian model, which takes into account particle size, wind speed, and contaminated area size. The program assumes that some particles within the area are not contaminated and originated from land surrounding the area of contamination. Dr. Yu said this assumption is supported by air sampling studies and does make logical sense.

The May meeting focused on input parameters for the residential scenario. Tom Pentecost, CDPHE Radiation Services Group, provided some analysis he had gathered from a run using the D&D code. A run had been made that included a ranch scenario where the residents consumed all food grown on-site, including vegetables, meats, and fish from an on-site pond. The code was run using all default parameters within the D&D program. The run assumed a level of 1 PCi/gram of plutonium and 1 PCi/gram of americium in the soil. The outcome provided a maximum annual dose of 302 mR received by a resident in year 10. The primary exposure resulted from consumption of fish from a pond. In fact, nearly 64% of the dose was due to consumption of fish from a pond, while 20% of the dose came from irrigation water and 12% from drinking water. This run demonstrated that the D&D program assumes that plutonium is very soluble, while results from the actinide migration studies to date reflect the opposite. A run was then made with the following modifications: no fish from a pond, reduction of the amount of site-grown vegetables, as well as a change in the default for a plant's soil content. (The D&D code default assumes that 10% of the plant is actually dirt, so this number was reduced.) The outcome was a peak dose of .2 mR one year after closure. The bottom line seems to be that D&D is really designed as a screening tool, so it is important to remember that and interpret results accordingly.

<u>PROJECT UPDATE*</u> - Discussion Lead: Dr. John Till, *Risk Assessment Corporation*
*Copies of presentation materials and Milestone Report 3 available by calling Anna Corbett, AIMSI, 303-456-0884

Dr. Till provided the following recap on project status to date:
<u>Task 1</u>: Cleanup Levels at Other Sites – The draft final report was distributed at an earlier meeting; however, a correction has been made to the cover page that reflects the correct name of the Panel. An updated cover page was distributed on the information table for members to use as a replacement on individual copies of the final draft report. The report is called a "Draft Final" report – this means that all the draft final reports will be incorporated into the final report at the project's conclusion.

<u>Task 2</u>: Computer Models – This draft report was distributed two months ago, and comments have been received from the Peer Review Team. Written responses to those comments were available on the information table. Panel comments are being delivered to RAC at this meeting. As discussed earlier, Panel comments to future

reports will have the same due date as comments from the Peer Review Team. This will facilitate more efficient review and processing of the information.

Task 3: Inputs and Assumptions – RAC is currently working on this report and has developed a draft outline. The basic approach is to focus on the parameters that are important and not dwell on inputs or parameters that would result in little or no difference to the outcome if changed.

Task 4: Methodology – No report is due on this effort; rather this is an ongoing discussion of the project methodology.

Task 5: Independent Calculation – this is the "meat" of the project, and team members are busy working on this report, including developing methodologies and calculations.

Task 6: Sampling Protocol – this report will be discussed and distributed this evening.

Task 7: Interaction with the Actinide Migration Panel – this is an ongoing effort that is providing useful information to the project.

Task 8: Public Interaction – this is an ongoing effort. The first public meeting has been conducted, and we will continue to plan ahead for the final two public meetings.

Budget Status – Overall the project is proceeding well. At the end of April, the budget was ~40% spent.

Milestone Report 3 – This report, which was due this month, outlines some of the steps taken to date and summarizes reports due at this point in the project. Copies were available on the information table.

Groundwater – This has been an ongoing concern in scenario development. Groundwater will be addressed in one of the scenarios, but Dr. Till stressed the difficulty and complexity of dealing with groundwater issues. A lot of work on this subject is currently taking place both at the site and within the Actinide Migration Studies group. This work will continue for many years. It is important to keep in mind that it is very possible that the results of some of these studies could change the results of this project over time. Although it is difficult to predict the likelihood of this happening, it is entirely possible. Dr. Till elaborated by saying that at this time his guess is that when "all is said and done" plutonium contamination on the top layers of soil will be most important, and that the inhalation pathway will be the critical factor. Researchers do not know everything about groundwater contamination or plutonium solubility issues at this time, and work will be continuing for some time in this area.

At the last meeting, a question was raised as to how RAC was going to critique the scenarios and parameters used in the original calculations used to determine interim RSALs. Dr. Till indicated that RAC will be addressing these issues but will not be suggesting why a value was "right" or "wrong". Researchers selected values and inputs for a variety of reasons, and RAC will certainly be able to explain the selections in the current evaluation. In some cases, they will be different, and although they may be able to explain the difference in some instances, it may not be possible to explain the differences in absolutely every case. RAC does not intend to provide an in-depth critique of work done earlier, but will lay out very carefully what was used previously and what is used for this project. Overall, we will likely see more similarities than differences.

There were also some comments received regarding scenario selection. RAC believes that the rancher scenario is probably the most limiting of the scenarios. This scenario represents an individual who lives where the site sits today, farms the land, consumes much of the foodstuffs grown on the site, and spends a substantial part of each day on that site. Some input suggests that with the current population trends, it is not likely that future use of the site will include an individual engaged in ranching. In reality, nobody knows how the site will be used. RAC is proposing that a calculation be used with realistic inputs for an individual residing and working at the site, with the contention being that if a scenario is developed to protect that individual, then there is assurance of protecting other people. Dr. Till further stressed that given his experience with farming and ranching families, the scenario is reasonable in that many farmers and ranchers spend nearly every waking moment at home – not every single day of the year, certainly – but a sizeable portion of each day. Given the level of work it takes to farm and ranch, the breathing rates also seem realistic. This scenario, as developed, may not be representative of everybody, but it does set a scenario that will provide a level of protection not only for a potential rancher but the general population as well. Even if a rancher doesn't live at the current site, and instead it is a community of 1,000 people, this scenario would provide the same level of protection for those 1,000 people. The day-to-day dose for those 1,000 people would almost certainly be less, but the point is that this scenario does not suggest anything that is absolutely not possible.

Dr. Till then briefly introduced and discussed the recently released ***ICRP Report #129: Recommended Screening Limits for Contaminated Surface Soil and Review of Factors Relevant to Site-Specific Studies.*** This report has been under development for roughly five years and is an excellent reference document, with particular applicability to this project. Dr. Till encouraged the Panel and/or RFCAB to consider purchasing a copy of the document for reference. This document will be used as a reference on the project, but it is not a model in the same sense as RESRAD or MEPAS, but is an excellent tool when evaluating contaminated sites and determining screening limits.

Dr. Till outlined the Task 3 Report. The report will likely consist of sections discussing: the issue of "uncertainty", how calculations of uncertainty are made, selected parameters, different RESRAD versions and impacts on the results of the original DOE scenario calculations, scenarios applied in the analysis, sensitivity analysis, uncertainty distributions for selected input parameters (which will include a discussion of high wind events at the site), Monte Carlo interface, and the results of uncertainty runs using RESRAD Version 5.82 and the DOE scenarios.

Dr. Till stressed that he felt it was important to consider the high wind events at the site. In fact, this study will benefit from the work that has been done over a period of years on the dose reconstruction study. In that study, RAC has take some incredible lengths to reconstruct certain days of high wind events; i.e., days with 60-70 mph winds that picked up tremendous amounts of dust. RAC was interested to see how important events were that occurred only a few days over many years, but picked up large amounts of plutonium which were then redistributed – and how those events compared to the day-to-day light winds that may pick up and redistribute materials. The finding is quite important: Even though the high winds resuspended larger amounts of plutonium, they were resuspending larger particle sizes. This actually meant that the doses from these events were lower even though the quantity of material was greater. This is important to include because this study is concerned about resuspension over very long periods of time in the future, and it is likely that we will receive questions regarding high wind events. Inclusion of this information will demonstrate that this occurrence has been considered, although it will not be specifically modeled.

Dr. Till provided some additional detail regarding the two versions of RESRAD. When the project began in October, the only available RESRAD version was 5.61. Subsequently, Version 5.82 was released which incorporates a modification in the resuspension model and the area factor. Basically, the area factor is a value multiplied by the air concentration predicted for an infinite contaminated area to make it possible to determine the concentration in air resulting from the finite area. Earlier versions of RESRAD provided for a contaminated area measuring 40,000 cubic meters, a dilution length of 3 meters, and an area factor of **.985**. Using the new area factor in the most recent RESRAD version, combined with a mean wind speed of 4 meters per second (the Denver mean air speed), the area factor changes to **.104**. The air concentration arrived at with RESRAD Version 5.82 can be nearly a factor of 10 times less than that calculated with the old value. This results in a **lower** dose with a **higher** allowable soil concentration (soil action level). Dr. Till then showed and discussed a slide that reflected some marked differences between RESRAD Version 5.61 and 5.82. As an example, incorporating Pu-239 as the contaminant of concern, the soil action level for an office worker calculated with Version 5.61 would be 1,088 pCi/g, while Version 5.82 arrived at a level of 7,116 pCi/g. The only thing changed would be the area factor model. Scenarios for open space and residential scenarios also represented significant increases. Dr. Till stressed that he had one point to make with this information: one must be extremely careful with these codes and not blindly insert numbers into the codes. This is an example of why RAC is approaching this exercise so deliberately. *RAC's* with the resuspension model will be to try to insert something that they believe is an improvement over RESRAD Version 5.82. One subtle change can make a huge difference in the results. RAC believes that the newer version of RESRAD is improved, but that doesn't mean that RAC will come up with the same number.

Panel Discussion

- *Several panel members expressed their dismay at the outcomes reflected in the new version of RESRAD*
  Dr. Till reminded the Panel that his only purpose in developing the slide reflecting the difference between the two versions was to illustrate the importance of changing input parameters for the models. RAC is not

362

concerned about these numbers but is only trying to make a point of the importance of carefully proceeding carefully when developing scenarios and input parameters.

- *Hank Stovall said that he was so concerned about the science that went into both the original and revised versions of RESRAD that he believes the Panel needs to draft a letter to DOE officials inquiring as to the original scope of work issued to Argonne National Laboratory for development of the RESRAD program.*
- *Joe Goldfield said that application of any of the numbers reflected in this slide from the new program is reducing this project to absurdity. Use of numbers like this would result in the site being categorized as a waste dump.*

  Dr. Till again stressed his purpose for discussing this information: he merely wanted to demonstrate what the difference would be if the same data used for the first version of RESRAD was put into the revised model with no changes other than inputting the wind speed to run the calculation. One other point he made is that this is a scientific process that we are undertaking, but there must be a certain "comfort level" associated with whatever answer is derived.
- *Niels Schonbeck said that the lesson he takes from this is that he is uncomfortable with computer models in general; i.e., if one can see this much of a difference between two versions of RESRAD by changing one factor, he needs further proof that the model is sound.*

  Dr. Till agreed with this statement and said that RAC representatives had pointed out this very thing in the Task 2 report.
- *Steve Gunderson reminded the Panel that the interim levels – or any levels, for that matter – do not take into account protection of surface water. Dr. Till mentioned the importance of the Actinide Migration Studies related to groundwater, but it is also important to emphasize the importance relative to surface water. Information coming from these studies will likely have tremendous influence on future soil action levels.*
- *Joe Goldfield added that when looking at the 53,130 pCi/g for a resident, he realized that the number translates to about 1 microgram of plutonium per gram of soil. A microgram is the allowable lifetime body burden of a worker in an atomic plant. One gram of that soil contains plutonium equal to the allowable lifetime body burden of an atomic worker.*

  Dr. Till again emphasized that he is not proposing these levels, but is only discussing them to make a point of the importance of input parameters.
- *Bob Kanick reflected that if one were to call into question models, per se – and it is a valid argument that sometimes you just can't capture a certain process with a model – are there any alternatives? Has RAC thought of any alternatives in terms of assessing what exists at this site?*

  Dr. Till's answer was "No – and I don't think there are alternatives. I think all we can do is take our best shot at the models we use and the parameters we put in them. The other thing we can do is look at levels at other places and where people have lived and just develop in your own mind some level of comfort with the answer provided by the models. But, I don't think there is an alternative."
- *Bob Kanick added that Dr. Till had touched on something there and that is the empirical aspect of this. Is there any clinical or epidemiological information about people who have lived on sites like this?*

  Dr. Till responded that he knows of no place in this country where people have lived on a plutonium-contaminated area that has been studied.
- *Niels Schonbeck reflected that if we "hang our hat" on science and science does not come up with what we need, then where are we? It is quite possible that these models will not satisfy, so we may need to be thinking about what is the alternative. Not the alternative for the contractor for the duration of this study, but our alternative as to what recommendations the Panel might make in the end. How wise is it for us to hang our hat on science when it may not provide us the answer that will meet our comfort level?*
- *Bob Kanick said that on the flip side of that, he becomes very wary of starting to question science. He reminded the group this is way to premature to question the validity of science and reaffirmed that the examples provided do not necessarily reflect the parameters that will be used by RAC in the analysis. He added that he is not even close to thinking that science has failed us in this effort.*
- *LeRoy Moore asked if RAC understands what it is in the codes that results in such a difference in numbers. Are things embedded in the computer code itself that could account for such a difference in numbers?*

  Dr. Till responded that yes, they do know why the difference – and that is the resuspension numbers, and yes to a point there are some components embedded in the program that could affect the outcome. There are also some differences in the numbers RAC will be proposing versus what was earlier used. In addition, he stated that if RAC had done the first calculation they already know some places where there would have been changes to parameters, and they did not like the resuspension model in the earlier RESRAD version. As an example, one key parameter is the mass loading (i.e., how much mass is in a cubic meter of air at a given time on the average). RAC is looking in-depth at this critical parameter. The value used in the original calculation is on the low end of that distribution, so that is one very key thing that they will be looking at when performing calculations.

- *Victor Holm interjected that it is important for the Panel to realize that these computer programs really are not "black boxes". Although some of the formulas are very complicated, the inhalation formulas are not that difficult to understand. One can actually use a calculator to arrive at the exact numbers. It is not the "black box" that is the problem, it's the parameters and whether or not the equations used are appropriated. He also said that he believes it is a mistake to think that DOE has somehow "cooked up" a black box, shoved things in, and gotten answers out the other end. Mr. Holm said that he understands the equations very well, as does John Till.*
- *Joe Goldfield reflected that we continually use the term "science" in discussions, when it is his opinion that "this is not science". He added that science, when dealing with a poisonous material, looks for data to determine its toxicology. Every other poisonous material that he is familiar with had epidemiological studies conducted to determine the effects of that material on human beings. Mr. Goldfield stated that when the interim soil action levels were set at 1429 pCi/g, he wrote to DOE and asked if officials knew of anyplace in the world where people have lived or are living on soil contaminated to that level. To date he has received no answer, and he believes that there is no place that fits that description. Therefore, we are dealing without any data – and that's not science. Now we are trying to take whatever parameters we choose and calculate something for which we have no data. The basic missing data deals with potential health problems of individuals living on sites contaminated to this level. Missing that data, we get into all kinds of incredible calculations that seem to have less and less validity.*

PUBLIC COMMENT

None

SOIL INGESTION INFORMATION UPDATE* - Discussion Lead: Dr. Kathleen Meyer, *Risk Assessment Corporation*

*Copies of presentation available by calling Anna Corbett - 303-456-0884

Dr. Meyer began her discussion with an update on the Actinide Migration Studies project. Los Alamos National Laboratory researchers are employing state-of-the-art techniques and using the Stanford accelerator to perform some sophisticated analyses, including a characterization of the plutonium in soil samples extracted from the RFETS 903 pad area. Their work has shown that plutonium from soil under the 903 pad is insoluble $Pu0_2$ (plutonium oxide). This work provides solid proof for what many have assumed; i.e., the plutonium in the soil at Rocky Flats is large insoluble $Pu0_2$. No report on this work has been published to date, but that is anticipated in the near future. All of this work is trying to define potential exposure pathways, but RAC still feels confident that inhalation is the major pathway, which is supported by some of this work.

Dr. Meyer then moved into providing additional findings on soil ingestion related to geophagia (a condition in which a person eats inedible substances such as chalk, clay, or earth). Dr. Meyer has identified some relatively new studies on this subject with more specific details: This condition is seen worldwide and occurs in all ages as well as many subpopulations including children, adolescents, and pregnant women. One thing learned in looking at the studies is that most of the studies tend to be undertaken with children. This is likely due to the fact that this is an easier group to control under experimental conditions; e.g., studies set in a day care program or school setting can be tracked, observed, and controlled in a way that is not typically possible with adults. As a result, there has been more research on geophagia in children, but the condition is certainly seen in other individuals. Soil ingestion, per se, is quite difficult to verify and quantify. In fact, some studies do not differentiate between inadvertent or intentional intake. However, after looking at the studies, RAC believes that the behavior is not one that should be included as a separate scenario. In looking at the studies, RAC also realized that most of the studies are conducted under idealized conditions – not necessarily in the laboratory – during mild seasons or in day care settings. Although the authors clearly point out that they don't necessarily want a setting that encourages soil ingestion, it is desirable to create a setting that provides the ability to better observe the phenomenon. Some of the studies took place over a few days or weeks, while some of the more elaborate projects took place over a month. The studies seem to be quite valid with valid ingestion rates. However, the difficulty arises in taking a daily soil ingestion rate and translating it into an annual rate. One must be careful in doing that due to weather variations when soil is not readily accessible. As a result, RAC reviewed the distributions and included more studies in those distributions and recognized that it would be more realistic to take the 50^{th} percentile value of the daily soil ingestion rate for use in the scenarios. From that, the annual soil ingestion rate could be calculated based upon the number of days the person would be on-site. This method would still provide a conservative approach to soil ingestion as well as a plausible annual ingestion rate. Dr. Meyer briefly mentioned several soil ingestion studies and then discussed how they would fit probability distribution to the data from those studies and then looked at how deterministic values from studies fit into the distribution. A comparison of key scenario parameters for the seven proposed scenarios was briefly recapped. Dr. Meyer added that the rancher scenario will include some use of groundwater for irrigation and drinking water; however, as previously discussed, groundwater is a very complex issue. As a result, existing codes within the model will be used. This is an area that will continue to change, and it is likely that information from the Actinide Migration Studies will provide some impact.

Following the discussion, the Panel reached consensus on the scenarios as discussed and developed; therefore, RAC representatives will proceed with the project with the approved scenarios.

BREAK

TASK 6: SAMPLING PROTOCOLS – David Thorne, Risk Assessment Corporation

*Copies of presentation available by calling Anna Corbett - 303-456-0884

The purpose of this task was to review the soil sampling protocols and related quality assurance measures that are currently in place at Rocky Flats and in turn make a recommendation to the Panel for a future approach that could be used to verify radionuclide soil action levels. This report basically provides recommendations to the Panel for consideration in developing a sampling protocol for the Rocky Flats site. RAC representatives began with a review of the current site sampling program and procedures to evaluate the current program against established guidance and standards. Included in the review was the overall sampling program, quality assurance, standard operating procedures, and individual site sampling and analysis plans. Overall, the site's sampling program incorporates the current guidelines and requirements of numerous agencies including the American Society of Mechanical Engineers, U.S. Department of Energy Orders 5700.6C and 5400.1, U.S. Environmental Protection Agency guidance for CERCLA, and Multi-Agency Radiation Survey and Site Investigation Manual methodologies. In addition, review of the site's sampling program determined that appropriate quality assurance, standard operating procedures, and data quality objectives development processes and documentation exists to support soil sampling field and analytical data.

Rocky Flats uses four radionuclide sampling methods: CDPHE, Rocky Flats, Grab Sampling, and Vertical Soil Profile. The primary area of concern focuses on the varied use of two of the soil sample collection methods: (1) the CDPHE method and (2) the Rocky Flats method. The two methods, which provide for differing sample collection depths, have created problems when attempting to compare data sets from numerous studies. Recent studies, including the Phase II Remedial Feasibility Investigation/Remedial Investigation Report for the 903 Pad, Mound, and East Trenches Area Operable Unit No. 2 used both methods so that comparisons to older data sets could be made.

Additional information was provided on radionuclide soil sampling methods, as follows:

<u>CDPHE Method</u> - uses a sampler designed to sample upper soil surface to a ¼" depth. Prior to sampling, vegetation and any undesirable top surficial material layers are removed. Twenty-five evenly spaced samples and composites are typically collected into one sample for each sampling location.

<u>Rocky Flats Method</u> - designed to collect a soil sample 5-cm deep with a total volume of 5000 cm^3. Soil is then removed from outside of the jig and a scoop is used to finish cut on the open face side as well as the bottom surface. Ten samples are collected at each location and composited into one sample for analysis. One sample is pulled from the center and two corners of two 1 m^2 areas that are spaced 1 m apart. Soil samples are then passed through a 10-mesh sieve to remove large particles.

<u>Grab Sampling Method</u> – uses a spade and scoop to collect samples. Vegetation and undesired surficial materials are removed prior to sampling. Soil samples are collected to the desired depth using a stainless steel scoop or spade. The total numbers of samples are specified in the site-specific sampling plans developed for the specific project.

Vertical Soil Profile Method – designed to define the distribution of radionuclides in the top 6" of soil to verify survey results. Discrete soil samples are collected at 2" depth intervals down to a maximum of 6". The total number of samples and specific locations are specified in the site-specific sampling plans. A sample of 500 g is typically obtained in this method.

After reviewing the four methods in-place at Rocky Flats, the RAC team compiled the following list of their recommendations for 10 key elements that should be a part of any sampling protocol:

1. Data Quality Objectives – consists of 7-step process for a sampling program
2. Multiple radionuclide consideration – use of the sum of ratios rule to ensure that the total dose due to the sum of all radionuclides does not exceed the release criterion
3. Classification/Identification of Survey Units – uses 3 classes for areas based upon the potential for contamination exceeding the action levels
4. Soil Sampling Depth – sampling depth must be sufficient to provide information on both the surface soil (resuspension) and soil layers to find the total inventory for other pathways such as groundwater or plant uptake
5. Sample Spacing & Methods – discussed five different approaches to sample spacing and associated pros and cons
6. Small Areas of Elevated Activity – discussed method that may be used to assure that a process is developed that will detect small areas of elevated levels within a sample area
7. Surrogate Measurements – this is considered important since a surrogate radionuclide is one that is easily measured and implies through correlation the concentration of other radionuclides
8. Number of Samples Based on Statistical Methods – an important part of a sampling program is calculating the number of required samples that will provide conclusive information
9. Independent Confirmatory Investigations – this element provides for an independent third party to provide data to substantiate the results of the final status survey
10. Soil Sampling Quality Assurance – this element consists of 6 data quality indicators that should be a part of every sampling program

After reviewing the current sampling protocols and incorporating the above ten elements of a sampling protocol, RAC is making the following recommendations for a future program at Rocky Flats to validate radionuclide soil action levels:

1. Include a member of the RSALOP on the Data Quality Objectives team
2. Consider assessing multiple radionuclides for comparison to the radionuclide soil action levels
3. Use a classification scheme for identifying survey units with contamination near or above the RSALs for more focused sampling efforts
4. Select survey units and determine the appropriate area of the survey units
5. Use appropriate sampling depth and sampling methods for comparison to various pathways of concern
6. Conduct systematic grid sampling
7. Implement additional methods to ensure that small areas of elevated contamination are identified and investigated
8. Use surrogate measurements to reduce the analytical cost of investigations
9. Employ statistical methods to determine the appropriate number of samples and ensure a statistically significant result
10. Use an independent verification survey to evaluate results
11. Establish quality assurance requirements for soil sampling methods to determine the number of required quality assurance samples for each survey unit

Panel Discussion

- *Joe Goldfield expressed concern about hot spots: let's take as an example that a mother may set a playpen right on the hot spot outside of the home. To complicate that, suppose the child ingests dirt – that child could receive a fatal dose of plutonium. In addition, let's suppose that the hot spot is upwind from an open window from a home – although RAC has commented that the wind averages everything out, he can't understand why any material lifted off the hot spot would not be sent undiluted a short distance into an open window.*
- *Hank Stovall said that from his background in a manufacturing environment, one of the key ways to assure quality is to be certain that the process is monitored along the way. He is concerned that this approach looks at quality at the end of the process versus being monitored along the way.*

  Mr. Thorne responded that he knows that Rocky Flats provides for audits throughout the process versus just at completion, although this may be a self-monitoring quality assurance check.

- *Niels Schonbeck questioned how the site will approach the area question – how will they approach the cleanup. In other words, what authority will this Panel or this study's outcome have in the way cleanup is ultimately approached by site officials? Mr. Schonbeck recommended that the Panel begin giving some thought to formulating a very strong recommendation for the process – specifically things like the maximum size of an area to be cleaned up.*

  David Thome responded that this could be quite difficult. In other words, there is a wide variety of approaches or protocols that could be taken, and none of the approaches may be considered wrong, per se.
- *Joe Goldfield asked if RAC was going to recommend anything specific for sampling.*

  David Thome responded that he is hesitant because there are so many variables in any process.

PUBLIC COMMENT

Diane Niedzwiecki, CDPHE, asked if in the scenarios the size or acreage was considered.

Dr. Kathleen Meyer responded that the size or acreage had not been specifically defined, but the idea was that the rancher would be located east of the 903 area, with some potential modifications to the code to handle that placement. However, no specific size has been defined for any of the scenarios.

ANNOUNCEMENTS

LeRoy Moore announced that following the Risk Workshop by Charlie Meinhold, he had sent a letter and accompanying materials to Dr. Meinhold for his information. Copies of these materials are available from Dr. Moore.

PANEL DISCUSSION

Bob Kanick asked for clarification regarding background materials that had been sent to the Peer Review Team. Mr. Kanick noted that when reading the Peer Review comments to the Task 2 Report, he noted that mention was made of some of the background materials that had been provided. It was his belief that this Panel had gone to great lengths to assure that the Peer Review would be independent and did not want to influence the peer review efforts in any way. He expressed dismay to learn that they were sent several reports, and he asked for clarification of why those materials were sent and how we might avoid such an occurrence in the future.

Hank Stovall responded that in the conference call with the Peer Review Team, they specifically requested background materials to provide them with overall knowledge of the project and why it was begun. It was determined by the participants in the conference call, including members of the Peer Review Subcommittee, agreed to forward the materials.

FUTURE AGENDA ITEMS

- Elevated areas (follow-on to Task 6 Report)
- Brief discussion of Task 3

MEETING WAS ADJOURNED AT 7:00 P.M.

NOTE:
COMMENTS ON THE DRAFT TASK 6 REPORT ARE DUE TO CARLA SANDA BY JUNE 4, 1999
PLEASE EMAIL YOUR COMMENTS TO CARLA AT: candftrvl@msn.com
YOU MAY ALSO FAX COMMENTS TO: 303-456-0858

Upcoming Meetings & Activities

All future meetings will be held from 4 - 7 p.m. at the Broomfield City Building, One Descombes Dr., Broomfield, CO - Zang's Spur/Bal Swan Conference Rooms, on the following dates: June 10, July 8, August 12, September 9, October 14, November 11

NOTE: The previously-elected Steering Committee, made up of: Mary Harlow, Hank Stovall, Leroy Moore and Lisa Morzel routinely meets each Monday prior to the regularly scheduled meeting to plan the agenda. Panel members may attend this meeting. To confirm meeting date, time and place, please contact either Mary Harlow or Hank Stovall.

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P	Joel Selbin	UCD Chem Dept	[redacted]	303-492-5894
P	Todd Margulies	TM Consulting	303-279-6699	Mail or e-mail

Jill M. Weber *Scientific Consulting, Inc.*

April 15, 1999

Carla Sanda
Anna Corbett

Here is the draft final version of the Task 1 report. I spoke to Ken Korkia about the delivery of this report, and he requested that I mail it to you for copying and distribution to the panel.

Please note that the report is printed double-sided to insure that it is copied appropriately.

Thanks much!

Jill

Jill Weber, president
Scientific Consulting, Inc.
Consultant to *Risk Assessment Corporation*

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DRAFT FINAL REPORT

Task 1: Cleanup Levels at Other Sites

Rocky Flats Citizens Advisory Board
Radionuclide Soil Action Level Oversight Panel

April 1999

Submitted to the Rocky Flats Citizens Advisory Board in Partial Fulfillment of Contract between RAC and RFCAB

"Setting the standard in environmental health"

Risk Assessment Corporation
417 Till Road, Neeses, SC 29107
Phone 803.536.4883 Fax 803.534.1995

370

DRAFT FINAL REPORT

Task 1: Cleanup Levels at Other Sites

Rocky Flats Citizens Advisory Board
Radionuclide Soil Action Level Oversight Panel

April 1999

Author
Jill M. Weber, Scientific Consulting, Inc.

Principal Investigator
John E. Till, Ph.D., *Risk Assessment Corporation*

Submitted to the Rocky Flats Citizens Advisory Board
in Partial Fulfillment of Contract between RAC and RFCAB

371

CONTENTS

TASK 1: CLEANUP LEVELS AT OTHER SITES

INTRODUCTION

Soil action levels are calculated to identify the concentration of one or more radionuclides in the soil above which action should be taken to prevent people from receiving unacceptable radiation doses. The soil action levels for radionuclides calculated for the Rocky Flats Environmental Technology Site (RFETS) by the U.S. Department of Energy (DOE), U.S. Environmental Protection Agency (EPA), and the Colorado Department of Public Health and Environment (CDPHE) have come under scrutiny because of lack of public involvement throughout their development. As a result of public concern, DOE provided funds to the Rocky Flats Citizen's Advisory Board to establish the Radionuclide Soil Action Level Oversight Panel (RSALOP) and to hire a contractor to conduct an independent assessment and calculate soil action levels for Rocky Flats. *Risk Assessment Corporation (RAC)* was hired to perform the study.

The first task of the study (Task 1: Cleanup Levels at Other Sites) was designed to provide the Oversight Panel with a clear and unbiased evaluation and comparison of previously developed soil action levels for the RFETS and other facilities. This report documents the findings of Task 1.

SOIL ACTION LEVELS AND CONCENTRATIONS AT OTHER SITES

A number of national and international sites have established soil action levels, cleanup criteria, or soil concentrations that are either calculated or measured. These soil action levels have been determined to be protective of human health based on a reasonable land use scenario and predetermined dose criteria. This section briefly summarizes each site in terms of the dose, scenario, and pathways used to calculate the cited soil action level. A later section of the report describes the details of each calculation, including important parameter values, and provides equitable comparisons, where possible.

The one constant across all the sites is that the soil action level was calculated or soil concentration determined for $^{239,240}Pu$. This concentration is provided for each site. Where ^{241}Am soil concentrations are available, they are also given.

The sites evaluated in this analysis are

- Rocky Flats Environmental Technology Site
- Hanford, Washington
- Nevada Test Site
- U.S. Nuclear Regulatory Commission (NRC) codes for remediation
- Johnston Atoll, Marshall Islands
- Enewetak Atoll, Marshall Islands
- Maralinga, Australia
- Semipalatinsk Nuclear Range, Kazakhstan
- Thule, Greenland
- Palomares, Spain.

Rocky Flats Environmental Technology Site

Soil action levels were calculated for the RFETS and documented in a 1996 report (DOE 1996). The RESRAD computer code (Yu et al. 1993) was used to calculate these action levels for three different land use scenarios at two different dose levels.

The three scenarios used in the Rocky Flats calculations were (1) an open space exposure scenario, (2) an office worker exposure scenario, and (3) a hypothetical future resident scenario. Action levels were calculated for ^{241}Am, ^{238}Pu, ^{239,240}Pu, ^{241}Pu, ^{242}Pu, ^{234}U, ^{235}U, and ^{238}U. Soil action levels for the open space and office worker scenarios were calculated for the annual effective dose equivalent limit of 15 mrem, and the hypothetical future resident scenario soil action levels were calculated for both the 15 mrem and 85 mrem annual effective dose limits, as selected by the DOE (1996).

The open space exposure scenario assumed that an individual visited the area a limited number of times during the year for recreation (DOE 1996). This recreation might include hiking, biking, or wading in creeks. For this exposure scenario, soil ingestion, soil inhalation, and external gamma exposure were the pathways considered. The remaining pathways available in RESRAD (plant ingestion, meat ingestion, milk ingestion, aquatic food ingestion, ground and surface water ingestion, and radon exposure) were not considered (DOE 1996).

The office worker exposure scenario assumed an individual worked mainly indoors, in a building surrounded by paved areas or landscaping. Exposure pathways considered were soil ingestion, soil inhalation, and external gamma exposure (DOE 1996).

The hypothetical future resident scenario assumed that a person resided at Rocky Flats all year and ate produce grown in contaminated soil. Pathways included in this analysis were soil ingestion, plant ingestion, soil inhalation, and external gamma exposure. The pathways removed from consideration were either inconsistent with the site conceptual model or not significant dosimetrically (DOE 1996). For instance, the groundwater and surface water ingestion pathway was removed from the analysis because it was assumed that the water found on the Rocky Flats site would not be sufficient to support domestic use (DOE 1996).

In Table 1, action levels for each scenario (in units of picocuries per gram) are given for each dose level for the radionuclides ^{239,240}Pu and ^{241}Am.

Table 1. Soil Action Levels for Each Scenario and Dose at the RFETS (pCi g^{-1})

	Scenario used for soil action level calculation			
Radionuclide	Open Space Exposure Scenario (15 mrem y^{-1})	Office Worker Scenario (15 mrem y^{-1})	Hypothetical Future Resident (15 mrem y^{-1})	Hypothetical Future Resident (85 mrem y^{-1})
^{239,240}Pu	9906	1088	252	1429
^{241}Am	1283	209	38	215

These action levels are for single radionuclides. That is, each action level is calculated assuming that the radionuclide of interest is the only radionuclide found on site.

Hanford, Washington

Calculations of soil action levels at Hanford were also done using the RESRAD code, and details of these analyses were published in a 1997 document (WDOH 1997). The two scenarios considered in this study were (1) rural residential exposure and (2) commercial/industrial exposure. These two scenarios are somewhat parallel to the hypothetical resident and office worker Rocky Flats scenarios.

The rural residential scenario assumed a person lived full-time on the Hanford facility. This individual was exposed chronically, indoors and outdoors, to radionuclides in soil, via ingestion, inhalation, and external exposure. The rural residential scenario assumed that the individual worked primarily offsite and engaged in light farming and recreational activities onsite. A portion of the produce, meat, milk, and fish consumed were assumed to come from the site, and drinking water was from an onsite well (WDOH 1997).

The commercial/industrial scenario assumed a person worked onsite, primarily inside a building, although outdoor exposures were also assumed to occur. This scenario assumed that the office worker lived offsite. No ingestion of homegrown food was included in this scenario. Pathways included were limited to external gamma, inhalation of soil, and ingestion of soil (WDOH 1997).

Table 2 shows soil action levels for the two Hanford scenarios, calculated for an annual effective dose limit of 15 mrem.

Table 2. Soil Action Levels for each Scenario and Dose at Hanford (pCi g^{-1})

	Scenario used for soil action level calculation	
Radionuclide	Rural Residential Scenario (15 mrem y^{-1})	Commercial/Industrial Scenario (15 mrem y^{-1})
$^{239,240}Pu$	34	245
^{241}Am	31	210

Nevada Test Site

Calculations of soil action levels were done for the Nevada Test Site by the DOE Nevada Operations Office (DOE-NV 1997). These calculations were performed to show that, subsequent to remediation, the doses received by individuals who may occupy the Tonopah Test Range at the Nevada Test Site would not exceed the dose limits established by the DOE of 100 mrem y^{-1}.

Calculations were done assuming that all areas of the Tonopah Test Range Clean Slate Sites where radiation levels due to $^{239,240}Pu$ exceeded 200 pCi g^{-1} would be remediated to 200 pCi g^{-1} or lower. The RESRAD code was used to calculate dose from the assumed radiation levels in soil.

Four scenarios were used in the dose calculation: a residential rancher, a residential farmer, a rural residence (nonfarming), and a person who worked in light commercial industry. In addition to these adult scenarios, a scenario involving a child who participated in the rancher exposure scenario was included. The rural resident scenario was exposed to external radiation; inhalation of contaminated soil and radon gas and daughter products; and ingestion of soil, drinking water, homegrown produce, meat, and milk. This person was, however, assumed to work offsite and spend only limited time gardening and recreating onsite.

The rancher and farmer scenarios are the closest comparisons to the Rocky Flats rural resident because these scenarios include a significant fraction of time during the year spent onsite. These two scenarios both included exposure pathways of external exposure, inhalation of soil and radon gas and daughter products, and ingestion of soil and drinking water. The rancher scenario included the additional pathways of ingestion of meat and milk, and the farmer scenario included ingestion of homegrown produce. The child scenario implemented the same pathways as the rancher scenario, but it included breathing rates and diet parameters consistent with those of a child.

The industrial worker scenario at the Nevada Test Site is somewhat comparable to the office worker scenario calculated for Rocky Flats. The industrial worker was exposed to external radiation, inhalation of soil and radon, and ingestion of soil and groundwater. This scenario included an 8-hour work day involving both indoor and outdoor work.

Doses for the five scenarios (four adults and one child) were calculated for an achievable $^{239,240}Pu$ soil concentration, determined by the site, of 162 pCi g^{-1}. A soil concentration of 13.2 pCi g^{-1} was presumed for ^{241}Am. Table 3 shows the doses resulting from this soil concentration for both ^{241}Am and $^{239,240}Pu$.

Table 3. Doses for each Scenario for Soil Concentrations Shown at the Nevada Test Site (mrem)

	Scenario used for dose calculation for given soil concentration				
Radionuclide	Rural Residential Scenario	Rancher Scenario	Farmer Scenario	Industrial Worker Scenario	Child Rancher Scenario
^{241}Am (13.2 pCi g^{-1})	1.00	3.56	1.84	0.42	1.61
$^{239,240}Pu$ (162 pCi g^{-1})	10.7	42.6	20.1	3.97	16.7

U.S. Nuclear Regulatory Commission DandD Code Scenarios

The Decontamination and Decomissioning software (DandD) was written for use by NRC licensees to assist them in making screening calculations for cleanup of contaminated facilities. The residential farmer scenario outlined in the DandD code was for a full-time resident of the facility of interest, allowing for some time offsite, as did the Rocky Flats residential calculation. This resident grew as much food as reasonably possible on the facility of interest. The pathways included in the analysis were external gamma exposure; inhalation of soil; and ingestion of soil, water, plants, meat, milk, fish, and poultry. The calculation also included a pathway for irrigation of crops and livestock fodder with contaminated water.

On the whole, the pathway calculations in DandD are highly conservative. We encountered a great deal of difficulty in comparing DandD and RESRAD results because the design of this code is still in preliminary stages and the documentation describing the pathways is not complete or publicly available.

Using default parameters for the DandD residential scenario (Beyeler et al. 1998) (which were selected by the NRC as screening level values), for a soil concentration of 1 pCi g^{-1}, the calculated maximum dose for $^{239,240}Pu$ is shown in Table 4.

Table 4. Dose for Given Soil Concentration in the U.S. NRC DandD Code (mrem)

Radionuclide	Residential Farmer Scenario
$^{239,240}Pu$ (1 pCi g^{-1})	288

Johnston Atoll, Marshall Islands

The dose assessment done for Johnston Atoll in the Marshall Islands was completed after the cleanup efforts were finished. Soil was cleaned to approximately 15 pCi g^{-1} using mining techniques, and this cleanup was verified by Oak Ridge National Laboratory (Wilson-Nichols et al. 1997).

A permissable soil concentration at Johnston Atoll was calculated for a full-time resident exposed to radioactive material through inhalation of contaminated soil. This was the only pathway considered in this dose assessment, and concentrations were calculated for a dose limit of 20 mrem y^{-1}. Because only the inhalation pathway was considered, establishing a detailed scenario was not necessary. Because occupation of the site by the exposed individual is year-around, the Rocky Flats hypothetical future resident scenario exposure traits are the most comparable.

For the Johnston Atoll residential scenario, the dose was calculated for generic compounds of plutonium or americium. The soil concentration was defined as that for $^{239,240}Pu$.

Table 5. Soil Concentration for the Residential Scenario at Johnston Atoll (pCi g^{-1})

Radionuclide	Residential Scenario (20 mrem y^{-1})
$^{239,240}Pu$	17.0

Enewetak Atoll, Marshall Islands

The soil concentrations established for use at Enewetak Atoll have not been discovered to be correlated to a dose assessment. Three different categories of land use were selected, and these categories are shown in Table 6 with their soil concentration limits. Although attempts have been made, the dose calculations associated with these soil concentrations have not been found in the literature.

Table 6. Soil Concentrations Established for Different Land Uses at Enewetak Atoll (pCi g^{-1})

Land use		
Food gathering	Agricultural	Residential
160	80	40

Maralinga, Australia

At the Maralinga Range in Australia, soil concentrations were calculated for a population of semi-traditional aboriginal people permanently residing in the area. Soil concentrations were calculated for a publicly accepted dose limit of 500 mrem. The only pathway considered in this analysis was exposure via inhalation of contaminated soil. The scenario from the Rocky Flats analysis most comparable to the Maralinga soil concentrations is the hypothetical future resident.

Soil concentrations calculated at 500 mrem for this residential aboriginal population are shown in Table 7.

Table 7. Soil Concentration Calculated for the Residential Scenario at Maralinga (pCi g^{-1})

Radionuclide	Residential Scenario (500 mrem y^{-1})
$^{239,240}Pu$	280

Semipalatinsk Nuclear Range, Kazakhstan

This facility in Kazakhstan was the site of many Russian nuclear tests. The dose and soil concentration information from this facility included no summary of the calculational method used to obtain the dose information. It was not apparent from reading through the available documentation whether the doses and deposited activities were associated with each other in any way. Deposited activities were converted to soil concentrations, assuming normal soil density and depth of contamination. The dose and soil concentration information is shown in Table 8.

Table 8. Activity and Population Dose at Principal Settlements in Semipalatinsk

$^{239,240}Pu$ Deposited Activity (pCi g^{-1})	Individual Dose to Population (mrem)
1.32	Up to 1.5×10^5

Thule, Greenland

The nuclear accident at Thule, Greenland, resulted in concentrations in sediments and not in soils. Because these concentrations are not comparable to Rocky Flats, we do not relate them to Rocky Flats concentrations in this section.

Palomares, Spain

Following a nuclear accident, soil contamination at Palomares, Spain, was immediately cleaned. A dose assessment was completed later by Iranzo et al (1987). For a residential receptor, the pathway of concern was the inhalation of contaminated soil. For this pathway, the acceptable air concentration was calculated based on an annual acceptable dose of 100 mrem. The soil concentration is shown for $^{239,240}Pu$ in Table 9.

Table 9. Soil Concentration for the Residential Scenario at Palomares (pCi g^{-1})

Radionuclide	Residential Scenario (100 mrem y^{-1})
$^{239,240}Pu$	1230

Summary of Available Site Information

Across the mentioned sites, soil concentrations and associated doses vary greatly. The following table is a summary of the soil concentrations measured or calculated at the sites reviewed for this study. Only the scenarios that are comparable to Rocky Flats scenarios are shown. In the next section, we compare all calculations from the different facilities possible to the Rocky Flats in an effort to identify the differences.

Table 10. Soil Concentrations and Associated Doses for ^{241}Am and ^{239,240}Pu Across Sites

Site	Scenario	Soil Concentration (pCi g^{-1})		Dose (mrem y^{-1})	
		^{241}Am	^{239,240}Pu	^{241}Am	^{239,240}Pu
Rocky Flats	Hypothetical future resident	215	1429	85	85
	Office worker	209	1088	15	15
Hanford	Rural resident	31	34	15	15
	Occupational/Industrial worker	210	245	15	15
Nevada Test Site	Rancher	13.2	162	3.56	42.6
	Industrial worker	13.2	162	0.42	3.97
U.S. NRC Codes	Residential farmer	NA	1.0	NA	288
Johnston Atoll	Residential (inhalation)	NA	17.0	NA	20
Enewetak Atoll	Residential	NA	40	NA	unavailable
Maralinga	Residential (inhalation)	NA	280	NA	500
Semipalatinsk	Settlements	NA	1.32	NA	150000
Palomares	Residential (inhalation)	NA	1230	NA	100

SENSITIVITY ANALYSIS

Initial sensitivity analyses of the RESRAD code and parameters used for the Rocky Flats hypothetical future resident scenario at the 85 mrem y^{-1} dose level show that a few parameters dominate the outcome of the action level calculation. These parameters were identified using a single-parameter sensitivity analysis (that is, only one parameter was altered at a time to explore the sensitivity of the RFETS calculation to changes in the parameter). This sensitivity analysis helped identify those parameters that controlled the Rocky Flats soil action level calculation for the Task 1 study. For example, when an action level at another site was significantly different from the RFETS value, we could identify what was likely controlling the difference. Two parameters at the RFETS emerged from the sensitivity analysis as most important and most sensitive to change: mass loading factor and dose conversion factor. The mass loading factor for the RFETS calculations was 0.000026 g m^{-3}. The dose conversion factor for ingestion was 0.000052 mrem pCi^{-1} and for inhalation was 0.308 mrem pCi^{-1}. These dose conversion factors are consistent with Class Y (insoluble) plutonium with a particle size of 1 μm activity median aerodynamic diameter (AMAD). These parameters will be explored in more detail in Tasks 2 and 3, but their importance affects the Task 1 study.

METHOD OF COMPARISON

Action and cleanup levels are often determined independently of dose levels or are based on a dose other than the 15 or 85 mrem y^{-1} used in the RFETS scenario calculations. These varying dose levels made direct comparison more difficult; therefore, we mathematically compared different soil action levels among sites by normalizing the action level to annual dose. In the remainder of this report, annual dose is understood, and dose is represented in units of millirem (mrem). Normalization means that a ratio was calculated for soil action level or concentration to dose level, representing the action level for a unit dose, or 1 mrem. This equitable comparison allows for straightforward identification of pathway, scenario, and parameter differences that affect the ratio. If these differences can be identified among the RFETS and other sites, the ratios between sites should be comparable.

Each ratio is identified in two ways:

1. Dose to soil action level (millirem per picocurie per gram) (mrem [pCi $g^{-1}]^{-1}$) and
2. Soil action level to dose (picocurie per gram per millirem) ([pCi g^{-1}] $mrem^{-1}$).

These ratios are reciprocals. They each have their merits and many different readers find one of the two easier to understand. For a true normalization to dose, the focus should be on the soil action level to dose ratio, which identifies the action level per unit dose, or the soil concentration for each site consistent with a 1 mrem effective dose level. Therefore, if the soil action level to dose ratio is higher for the RFETS than it is for another site, then the allowable soil concentration is greater for the same dose. The opposite situation may also be true. In all cases, this report identifies possible sources for the difference in ratios and calculates the effect of each difference on the ratio to identify the contrast between the ratios.

Because the primary goal of this task was to understand why Rocky Flats soil action levels are consistently greater than those at other sites, we limited out calculations to gaining an understanding of the parameters that drive the action levels to such high levels. Identifying and comparing critical parameters for the RFETS with each site was the endpoint of each investigation. Precisely equating the soil action level to dose ratio between other sites and the RFETS was not our goal. Instead, it was important for us to identify the parameters controlling the action level and show their impact, thereby, making the RFETS action level calculation more transparent.

In some cases, cleanup at a site was conducted independent of dose, and a dose calculation could not be found in the available literature. In these cases, we described the cleanup level along with the soil concentration, but we did not make an effective or meaningful comparison. Without a ratio and some indication of how the calculation was completed, it was impossible to identify the differences among the sites in a way that is meaningful for this study.

COMPARISONS OF ROCKY FLATS SOIL ACTION LEVEL TO SOIL ACTION LEVELS AT OTHER SITES

Several of the previously discussed sites employed alternate action level calculations that lent themselves to comparisons to the Rocky Flats soil action levels for the Task 1 report. These included:

- Hanford, Washington
- Nevada Test Site
- Johnston Atoll, Marshall Islands
- Maralinga, Australia
- Palomares, Spain.

Additionally, the following sections discuss the events that resulted in soil concentrations at Enewetak Atoll, Marshall Islands; Semipalatinsk Nuclear Range, Kazakhstan; and Thule, Greenland. Because no information about dose calculations was available for these facilities, however, our discussion is limited to the facts and does not analyze the calculation or make a comparison of a ratio for these facilities to Rocky Flats. We also describe the U.S. NRC calculations and codes in more detail, but no comparisons of ratios are made to Rocky Flats because of the lack of documentation on the DandD code and the time frame and scope of this project.

Table 11 identifies the dose to soil action level and soil action level to dose ratios for each site where information was available. All ratios shown are for $^{239,240}Pu$, and additional ratios for ^{241}Am are shown when the data were available. The scenarios identified in Table 10 are shown for each site. Ratios and scenarios are described in more detail in the following sections.

Table 11. Ratios for Comparison among Different Sites[a]

Site	Scenario	Soil action level to dose ratio ([pCi g^{-1}] mrem^{-1})		Dose to soil action level ratio (mrem [pCi g^{-1}]$^{-1}$)	
		$^{239,240}Pu$	^{241}Am	$^{239,240}Pu$	^{241}Am
Rocky Flats, Colorado	Rural Residential	17	2.5	0.06	0.39
	Office Worker	73	14	0.01	0.07
Hanford, Washington	Rural Residential	2.3	2.1	0.44	0.48
	Industrial Worker	16.3	14	0.06	0.07
Nevada Test Site[b]	Rancher	3.8	3.7	0.26	0.27
	Industrial Worker	41	31	0.02	0.03
Johnston Atoll[c]	Residential (inhalation)	0.85	NA	1.2	NA
Maralinga, Australia	Residential (inhalation)	0.56	NA	1.8	NA
Palomares, Spain	Residential (inhalation)	12.3	NA	0.08	NA

[a] References identified in appropriate section of text.
[b] Ratios from Clean Slate Site 1.
[c] Dose from all alpha particles, soil action level for $^{239,240}Pu$.

It is clear that the values are not the same for all sites. In fact, the soil action level to dose ratio is less than 1 in some cases. For similar scenarios, the Rocky Flats soil action level to dose ratio for $^{239,240}Pu$ is always larger than the ratio at another facility. The following paragraphs provide a site-by-site analysis of each $^{239,240}Pu$ ratio for each scenario and why it differs from the ratio for the RFETS residential or office worker scenario.

Because the ^{241}Am soil action level to dose ratio was either the same for similar scenarios between Rocky Flats and another facility or larger at the other facility, we did not examine ^{241}Am

further. For this task, we were interested primarily in why Rocky Flats ratios exceeded those at other facilities. This condition did not apply to ^{241}Am.

Hanford, Washington

The Hanford Site in Washington was part of the nuclear weapons production complex and it still operates as a DOE laboratory. Dose reconstruction and cleanup efforts are underway at the facility. As a part the clean up, soil action levels were calculated for the facility using parameter evaluation techniques similar to those undertaken at the RFETS. The Hanford calculation is described in detail in a document issued by the State of Washington (WDOH 1997). All parameter values for Hanford cited and used in this section come from WDOH (1997).

For the residential scenarios at Hanford and RFETS, the soil action level to dose ratio for $^{239,240}Pu$ at Hanford is 2.3 (pCi g^{-1}) $mrem^{-1}$, compared to 17 (pCi g^{-1}) $mrem^{-1}$ at Rocky Flats. At Hanford, this scenario represented a person who lived on the current Hanford site all year, eating crops and livestock grown onsite, drinking from site streams, inhaling air, and ingesting soil. The Rocky Flats ratio for plutonium was significantly higher than that at Hanford, so an investigation was warranted.

To compare the Hanford and Rocky Flats ratios, we identified differences in significant parameters and observed how making these parameters the same affected the outcome of the ratio comparison.

The most obvious difference between the Rocky Flats residential scenario and the Hanford residential scenario was the active exposure pathways. The Hanford residential scenario included all exposure pathways allowed in RESRAD except the radon pathway. Compared to Rocky Flats, Hanford included four additional pathways: ingestion of drinking water, ingestion of meat from animals raised on contaminated land, ingestion of milk from animals raised on contaminated land, and ingestion of locally caught fish containing radionuclides.

Holding all other parameters in the Hanford calculation constant, removing these pathways made very little difference to the calculation's outcome. The ratio of soil action level to dose for $^{239,240}Pu$ changed indistinguishably. It is interesting to note that the ingestion pathways (milk, meat, fish, and drinking water) had almost no effect on the ratio for $^{239,240}Pu$. The largest change in soil action level to dose occurred for ^{137}Cs and ^{90}Sr because the transport of these radionuclides is primarily through such food chains. These radionuclides were not of concern for the RFETS, so we focused primarily on changes in the $^{239,240}Pu$ calculation.

The two parameters identified in the RFETS sensitivity calculation (mass loading factor and dose conversion factor) differed between the RFETS and Hanford calculations. We examined these parameters to see how changes affect the Hanford and RFETS calculations.

A major difference between the Hanford and RFETS calculations was values for dose conversion factors. In the Hanford calculation, dose conversion factors for soluble plutonium were used, which are larger, or more conservative, than those for insoluble plutonium. In the RFETS calculation, plutonium was assumed to be insoluble, and smaller dose conversion factors for both inhalation and ingestion were used. Maintaining our previous pathway modification and using the dose conversion factors for insoluble plutonium in the Hanford calculation, the soil action level to dose ratio for $^{239,240}Pu$ changed from 2.3 to 9.9 (pCi g^{-1}) $mrem^{-1}$. This ratio was much closer to the RFETS ratio of 17 (pCi g^{-1}) $mrem^{-1}$, indicating that the form of plutonium identified in the environment plays a significant role in the difference between these two calculations.

The mass loading factor used in the Hanford calculation was 0.0001 g m^{-3}, compared to the value used in the RFETS calculation of 0.000026 g m^{-3}. Maintaining all previous modifications to the Hanford calculation and altering the mass loading factor to match the RFETS value, the soil action level to dose ratio for ^{239,240}Pu changed from 9.9 to 34 (pCi g^{-1}) $mrem^{-1}$. This large increase in the ratio occurred for two reasons. First, assuming the plutonium was in an insoluble form made inhalation the dominant pathway for dose. Second, decreasing the mass loading factor decreased the amount of plutonium in the air, making less plutonium available for inhalation. The combination of these two changes increased the allowable concentration of plutonium in soil, and correspondingly increased the soil action level for a unit dose.

When the Hanford calculations using RESRAD were run implementing the RFETS pathways and parameter values for mass loading and dose conversion factor, the soil action level to dose ratio for Hanford exceeded that for the RFETS. Table 12 shows the incremental change in the soil action level to dose ratio when the parameters in the Hanford calculation were altered.

For the office worker scenario at Rocky Flats and the industrial worker scenario at Hanford, the pathways analyzed were identical: external gamma exposure, inhalation of soil, and ingestion of soil. The soil action level to dose ratios for ^{239,240}Pu for Hanford and RFETS, respectively, were 73 and 16.3 (pCi g^{-1}) $mrem^{-1}$.

We assumed that the same parameter changes that controlled the residential scenario calculation, dose conversion factor and mass loading, would have significant control over this calculation. In fact, this proved to be true. When dose conversion factors were changed to conform to the insoluble form of plutonium, the soil action level to dose ratio for Hanford went from 16.3 to 44. Maintaining this change and changing mass loading from 0.0001 g m^{-3} to 0.000026 g m^{-3}, the soil action level to dose ratio for the Hanford calculation went from 44 to 159 (pCi g^{-1}) $mrem^{-1}$, exceeding the Rocky Flats ratio of 73 (pCi g^{-1}) $mrem^{-1}$. In the case of both residential and worker scenarios, the same parameters controlled the soil action level calculation for ^{239,240}Pu. Table 12 also shows the changes in parameters that controlled the outcome of the industrial worker scenario.

Table 12. Changes in the Soil Action Level to Dose Ratio with Parameter Value Changes for $^{239,240}Pu$ in the Hanford and RFETS Calculations

Site and Scenario	Parameter change	Soil action level to dose ratio ([pCi g^{-1}] $mrem^{-1}$)	Dose to soil action level ratio (mrem [pCi $g^{-1}]^{-1}$)
Rocky Flats residential	Original calculation	17	0.06
Hanford residential	Original calculation	2.3	0.44
	Remove meat, milk, fish, drinking water	2.3	0.44
	+ change dose conversion factor	9.9	0.10
	+ change mass loading	34	0.03
Rocky Flats office worker	Original calculation	73	0.01
Hanford industrial worker	Original calculation	16.3	0.06
	Change dose conversion factor	44	0.02
	+ change mass loading	159	0.006

Nevada Test Site

The Nevada Test Site was the location of numerous nuclear weapons tests in the 1940s, 1950s, and 1960s during the buildup and testing of the nation's nuclear arsenal. Two documents reported dose calculations for individuals who might live or work onsite after cleanup of the site. One of the dose assessments assumed very realistic scenarios for future site uses and calculations were performed for scenarios including an industrial worker, bomb detonation, removal of safe munitions, aircraft crew flying overhead, ground troops being deployed onsite, explosive ordinance demolition, and a construction worker. In short, these scenarios were designed assuming that the site will be under military control in the future. Ratios associated with these scenarios are large; they are not discussed here because they do not relate to the Rocky Flats scenarios (DOE 1998).

In the second document, doses were assessed for presumed cleanup levels given scenarios similar to those we looked at for the RFETS (DOE-NV 1997). This assessment was performed with RESRAD but reported dose from a given soil concentration, instead of soil action level.

The 100 mrem y^{-1} public dose standard is presumed to be the primary standard for protection of the public based on the DOE Order 5400.5 (DOE-NV 1997). DOE-NV (1997) cited a number of studies detailing soil action levels that resulted in doses similar to or less than this standard. Based upon this information, this dose assessment assumed that the soil needed to be cleaned to a level not exceeding 200 pCi g^{-1} of $^{239,240}Pu$. Given existing concentrations in soils, hypothetical concentrations after remediation were identified, and dose calculations using RESRAD were completed to assess the dose resulting from both the unremediated and remediated soils. If these doses were less than the 100 mrem y^{-1} public limit, the remediation was termed adequate, or even unnecessary, if the precleanup levels met the dose requirement.

Two scenarios from the Nevada Test Site evaluation related most closely to the Rocky Flats scenarios: the rancher scenario and the industrial worker scenario. In the rancher scenario, a person lived on and farmed the land for personal livelihood, eating many of the crops and livestock produced. Pathways included external radiation; inhalation of soil and radon; and ingestion of soil, drinking water, meat, and milk. The same scenario at Rocky Flats did not include radon inhalation, or ingestion of drinking water, milk, or meat. The cited post-remediation soil concentration level for ^{239,240}Pu of 162 pCi g^{-1} and dose of 38.9 mrem y^{-1} yielded a soil action level to dose ratio of 3.8 (pCi g^{-1}) $mrem^{-1}$. The ratio for a similar scenario at the RFETS was 17 (pCi g^{-1}) $mrem^{-1}$. Because the plutonium ratio at Rocky Flats was larger than the ratio at Nevada Test Site, this ratio was worthy of examination for this task.

The industrial worker scenario included exposure pathways for external gamma radiation, inhalation of soil, inhalation of radon, ingestion of soil, and ingestion of drinking water. This scenario included two pathways not used in the Rocky Flats calculation: inhalation of radon and ingestion of drinking water. The soil action level to dose ratio for the industrial worker Nevada Test Site calculation for ^{239,240}Pu was 41 (pCi g^{-1}) $mrem^{-1}$, compared to the RFETS ratio of 73 (pCi g^{-1}) $mrem^{-1}$. Again, the plutonium ratio was significantly larger.

The primary difference between the RESRAD calculations for the Nevada Test Site and the RFETS was the assumed solubility class of plutonium. The Nevada Test Site calculation used the RESRAD default value for plutonium dose conversion factor, which corresponded to Class W (soluble) plutonium. For purposes of simplicity, changes were made to the readily available RFETS calculation. When dose conversion factors for soluble plutonium were used in the Rocky Flats residential calculation, which originally used Class Y (insoluble) plutonium dose conversion factors, the RFETS soil action level decreased from 1429 to 242 pCi g^{-1}, and the soil action level to dose ratio decreased from 17 to 2.8 (pCi g^{-1}) $mrem^{-1}$.

When this same change was made in the Rocky Flats office worker calculation, the soil action level to dose ratio decreased from 73 to 16 (pCi g^{-1}) $mrem^{-1}$. This single parameter accounts for the difference between these two calculations. Table 13 summarizes the differences between the ratios and the parameter changes employed.

Table 13. Changes in the Soil Action Level to Dose Ratio with Parameter Value Changes for ^{239,240}Pu in the Nevada Test Site and RFETS Calculations

Site and scenario	Parameter change	Soil action level to dose ratio ([pCi g^{-1}] $mrem^{-1}$)	Dose to soil action level ratio (mrem [pCi g^{-1}]$^{-1}$)
Rocky Flats residential	Original calculation	17	0.06
	Change dose conversion factor	2.8	0.36
Nevada Test Site residential	Original calculation	4.1	0.24
Rocky Flats office worker	Original calculation	73	0.01
	Change dose conversion factor	16	0.06
Nevada Test Site industrial worker	Original calculation	41	0.02

U.S. Nuclear Regulatory Commission DandD Code Scenarios

The NRC produced its own computer code using models similar to those in RESRAD. This code, called DandD, was designed for use by NRC agencies as a guideline for cleanup and remediation of contaminated sites. Two sets of scenarios were developed for generic use with DandD: (1) scenarios for the release of buildings and (2) scenarios for the release of contaminated land. Only the contaminated land scenarios are comparable to the RFETS calculations. Of the land use scenarios, the residential use, or surface soil, scenario is the most directly comparable to the situation at Rocky Flats.

This scenario assumes residential farming of land with limited gardening activities. The pathways considered are inhalation of soil; ingestion of soil, water, milk, meat, poultry, and fish grown/raised and irrigated by contaminated water; and external gamma exposure. Indoor radon is not considered.

The total effective dose equivalent for the residential scenario for $^{239,240}Pu$, assuming surface soil activity of 1 pCi g^{-1}, is 288 mrem. This yields a soil action level to dose ratio of 0.003 (pCi g^{-1}) $mrem^{-1}$, much smaller than the Rocky Flats ratio.

The differences between these two calculations are numerous, and are not, in all cases, completely transparent without the benefit of the code documentation. Upon running the DandD code, the most noticeable difference is that the primary contributors to the dose are the aquatic pathway (66%), the irrigation pathway (21%), and the drinking water pathway (13%). This results from the use of dose conversion factors that correspond to a soluble class of plutonium, as well as very conservative pathway assumptions relating to concentration factors in fish and plants.

The pathways used in DandD appear to be quite different from those in RESRAD, making it very difficult to compare results from the two without extensive documentation. Representatives from the NRC have indicated to *RAC* that DandD was written for a purpose very different than the calculation of soil action levels, and they did not recommend that actual scenario dose calculations be made with this code; rather, the code is intended to be used for screening level, conservative calculations only.

The differences between the RESRAD and DandD codes are so extensive that a comparison of Rocky Flats residential calculations with RESRAD and the DandD residential farmer scenario is not instructive or possible given the limited time and scope of this project. DandD is reviewed somewhat more extensively in the Task 2 report.

Johnston Atoll, Marshall Islands

Plutonium contamination in the environment at the Johnston Atoll in the Marshall Islands resulted from three accidents in 1962: the destruction of two offcourse rockets at high altitude and one explosion on the rocket launching pad (Spreng 1999). Using mining techniques, the soil was cleaned to about 15 pCi g^{-1} (Bramlitt 1988). An independent verification of the cleanup was performed by Oak Ridge National Laboratory (Wilson-Nichols et al. 1997). Currently, a company called GeoCenters is reviewing the cleanup levels and revising the calculations using more realistic receptors. A draft report of this work was due in March 1999 (Spreng 1999).

The scenario used in the Johnston Atoll calculations was a residential scenario using only the inhalation pathway. This resident differed from the Rocky Flats resident in that residence was assumed 24 hours a day, 365 days per year. Using existing information, the soil action level to

386

dose ratio for a Johnston Atoll resident was calculated to be 0.85 (pCi g^{-1}) $mrem^{-1}$ (Wilson-Nichols et al. 1997). The soil concentration was calculated for doses only from inhaled alpha emitters. The soil screening limit, *SSL*, (or soil action level) was calculated using Equation (1).

$$SSL = \frac{C_{air,acceptable}}{ML \cdot EF} \qquad (1)$$

where

$C_{air,\ acceptable}$ = acceptable air concentration (pCi m^{-3})
ML = mass loading (g m^{-3})
EF = enrichment factor (unitless).

The acceptable air concentration is calculated for the accepted annual committed dose. For the Johnston Atoll calculation, the annual committed dose limit was 20 mrem y^{-1}, which corresponds to an air concentration of 2.6×10^{-3} pCi m^{-3} for the alpha emitters, plutonium or americium compounds, assuming a quality factor of 20 (Wilson-Nichols et al. 1997). This air concentration was calculated for Class Y (insoluble) compounds of plutonium that are retained in the lung for years. The committed dose applies to the pulmonary region of the lung.

It is important to note that this calculation was performed based upon a significantly older version of the International Commission on Radiological Protection (ICRP) lung model than that currently in use. The lung model was described in ICRP Publication 19 (ICRP 1972) when recommendations from ICRP 2 (ICRP 1959) were outdated, but ICRP 30 (ICRP 1978) had not yet been published. The ICRP 19 (ICRP 1972) document was prepared by a task group and described an updated version of the lung model. However, ICRP 19 did not yet include calculation of total body dose; the emphasis at this time was still on organ-specific dose. As a result, acceptable air concentrations for the Johnston Atoll were calculated based only on doses to the pulmonary region of the lung. In contrast, the RFETS calculation, which was founded on later ICRP recommendations, describes dose to the entire body. Therefore, the ratios should be compared with caution.

The mass loading factor selected for this calculation was 0.0001 g m^{-3}, as defined by the EPA for developing a soil screening limit (EPA 1977). Even during cleanup and soil disturbance activities at the Johnston Atoll site, mass loading factors were smaller than this value, so the 0.0001 g m^{-3} value was assumed to be a conservatively high (Wilson-Nichols et al. 1997).

The enrichment factor considers how the $^{239,240}Pu$ concentration in the respirable fraction of the soil compares to plutonium concentrations in soil of all particle sizes. An EPA study that looked at five sites in the U.S., including the RFETS, listed enrichment factors for each site (EPA 1977). According to this study, Rocky Flats had the largest enrichment factor of the sites studied across the U.S.. To be conservative, the Johnston Atoll study used an average of the Rocky Flats data to develop an enrichment factor of 1.5.

Using this information and Equation (1), the soil screening limit for the Johnston Atoll was calculated to be 17 pCi g^{-1} for a committed dose equivalent of 20 mrem y^{-1}, giving the ratios cited above. Using Rocky Flats data in this equation helps clarify the differences between the ratios for Johnston Atoll and the ratios for the RFETS.

The first step was to determine the difference between dose conversion factors for the two sites. To extract the Johnston Atoll dose conversion factor from the existing information, we used an equation for effective dose from inhaled material. Equation (2) calculates dose (in units of millirem) from inhaled material.

$$Dose = V_{inhaled} \cdot C_{air} \cdot DCF \tag{2}$$

where

$V_{inhaled}$ = volume inhaled ($m^3\ y^{-1}$)
C_{air} = concentration in air ($pCi\ m^{-3}$)
DCF = dose conversion factor ($mrem\ pCi^{-1}$).

The volume inhaled in the Johnston Atoll calculation was 8395 $m^3\ y^{-1}$, based on the ICRP reference man (ICRP 1975) for full-time occupation. The concentration in air was 2.6×10^{-3} pCi m^{-3} for a 20 mrem dose. The dose conversion factor that results from inputting these values and rearranging Equation (2) is 0.91 mrem pCi^{-1}. This contrasts with the RFETS dose conversion factor for insoluble plutonium of 0.308 mrem pCi^{-1}. It is important to remember that the RFETS dose conversion factor is for total body dose, and the Johnston Atoll dose conversion factor is only for dose to the pulmonary region of the lung.

Equation (2) can be used to calculate an acceptable air concentration for Johnston Atoll using RFETS parameters. For a Johnston Atoll limit of 20 mrem effective dose limit, RFETS volume inhaled of 7000 $m^3\ y^{-1}$ and RFETS dose conversion factor identified above, the concentration in air is equal to 9.27×10^{-3} pCi m^{-3}.

Equation (1) is used to calculate the Johnston Atoll soil screening limit using Rocky Flats values. The Rocky Flats value for mass loading was 0.000026 g m^{-3}. The air concentration was calculated above, and in the RFETS calculation, no enrichment factor was employed. The soil screening limit for Johnston Atoll using RFETS parameter values is 356 pCi g^{-1}, which gives a soil action level to dose ratio of 17.8 (pCi g^{-1}) $mrem^{-1}$ and matches that of the RFETS. Table 14 summarizes the results of this analysis.

Table 14. Soil Action Level to Dose Ratio for $^{239,240}Pu$ Changes with Parameter Alteration for Johnston Atoll and RFETS Calculations

Location	Parameter change	Soil action level to dose ratio ($[pCi\ g^{-1}]\ mrem^{-1}$)	Dose to soil action level ratio ($mrem\ [pCi\ g^{-1}]^{-1}$)
Rocky Flats	Original calculation	17	0.06
Johnston Atoll	Original calculation	0.85	1.2
	Calculate concentration in air using RFETS dose conversion factor and volume inhaled	3.1	0.32
	+ change to RFETS mass loading	11.9	0.08
	+ change to RFETS enrichment factor	17.8	0.056

Enewetak Atoll, Marshall Islands

The cleanup levels established for the Enewetak Atoll are very different in scope and intent than those discussed previously. This cleanup was driven more by time, money, and military concerns than an identified limit for concentrations in soil.

The Defense Nuclear Agency published a book describing the cleanup of Enewetak Atoll after numerous U.S. nuclear tests took place there in the 1950s and 1960s (DNA 1981). This book primarily documents the cleanup efforts and decisions made throughout the process; it does not provide a clear assessment of doses and accepted cleanup levels for the islands.

The cleanup of the Marshall Islands was one of the first efforts of its magnitude. Although accidents had occurred at other facilities, guidance was just beginning to be developed for nuclear material soil standards, particularly for transuranics. The EPA guidance on transuranic elements in the environment had not yet been released, and ICRP models for dose were still limited at the time of cleanup.

As a result of limited guidance, decisions about soil cleanup came slowly and only after considerable discussion, disagreement, and finally consensus. As many as three committees produced recommendations for the Enewetak Atoll cleanup, and all committees agreed on some levels and disagreed on others.

The first remediation goal, established by the Environmental Research and Development Agency (ERDA) in conjunction with the U.S. Army Support Command, was to reduce plutonium concentrations in soil to levels below 40 pCi g^{-1}. This concentration level would qualify the land for residential and agricultural use (DNA 1981).

At a workshop held to discuss ERDA plans for the Marshall Islands, doubts and objections to this cleanup strategy were raised, questioning whether the guidelines for soil removal were supportable. As a result of these questions, ERDA convened a panel of scientists, known as the Bair Committee, to review Atomic Energy Commission (AEC) recommendations. An Atomic Energy Commission task group that suggested 400 pCi g^{-1} as an acceptable limit in soil because it was conservatively equivalent to the maximum permissible concentration in air for radiologically unrestricted areas. The task group then introduced a safety margin of a factor of 10, recommending that no cleanup was required below 40 pCi g^{-1}. The areas with soil concentrations between 40 and 400 pCi g^{-1} would be assessed on a case-by-case basis depending on the use of the land. Finally, this task group suggested that after cleanup was initiated, soil levels should be reduced to the lowest possible level (DNA 1981).

Following the AEC recommendations, ERDA established an Operating Plan recognizing that cleanup of all areas to below 40 pCi g^{-1} would require removing large quantities of soil for no appreciable benefit. The Operating Plan suggested conditions for soil use. Condition A specified that an island could be used for food gathering if surface plutonium did not exceed 400 pCi g^{-1}. Condition B allowed agricultural use of land if surface plutonium did not exceed 100 pCi g^{-1}. Residential use, outlined by Condition C, required cleanup to levels below 40 pCi g^{-1}. The final condition involved using the land for all three purposes if the surface conditions met the appropriate requirements and subsurface plutonium concentrations did not exceed 400 pCi g^{-1}.

The Bair Committee approved of the ERDA Operating Plan cleanup criteria and suggested that more specific guidance be established for the soil concentrations between 40 and 400 pCi g^{-1}. When the 1977 EPA guidance on transuranics was released, the Bair Committee adapted its recommendations for agricultural land soil concentrations to 80 pCi g^{-1} and food gathering land soil concentrations to 160 pCi g^{-1}. These values were apparently based on a dose assessment study performed by Lawrence Livermore National Laboratory. A first study done by Lawrence Livermore National Laboratory was based on the original soil cleanup criteria, but the results were deemed incorrect because of a mathematical error. The Laboratory performed a new dose assessment. Results from this new dose assessment influenced the Bair Committee's decisions concerning action levels for different soil uses.

We could not locate the Lawrence Livermore National Laboratory study in the literature. The Defense Nuclear Agency document lists the radiation doses from this study only unit of millirad; however, these values cannot be converted to effective doses without knowing more about the dose model used to make the calculations. We can assume that Lawrence Livermore National Laboratory scientists used the same model as that used in the Johnston Atoll study, with a large dose conversion factor. However, we would need to have access to the Lawrence Livermore National Laboratory study to make comparisons to RFETS values. We contacted Dr. William Bair, Chair of the Bair Committee, in an attempt to locate documentation. He no longer had copies of the pertinent information, but referred us to Bill Robison at Lawrence Livermore National Laboratory. He has been contacted, and we await a response from him concerning the Lawrence Livermore National Laboratory dose assessment documentation.

Maralinga, Australia

Nuclear weapons trials conducted between 1953 and 1963 by the United Kingdom contaminated the Maralinga site in Australia. This land was the home of semi-traditional Aboriginal tribes, and it became necessary to restore it for their use. A rehabilitation project was undertaken in 1996 because of the extensive $^{239,240}Pu$ contamination in the area. This facility is more difficult to compare to Rocky Flats because RESRAD calculations were not performed. However, a dose evaluation was performed and cleanup criteria were established, so we did have some mechanism to compare the facilities. Doses for the Maralinga facility were calculated for a resident living in a semi-traditional Aboriginal life style, but they focused only on doses from inhalation. This resident lived at the site 24 hours a day, 365 days per year.

In the context of the Maralinga site, the term soil action level is used loosely because cleanup criteria is a more appropriate term. However, we use the term soil action level here for consistency.

The soil action level to dose ratio for the Maralinga site is 0.56 (pCi g^{-1}) $mrem^{-1}$. This ratio was calculated by rearranging the equation used at the Maralinga site to calculate dose. Equation (3) shows the dose calculation used at the Maralinga facility.

$$Dose\,(mrem\ y^{-1}) = C_{air} \cdot BR \cdot DCF \qquad (3)$$

where

C_{air} = concentration in air (pCi m^{-3})
BR = breathing rate ($m^3\ y^{-1}$)
DCF = dose conversion factor (mrem pCi^{-1})

and

$$C_{air} = C_{soil} \cdot ML \qquad (4)$$

390

where
C_{soil} = soil concentration (pCi g^{-1})
ML = mass loading (g m^{-3}).

Combining and rearranging Equations (3) and (4) yields Equation (5), which gives a direct calculation of the dose to soil action level ratio. The reciprocal of Equation (5) is the soil action level to dose ratio.

$$\frac{Dose\,(mrem)}{C_{soil}\,(pCi\,g^{-1})} = ML \cdot BR \cdot DCF \tag{5}$$

where all quantities are as previously defined.

The values used in Equation (5) for the Maralinga calculation and the information about the site were extracted from two sources: the journal of *Health Physics* (Johnston et al. 1992) and the Australian Radiation Laboratory (ARL 1998).

Mass loading for the site was determined by simulating some Aboriginal dust raising activities. These data were the only data available to the Australian Radiation Laboratory group, and a value of 0.001 g m^{-3} was used for adults. Breathing rates were taken by the Australian Radiation Laboratory from Haywood (1987). For adults, an annual breathing rate of 8400 m^3 y^{-1} was used. The dose conversion factors were extracted from ICRP 56 (ICRP 1989), but they were corrected for 5 μm AMAD particles because a study indicated this particle size best represented the respirable fraction at the Maralinga site. The dose conversion factor for $^{239,240}Pu$ was calculated assuming the worst case scenario translocation rate for the Australian test sites would be represented by 25% of the plutonium being Class W (soluble) and 75% being Class Y (insoluble). This series of conversions results in a dose conversion factor for $^{239,240}Pu$ of 0.215 mrem pCi^{-1}.

The three parameter values used in Equation (5) lead to a dose to soil action level ratio of 1.8 mrem (pCi $g^{-1})^{-1}$ and a soil action level to dose ratio of 0.56 (pCi g^{-1}) $mrem^{-1}$ for the Maralinga site.

To compare the ratio for the Maralinga site to the Rocky Flats ratio, we inserted RFETS parameter values into the Maralinga calculation. Using the Rocky Flats values for mass loading (0.000026 g m^{-3}), breathing rate (7000 m^3 y^{-1}), and $^{239,240}Pu$ inhalation dose conversion factor (0.308 mrem pCi^{-1}) in Equation (5), yields a dose to soil action level ratio of 0.056 mrem (pCi $g^{-1})^{-1}$ and a soil action level to dose ratio of 17.8 (pCi g^{-1}) $mrem^{-1}$.

Using the Rocky Flats values in Equation (5) accounts for the difference in the two ratios. Table 15 summarizes the changes in the ratios between Maralinga and the RFETS by altering the parameter values used in the calculation.

Table 15. Soil Action Level to Dose Ratio for $^{239,240}Pu$ Changes with Parameter Alteration for Maralinga and RFETS Calculations

Location	Parameter change	Soil action level to dose ratio [(pCi g^{-1}) $mrem^{-1}$]	Dose to soil action level ratio [mrem (pCi $g^{-1})^{-1}$]
Rocky Flats	Original calculation	17	0.06
Maralinga	Original calculation	0.56	1.8
	Change to RFETS breathing rate	0.67	1.5
	+ change to RFETS mass loading	26	0.039
	+ change to RFETS dose conversion factor	17.8	0.056

Semipalatinsk Nuclear Range, Kazakhstan

At this location in the former Soviet Union, 124 atmospheric nuclear tests were carried out between 1949 and 1962 (Zeevaert et al. 1997). These tests resulted in environmental contamination and radiation exposure. The contamination was extensively documented and radiation dose rates measured. The results from this work do not yield a soil cleanup level, but they do document existing surface contamination and resulting doses.

It is important to point out that the values given in the literature document either a range of surface radiation levels associated with a single dose or a range of doses associated with a single radiation level. It is very difficult to correlate dose to corresponding soil concentration, not only because surface radiation levels are only tenuously converted to concentrations but also because the surface levels are not related directly to an inhalation dose. Zeevaert et al. (1997) should be carefully reviewed if more information is desired.

For settlements at the Semipalatinsk site, maximum soil activity was given as 11 kBq m^{-2}, corresponding to a soil concentration of 1.32 pCi g^{-1}. We assumed a depth of contamination of 15 cm and a soil density of 1.5 g cm^{-3} to enable us to make this conversion because these factors were not given in Zeevaert et al. (1997). The individual dose to the population resulting from this concentration is identified as 1.5 Sv, or 150,000 mrem. It is not clear from the documentation what this individual dose represents, how it was calculated, or if it correlates in any way to the defined surface soil activity.

The resulting soil concentration to dose ratio is 8.8×10^{-6} (pCi g^{-1}) $mrem^{-1}$. This ratio is fraught with uncertainties, both in measurement techniques and capabilities and difficulty correlating dose to soil concentration in the literature. While this is smaller than the Rocky Flats ratio, it is impossible to account for the differences because the Semipalatinsk soil concentration was measured in the environment, not calculated. Furthermore, Zeevaert et al. (1997) does not describe the dose calculation techniques. We present the ratio only in the interests of completeness, and do not compare it to Rocky Flats.

Another territory affected by the Semipalatinsk tests was Ouglovski, with soil concentrations of 0.66 pCi g^{-1}. The doses cited for this region are external doses, however, and cannot be applied to obtain a ratio.

Thule, Greenland

Near the Air Force Base at Thule, Greenland, on January 21, 1968, a military plane carrying four nuclear weapons crashed and burned. Plutonium contamination was spread about the crash site on the ice, with a maximum contamination level of 14.8 kBq m^{-2}. This site had to be cleaned up before the ice melted in the spring, dictating the time frame of the project. As a result, the only data we have from this crash site are concentrations of plutonium in sediments and estimated dose data from ingestion of sea mussels. Comparisons between this site and the RFETS are impossible because of lack of appropriate data and dissimilar pathway analyses. We report the dose and concentration data in this report for completeness.

After cleanup, the maximum concentration of ^{239}Pu in sediments under the crash site was 1.85 Bq g^{-1}, or 50 pCi g^{-1}. Inhalation is not an appropriate pathway because plutonium is contained in sediments, not dry soil; therefore, the pathway of interest is consumption of mussels. In 1974 (6 years after the accident), the average concentration of plutonium in the edible part of mussels was 0.74 Bg g^{-1} (20 pCi g^{-1}). With a consumption rate of 100 g d^{-1} of mussels for 70 years, the annual committed dose rate to the bone was calculated to be 0.75 mGy (75 mrad) (Church 1998).

Palomares, Spain

Another nuclear accident occurred in Palomares, Spain, on January 17, 1966, when a U.S. Air Force bomber collided with its tanker and exploded above the town. Two of the bomber's four nuclear weapons impacted very near the town and released plutonium. Plutonium oxide contaminated about a 225-hectare (560-acre) area of brushland, farmland, and urban area.

The contamination of this area was so great that immediate cleanup was warranted. Soil concentrations measured just after the accident indicated areas of ^{239,240}Pu contamination ranging from 212 μCi g^{-1} (2.12×10^8 pCi g^{-1}) down to 2.12 μCi g^{-1} (2.12×10^6 pCi g^{-1}) (Iranzo et al. 1987). Cleanup was immediately undertaken, with the soil layer at the highest contamination level removed (10 cm deep) and disposed of as radioactive waste. The remainder of the soil was irrigated thoroughly, plowed to a depth of about 30 cm, and homogenized to move contaminated soils to lower levels. At lower levels, the soil would not be available for resuspension to become a potential source of inhalation and dose to residents (Iranzo et al. 1987).

At the time, a dose assessment based on these contamination levels was not performed. The contamination was so widespread that cleanup was the issue at hand. After the cleanup was complete, a monitoring program was established, which included air sampling, soil sampling, crop sampling, and urine and lung counting of the residents.

Air concentrations measured in the environment were compared to (a) annual limits on intake and (b) derived air concentrations from these limits as recommended by the ICRP for radiation workers (ICRP 1978). Because values for acceptable air concentrations for the public were not provided in ICRP 30 (1978), the radiation worker values were multiplied by the ratio of dose limits recommended for the public to those recommended for radiation workers (0.1). This concentration was again reduced to account for ICRP recommendations that effective dose equivalent throughout the life of a member of the exposed population does not exceed the value resulting from a 1 mSv (100 mrem) annual effective dose equivalent. Therefore, acceptable concentration values for members of the public were set at 1.2 mBq m^{-3} (3.2×10^{-2} pCi m^{-3}) for

Class Y (insoluble) compounds of plutonium and 0.5 mBq m^{-3} (1.35×10^{-2} pCi m^{-3}) for Class W (soluble) compounds of plutonium. In the context of the RFETS parameter values, with insoluble Class Y plutonium and a mass loading factor of 0.000026 g m^{-3}, this air concentration corresponds to a soil concentration of 1230 pCi g^{-1}.

Using these values to establish a soil concentration to dose ratio (for the 100 mrem dose for which the air concentration was calculated) results in a ratio for $^{239,240}Pu$ of 12.3 (pCi g^{-1}) $mrem^{-1}$. This ratio is only for inhaled plutonium, and it is based upon the ICRP reference man, who breathes at a rate of 23 m^3 d^{-1} (ICRP 1975). For an exposure time of 8760 h y^{-1} (a full-time resident), this corresponds to an annual breathing rate of 8395 m^3 y^{-1}, which contrasts with the RFETS breathing rate of 7000 m^3 y^{-1}.

Placing the breathing rate of 8395 m^3 y^{-1} into the RFETS calculation yields a soil action level of 1202 pCi g^{-1} and a soil action level to dose ratio of 14.1 (pCi g^{-1}) $mrem^{-1}$. We were unable to discover the reason for the remaining difference between these two ratios during this assessment.

Table 16 summarizes the changes made to the RFETS calculation and ratio.

Table 16. Soil Action Level to Dose Ratio for $^{239,240}Pu$ Changes with Parameter Alteration for Palomares and RFETS Calculations

Location	Parameter change	Soil action limit to dose ratio ([pCi g^{-1}] $mrem^{-1}$)	Dose to soil action level ratio (mrem [pCi g^{-1}]$^{-1}$)
Rocky Flats	Original calculation	17	0.06
	Change breathing rate	14.1	0.07
Palomares	Original calculation	12.3	0.08

It is important to note that at the Palomares site, the air concentrations measured in the environment after cleanup were almost always below the acceptable limits, with the exception of four 10-day periods during 1966–1969. During these periods, the increases in contaminated air above the acceptable level could be attributed to cultivation activities, which were hypothesized to raise contaminated soil to the surface and make it available for resuspension (Iranzo et al. 1987).

CONCLUSIONS

The soil action levels at the RFETS are significantly higher than action or cleanup levels at other facilities, even when normalized to dose. However, we understand the reasons for these elevated levels. The outcome of the RESRAD calculation is strongly controlled by a few parameters, and almost without exception, it is these parameters that affect the differences in the soil action levels for a unit dose between sites. The parameters are

- Dose conversion factor (solubility class of plutonium),
- Mass loading (resuspension), and to a lesser degree
- Breathing rate.

Breathing rate is less significant because the range of possible values is limited to within reasonable boundaries. The dose conversion factor varies depending on the assumed solubility of plutonium. For soluble Class W plutonium, the inhalation dose conversion factor is 0.429 mrem pCi^{-1} and the ingestion dose conversion factor is 0.0035 mrem pCi^{-1}. For insoluble Class Y plutonium, the inhalation dose conversion factor is 0.308 mrem pCi^{-1} and the ingestion dose conversion factor is 0.000052 mrem pCi^{-1} (ICRP 1978). When soluble plutonium is assumed, the ingestion pathway becomes a more dominant contributor to the dose, and the dose per unit intake is considerably greater. For the RFETS, we can determine the appropriate assumption based upon the oxidation state of the plutonium found in the soil at Rocky Flats.

The mass loading parameter can vary over orders of magnitude depending on assumed environmental conditions. Mass loading and similar resuspension parameters have been extensively measured at Rocky Flats under a variety of conditions, and it will be important to use this information to establish a plausible range of values for this parameter. If insoluble plutonium is assumed, inhalation will dominate dose, and mass loading will become a critical parameter.

We reviewed the soil action level to dose ratios for the other sites studied during Task 1 in terms of the calculations, models, and parameters used to calculate soil concentrations and/or dose. In almost every case, differences between sites could be explained by the different assumptions made for one or more of the key parameters identified above (see Table 17).

With Task 1, we identified the input model parameters that are of primary importance in determining the soil action levels so we can carefully review them when completing the Task 3 report, Inputs and Assumptions.

Table 17. Summary of Comparisons between RFETS Calculations and Those for Other Facilities

Location	Parameter change	Soil action limit to dose ratio ([pCi g^{-1}] $mrem^{-1}$)	Dose to soil action limit ratio (mrem [pCi g^{-1}]$^{-1}$)
Rocky Flats residential	Original calculation	17	0.06
Hanford residential	Original calculation	2.3	0.44
	Remove meat, milk, fish, and drinking water pathways and change to RFETS dose conversion factor and mass loading	34	0.03
Rocky Flats office worker	Original calculation	73	0.01
Hanford industrial worker	Original calculation	16.3	0.06
	Change dose conversion factor and mass loading	159	0.006
Rocky Flats residential	Original calculation	17	0.06
	Change to Nevada Test Site dose conversion factor	2.8	0.36
Nevada Test Site residential	Original calculation	4.1	0.24
Rocky Flats office worker	Original calculation	73	0.01
	Change dose conversion factor	16	0.06
Nevada Test Site industrial worker	Original calculation	41	0.02
Rocky Flats	Original calculation	17	0.06
Johnston Atoll	Original calculation	0.85	1.2
	Change to RFETS mass loading, enrichment factor, and calculate air concentration using RFETS dose conversion factor and breathing rate	17.8	0.056
Rocky Flats	Original calculation	17	0.06
Maralinga	Original calculation	0.56	1.8
	Change to RFETS mass loading, breathing rate, dose conversion factor	17.8	0.056
Rocky Flats	Original calculation	17	0.06
	Change to Palomares breathing rate	14.1	0.07
Palomares	Original calculation	12.3	0.08

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398

Radionuclide Soil Action Level Project

Milestone Report 3

Risk Assessment Corporation

May 1999

The main deliverable for the Soil Action Levels Project between the Radionuclide Soil Action Level Oversight Panel (RSALOP) and *Risk Assessment Corporation* (*RAC*) will be a comprehensive report issued at the end of the project (November 1999). The main body of the report will be written for the public and will summarize *RAC*'s findings and recommendations. Appendices will provide the technical details of the work. The seven milestone reports will outline *RAC*'s progress in completing the Work Tasks and Deliverables, and the compensation requested according to the schedule provided in the contract. The purpose of this milestone report is to describe the activities that *RAC* has accomplished to date.

Milestone 3 (5/8/99) – 4 milestone items

- Final report of a review of soil action levels at other sites (Appendix A) will be submitted.
- Probability distribution for parameters identified in Task 3a will be provided.
- Evaluation of quality assurance procedures for soil sampling will be provided and a draft report of Appendix C will be submitted to the panel.
- *RAC* will provide a review of other potentially important pathways of exposure based on our interaction with the Actinide Migration Panel (part of Appendix D).

The first milestone item was met when *RAC* distributed the Draft Final Task 1 report, *Cleanup Levels at Other Sites*, to panel members in late April 1999. The next milestone item has been in progress as preliminary sensitivity analyses were carried out and a draft outline for the Task 3 report is prepared and presented at the May 1999 meeting. The third milestone is completed with the distribution of the draft Task 6 report, *Sampling Protocols*. This report will be finalized and incorporated into Appendix C of the final report. The final milestone for this period has been met with *RAC*'s attendance at the Actinide Migration Panel meetings and providing a written summary of the topics covered with this report.

- ***Final report of a review of soil action levels at other sites (Appendix A) will submitted to the panel.***

This milestone was completed when *RAC* revised and distributed the Draft Final Task 1 report, *Cleanup Levels at Other Sites*, to panel members in early May 1999. This report discusses our work comparing cleanup levels at other sites to those at Rocky Flats, and identifies information from other facilities that may be applicable in conducting the independent analysis at Rocky Flats. Comments were received on the draft Task 1 from a few members of the RSALOP. For the most part, these comments were considered beneficial to the Task 1 report, and they were integrated into it. The primary comment from both reviewers indicated that a table showing the actual cleanup values and the doses associated with them might be instructive. An entire section devoted to this has been integrated into the front section of the report. *RAC* is continuing to seek more information on a number of sites, as requested by reviewers. Recently, we received dose assessment information completed for Enewetak Atoll but not in time to include it in the Draft Final version of Task 1. The data will be reviewed and applicable information will be incorporated into the Final version of Task 1, as Appendix A to the final report.

- ***Probability distribution for parameters identified in Task 3a will be provided***

The Task 3 report, *Inputs and Assumptions,* will be a working report to document the results of the sensitivity analysis, distributions for uncertain parameters, and Monte Carlo calculations. This report will focus mainly on parameter distributions for input values to the RESRAD calculation deemed significant through the help of the sensitivity analysis. *RAC* has developed an outline for the Task 3 report, which consists of an introduction, where the purpose of the report is described. Part of the introduction will contain a short description of the differences between RESRAD v5.61 (the version used for the DOE calculations) and RESRAD v5.82 (the most recent version under consideration, and the version *RAC* will use for the Monte Carlo analysis). We have done calculations using the DOE/EPA/CDPHE scenarios and will present the results of these calculations in this section.

The second part of the report will describe the scenarios developed for this project, both by DOE and by *RAC.* Section 3 will contain the results of the sensitivity analysis run using Version 5.82, including methodology and results, as well as the parameters that emerge from this analysis as significant parameters for which distributions will be created. The next section will include uncertainty distributions developed for different parameters. We will also include a discussion of high wind events as Rocky Flats, and the knowledge gained in the dose reconstruction about their impact on dose and risk. The report will conclude with a description of the Monte Carlo add-on created by *RAC* and the results of the calculations done using the DOE scenarios and the distributions of parameters created by *RAC.* Some parameters already identified through the initial stages of the sensitivity analysis as significant are mass loading, average annual wind speed, and the area of the contaminated field. These three parameters have an impact on the resuspension of contaminated soil in Version 5.82 of RESRAD. Additional parameters will undoubtedly emerge, and soil-to-plant transfer factors are also being considered.

- ***Evaluation of quality assurance procedures for soil sampling will be provided and a draft report of Appendix C will be submitted to the panel***

RAC distributed the Task 6 draft report, *Sampling Protocols,* to the Rocky Flats Soil Action Level Oversight Panel (RFSALOP) at the May 1999 meeting to complete this milestone. This draft report provides recommendations to the panel for consideration in developing a sampling protocol for the Rocky Flats Environmental Technology Site (RFETS) in support of the effort to conduct an independent assessment and calculate radionuclide soil action levels for Rocky Flats. *RAC* conducted a review of the available statistical methods and applications for assessing the soil action levels in the Rocky Flats environment and this report provides recommendations for sampling protocols applicable to the soil action level study. As part of this task, we conducted a review of the RFETS soil sampling program to determine the present status of soil sampling at the site. Several areas of the current RFETS soil sampling program were considered acceptable for use in the RFETS soil sampling protocol for the soil action level study. for elements of a soil sampling protocol that are considered important to the study. These elements include (a) data quality objectives process, (b) multiple radionuclide considerations, (c) classification and identification of survey units, (d) soil sample depth, (e) sample spacing and methods, (f) small areas of elevated activity, (g) surrogate measurements, (h) number of required samples based on statistical methods, (i) independent confirmatory investigations, and (j) soil sample quality assurance. A number of specific recommendations are made in this report for the panel's consideration.

- ***RAC* will provide a review of other potentially important pathways of exposure based on our interaction with the Actinide Migration Panel (part of Appendix D).**

RAC has attended the Actinide Migration Studies (AMS) quarterly meetings, and continues to interact with study participants. The January 21, 1999 AMS meeting focused on studies of plutonium migration at Rocky Flats site. Dr. Greg Chopin from the University of Florida described his work with the use of oxidation state actinide analogs to observe effects of geochemical processes over long time periods. He and his colleagues have studied old uranium and thorium locations around the world to find analogs for plutonium, (e.g., Th^{4+} for Pu^{4+}, and U^{4+} for Pu^{4+}). The main message is that natural analog sites provide valuable information on actinide chemistry and fate and transport; to date these studies show very little movement of plutonium over long time periods. Their studies indicate that Rocky Flats plutonium is insoluble but they emphasize that solubility studies are complex. At that same meeting, Mike Murrell and Chris Brink from Los Alamos National Laboratory (LANL) explained how they are tracing uranium migration at the RF solar ponds using refined analytical techniques in ion counting to follow the transport of uranium and to differentiate between "Rocky Flats" uranium and "natural" uranium.

At the April 29, 1999 AMS meetings, researchers described progress on collecting borehole samples from the South Interceptor Ditch, runoff samples from a buffer zone area near Walnut Creek, and water samples from Pond B-5 discharge that will be used for suspended solid fractionation experiments. Jim Ranville from the Colorado School of Mines, described his work on soil aggregation at Rocky Flats and how it might affect solubility. Mary Neu from LANL then described results of current experiments done on characterizing plutonium in samples from the 903 area. Using powerful, new state-of-the-art analytical techniques, she and her colleagues have demonstrated that plutonium from under the asphalt pad at the 903 area is insoluble PuO_2. The Pu/Am ratio also indicates insoluble plutonium. These new results provide solid proof for what many have assumed all along –that plutonium in the soil at Rocky Flats is insoluble PuO_2, and thus may not get into the groundwater.

These studies are exciting and very relevant to the current soil project because they help to characterize the chemical and physical form of plutonium at the Rocky Flats site. The AMS research that is underway has helped to define the potentially significant pathways and we still see inhalation as the major pathway for this work. Recent work at LANL indicates that the plutonium from soil samples under the 903 pad is insoluble PuO_2. While results from some of the AMS studies indicate that this insoluble form of plutonium may not enter groundwater, we are examining a conservative calculation to address the question of whether or not the pathway can be ruled out of the current analysis. We understand the importance of groundwater and surface

4/00

water pathways in the long term, and include the groundwater pathway in one of our scenarios. We do recognize, however, that our assessment of the groundwater pathway is limited by the complexity of the pathway.

RAC RESPONSES TO PEER REVIEWER COMMENTS

Task 2: Computer Models

Radionuclide Soil Action Level Oversight Panel

May 1999

"Setting the standard in environmental health"

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401

Responses to Reviewers' Comments on RSAL Task 2 Report

Since the reviewers are not openly identified by name, there is no satisfactory way to indicate which reviewer's comments we are responding to at any particular time. This situation thwarts a topical organization of these responses. Instead, we present the responses in five sections (one per reviewer), and we identify each reviewer by the number of pages in his or her printed copy (fortunately, no two reviewers produced copies of equal page length). In each reviewer's section, we respond to selected comments in the order in which they appear in the copy. References are placed at the end of the section in which they were called out.

Reviewer Two

This is a useful and helpful review. The reviewer is familiar with the Rocky Flats site and the history of radionuclides in the soil there. We will give serious consideration to all of this reviewer's suggestions.

2. It is extremely important to use every opportunity to apply site-specific data for soil concentrations and parameter values and their uncertainty distributions to the models that are chosen for the analysis. It is equally important to understand the inherent structure and workings of the models and to be able to modify them as necessary to make them relevant to Rocky Flats. The models should be both verified and validated to the extent possible.

3. I do not feel that *RAC* should limit their analysis to one or two models such as RESRAD or GENII. Other models that may have been used to develop soil action levels at Rocky Flats or elsewhere should also be examined in an effort to understand why such different numerical action levels have arisen. One recent report ("Recommended screening limits for contaminated surface soil and review of factors relevant to site-specific studies", NCRP Report 129, issued January 29, 1999) should definitely be consulted, for example. As a general philosophical point, the skill, knowledge and effort of the model user is often more important that the model itself in arriving at credible predictions.

These comments support *RAC*'s contention that this project should place less emphasis on specific computer programs and more on appropriate models (remembering that we are careful to distinguish between models and computer programs), data, and the knowledge and skills of the analyst. NCRP Report No. 129 was not available before about April 1 (at which time the work for this task was in its late stages). We are familiar with the report and are examining it for its relevance to this work.

5. The amount of resuspension of contaminants from the soil surface is dependent on many processes, both natural and anthropogenic. It is my experience that management of the land is a first-order determinant of resuspension, and this should be recognized and built into the various land use scenarios. Any form of human disturbance, especially anything which disturbs the natural vegetation cover, is bound to increase resuspension during high winds, as well as surface

> runoff following rainstorm events. Unpreventable phenomena that could cause major disturbances are fires, tornadoes, and floods. These should perhaps be considered by the *RAC* as stochastic events with a certain probability of occurrence. If any of these phenomena were to occur, then short to medium-term increases in resuspension or runoff, perhaps of dramatic proportions, could result.

This perceptive comment sets a potentially difficult task for this project. We expect to be able to check model predictions of resuspension against (at least) Langer's measurements in the 1980s, which provide two years of data, but which consider only the ground cover that existed at that time. A fire that denuded the landscape would increase resuspension by an unknown amount. A tornado that touched down near the site of the 903 pad would immediately send substantial quantities of contaminated soil and litter airborne, and the resulting disturbance of ground cover and surface soil would permit an enhanced resuspension of radioactivity until the previous state was restored. Credibly quantifying the aftermath of these events is very difficult. They can be discussed in the reports, but systematically incorporating them into scenarios would require a great deal more effort and debate than the stringent schedule of this project permits.

Reviewer Three

This reviewer appears to have missed some things in his or her reading of the report. Over all, the review is not particularly helpful.

> . . . The review of the models, in general, seems sufficient with a few exceptions. The report lacks a clear, concise statement of the criteria used to identify the models that would be selected for review. This should appear in the Introduction.

Such a list of five criteria appears at the beginning of Section 4.1 (page 29). It could be replicated in the introduction, but the existing placement seems more appropriate.

> . . . In addition, *RAC* did not explicitly address the models' capabilities to address offsite exposures. This was explicitly mentioned in the RFP and *RAC*'s proposal of work and should be explicitly addressed in the review.

In the overview of GENII, Section 4.4.1, third paragraph, we find the following: "The proposed soil action levels developed for the RFETS are essentially based on a near-field scenario. The RESRAD code is not capable of addressing directly what GENII defines as a far-field scenario, and therefore, GENII appears to have an advantage as a model that may provide dose estimates to off-site individuals." Perhaps the point also deserves mention in the introduction to Section 4.

1) Include a list of definitions of acronyms and variable names used in the equations.

We will consider this recommendation. If the reviewer means variables used in the equations, this could be done, but variable names in the programs run into the hundreds and including them would be out of the question.

2) The second paragraph of the introduction requires clarification. In order to "...make clear our [*RAC*'s] conception of the task to which the programs would

be applied…" ; *RAC* provides a vague definition of SALs. The introduction should be where a succinct, readily understandable definition is provided. I suggest:

What follows in the comment (which we do not reproduce here) is hardly succinct; it is longer (226 words) than the paragraph referred to (179 words). We will reexamine the definition and decide whether we believe it requires further work.

3) In the detailed discussion of the use [of] SR (Section 2) , it should be emphasized that the use of the SR is predicated on the assumption that the model estimated radiation dose is linear to the initial radionuclide concentration in soil. It is important to ensure that this is true for the models reviewed.

This condition is set forth as Equation 2.1-2. The point hardly seems to deserve emphasis, since few assessment models are implemented with nonlinear dependence of committed dose (the end point of these predictions) on environmental concentrations. If the reviewer had instances in mind that might confuse a reader, he (or she) should have mentioned them.

4) In eq. 2.1-1, it seems to me that there is no reason to include scenario as an index. It confuses the discussion. In addition, EPA and et al. have traditionally kept exposure scenario- and dose limit -specific SALs separate (e.g., Table 5-1 in US DOE, 1996). When a particular SAL is selected for a site, it seems sufficient to indicate that the selected SAL is or is not protective of whatever other exposure scenario/dose limit combinations have been evaluated.

We did not include the index just to seem erudite. In our analysis, a scenario corresponds to a single individual. Thus the rancher, his wife, and his child would ideally be implemented as three correlated scenarios. However, we acknowledged that "as a practical matter, we may wish to treat different scenarios as if they were independent" (page 9, parenthetical remark in the next-to-last sentence). But we think the generic formulation we gave is rigorous and defensible.

5) I am not sure how the soil action levels "represented as a joint probability distribution" that *RAC* proposes developing should be interpreted in field applications. After all, the purpose of SALs is to be useful in the field, i.e., to provide either a means of determining the acceptability of measured radionuclide concentrations and/or a quantifiable remediation goal. How will measured concentrations be compared to SALs specified as joint distributions (i.e., compare means, variances, and correlation coefficients?—what if mean is the same, but variance or correlations are different?) I think SALs are more appropriately expressed deterministically for comparison to mean measured contaminant concentration levels, as described in Yu et al.(1993) for sites with homogeneous contamination (1993,see p.33-34, and especially see eq. 3.4. Note that there is a separate discussion on how to handle inhomogeneous contamination on p. 35). (In addition, RESRAD (Yu et al., 1993) (and likely the other models ??) assume uniform initial contaminant concentrations in the contaminated soil layer. This is, to be sure, a simplification of reality. When contaminant concentrations are not uniform, the deterministic initial contaminant concentrations input to the model can most appropriately be interpreted as the

spatially-weighted mean contaminant concentration. There is, to be sure, some uncertainty in this mean due to sampling statistics. However, this uncertainty can be minimized by an adequate sampling strategy. I would caution against thinking that applying an uncertainty distribution to the input initial contaminant concentration would account for variability of contaminant concentrations in the contaminated layer.)

We explained our recommendation for using the distribution of the sum of ratios as an action level criterion (Section 2.2 and Fig. 2.2-1). There is nothing in the formulation to preclude handling the concentrations as constants, if everyone is satisfied that this approach is justified by estimates of sampling error and consideration of possible uncertainties in the representations of the concentrations as spatial averages. We deliberately left this choice open. However, the SALs in the denominators of the ratios are still uncertain, and the sum of ratios needs to be treated as a distribution. The reviewer is clearly uncomfortable with the idea of applying uncertainty to environmental assessments. We think the remarks about what is useful "in the field" do not reflect what really goes on as remediation work is planned and executed (we doubt that the calculations supporting the planning are carried out by an engineer in a field tent while the bulldozers sit with their engines idling). There is, of course, no question that the document of Yu et al. describes deterministic models, and RESRAD was designed to implement such models, but this can hardly be offered as an argument that the methodologies should not expand to accommodate a more contemporary view. The reviewer may not be aware that there is a beta-test version of RESRAD that incorporates Monte Carlo facilities for parameter uncertainties, which indicates an awareness on the part of the developers of the changing methodology.

6) I suggest that it is more appropriate to develop SALs by answering the following question: What is the contaminant concentration in soil that results in an acceptable dose limit (for a specified exposure scenario) with a specified level of confidence (given uncertainty in environmental fate/transport and exposure parameters)? I propose use of the equations presented below as a straightforward means of addressing this question.

We believe we have posed this question, along with considerable discussion to guide the reader. What follows this comment is the reviewer's proposed formulation consisting of five equations with some explanation of the notations (which are similar to the ones we have used). We have the following problems with the presentation:

A) It is based, in part, on an erroneous assumption.
B) The introduction of the ratios b_i, it seems to us, clarifies nothing. In particular, if such ratios are to be explicitly introduced, it would be preferable to refer every nuclide to ^{239}Pu; those ratios are available from Krey et al. (1976) and are less awkward in the formulation.

The erroneous assumption consists of the following claim:

c) The **maximum** [our emphasis] total dose due to any individual radionuclide can be calculated using:

$$D_i = T_i \cdot C_i \qquad (2)$$

At Rocky Flats, some of the radionuclides are decay products of others; in the most important case, ^{241}Am is a decay product of ^{241}Pu, which in turn decays to ^{237}Np, a long-lived alpha

405

emitter. At present, the levels of ^{241}Am (and ^{237}Np) are rising as ^{241}Pu decays, and they will do so until the early 2030s (Krey et al. 1973; our calculations give the same result). Thus it would be incorrect to assume, for any initial time before 2030, that the proposed equation (2) represents the maximum dose from ^{241}Am and particularly ^{237}Np. Whether or not this would result in palpable error in the total dose remains to be seen from the Task 5 calculations (the early plutonium dose may dominate the much later neptunium dose and render the point moot). Also, different rates of removal of isotopes from the surface soil complicate the question. But we spent considerable time and effort developing the formulation with sufficient generality that such questions are likely avoided in preference to having them arise later and require additional calculations and explanations.

Krey P., E. Hardy, H. Volchok, L. Toonkel, R. Knuth, and M. Coppes. 1973. Plutonium and Americium Contamination in Rocky Flats Soil. Report HASL-304. U.S. Energy Research and Development Administration, Health and Safety Laboratory.

Reviewer Five

This review is mostly unhelpful and contains some inappropriate remarks.

> This reviewer has at least one suggestion for an additional source of information, similar to a computer model, that *RAC* should consider [this seems to refer to the item just below].
>
> P. 29 The candidate computer programs are introduced. The choice of codes for review is sensible but not necessarily complete. *RAC* should at least make a comparison to screening levels *already* calculated for various scenarios by the National Council of Radiation Protection and Measurements (Report 129, issued January 1999, see the reference list).
>
> In addition, a review of how each of these models treats soil ingestion is reviewed in *Health Physics* (Simon 1998) and should be referenced. It can be seen from Table 5 of that publication that soil ingestion values for the GENII code, in particular, are not credible.

The NCRP document (which was also recommended by Reviewer Two) has been examined (it was distributed about the beginning of April and was not available to us during most of the work on Task 2). It will be used to the extent that it is relevant. It is interesting that this reviewer, who elsewhere demands such stringent adherence to the letter of the contract, now advocates that something other than a computer program be examined. Matters related to bringing the GENII database up to date will be dealt with in Task 5.

> In addition, a level of commentary was included in the report which I found to be inappropriate. In particular, those comments directed to the Department of Energy, which is neither a sponsor or direct recipient of this report, are out of place.
>
> Furthermore, I found it interesting that *RAC* discouraged the Rocky Flats Citizens Advisory Board (RFCAB) and Rocky Flats Soil Action Level Oversight

> Panel (RFSALOP) away from the concept of soil action levels. Though I might agree with that insight, I can not help but feel that such advice is inappropriate in this report for the following two reasons: 1) the report is allegedly concerned only with the suitability of a set of specific computer models, and 2) the contract with *RAC* was (apparently) for the purpose of evaluating those computer programs assuming the concept of soil action levels was already accepted. It seems to this reviewer that it is presumptuous on the part of *RAC* to try and steer the Advisory Board and Oversight Panel away from the concept in this document. That level of discussion should be held in public meetings or in contractor/contractee negotiations.

Since the Department of Energy is paying for the work, we are confident the reports will be read within the agency. We consider the recommendations we made to be constructive and entirely appropriate. As to the contractual obligation to comment on and develop soil action levels, we think our report makes it entirely clear that we intend to honor that obligation. But our proposal made plain our intention also to explore more contemporary approaches to this assessment, and if such exploration had been considered inappropriate, we assume that our proposal would have been turned down. The reviewer oversteps in characterizing our recommendation as presumptuous.

> P.7, 1st paragraph. The text states: "Thus, the same set of soil action levels could be used for determining the need for remediation, planning the remediation and verifying that the remediation has been successful..." It is unclear whether *RAC* is saying that the <u>same</u> soil action level is <u>necessary</u> for all of these activities. There is actually no scientific reason that is apparent to me to force the same action level for all activities. It would be perfectly acceptable and reasonable to have different soil action levels for different activities, depending on their purpose.

We do not know what the reviewer is objecting to. We had in mind a comprehensive set of soil action levels, based on all relevant scenarios and dose limits. These action levels, after all, do not depend on specific concentrations, and thus they should indeed be suitable for the applications we enumerated.

> P.8, 3rd paragraph. The text discusses the notion that soil action levels are not needed. As mentioned above, this discussion is outside the goal of reviewing computer programs suitable for the purpose intended. It seems to self-defeating as well as a means for the contractor to control the direction of the study, which also seems improper.

It seems likely that this reviewer did not read our proposal. There is nothing self-defeating or improper in our suggestions for decreasing reliance on soil action levels.

> P. 9. 2nd paragraph. The text states: "In general, we allow both the numerators and the denominators ... to be uncertain quantities." The approach discussed here is appropriate, however, the discussion does not illuminate the fact that <u>spatial variability</u> is a more important concept to the numerator than is <u>uncertainty</u> (i.e., lack of knowledge).

The statement does not indicate which is more important because we do not yet have final formulations that settle the representation of spatial variability. The reviewer seems confident that this will be the more important component, and that may be the case. But the question is better dealt with in Task 5.

> P.10. Following eq. 2.1-2, it is stated that "...the dose limits are not the same for all scenarios." I don't have a dispute with this statement but it needs clarification. Admittedly, this location in the report is probably not the best place to discuss details of the various scenarios and their dose limits, but it would help to at least reference parenthetically where in the report such a discussion could be found.

Another reviewer suggested saying "the dose limits are not <u>necessarily</u> the same for all scenarios, and this addition may be sufficient to alert the reader. The scenarios sketched in the 1996 DOE/EPA/CDPHE document Action Levels for Radionuclides in Soils for the Rocky Flats Cleanup Agreement are not uniform in their limiting doses, and we are allowing for such disparities, but as noted, this is not the place in the text to go into detail

> P. 12. 1st paragraph in Section 2.2. The text states "...The 1000 doses define an empirical distribution..." I have a bit of a quarrel calling this distribution "empirical." Such a term gives the distribution more credibility than it deserves because it implies that the values are derived from experiment or observation. Monte Carlo calculations are only simulations and may not represent reality at all. In fact, this particular distribution characterizes "uncertainty" which is not even a directly measurable quantity. The authors need to better characterize the distribution as a calculation of possible alternatives which include a substantial degree of subjectivity; there is nothing empirical about it.

This usage, in exactly this context, is fairly common, even in authoritative published material (for example, IAEA 1989). In fact, one is doing a kind of "experiment" with a computer, by analogy with taking samples in real world measurements. Throughout the history of Monte Carlo methods (which go back to the 1940s at least), computer scientists regularly described these methods in terms of carrying out experiments with computers. The word "empirical," as the reviewer knows, is intended to distinguish the distribution from its theoretical counterpart. The nature of the process is described in the surrounding text.

> Throughout the report there are a number of locations, where as a reader, I could not determine <u>why</u> *RAC* was discussing a particular subject in detail. The first of these is located on p. 14, 2nd large paragraph. The discussion of the methods for determining weighted breathing rates seems out of place in a major section on Exposure Scenarios. <u>How</u> the weighed breathing rates are determined is best suited for a Methods section (which does not exist in this report) rather than a section which defines the scenarios.

We do not share the reviewer's organizational preferences for the report, insofar as we can deduce them from remarks like this one.

> P. 16, Scenario 9. The soil ingestion rate described here (88 grams per year) is an interesting, but not credible, value unless it is an upper bound. First, I cannot help but wonder how a figure of 2 significant digits was arrived at. Second, a continual daily ingestion of 240 mg per day (every day for a year) is not a credible estimate, particularly for adults. There are no studies anywhere, except perhaps those relavent [*sic*] to indigenous populations living primitive lifestyles, that have provided evidence of such high continuous, inadvertent intakes. This particular issue will likely be controversial throughout the entire RFETS evaluation process. Numerous publications in this field should be consulted, e.g., Calabrese et al. (1994), Sheppard (1995), Simon (1998), only to name a few. These references are noted at the end of this review. I note from Table 2.3-1 that similar values have been recommended by *RAC* for additional scenarios and their credibility is equally questionable.

The scenarios proposed and briefly described in the Task 2 report were provided as "examples of the scenarios that are under consideration." An important part of the process has been to involve the panel in the development of the scenarios by thoroughly reviewing studies with a range of possible input values for the parameters such as soil ingestion. We are selecting parameter values for the scenarios using the data from scientific literature for use in developing uncertainty distributions. When data from a number of studies on soil ingestion (Calabrese et al., 1991, Stanek and Calabrese 1995, Thompson and Burmaster, 1991; Simon 1998) are used to develop a distribution of soil ingestion values (with ingestion values for geophasic children removed from the distribution),and with each study weighted equally, then the median, or 50th percentile of the lognormal distribution is 200 mg per day (5th and 95th percentile values of 60 and 730 mg per day).

RAC agrees that most soil ingestion studies, even the more recent studies using a mass-balance approach, are conducted under fairly idealized conditions, or during more mild seasons of the year (Calbabrese et al. 1991; Binder et al. 1986). This timing factor provides conditions where children may have more ready access to open play areas and outdoor activities and adults may be more involved in gardening activities. While these values that are derived from studies conducted from a few days to a few weeks are quite valid in estimating daily soil ingestion rates, there is a need to carefully consider the implications of translating this daily soil ingestion rate to an annual soil ingestion rate when the year includes large periods of time where outdoor inadvertent soil ingestion activities may be somewhat limited by snow cover, frozen ground, and inclement weather. Because we are estimating an annual rate, *RAC* is using the 50th percentile of our distribution of daily soil ingestion rate, rather than the more conservative 95th percentile value. From the daily soil ingestion rate, we then calculate an annual soil ingestion value based on the number of days of exposure. In the scenario noted by the reviewer, we had chosen a central value from the distribution.

RAC is aware of the publications noted by the reviewer and will reference them in the Task 3 report, Inputs and Assumptions. Our approach to selecting input parameter values will be thoroughly described in the Task 3 report.

> P.19, 2nd paragraph. The text states: "Soil action levels are defined in terms of dynamic models..." This statement came as a complete surprise. Furthermore, I can not see that there is any basis for the statement. Soil action levels are actually a value derived from conditions which are assumed to represent a

409

steady-state contamination condition, an accepted dose standard, and a lifestyle description (which is used to describes the pathways of potential exposure). The only use for a dynamic model would be if the contaminant has to be modeled from its release point until environmental conditions equilibrate or at least, become predictable. However, I would never want to base soil action levels on such calculations. I see no use for this sentence.

Dynamic models most assuredly *are* the basis for these calculations, and we are astonished to read such a remark from a reviewer. A model of the surface soil compartment, as implemented in RESRAD and other codes, simulates removal of radionuclides from this compartment over time and the movement of the material into ground water (if that option is exercised). It is this dynamic process that gives calculated annual doses that vary with time during the 1000-year period that we are required to consider. The decay chain calculations that run throughout these assessment programs are based on a dynamic model of nuclear transformation. Even when steady-state conditions are applied to estimates, the conceptual (and often the practical) basis for the steady-state is generally a dynamic model represented by a system of ordinary or partial differential equations. To assert that dynamic models are the basis for a calculation does not necessarily imply that transients are being explicitly solved for and examined.

P. 20. Section 3.1.1 The first mention is made that the temporal scope of the scenarios is 1000 years. If I were to give RFCAB or RFSALOP advice, I would state how ludicrous the idea is of predicting consequences more than 50 years into the future. Not only is there no environmental data or models on which to base those assumptions, human behavior, societal norms, and societal stability, etc. is impossible to predict. Soil action levels should be determined only for those conditions which are presently understood. Anything more than that is part of the "garbage in/garbage out" syndrome of modeling. Furthermore, it deludes the public that scientists are capable of more than is actually possible.

For the record, we stipulate that millennial predictions of the kind required by the contract are, in our opinion, almost meaningless. Even as we carry them out, as we are required to do, we intend to help readers achieve a proper perspective about what (if any) meaning can be derived from such predictions. We would add that in the forecasting business, even 50 years is a very long time.

P.21. Section 3.1.2 This is a rather small point but the phrase "Figure 3.1.2-2 shows the variation of ^{239}Pu concentrations" should actually read "Figure 3.1.2-2 shows the trend in ^{239}Pu concentrations". It is not incorrect to state that it shows the variation but it is misleading for the following reason, Actinide contamination of soil is extremely variable, primarily because of the particulate nature of most plutonium contamination — a reflection of the circumstances which generated the contamination and its low solubility. Few studies carefully document this variation except on a gross, macroscopic scale. Here the data points are a km apart. Variation of plutonium contamination exists on a spatial scale measured in cm.

Though only a word change is suggested above ('variation' to 'trend'), the idea has greater importance in the discussion which states "RESRAD proceeds on the

> assumption of a uniformly contaminated area..." and 'For some scenarios, it could be desirable to subdivide the site .... each having a uniform concentration." What does it mean: "...**could** be desirable? At what spatial scale do you make a determination of "uniform concentration" and what is the rationale for that scale? There is no discussion of the ramification of ignoring the heterogeneity of the contamination, yet, there should be. When spatial variation is properly considered, the extremely wide probability range of possible doses become apparent. It is my opinion that none of the programs reviewed can adequately handle the true spatial variation of actinide contamination in predicting environmental transport and dose to human. Thus, it is necessary to at least state this weakness and possibly discuss the consequences of this inability to model the environment correctly.

(First paragraph) Point taken, but in the text the concern has to do with differences over a two dimensional region, and this seems more appropriately described as "variation." The word "trend" suggests low frequency variation along a line (i.e., one dimension).

(Second paragraph) We think the reviewer knows perfectlywell that this is a question without an easy answer. We are working on it for Task 5, and we cannot answer it in this Task 2 report. The codes reviewed here could be applied to one subplot at a time and the results summed, but the process is complicated to set up and execute and difficult to explain to casual readers, and we are not convinced that such a scheme would be necessary or even useful.

> P.23, 2nd large paragraph. In this paragraph I note that concentration units of pCi per grain are used but elsewhere, units of Bq per gram are used. I advocate two things: 1) SI units exclusively, and 2) consistency throughout the document. Many reviewers give the caveat that they are reporting what previous authors used and thus, are hesitant to change. This negative inertia only serves to continue an outdated system.

This was an oversight. For the illustration cited, the unit can just as well be Bq.

> P.23, last paragraph. The text states: "47 μg m^{-3} with a standard deviation of 9.0 μm. These units are not stated to be the same though they must be made consistent.

This was a misprint.

> P. 27. Section 3.2 1 found the reference of "introduction of radioactivity into blood through injection" as a contamination pathway to be offensive and inane. It contradicts P. 19 which defines "pathway" to be "the succession of environmental media through which radionuclides move."

Injection of radioactivity has been, for many years, one method of introducing radioisotopes into the body for therapeutic and imaging purposes. This specific intake mode is not likely to be applicable to the problem at hand, but when one is making a generic list of intake modes, this is one of them. Nothing sinister was intended, and we think that would be obvious to any reasonable reader.

414

And in the other matter raised in this remark, we have not confused our usage of the words "mode" and "pathway," as the reviewer seems to allege. A careful reading of the first sentence reveals that the word "pathway" refers back to discussions of pathways (e.g., soil to air) in which some exposure modes (e.g., inhalation) were mentioned. A mode can be talked about in connection with a pathway without being confused with it.

> P. 27, Section 3.2 The speculation that beta emitters in close proximity to the skin may "possibly [cause] skin cancer" should either have a legitimate literature citation that provides evidence of that effect or be removed.

The hedging here had to do with how much, how close, and how long. NCRP Report No. 106 (p. 11) can be cited. [National Council on Radiation Protection and Measurements (NCRP). 1989. *Limit for Exposure to "Hot Particles" on the Skin*. NCRP Report No. 106. NCRP, Bethesda, Maryland.]

> P. 28. The discussion of the various metrics of radiation dose (with its various combinations of weighting factors) seems out of place in a section on "Exposure modes." Furthermore, I doubt whether discussion on the concept of "effective dose" has a place at all in that only the ICRP has found a use for this concept. I have never been convinced that the concept, which simply dilutes the absorbed dose to a specific organ, by the use of weighting factor (less than 1.0), to be of any value. Risk coefficients (other than those derived by ICRP) are organ specific and not applicable to effective dose.

The dose limit is expressed as (annual) effective dose, and we are required to use that metric. We are also required to perform corresponding estimates of risk.

> P. 29 The candidate computer programs are introduced. The choice of codes for review is sensible but not necessarily complete. *RAC* should at least make a comparison to screening levels *already* calculated for various scenarios by the National Council of Radiation Protection and Measurements (Report 129, issued January 1999, see the reference list).
>
> In addition, a review of how each of these models treats soil ingestion is reviewed in *Health Physics* (Simon 1998) and should be referenced. It can be seen from Table 5 of that publication that soil ingestion values for the GENII code, in particular, are not credible.

As noted previously, we will consider NCRP Report No. 129 for its applicability. However, the reviewer needs to be reminded that we were required to consider computer programs, not tables or unprogrammed models. The matter of the GENII predictions may have to do with an obsolescent database, which we will be examining in Task 5.

> P. 43. Mention is made that GENII uses organ weighting factors from ICRP 26 (a 1977 publication). I have to question why such old data is used (newer factors were recommended in 1991 by ICRP) though again, the doubtful usefulness of the effective dose is still an issue. Though this may not be the forum to debate the wisdom of the effective dose concept, it is particularly important that public

> readers understand that actinides do not contaminate or expose the body uniformly, thus, the organ dose to the lung, liver, or skeleton will be greatly diminished through the use of the weighting factor. The unfortunate situation exists that the same metric (Sv) is used for both equivalent and effective dose, thus leaving the uniformed [*sic*] reader with little information as to what the calculated dose really applies to.

Indeed, this is not the forum for debating the usefulness of the effective dose, which we are required to compute. The GENII database will need to be made comparable to that of RESRAD to permit meaningful comparisons, and this is work for Task 5.

> P. 53. Paragraph 5. *RAC* again urges "everyone ... to pay less attention to soil action levels and instead concentrate . . ." Again, it seems inappropriate that the contractor attempts to circumvent the intention of their task in print. This level of discussion should be relegated to workshops and discussion sections.

And again, we most emphatically take issue with the unwarranted allegation that we are attempting to "circumvent the intention of [our] task in print." (The reviewer seems to have no such qualms when the question at issue is 1000-year scenarios or effective dose.) We fully intend to satisfy the terms of our contract and calculate soil action levels; there has never been a question about that. But we believe that such hazard indices conceal information that ought to be explicitly reviewed, and we intend to remind all parties to the discussion of that fact and to direct their attention to other ways of viewing the relationship between radionuclides in the soil and possible consequences — as we have every right and obligation to do.

> P. 54. The recommendations to the Department of Energy regarding their choice of computer interface is embarrassingly out of place in this text. DOE is neither the sponsor or a recipient of this report. Such recommendations should be make by private communication from the contractor to DOE or at most, brought to light public meetings.

This remark is very much out of place and is contradicted by other reviewers. A careful reading of the recommendations would have indicated that we were not criticizing the choice of an interface or that the graphic user interface (GUI) did not serve a purpose for many users of the program ("We are not suggesting that the GUI be eliminated . . ."), but only that it gets in the way of using RESRAD in the way we want to use it. We pointed out how the program can be made more useful for applications like this one, without changing anything about how most people use it. It is entirely appropriate that such recommendations be conveyed in a context in which the relevant subjects and motivations are under active discussion, and that the recommendations be precisely documented, as they are in this report. We are not in the least embarrassed by having made these recommendations in this report. We find disingenuous the reviewer's insinuation that no one at DOE (which sends representatives to every OSP meeting and is paying for the project) will read this report.

References

Calabrese, E. J.; Stanek, E. J. 1994. Soil ingestion issues and recommendations. Journal of Environmental Science and Health A28(2):517-530.

2413

International Atomic Energy Agency (IAEA). 1989. Evaluating the Reliability of Predictions Made Using Environmental Transfer Models. Safety Series 100. International Atomic Energy Agency, Vienna, Austria.

NCRP (National Council on Radiation Protection and Measurements). 1999. Recommended Screening Limits for Contaminated Surface Soil and Review of Factors Relevant to Site-Specific Studies. NCRP Report No. 129. Bethesda, MD: National Council on Radiation Protection and Measurements.

Sheppard, S. C. 1995. Parameter values to model the soil ingestion pathway. Environmental Monitoring and Assessment 34(1):27-44.

Simon, S. L. 1998. Soil ingestion by humans: a review of data, history, and etiology with application to risk assessment of radioactively contaminated soil. Health Physics 74(6):647-672.

Reviewer Six

These are generally useful comments from a very well-informed reviewer. We are particularly impressed by his (or her) examination of background documents. The reviewer's major comment, concerning our view of treating the parameterization of each scenario as a set of constants indicates that we have not yet communicated this part of our methodology clearly, because the comment does not accurately depict our view or intended approach. We do not intend to respond to this point in detail here, but rather we will amplify the discussion in the Task 2 report in an effort to clarify it for readers (or possibly defer some aspects of it to the Task 5 report). If it is not clear to this reviewer, we accept that we probably have not made it clear to anyone.

> P. 7. Points 3 and 4 would benefit by being generalized to encompass dose or risk coefficients, and annual dose <u>or</u> lifetime risk. This would be less parochial (i.e., radiation oriented) and more consistent with Superfund. Soil Action levels are most frequently used for chemicals, based on lifetime risk and the present action levels based on dose are themselves a special case that is derived from the Superfund risk criterion of 10^{-4} lifetime risk from carcinogens (40 CFR Part 300.450(e)(2)(I)(2)).

We do not disagree in principle, but we agreed to the dose criteria as part of the contract. A lifetime risk calculation is required for each of the dose criteria, and we will provide that.

> P. 10. Following eq. 2.1-2: ... are not *necessarily* the same for all scenarios.

The dose limits presented to us are not all the same, but we agree with the added word.

> P. 11, First full para. following eq. 2.1-9: The probability that the inequalities hold in the real world also depends on the accuracy of the scenario choice. The standard must be met for most real world people, and with a reasonably good probability.

This is part of our reason for viewing the scenario as a standard rather than a statement about real people. The standard must be carefully defined with the aim in mind that meeting it would protect most real world people finding themselves in the exposure situation hypothesized by the scenario. There is no difference of opinion on the goal, but only on the best formulation for attaining the goal.

> P. 13. Last para.: Scenarios do not usually represent single people, but significant subgroups of a population that, it is assumed, can be represented by a common set of characteristics. (E.g., it would be inconsistent with the concept of RME individuals to use average breathing rates, unless the RME individuals received above average exposures for reasons not related to inhalation.)

This depends on the use to which the calculations are to be put. And we are not proposing the use of average breathing rates for a scenario subject, as the next paragraph should indicate.

> P. 14. First full para.: Why must this process be any different from that described for environmental parameters in Section 2. 1 ?

In principle, it is not. But as a matter of interpretation, combining the uncertainties associated with the source term and environmental transport with parameter distributions for a conceptual population that may or may not ever contribute a member to the envisioned exposure conditions yields a composite distribution that requires careful probabilistic interpretation, and to us the interpretation seems strained and possibly misleading. We must think of the probability that an individual chosen at random from such a population, given that such an individual encounters the exposure conditions of interest at the specified place and time, receives an annual dose not exceeding the given limit. It seems preferable to us to formulate the scenario according to the principle that the parameters should be chosen to define a hypothetical individual who would experience a dose per unit exposure at least as great as, say, 95% of the population that the individual is assumed to represent. Then this fixed scenario functions as a standard, which can be specified by listing its parameter values (not a set of distributions). With this formulation, our interpretation of the probabilistic statement is simple: it is the probability that the dose limit will not be exceeded for this scenario, period, and we may focus attention on the environmental uncertainties. This formulation is more conservative than the one the reviewer prefers, but we think not unreasonably so. Of course it is possible to combine the two kinds of distributions, but the question is, should one?

> P. 21. Is there any way to provide for the possibility of colloidal transport in the uncertainty analysis?

We are considering this question. We do not yet know the answer.

> Section 3.1.4.2. Table 3.1.5-1 indicates that the dose from Am-241 could be increased by a factor of two if ground water is included in the analysis. Given the major contribution from this isotope, it would seem imperative to include this pathway in calculating soil action levels. This is particularly the case for the rural residential scenario Tier 11 case, when institutional controls are assumed to be absent. It should also apply to any residential case applied to Tier I analyses if institutional control is not assured for the full 1000 years. It seems reasonably

> obvious to this reviewer that it should be assumed that the RME individual will use ground water if it is not institutionally prevented.

We substantially agree.

> P. 40. The resuspension issue is clearly critical In view of the precedents found in draft Task I for action levels at other sites it would appear to be essential to make a strong case for any lower value to be applied to the Rocky Flats site. Perhaps an uncertainty analysis of environmental parameters, coupled with a somewhat conservative view on the degree of assurance required for compliance with the standard by the RME individual would be the most supportable approach. In this regard (the degree of conservatism appropriate), to what extent can we predict the effects of climate over a 1,000-yeat period on enhancement of resuspension?

The question is a reasonable one and is similar to one raised by another reviewer. The programs can be manipulated to permit analysis with different assumptions about resuspension, but the only real calibration available to us is tied to measurements made under the environmental conditions of 1983–1984. It is possible, for example, to assume that a tornado (or fire) denudes the soil east of the 903 area and enhances the resuspension for nearby off-site scenarios who may have escaped the immediate fury of the natural events. We can explore such possibilities, but our time and budget will severely limit the extent to which they can be pursued.

> Section 4.3. Could not deterministic comparisons be made, once the relevant values of parameters (e.g., 50 and 90% confidence levels) had been evaluated using RESRAD?

Without making a commitment, we will consider this possibility.

> P. 43. Second full para.: I assume that the outdated external and internal exposure factors in GENII would be updated by *RAC* for the relevant isotopes for any use of this model.

> P. 45. The result showing differences for external exposure is particularly disturbing. This pathway should be the least subject to large differences between models. I would have thought that this code would by now have incorporated the newer calculations of Eckerman and Ryman reported in Federal Guidance Report 11, in place of the old 1981 calculations of Kocher, or the 1983 soil calculations of Kocher and Sjoreen.

To the extent possible, we will reconcile the databases of GENII and RESRAD. Even RESRAD does not have the most up-to-date dosimetric data.

> P. 53. Next to last para.: While I emphatically disagree with the comment that soil action levels will become cumbersome to deal with and will offer little if any advantage, I equally emphatically agree with the suggestion that primary attention should be paid to the dose levels achieved. Even more to the point would be to pay attention to the lifetime risk levels achieved. To this end, it is

4116

> recommended that the Task 5 report include a calculation of the lifetime risk for each of the action levels. This can be carried out without any difficulty using the tables in Federal Guidance Report 13 - Part I "Health Risks from Low-Level Environmental Exposure to Radionuclides" by Eckerman et al.

We think the reviewer would find that soil action levels for individual radionuclides would become cumbersome if represented by correlated distributions (think of a computer file with 1000 lines, and ten or so numbers to a line). But if isotope ratios derived from measurements by Krey and others may be assumed, it would be possible to maintain a distribution of the SAL for ^{239}Pu, which would be derived with the assumption that the specified isotope ratios prevailed at the starting time for the scenario.

The calculation of the lifetime risks is part of the contract and will be done.

> Regarding the first point, introducing uncertainties should assist rather than deter the selection of action levels. The relative abundances of the various isotopes should not vary widely over the areas of significant contamination, and thus the conditions set forth inequation2.1-1 should be relatively stable across the relevant area at the limiting levels of concentration for each scenario. It should not be difficult to select a single value for each isotope, based on the probability distributions for the SALs (as shown in Fig. 2.2-1), once the desired probability of satisfying the dose criterion is specified. Such values would be clearly easier to implement onsite during cleanup than the implied alternative, which could require extensive inputs of expensive-to-obtain point-by-point analytical data, in addition to field use of computer modeling.

We do not disagree with the comment, if we are interpreting it correctly. We think it likely that the relative abundances estimated by Krey et al. (1976), corrected for radioactive decay and formation of progeny from the early 1970s to the baseline time for the SAL, can be assumed to vary little from point to point. We did not intend to recommend the excessive analysis that would result from ignoring these isotope ratios, but we wanted to leave the handling of the question open until we formulated the Task 5 calculations.

Reviewer Seven

This reviewer's extensive and thoughtful comments deserve a fuller response than we are able to give them.

First, regarding the concern about excluding MEPAS. The rigidly enforced schedule of this project made it unavoidable that computer programs for which access could not acquired in the first two or three months could not be given further consideration. The intent, of course, is not to express prejudice against MEPAS, but we would be unable to treat MEPAS on an equal basis with the other programs. We have said in response to a previous reviewer's comment that we will consider making some deterministic calculations with MEPAS, if there is time to carry them out and include them in the report, but we do not intend that this statement be taken as a commitment that we will do so.

> The draft is thorough, accurate, and credible. It is coherent, and even though there were several authors, it does not appear to be written by a committee.

> However, it will not be easily understood by those unfamiliar with the task requirements, history of this particular issue at Rocky Flats, etc. Consideration should be given as to whether the final report for each task should also have a separate brief document (not the abstract in the draft) that presents the results and conclusions in a manner more generally accessible to interested non-professionals. More important, if it is not already planned, *Risk Assessment Corporation* (*RAC*) and the Oversight Panel should be planning One or more summary reports at the end of the project that present the overall conclusions in a manner easily understood by various segments of the public.. This might include audio-visual summaries as well as written ones. (It would probably be more efficient overall if the summary segment on each task was prepared at the same time that the final report on each task is completed).

In technical reports, one is obliged to deal with technical matters in some detail; otherwise, reviewers complain that the authors have not been forthcoming with supporting information. We believe that an executive summary of the final report can deal with the reviewer's concerns, and we take the point about preparing task summaries as the tasks are completed.

> Page 3-4. The distinction between deterministic and probabilistic approaches is presented about as clearly as it could be. However, it should probably be stated that the 1996 soil action levels (SALs) were developed deterministically, and *RAC* might want to provide its opinion as to whether that was standard *at that time,* or whether in *RAC*'s view a probabilistic approach would have been the "contemporary modeling practice" even then.

It would be awkward to try to designate a date marking a transition of contemporary practice in this regard. The development of uncertainty analysis as a part of environmental assessment methodology goes back at least to the 1970s. It still lacks uniform and explicit acceptance by government agencies, particularly where regulatory definitions are involved, but we believe it is fair to say that contemporary practice in assessment methodology supports uncertainty analysis (and has done so for a decade or more).

> Page 4. I suggest adding one or more summary tables that provide the key comparative features of the five models considered, either here or in Section 4 (e.g., developer, year first published, applicable directly to radionuclides, yes or no; etc.) Editorial: GENII is termed a "mature and stable" product. No other model is anointed with either such a fulsome (or denigrating) short summary. (RESRAD and MMSOIL probably deserve tile same description.) There should be a summary statement for all or for none.

We will consider the comparison table. "Mature and stable" meant nothing more than that GENII has been through numerous versions and is unlikely to be modified further. But RESRAD is likely to undergo further development; we do not know about MMSOILS.

> Page 5. Editorial. Is it worth considering telegraphing the conclusion regarding previous and current versions of RESRAD here?

Probably so.

> Page 7. Editorial. The statement in the first paragraph "The soil action levels as defined do not depend..." will probably be confusing to many readers. I suggest this paragraph be broken in two, with one paragraph defining soil action levels and a second one, which might come later, discussing the "sum of ratios" topic. Also, perhaps an example could be given to more specifically show the relationship of soil action levels to actual concentrations (need for remediation) and the other uses.

We will add another clause to the flagged sentence. We would prefer to defer comparisons of soil action levels with existing levels in RF soils to Task 5.

> Page 10. Editorial. it might be helpful for there to be a second figure, after Figure 2.1-2, to show the geometric interpretation for a slightly more complicated scenario, especially since *RAC* emphasizes the sum of ratios approach throughout the draft. (Also, shouldn't this figure be 2.1-1, to be consistent with later numbering? (See, e.g., Fig. 2-2.1 on page 13).

We do not know what kind of second figure would be effective. A three-dimensional interpretation would be less clear because of the difficulty of indicating the inside, outside, and boundary of the tetrahedron that would correspond to the triangle in Figure 2.1-1 (number corrected), and we do not think such a figure would add any information. Perhaps some words added to the caption, indicating that all combinations of C1, C2 for which the point (C1,C2) lies on the line would make SR = 1 (although the labels in the figure also indicate this).

> Page 12. Editorial. Most readers who get this far will know what Monte Carlo techniques are, but Latin hypercube sampling may be less familiar. Do you really need to mention it specifically, or could you just refer to "other sampling techniques"?

It is not necessary to mention Latin hypercube sampling specifically.

> Page 12 and elsewhere, general point. Intellectually, I understand and agree with *RAC*'s emphasis on the use of uncertainty analysis, though that feature will eventually prove very hard to present to many segments of the public in an educational sense. However, there is another implication. Assuming the original SALs were developed deterministically (and if *RAC* has the view that was wrong at that time -- see my earlier point), then consciously or unconsciously *RAC* is raising the specter that the original SALs should be re-done. This is, as far as I can tell, both beyond the scope of the contract and more important beyond the scope of the agreement between DOE and the Rocky Flats Citizens Advisory Board. *RAC* should not lightly set the stage for such a confrontation. The *technical* answer may lie in the realm of running the models *RAC* chooses (including the newer version of RESRAD) in a "deterministic" manner (using single values instead of distributions, perhaps with a choice of reasonable but high, reasonable but low, and some median level for key parameters), to compare them "head to head" with the original SALs, as well as in the *RAC*-preferred probabilistic manner. This is an important point in my mind, perhaps one of the two most important in my review of the draft.

419

We do not see the conflict. *RAC* will calculate SALs as required by the contract, but *RAC* made clear in its proposal that its approach was about more than specific computer programs. *RAC* will provide deterministic SALs, along with distributions, and the deterministic versions may or may not agree with the ones that DOE has computed. *RAC*'s methods do indeed imply a critique of the DOE SALs, and we see no way of avoiding this implication of a comparison (but if this document review proves anything, it certainly demonstrates that *RAC*'s methods will also be subject to scrutiny). After reviewing our calculations, DOE may wish to revise its own or it may defend them. It is not up to *RAC* to make decisions about how our information will be used. We do not agree with the conclusion that the deterministic calculation of vintage 1996 must be "wrong" if the uncertainty approach could have been considered contemporary at that time. Assessment analysts have frequently found themselves involved with obsolescent (even obsolete) and new methodologies at the same time. What is new and considered "best" usually languishes for a long time until the nuts and bolts can be assembled to permit everyone to implement it, and sometimes regulatory criteria are not promptly revised to accommodate it. For example, the dose conversion factors in RESRAD belong to a methodology that is at least 25 years old, and the replacement factors from ICRP are now mostly available. But we suspect that the conversion will be some time coming.

> Page 15. The resident rancher scenario has the rancher spending a total of about 15 days per year (one hour per day) off the ranch. I am personally familiar with both ranching and farming families in the northern Rockies and other semi-rural areas, and believe that this underestimates the amount of time spent off the site (trips to town for supplies, coffee shop visits with other ranchers, picking up the mail, longer duration business or family travel, vacations, etc.). Unless the scenario has been accepted by the RSAL already, or *RAC* has studies to support the one hour per day estimate, I <u>recommend</u> increasing it to 2 hours per day, and based on the ranching families I know, even 2 hours is probably conservative (that is, a low estimate of the time spent off the ranch).
>
> Page 16. The current industrial worker scenario is an excellent addition. If the overall list of scenarios is shortened for some reason, this one should definitely be retained. As a minor point, if the current union contract stipulates only 2 weeks of vacation for a new employee, then 50 weeks is an appropriate time period. However, if there is a pattern of overtime suggesting that 2100 hours per year (or 50 weeks total time per year) is routinely exceeded, even for new employees, then 52 weeks per year should be used. In contrast, if new employees are given more than two weeks vacation per year, and there is no pattern of overtime, then a smaller number of weeks should be used.

While the recommendations made by the reviewer are reasonable for exposure scenarios in a retrospective study, for this project we must develop exposure scenarios for the distant future when we are quite uncertain about the land use. As a result, we think it is appropriate to bias some of the scenario parameters in a way that would increase estimated annual radiation dose. One of these parameters is time spent on site. We are not certain what the future may hold and therefore assume, for some of the scenarios, on-site occupancy time of 52 weeks per year. We are still in the process of finalizing our scenarios and will consider the comments made by the reviewer very carefully.

> Page 20. Editorial. The phrase at the end of the second full paragraph, beginning "sometimes they cannot..." may shed not fight but rather cast a shadow on the first clause. I recommend it be dropped. Alternatively, in later reports on other topics, *RAC* could explicitly point out where it strays from the highly appropriate "general guidelines" that are presented here.

This is only a "full disclosure" impulse that is based on our experience. If we elaborated to explain those occasions when the guidance cannot or should not be followed, it would become tedious. Since we have used the word "try" in the sentence preceding the one in question, we think deleting the offending sentence would be the better choice.

> Page 21. It is appropriate to mention the colloidal transport mechanism. Even though there is no body of data available to calibrate the models for this phenomenon, is there a way for some of the model runs to incorporate "worst case" assumptions as the analysis proceeds? Or perhaps there is another way to deal with this issue in a later task? It is important for *RAC* to try to find a way to address this issue, if at all possible under the terms of the contract it has. At the least, *RAC* should consider providing a perspective on the potential importance of such transport, and/or recommendations how DOE or others should follow up on this issue, either right away or in the near future. Otherwise, at the end of the project, no matter what *RAC*'s overall conclusions are, there will be a lingering worry that this potential threat will dwarf any other potential risks in the future.

We continue to ponder this question. We do not know what would constitute a worst case for colloidal transport, and we are doubtful that much theory can be developed during this project.

> Page 21. Regarding dividing Rocky Flats into smaller plots of land for the purpose of this project, I firmly agree with *RAC*'s "reluctance to recommend this refinement". In the final version of the report, I suggest that *RAC* be even more conclusive. This could mean a firm opinion that this degree of refinement is simply not justified, given known site conditions (in particular, the small area of high contamination, which will no doubt dominate the results), or, less satisfactory in my view, listing the "factors" that, after "careful evaluation", would require such a step, and then concluding the evaluation means this step not be taken.

This issue affects calibration of the resuspension model as well as routine calculations, and the full solution will have to await Task 5. The problem will be better formulated in terms of how the soil concentrations should be spatially averaged.

> Page 26. Editorial primarily, with one substantive suggestion. Section 3.1.4.2 states that the *RAC* team agrees with the cited 1996 study, but then states that research should be continued and groundwater issues should not be dismissed. Colloidal transport could well be mentioned as a specific research/monitoring need that others should definitely pursue (see my earlier comment), and would give some precision to the statement, In addition, one of the scenarios postulates groundwater use, and could be mentioned here as one step *RAC* is taking to deal with groundwater. In that regard, as a suggestion, some consideration could be

given to revising one of the Woman Creek scenarios to substitute ground water in whole or in part for surface water. However, I do not recommend that additional scenarios be added-there are enough already.

Page 26. 1 am not certain the phrase "simple screening exercise" does justice to the choice made and analysis done by *RAC* and the way both are presented. Instead, I suggest that *RAC* not use that phrase and elaborate more on why it chose to do what it did and reached the final view that it did ("should perhaps be investigated further.")

Page 26-27. Primarily editorial. The last full paragraph on page 26 and the next paragraph on page 26-27 should be clarified and firmed up. One change is to move the sentence starting "For the radionuclide..." up to be the last sentence in the prior paragraph, and starting the next paragraph with "The results of this exercise... " The implications of Table 3.1.5-1 should probably be spelled out more explicitly. Even more important, there should be a better explanation of why *RAC* "will ignore the groundwater pathway" (in fact, one of the scenarios includes it), and what the implications are (minor, major or unknown) of ignoring it. In addition to its technical implications, the way these two paragraphs ate worded raise the same specter noted earlier regarding colloidal transport. I can imagine the reaction of some segments of the public: How can we put any trust in the *RAC* conclusions if, according to their own report, *RAC* chose to 'ignore the groundwater pathway"?

We have incorporated these suggestions for editorial changes and have added some additional text to provide further explanation of the Soil Action Levels that include the groundwater pathway. In doing so, we have uncovered several misinterpretations of the analysis and have made corrections.

On the basis of these comments and the fact that one of the scenarios included groundwater ingestion, we have decided to include the groundwater pathway in our calculations for at least one of the scenarios. The groundwater analysis will only consider dissolved phase transport because colloidal transport models have not been extensively developed and could not be implemented within the time and budget constraints of this project. We note that this will probably make little difference in the overall action levels because doses are driven by inhalation and external radiation sources for most nuclides. The nuclides where differences are expected include ^{241}Pu, ^{241}Am, and ^{234}U.

Page 29. 1 have two major comments on this page.

First, the draft states that RESRAD was included "in accordance with the contract," which is of course true and also fundamentally needed-since this project is the direct result of the earlier use (of an earlier version) of RESRAD that led to the levels currently embodied in the cleanup effort. However, the use of the quoted phrase implies that but for the contract, *RAC* would not have chosen RESRAD. In short, this is damning with faint praise. Is this what *RAC* believes? In other words, on the basis *of* the five criteria, would RESRAD have been *rejected?* If so, say so. If not, and RESRAD would on the merits meet the five selection criteria (I think it definitely would), say so. (Editorial: why is "nominal" used before "criteria"? Are there "nominal" criteria and separate "really important" criteria?)

Second, the fifth criterion sets the final stage for rejection of MEPAS, though the scenery for this final act was put in place earlier in the draft report. I take at face value *RAC*s statement that the criteria were developed before final decisions were made, and I understand the practical reasons MEPAS was dropped (presented on page 4 1). However, this is not totally satisfying. MEPAS is very well-known in the modeling community, as indicated by the benchmarking exercise cited in the draft, and at least in my experience is for more widely known (and understood-and used) than *GENII. (GENII* was not included in the benchmarking exercise.) In my opinion, it is a very serious matter that MEPAS was rejected, even though I understand why (because the source code was not provided).

Separately, as part of this review, as a policy issue, I am recommending that the Oversight Panel consider formally asking DOE to direct Battelle to release the source code immediately for *RAC*s evaluation, even if on a confidential basis. In a more technical mode, for *RAC*s consideration, I strongly urge that *RAC* determine if there is a way that MEPAS can be evaluated, even though (and if) source code or the equivalent "special instructions" (page 41) is not available to you. One possibility would be to reduce the results *of* the probabilistic runs *RAC* makes to single or a small set of single values (such as mean, median, mean + one standard deviation, mean - one standard deviation) and use these as inputs to a few runs of MEPAS. There may be other approaches that skilled modelers can conceive that would overcome the problem that the "front end" of MEPAS as now available to *RAC* does not lend itself to the use of the Monte Carlo approach that *RAC* understandably prefers. (In fact, it seems likely to me that this particular problem has probably been faced conceptually in recent years as the probabilistic approach has become the preferred approach, while many earlier models, not just the ones *RAC* is considering, were developed based on a "deterministic" basis.)

It is virtually certain that RESRAD would have been included in the lineup in any case, and perhaps the language used here should clarify that. The word "nominal" refers to the fact that these criteria were stated in the RFP and proposal, but other sections of the draft report indicate why some of them (e.g., (2)) should not be interpreted too literally (pure validation results are unlikely to be available for the codes, for reasons indicated in Sections 4.1.1 and 4.1.2, but they may be suitable for some validation comparisons using local data). We can drop the word "nominal" if it causes confusion.

As to MEPAS, insufficient time and resources are available at this point in the project to prepare front-end code for doing uncertainty calculations with MEPAS. We hope the panel will not follow the reviewer's well-intended recommendation to make another attempt. We have indicated previously that we will consider performing some deterministic calculations with MEPAS for Task 5 if time and resources permit, although we cannot make a firm commitment to do this.

> Page 31. Editorial. Many readers will not automatically understand that "claiming validation is akin to accepting a null hypothesis." Perhaps a better comparison can be found.

We do not know a better analogy. Perhaps more explanation could replace the reference to a null hypothesis.

> Page 33ff. The issues related to different versions of RESRAD, different manuals, etc. are as well presented as they possibly could be. However, I recommend *RAC* consider, either in this report or perhaps better in a later report, presenting in some way (perhaps using tables) major differences that would result if the newest version of RESRAD were run, compared to the version used to develop the original soil action levels. My own prediction is that except for the soil resuspension issue, there will probably not be dramatic differences. If *RAC* does not undertake this comparison as part of its original work, some entities, including very possibly the Oversight Panel itself, will ask that it be done later.

We will show the comparison in Task 5. The differences are all in the resuspension pathway, and if that is exempted from the comparison, there should be no difference.

> Page 36. Editorial. Why is "virtually" used before "exhaustive"?

Clients and reviewers will always find something else that they want to see in a printout.

> Page 37. *RAC*'s recommendation that DOE provide the RESRAD source code more readily is right on the money, and separately I am recommending that the Oversight Panel itself make that recommendation to DOE. If I understand the draft correctly, *RAC* itself is able to resolve the problem of the inconsistencies in the materials and can work with the source code available to it. Instead, the spirit of *RAC*'s observation is more to advance the quality of RESRAD in the long term, not to solve a current need that *RAC* has.

Contrast this with the inexplicably negative comments of another reviewer concerning this recommendation.

> Page 37. Editorial. I suggest adding the word "regarding" between "have" and "unauthorized".

This was a misprint and will be corrected.

> Page 38. Editorial. I suggest that for clarity, "(AF)" be added after *area factor*.

We will do this.

> Page 37-41. This was a particularly hard section to understand. Perhaps the easiest solution is to present part of the overall conclusion that begins on the bottom of page 40 ("In general ....) early in this paragraph, as a roadmap for the

> entire section. An additional idea might be to break this into smaller subsections. Because of the overall importance of the resuspension issue, this entire subsection should be made crystal clear. This is the only subsection that needs substantial editorial work to improve its clarity.

We doubt that we can make this material crystal clear for the casual reader, but we can add some prefatory material, as the reviewer suggests. The subject is technical, as is the RESRAD supplementary document that details and defends the changes. We do not think that several smaller technical subsections would be clearer than the one larger technical subsection. Without undertaking a rather long textbook type of exposition of the substantial body of theory on which this material depends, we really do not know how to make it clearer to a general reader. We certainly can flag the details as being of primary interest to specialists (as we did for the equations defining SALs in Section 2.1) and rely on the prefatory summary to give the general reader a qualitative idea of what the results are.

To: Rocky Flats RSAL Oversight Panel
From: LeRoy Moore
Date: May 7, 1999
Re: A question about the dose aspect of the Rocky Flats RSALs

The Rocky Flats RSALs as adopted in October 1996 are calculated in terms of dose rather than risk. The rationale for this shift from a risk-based to a dose-based approach is given in an EPA document called "The Relationship Between Dose and Risk and Its Implications in Developing the Radiation Site Cleanup Standard" (Fourth Draft, December 12, 1995). This document states (on pp. 22, 23, 33) that a 15 mrem/year dose limit equals a risk of approximately 3×10^{-4} (three excess cancers per 10,000 maximally exposed individuals) -- or three times the CERCLA requirement that sites contaminated with radioactive materials be cleaned to a risk level within the range of 1×10^{-4} to 1×10^{-6}. Does the Rocky Flats RSAL 15 mrem/year dose level therefore violate CERCLA?

Because DOE has not authorized a review of the dose aspect of the RSALs this question is simply being posed to the RSAL Oversight Panel with a copy to RAC.

cc: RAC

426

RSALOP

Radionuclide Soil Action Level Oversight Panel

memorandum

Date: May 11, 1999

To: ***Risk Assessment Corporation***

From: Carla Sanda - RSALOP Project Administrator

RE: **Panel Comments to Task 2 Draft Report:** ***COMPUTER MODELS***

Enclosed are comments from RSALOP panel members Mary Harlow, LeRoy Moore, and Victor Holm to the draft Task 2 report entitled ***TASK 2: COMPUTER MODELS***. If you should have any questions regarding this input, please feel free to contact the individual Panel Member.

I look forward to receiving and distributing your feedback regarding Panel input to the draft reports. Thank you for your assistance.

Enclosures:

As Stated

427

memorandum

Date: 5/10/99

To: John Till, *RAC*

From: Mary Harlow, Rocky Flats Coordinator - City of Westminster

RE: INPUT TO TASK 2 REPORT/GENERAL OBSERVATIONS

While I am pleased by the overall direction of the study, I am concerned as to whether the scope of work as outlined in the RFP is being met. Specifically, is *RAC* looking at the interim RSALs and reviewing their development and the input data used to set them? The scenarios used to set the interim SAL's must also be reviewed as part of this process.

REPORT: The report is difficult to read and follow. Paragraphs in the report need to be broken up by double spacing and shortened where possible. Page 24 is especially tedious to read and long. Isn't there some way to break out topic areas to give the reader some ideas as to what the page covers? Consider using sub headings.

Each section should have a summary paragraph at the end.

- Change title to RADIONUCLIDE SOIL ACTION LEVEL OVERSIGHT PANEL

- Offsite impacts and how they could or should be considered in selecting a model are not discussed. This is part of the scope of work. The goal of the project is to protect people who may in the near or distant future come into contact with a site where radionuclides contaminate the soil at levels above background and to also look at offsite impacts.

- Page 8 of the draft includes a discussion on the avoidance of soil action levels altogether and to base remediation planning and verification on direct simulations with the data, models and scenario definitions that would have been used to calculate the soil action levels. **The task is to review models and specifically to look at other models and determine whether they are applicable to RFETS.**

- Page 3 of the Peer review comments discusses a maintenance worker scenario that would take care of the grounds. Vegetation management will be necessary at the site. Please comment on this scenario

- Please provide information as to when *RAC* plans to review the INPUTS AND ASSUMPTIONS, and the methodology used to calculate the current interim RSALs. The panel needs to have an opinion on the original process and how the RSALs were originated. If the original methodology is not evaluated for strengths and weaknesses, it will be very difficult for the RSALOP to recommend an alternative approach to calculating RSALs. At what point in the review will this be done and documented?

- *RAC* did not discuss the various models' capabilities to address offsite exposures. This was requested in the Scope of Work. Please include a discussion on each model's capability to model offsite exposure.

- The report needs to provide backup information supporting the choice of only one of the two models considered. It is important that we have defensible, hard evidence to explain the choice *RAC* has made in regards to models.

- Critical testing with real site data will be necessary to substantiate conclusions on appropriateness of models and methods chosen.

- Deterministic versus Stochastic approach - several peer reviewers' comments, as well as those from some panel members, have questioned why a deterministic approach as well as a stochastic approach would not be appropriate when determining RSAL's.

- Monte Carlo calculations represent randomness. Running scenarios with deterministic numbers would provide some comparisons with the original SAL numbers and should be done.

- Page 24, Page 27 Groundwater and surface water transport. *RAC* states that they will examine the ramifications of dismissing the groundwater and surface water pathways in the assessment and also that they will ignore the groundwater pathway. This is an important pathway, especially since water is becoming more precious as time goes on. We should assume that it is very likely that sometime in the future there will be an attempt made to access the groundwater on site. Please discuss the ability of each of the models to address the water pathway. I would like the surface and groundwater pathway included in this study.

- Page 26, paragraph 2, should be written to state: "Walnut Creek does not flow into Great Western Reservoir. It is currently diverted around the Reservoir and the flows from Woman Creek do not flow into Stanley Lake. They flow into Woman Creek Reservoir." Neither stream enters reservoirs.

- Section 3.1.4.2, page 18 should also be corrected: discharges to surface water do not flow to drinking water reservoirs.

Mary Harlow, City of Westminster – Task 2 Comments

- Page 35 First Paragraph, last sentence states "we also recommend enforcement of better quality control for the binding of the document: the pages of the copy we received are separating from the spine and falling out" This statement should be removed, as it is not part of the process. It does not fit in this technical review document even though it is an aggravation.

- Page 53 Conclusions, paragraph 5 states that everyone concerned with the assessment pay less attention to soil action levels and instead concentrate on the relationship between particular measure or hypothetical sets of radionculide concentrations in soil and the predicated maximum annual dose to each scenario. Although I think this is an important statement it does not coincide with the RFP Scope of Work, which calls for a review of the interim soil action levels.

FAX

To: Carla Sanda & Anna Corbett
From: Victor Holm
Date: April 28, 1999
Subj: Comments on the RAC Task 2 Report

FAX: (303) 456-0858
Phone: (303) 456-0884

Please forward these comments onto RAC and to anyone else who may want to see them.

To: RAC
From: Victor Holm
Date: April 20, 1999
CC: RSALOP

While these comments are directed to the draft Task 2 Report, I will also be referring to the presentation on scenarios given by Kathleen Meyers and Jill Weber at the RSALOP meeting on April 8.

As I indicated in my letter to Kathleen Meyers on March 10, overall I believe RAC is on course and doing an excellent job. I particulary liked the discussion on Soil Action Levels (sec 2) and the Site Conceptual Model (sec 3). I am now familiar with the operation of three of the proposed computer models, RESRAD, GENII and D&D, and I concur that RESRAD is the best choice. I recently talked with Charlie Yu (April 13), developer of RESRAD, and I now have a much better understanding of the pitfalls with the air modeling. I look forward to your presentation on exactly how you will handle air modeling. In addition to the EPA Rapid Assessment Model you may also wish to look at the ICS-3 air dispersion model to see if it can be coded into RESRAD. In addition a beta version of RESRAD-OFFSITE is now available. This tool might be helpful in evaluating offsite exposure even if it can not be formally used because it not finalized.

Although the rest of this letter takes some exception with the scenarios suggested and the parameters used within them, I wish to assure you that the questions are asked in a constructive manner. I respect the work you are doing and realize that these are difficult questions. I also wish to assure the rest of the panel, although it may seem that I am always pressuring for a less conservative standard it is only because the other point of view is so ably represented. We are trying to obtain the best cleanup possible with the limited funds and time available. Whether we agree or not; when the money runs out DOE will build a fence around the site and we will have to live with the results. If this panel can not scientifically defend the results from what could be a concerted effort to discredit the work then we will have accomplished nothing.

The report discuses nine scenarios. At the last meeting the number was reduced to seven. Three of these are the RFCA scenarios which will not be modified. I do not consider the RFCA scenarios of much use to this study other than as points of reference. The current on-site worker scenario is interesting; but, I fail see how it can be used to set cleanup levels after closure of the plant and the current workers are gone. The infant and child scenarios are useful additions but are unlikely to be the controlling scenarios. We are then left with only one scenario, the rancher, which in my opinion will be difficult to defend because it not the best or most likely use of the land.

There is broad consensus both among stakeholders and local governments that the site should be used as open space. The EPA, under CERCLA, and the NRC, under the Licence Termination Regulations, both specify that regardless of the intended land use the site must be cleaned up to unrestricted standards unless it can be demonstrated that "complying with the unrestricted use

432

criterion would be prohibitively expensive, result in net public harm or not be technically feasible"(10CFR Part 20.1402(d)). The baseline scenarios must then address the unrestricted use standard of 15 mrem. The rancher scenario should be one of these. In my opinion the other should be a suburban resident since this is the most likely unrestricted scenario. These scenarios in no way interfere with the desire of the stakeholders and local government for open space. Since actual land use decisions made by local governments do not necessarily determine the scenario to be used in the cleanup. It is possible that an unrestricted cleanup will not be possible so we also need to consider restricted scenarios. I recommend that the current site worker be used for this purpose. This scenario could apply to an outdoor park worker maintaining vegetation, repairing trails and guiding visitors etc. Since he would work outside on site full time he would undoubtably have more exposure than the open space user.

My main confusion about the scenarios, which I believe is shared by others, is: Are they in fact standards? My reading of the applicable guidance is that this is how scenarios are normally considered in dose studies. If they are standards, then like any standard, the behavioral variables should be widely agreed upon and should not be site specific. There are many sources for this information; the EPA Exposure Factor Handbook, the NRC guidance, the default values given in the computer program documentation and the open literature. I question how much we should deviate from these sources. Another approach, which some panel members prefer, is to treat them as uncertainty values and use an appropriate probability distribution instead of considering them standards. It appears to me you trying to use both approaches at the same time. You call them standards; but, you derived them from probability distributions and then choose the 95th percentile. Perhaps I am being overly concerned about a trivial problem. In qualitative risk assessment the output distribution is supposed to be a measure of the uncertainty in the dose derived from a set contamination level. If the mean of the input distributions are already biased to include a large safety factor will we have an output distribution that is related to actual dose; or, one that is biased. How will we evaluate the extent of the bias ?

This bias is exhibited in nearly all the variables including: hours on site, breathing rate, vegetable ingestion and soil ingestion. From a practical point of view it is not a problem for breathing rate since the distribution used has little relative uncertainty, the mean and the 95th percentile vary by less than 10%. For the child soil ingestion rate the difference is significant. It can be argued that the distribution shown at the meeting represents two populations; a normal distribution and a near uniform distribution. The normal portion represents the uncertainty in ordinary children, while the uniform distribution is probably made up of children with a soil eating condition. The resulting joint distribution shown may not represents the uncertainty of soil ingestion at all. Moreover it is arbitrary and of debatable use to try to select the 95th percentile of a mixed population distribution such as this. One of the concerns some of us have had about this study from the beginning is that excessive safety factors would be introduced into the input parameters during the analysis and then another safety factor would be applied on the results. This was one reason that a probabilistic approach was adapted. If the input distributions are to be biased in favor of conservatism then the entire reason for this approach in questionable. I believe RAC needs to explain to the panel what it's approach to safety factors is going to be.

There are several other scenario variables that I recommend be reevaluated:

a. Time on site for the child of 8760 hr/yr does not consider time at school, play with other children or trips and vacations; is this reasonable? Why was the value of 5800 hr/yr in the draft report discarded ?

B. Time on site for the rancher of 8670 hr/yr does not consider time spent shopping or just socializing with neighbors or vacations. What was wrong with 8400 hr/yr which one reviewer already considered high.

C. Expecting the dry, rocky marginal land at Rocky Flats to provide all the plant food for the entire year is not defendable even at the 95th percentile and it is not the custom on other ranches in Colorado or elsewhere for that matter. Would not 25% be more reasonable?

D. At the April meeting distributions for breathing rate and soil ingestion were shown for the child scenario. The breathing rate distribution is not just a distribution of uncertainty; but, has a strong positive correlation with age. The highest rates correspond to older children. The soil ingestion distribution presumably has a strong negative correlation with age. In fact my reading of the available papers indicates that most of the children with the soil eating condition are less than 5 years of age. I could find no example in the literature that suggested the condition is common in teenagers. It is likely that the joint probability of a child breathing more than 8600 cu m/yr and ingesting more than 1 gram of soil per day in much less than the 5% you indicated, in fact I would suggest that they are mutually exclusive.

I have one editorial comments: on p.23 second paragraph I believe the East Gate referred to is not the same as the present East Gate on Indiana St.

Again I wish to commend you on the generally good job you are doing. I look forward to a continuing dialog. I for one learning a great deal from this project.

To: RAC
From: LeRoy Moore
Date: May 7, 1999
Re: A question that emerges from comments of a peer reviewer on Task 2, Computer Models

One of the peer reviewers for the independent assessment of the Rocky Flats RSALs states that the RSALs as adopted misapply the concept of "institutional controls" in relation to the 15/85 mrem/year dose (see attached "Review Comments on the March 1999 Draft Report . . . for Task 2: Computer Models," section 1, "Application of the 85 mrem/y criterion"). This suggests that the Rocky Flats RSALs violate CERCLA in the way the "institutional controls" concept is employed. What corrections need to be made?

cc: Rocky Flats RSAL Oversight Panel

435

**Review Comments on the March 1999 Draft Report
by the Risk Assessment Corporation (RAS) for
Task 2: Computer Models**

This is a carefully prepared and mostly excellent draft. Prior to commenting on the Task 2 Report, this reviewer reviewed several background documents: the DOE report "Action Levels for Radionuclides in Soils for the Rocky Flats Cleanup Agreement - Final, Oct. 31, 1996, and its accompanying "Responsiveness Summary;" the RAS draft report for Task 1, Feb. 1999; the report by Joseph Goldfield entitled "Breathing Rates of Exposed Persons Residing on Plutonium Contaminated Soil for Calculating Health Effects;" and two papers by LeRoy Moore entitled "Action Levels for Radionuclides in Soils for Cleanup of Rocky Flats" and "Seven Reasons for an Independent Review of the Rocky Flats Action Levels." Review of the first of these reports raised a number of concerns regarding the assumptions underlying their application of the 15/85 mrem/y dose criteria and their choice of exposure scenarios for implementing those criteria via soil action levels, including the selection of parameters characterizing the environment and individuals exposed. I was pleased to find that the authors of the Task 2 draft report reflected many of the same concerns.

By way of background for comments on the Task 2 report, the following summarizes my concerns with the DOE report:

1. Application of the 85 mrem/y criterion.

There is a conspicuous absence of a clear statement of the limited use of the 85 mrem/y criterion intended by EPA, and a strong implication that it is being misused. This criterion was proposed by EPA as an upper bound on the possible exposure of individuals in order to assure a minimum level of protection in the event of *unanticipated* failure of institutional controls. Such failure was expected normally to be of short duration, because it was assumed to be corrected when identified. The criterion was not intended for application to planned long-term land uses in the distant future for situations in which institutional controls are *assumed* to no longer exist. To the contrary, CERCLA regulations require the lead agency to review the efficacy of institutional controls *no less often than every five years* for as long as they are required to maintain conformance with the level permitting unrestricted use (in this case 15 mrem/y)(see 40 CFR Part 300.430(f)(4)(ii)). We note that in the current directive under which EPA regulates radiation cleanups (OSWER Directive No. 9200.4-18; August 1997) the 85 mrem/y criterion has been dropped entirely, since it is assumed to be unnecessary under the above periodic review requirement.

It is not obvious to this reviewer, especially for the two types of buffer areas (these are not differentiated in the DOE report), but also for the industrial area, that either the commitments or assurances of effectiveness for the necessary institutional controls exist. The DOE report depends on the documents "Action Levels and Standards Framework for Surface Water, Ground Water, and Soils" (ALF) and the "Rocky Flats Vision." These documents, as well as the "Rocky Flats Cleanup Agreement" (RFCA) and proposed "Modifications to the Action Levels

436

and Standards Framework" were not available for this review. However, a "vision" is not a legal commitment, and the discussion of near and intermediate term land uses and, more significantly, the absence of any discussion of long-term land use in the last paragraph on p. 6-15 of the DOE report creates the impression that the state of commitments for and assurances of effectiveness of institutional controls in the future is very uncertain.

The implication of the above, given the long-term contamination present at Rocky Flats, is clear. If the lead agency (DOE), State, and local officials cannot commit to and provide reasonable assurance of maintaining necessary institutional controls in an effective manner for 1000 years, then consideration must be given to cleanup of the site now to levels that would meet 15 mrem/y in the absence of such controls. Obviously, this point is critical to choosing the Tier I Action Levels for the so-called "buffer" and "industrial" areas.

There is also a need to develop a Tier I level applicable *outside* the buffer areas, since these locations must meet the 15 mrem/y criterion under unrestricted use (presumably under a rural or rancher residential scenario), and the action levels for the immediately adjacent buffer area, at least under the current proposal, would permit significantly higher levels. As noted above, if the necessary assurances for long-term institutional control cannot be met for the buffer and/or industrial areas, this level should apply there also.

2. Exposure Scenarios:

Under CERCLA, the choice of exposure scenarios is intended to assure protection of the "*Reasonably Maximum Exposed*" (RME) individual. This is not the same as the *average* member of the affected population, nor is it the *most* exposed individual. EPA has devoted considerable effort to clarifying this admittedly elusive concept. The following quotes are typical of EPA guidance:

"*...actions at Superfund sites should be based on an estimate of the reasonable maximum exposure (RME) expected to occur under both current and future land use conditions. The reasonable maximum exposure is defined here as the highest exposure that is reasonably expected to occur at the site... The intent of the RME is to estimate a conservative exposure case (i.e., well above the average) that is still within the range of possible exposures.*" ("Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual (Part A) Interim Final," EPA-502/1-88-020.)

"*The high-end of the risk distribution is, conceptually, above the 90th percentile of the actual (either measured or estimated) distribution. The conceptual range is not meant to precisely define the limits of this descriptor, but should be used by the assessor as a target range for characterizing "high-end" risk.*" ("Guidance on Risk Characterization for Risk Managers and Risk Assessors," Memo from F. Henry Habicht II, Deputy Administrator, EPA, to Assistant Administrators and Regional Administrators, February 26, 1992.

4237

RFCA RSAL Working Group Meeting Minutes
April 13, 1999

Mission Reminder

The Rocky Flats Cleanup Agreement (RFCA) Radionuclide Soil Action Level (RSAL) Working Group (RWG) is tasked with evaluating new information and determining its impact to the RSALs. (See, RFCA paragraph 5 and the Responsiveness Summary for *Soil Action Levels released on November 6, 1996.)* This includes developing an understanding of how the information impacts the RSALs. The RWG will evaluate the pluses and minuses of different approaches to developing RSALs.

Attendance

The RWG convened on April 13, 1999 at EPA. In attendance for DOE was Russell McCallister; in attendance for EPA was Richard Graham; attendees for CDPHE were Steve Gunderson, Diane Niedzwiecki, Dick Fox, and Carl Spreng; attendees for the Kaiser Hill Team were Laura Brooks, John Corsi, Bob Nininger, Martha Hyder, and Rick Roberts. Also in attendance were the following members of the public: Brady Wilson and Victor Holm.

Agenda

Update on RWG Meeting Minutes-3/17/99
Update of actions
Trip Report from the NRC Workshop held on March 18-19, 1999
Discussion on the RAC Report on Computer Models
Discussion on the air resuspension factor with agency experts
Conference call with RESRAD staff on air resuspension factor
Continue discussion on input parameters for the residential scenario
Other Items
Path Forward

Update on RWG Meeting Minutes-3/17/99

The RWG Meeting Minutes for the March 17, 1999 meeting have not been completed. When the draft minutes are available, the minutes will be distributed electronically.

Update of actions

•Prepare recommendations for input parameters for the residential scenario.

This action is ongoing.

•All RWG members have the action to provide comments on the draft comparison table to Laura Brooks.

The RWG decided to discuss this draft table at the May 26, 1999, meeting. RWG members should come prepared to discuss the draft table for that meeting.

•Laura Brooks has the action to prepare a draft summary table identifying the specific regulatory differences discussed in previous working group meetings.

This action is ongoing.

•Rick Roberts and Tom Pentecost have the action to evaluate the distinction between DandD annualized dose and RESRAD instantaneous dose.

RESRAD uses the total intake (i.e., grams/year, m3/year, etc.) over a year to calculate radiation dose for the entire year. RESRAD does not calculate radiation dose at a lesser frequency (i.e., daily, weekly, monthly, etc.) during the year. This simplification is sufficient since the annual radiation dose from plutonium, americium and uranium is assessed for a "Reference Man" over a 50 year period. Any discrepancies between the ways in which intakes are assessed over one year should be inconsequential when compared with the length of time the radiation dose is assessed for the annual intake.

438

Tom was not available to report on his evaluation. This action will carry over to the May 26, 1999, RWG meeting.

•All RWG members have the action to review the RAC draft report on computer models and to be prepared to discuss the report at the next meeting.

This discussion was postponed until the May 26, 1999, meeting.
•The agency and KH Team representatives have the action to discuss with their respective air experts the air resuspension factors used in RESRAD (versions 5.61 and 5.82).

See agenda item discussion below.

•Russell McCallister has the action to organize a conference call with the developers of RESRAD to coincide with the next RWG meeting. (The RWG goal is to discuss internally with the respective agency and KH Team air experts the issues and then have a conference call with the developers of RESRAD.)

Complete.

•Rick Roberts will provide copies of "Rapid Assessment" to Victor Holm, Diane Niedzwiecki and Laura Brooks.

Complete.

•EPA will review the concept of substituting the air suspension model from "Rapid Assessment" into RESRAD.

EPA has contacted modelers in EPA's radiation lab in Alabama. EPA Region VIII anticipates input from the modelers in June and will report to RWG when it has some information.

•RWG members working with models need to check what information is available on their model regarding verification/validation.

This action is ongoing.

•Laura Brooks has the action to send an electronic copy of the 1998 RFCA Annual Review report to Tom Pentecost.

Complete.

•Richard Graham has the action to determine if FGR-13 is final and to provide copies of FGR-13 to the RWG members.

Federal Guidance Report No.13 (Report) is anticipated to be finalized in late Spring 1999 and will include changes in slope factors. These changes reflect morbidity and mortality rates based on the most current cancer information from Hiroshima and Nagasaki. The changes will encompass all of the US population and are not specific to gender differences or children.

Richard also reported that he has heard that the ICRP personnel will also be reviewing FGR-13 and anticipates that the principles within the Report will be incorporated into future ICRP documentation. When FGR-13 is finalized, the RWG will review the final Report for use in assessing radiation risk. Any ICRP documents generated from the ICRP review of FGR-13 will also be reviewed at that time. The ICRP has also developed radiation dose conversion factors to assess the radiation dose from radionuclides in the environment. These ICRP documents include separate dose conversion factors for children and adults. The RWG plans to review both the final FRG-13 slope factors and the ICRP dose conversion factors for use in calculating soil action levels.

The radiation slope factors in FGR-13 would be used to assess the lifetime risks posed by radionuclides in the environment. The ICRP dose conversion factors would be used to assess the annual dose from radionuclides in the environment. Radiation risk assessment is different from radiation dose assessment in that risks are evaluated over a lifetime, and doses are evaluated over one year.

It is possible to use slope factors in RESRAD in place of dose conversion factors.

•All RWG members need to review Appendix D, Analysis of Assessment Needs for Rocky Flats Plutonium, in the October 31, 1996, "Final Action Levels for Radionuclides in Soils for the Rocky Flats Cleanup Agreement."

This action is ongoing and will be discussed at the May 26, 1999, RWG meeting.

Trip Report from the NRC Workshop held on March 18-19, 1999

Rick Roberts and Russell McCallister attended the NRC Workshop on their Radiological Criteria for License Termination on March 18 to 19, 1999. The subjects discussed at the workshop included 1) the DandD screening computer code developed by the NRC, and 2) how to implement an ALARA analysis with respect to license termination requirements. The following are the major issues discussed at the workshop.

1. The NRC emphasized that current environmental conditions and currently defined exposure scenarios need to be used when performing radiation dose modeling 1,000 years into the future. Extremes in environmental conditions and exposure scenarios are not necessary to satisfy NRC dose modeling requirements.
2. In conversations with participants at the meeting, there seems to be a realization that the building occupancy exposure scenario is really not applicable in many cases since most buildings will be torn down. The more applicable exposure scenario is a landfill scenario where building rubble is assessed. This may have implications for the RSALs if the RSALs are compared with the concentrations of radioactive material in building rubble.
3. The utilities are concerned that there will be two computer codes, RESRAD and DandD, to show compliance with the radiological criteria for license termination. They would prefer that only one code be available since this would eliminate any inconsistencies between the codes. NRC said that this was a possibility. DOE said that RESRAD would not go away.
4. A presentation was given at the workshop concerning partial site closures in unimpacted areas. There was concern at the meeting from utilities about how to perform partial site closures in impacted areas. This will be a topic at upcoming meetings.
5. The NRC stated that an ALARA analysis is needed for all license termination actions except if a cleanup is occurring for soils to meet the unrestricted release criteria. This is because remediation and radwaste disposal costs are high for a soil cleanup action. The NRC also stated that an ALARA analysis is required for all license termination actions even when the levels at a site are below the cleanup criteria.

The RWG discussed whether the state modelers (in Agreement States) agree with the NRC position discussed in point 1 above. The RWG acknowledges that this is an important issue. The workshop attendees believe that the intent of point 1 was in regards to physical conditions rather than policy issues, e.g., land use. The RWG discussed erosion as one example of physical conditions. One way to address erosion in the models is to take the current configuration of the land into account, even though erosion is occurring now, and bound with uncertainty bars. This approach may work for erosion and other physical parameters due to the incredible variation in climate from year to year in this area. The RWG recognized the difficulty in deciding how to practically state the likelihood of a given number and how to bound the number. The RWG will need to have further discussions on how to bound parameters that go into the models.

The RWG discussed the CERCLA five-year review process and the possibility of having to do additional remediation in the future based on changes to physical conditions. The RWG acknowledged that future

2440

remedial decisions and issues of funding such activities in the future was beyond the scope of this working group.

The second point above may become important in the future to RFETS if a dose-based standard were applied to cleanup of a building and/or if the RSALs were applied as the cleanup level of a building with the assumption that building rubble is like soil. Currently, RFETS buildings are either cleaned up to a free-release level or are disposed of as waste so this may not be a relevant point since RFETS may be cleaning up to a level that may not be required by the NRC.

Guidance on conducting an ALARA analysis can be found in DG4006. NUREG 5512 contains the criteria for an unrestricted release scenario. Some RWG members believe that NUREG 5512 defines an unrestricted release scenario as a suburban resident and not a rancher.

A teleconference line is available for the NRC Workshop if the RWG, or other interested people, would like to hear the workshop. If anyone is interested, please contact Russell McCallister. The next workshop is scheduled for June 23 to 24, 1999, and will focus on groundwater modeling.

Discussion on the RAC Report on Computer Models

The RWG postponed this discussion until the May 26, 1999, meeting. Comments to the RAC draft report are due to the RFSALOP by May 8, 1999.

Discussion on the air resuspension factor with agency experts

In RAC's draft report for Task 2: Computer Models, RAC proposes, as one possibility, using resuspension rate estimation provided by Cowherd in an EPA report (Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination Sites). Some RWG members have reviewed this EPA report and believe that the equations within the report may not be an appropriate replacement for the RESRAD air resuspension model. This is because the Cowherd equations are applicable to an emergency response situation where an assessment is needed quickly (within 24 hours).

The RWG wants to clearly understand why RAC does not believe the RESRAD air resuspension model is adequate, what RAC may use in place of what is currently in RESRAD (whether Rapid Assessment or some other possibility) and how the replacement model may be used. DOE and the Kaiser-Hill Team have prepared a letter for the RFSALOP that requested similar information from RAC. DOE will confirm that the letter has been forwarded to the RFSALOP. If the letter has been forwarded, then a copy of the letter will be shared with the RWG. The RWG will review the DOE letter to determine if the questions that the RWG is interested in were raised to the satisfaction of the RWG or if the RWG should send its own request for information.

Another potential concern with the EPA report referenced above is that the equations used in the report are approximately 15 years old. Are these equations still the best to use or is there more current guidance available? For example, the Industrial Source Complex (ISC) model used in the EPA report has been updated and the report may no longer reflect the current ISC model approach.

A general issue discussed by the RWG was whether it is possible to model inhalation exposure with only data from an air sampler given concentrations and TSP. One problem with trying to use air sampler data in this way is that the air sampler provides PM10 mass concentration data, not Pu-activity concentration in the PM10. The air samplers that do provide data on Pu-activity do not provide mass data. There may be some fractionation studies that could provide a snapshot in time of this information, but would it be representative?

Comparison of RESRAD Versions 5.61 and 5.75 (and newer)

The RWG is aware that changes to the RESRAD model have occurred between Versions 5.61 and 5.75 and later versions. Based on preliminary EPA RESRAD runs on versions older than RESRAD Version 5.75, the resulting RSAL may be higher (by approximately a factor of 5) than the 1996 RSALs. The primary difference for this value would result due to changes in the area factor calculation. Area factor is defined (in Version 5.75 and later) as the ratio of the airborne concentration from a finite area source to the airborne concentration from an infinite area source. The area factor therefore represents the dilution of the contaminated particles originating from the area of contamination by "clean" air that contains only "uncontaminated" particulates.

Version 5.75 and newer

Earlier versions of RESRAD used an area factor based on a simple box model that only depended on the size of the finite contaminated area. The new version (version 5.75 and later) has a more robust technical basis and takes into account both average wind speed and, at least conceptually, the average particle size, in addition to the size of the finite contaminated area. The new area factor is based on a simplified Gaussian area source formulation, the results of which were then approximated through a regression analysis for actual use in the model (the Gaussian code derived from ISC).

The underlying model that was used to derive the new relationship simulated an area source as a series of parallel line sources. The groundlevel concentration at the midpoint of the downwind source boundary was calculated by integrating the contributions from each of the (upwind) component line sources using a standard Gaussian line source equation. The model took into account gravitational settling and plume depletion by wet and dry deposition. The integration was achieved by first dividing the area into 10 and 11 line sources and seeing if the results were sufficiently similar to meet predefined convergence criteria. If not, the area was divided into 20/21 sources, then 30/31, etc. until the convergence criteria were satisfied.

The area factor was derived by increasing the area source size until the resulting concentrations leveled off; that is, approached an upper bounding value. The concentrations calculated for smaller area sources were divided by the concentration produced by this simulated "infinite" area source to estimate a set of area factors. The factors were produced for a set of simulations that varied wind speed, particle size, and source size. A logistic growth curve was fit to the set of area factors derived by the Gaussian simulations, with coefficients for the equation corresponding to the various wind speeds, particle sizes, and source sizes used in the simulations.

The derived logistic growth relationship is used in the RESRAD code. As implemented in the version 5.75, the relationship only varies with wind speed and source size (a default average particle size of 1 μm aerodynamic diameter was used). However, the code was structured to allow import of site-specific particle size data, if desired, in future versions of RESRAD.

Sensitivity analyses were conducted to review four assumed parameters that were used in the Gaussian modeling analysis. Those factors are: annual rainfall rate, diameter of raindrops, particle density, and atmospheric stability. The sensitivity analyses indicated that the model produces reasonable results, according to the authors (Chang, et. al., 1998).

Version 5.61

The area factor used in the previous version of RESRAD is based on a formula that takes into account the size of the contaminated area. The area factor equals the length of a side of the contaminated area divided by that same quantity plus a "dilution length." The dilution length is set to 3 meters in RESRAD, and represents the vertical dimension of the mixed area over the contaminated zone.

Gilbert, et al., 1983, give some background for the formulation. They discuss a "dilution ratio" that is the ratio of the rate at which uncontaminated particulate is blown into the air over a contaminated area from upwind to the rate at which contaminated particles are resuspended into the same parcel of air. The dilution ratio is a function of the size of the contaminated area, the average wind speed, the height of the mixed area directly over the contaminated zone, the mass loading of particulate in the air, the surface concentration of contamination, and the rate at which contaminated soil is resuspended. Based on reasonable ranges for each of the variables in the equation, Gilbert, et al. concluded that the dilution ratio ranges from about 1 (where the particulate over the contaminated zone is about half clean, upwind particles and about half contaminated particles) to approximately 10^{-4}, that is, virtually the entire mass loading over the contaminated area represents local, contaminated particles.

442

It is unclear how the RESRAD authors derived the final equation used in the model. However, the effect that the "old" formulation has is to show negligible dilution except for relatively small contaminated areas.

Additional discussion
Is there enough data to determine a fixed particle size? There may be some variation of particle size at RFETS; these values can be changed in the model.

Both versions of RESRAD reviewed look at the boundary of the contaminated zone. One potential issue is where is the receptor located? What is the impact of the model on concentrations at different sites? The older RESRAD version in not sensitive to contaminated areas or the impact of hot spots. If the size of an area is small, there tends to be a greater difference between the two versions. The old area factor equation used in RESRAD assumes that 97 to 98% of the particulates in the breathing zone are contaminated. Some RWG members have expressed that this assumption may be conservative. A previous study performed at Rocky Flats by G. Langer entitled "Resuspension of Soil Particles from Rocky Flats Containing Plutonium Particulates" indicated that 1% or less of particles in the air a very short distance downwind of a contaminated area are from the contaminated area.

The RWG must be careful when relying on modeling information. For example, actual results from perimeter sampling near the Site have been higher than model predictions, presumably because fugitive emission factors are difficult to determine accurately, and the contributions of nearby source areas are not well predicted.

Which model selected is not the real issue, the selection of appropriate input parameters that will give realistic results in the local Site environment is the issue.

There was a state report entitled "An Analysis of Colorado Department of Public health and Environment Air Monitoring Data for Particulates and Plutonium at the Rocky Flats Environmental Technology Site," dated February 3, 1998. The State air program representative does not recommend using the data from this report. The RWG agreed not to use the data from this report.

Pathforward on the RESRAD air resuspension factor
The RWG decided to rerun the modeling exercises described by Chang, et al, in developing the new area factor, using the Industrial Source Complex (ISC) III model. The model formulation should be similar enough that the resulting concentration data, based on area source size, wind speed, particle size, etc., should exhibit similar patterns. ISC III has been thoroughly tested and validated; such an approach should provide an independent check on the new RESRAD formulation. This analysis should provide insight into how conservative RESRAD is compared to ISCIII, may provide some basis for selecting one model over another, and should provide the RWG with some data to work with.

Conference call with RESRAD staff on air resuspension factor
A conference call was held with Dr. Charley Yu of Argonne National Laboratory concerning the "Area Factor" (AF) derivation within the RESRAD code. The AF calculation within the RESRAD code was changed when version 5.75 (v5.75) was distributed. The AF in the pre-v5.75 RESRAD was derived based on empirical data and was very conservative. The AF in the post-v5.75 RESRAD is based on a Gaussian dispersion model and is considered to be more realistic than the pre-v5.75 RESRAD AF derivation.

The reason for changing the AF within RESRAD was discussed. The post-v5.75 RESRAD AF was developed due to the conservatism within the pre-v5.75 RESRAD. The AF was developed by Argonne National Laboratory and is documented in a report entitled, "Evaluation of the Area Factor Used in the RESRAD Code for the Estimation of Airborne Contaminant Concentrations of Finite Area Sources."

The inputs to the RESRAD code were discussed. The post-v5.75 RESRAD now contains an annual average wind speed parameter. This is the only new input for RESRAD that directly affects the AF. All other AF parameters are hard wired into RESRAD. The sensitivity of these hard-wired parameters is outlined in the Argonne AF report above. Also, There is little information available on how the boundary of the model influences the AF calculation.

The basis for the post-v5.75 RESRAD AF was discussed. The AF is based on a mass loading model. The reason why a resuspension rate or resuspension factor model was not used for the AF is that the mass loading model is simple and easily measurable. Specific site data was not used as a basis for deriving the AF.

The benchmarking of the RESRAD model was discussed. RESRAD has been compared with GENII and EPA models. The report entitled, "RESRAD Benchmarking Against Six Radiation Exposure Pathway Models," details this comparison. RESRAD is currently being compared with the DandD computer code by Sandia National Laboratory.

Discussion on RFSALOP Meeting on April 8, 1999

Is the dispersion model in RESRAD 7.5 appropriate for RFETS conditions? The high wind conditions may or may not be the most dangerous condition when selecting input parameters.

Why is RAC choosing an old EPA value? Emissions are not accounted for in the dispersion models. RESRAD uses mass loading. The old EPA value does not use mass loading, but uses an emissions model.

The general approach to developing a model is to try to develop one that is as accurate as possible and covers the environmental transport mechanisms in a way that is adequately conservative, but realistic. This is the approach taken by the RESRAD model. A second approach is to develop a model that addresses the environmental transport mechanisms in a realistic manner, perhaps individually. If environmental transport mechanisms are done on an individual basis, then each transport mechanism (soil erosion, soil resuspension, air dispersion, etc.) may require a separate model. The RWG believes that RAC is proposing to take the second approach.

How much conservatism should the RWG be aiming for? The RWG will need to answer this question as it proceeds through its review. An answer will help avoid placing conservatism on top of conservatism in the selection of input parameters.

The RWG discussed the use of average values vs. 95th percentile values when selecting input parameters. RAC is currently proposing their exposure parameters (e.g., daily exposure frequency, annual exposure frequency, breathing rate and soil ingestion rate) for the resident rancher exposure scenario at the 95th percentile of the distribution. This approach is different from EPA's methodology for selecting exposure parameters. EPA generally uses a mixture of upper percentile values and mean values to arrive at an exposure scenario that describes an exposure in the 90-95 percent range. Specifically, EPA uses upper percentile values for the daily exposure frequency and annual exposure frequency while using mean values for the breathing rate and soil ingestion rate. This mixture of upper values and mean values represents a "Reasonable Maximum Exposure" (RME) for the exposure scenario being evaluated. This mixture is used to avoid redundant conservatism so that the final value is not based on an unreasonable receptor.

Alternatively, the average member of the critical group is the average exposure to the person in the maximally exposed group (critical group). The critical group concept is not as well defined as the RME concept. There may not be any difference between the two approaches. The RWG will continue to attend the RFSALOP meetings and will review RAC recommendations. The RWG anticipates further discussions on this topic.

The Risk Assessment Policy of the National Academy of Sciences recommends selecting reasonable (realistic) values. The RWG discussed whether a rancher scenario is appropriate for RFETS considering the urban nature of the area around RFETS. The RWG discussed that RFETS is a CERCLA site and that CERCLA is based on both policy and science. The RWG discussed whether it should express its concerns on the potential scenarios that may be evaluated by RAC and the potential approaches to input parameter selection that RAC has been discussing and if so, how to express these concerns to the RFSALOP. The RWG did not agree to do anything at this time, but will probably evaluate the concern further in future meetings.

Continue discussion on input parameters for the residential scenario
Due to insufficient time at the April 13, 1999, meeting, the RWG decided to have a separate meeting on May 5, 1999, to discuss this topic. The purpose of this meeting will be to focus on the input parameters for the residential scenario. RWG members that have been assigned a computer model must be prepared to discuss their model and the associated input parameters for a residential scenario associated with the model.

New Actions
Richard Graham will provide the web site for Federal Guidance Report No. 13 to Laura Brooks. Laura will forward the information to the RWG.

When Federal Guidance Report No. 13 is finalized, the RWG will review the final version and will compare the final report to the appropriate ICRP documentation.

Tom Pentecost has the action to report on the meaning of annualized dose in DandD.

Rick Roberts and Russell McCallister will provide a summary of the NRC workshop that will be included in the April 13, 1999, meeting minutes.

Russell McCallister will verify whether the DOE comments to the March 8, 1999, RAC presentation at the RFSALOP meeting and comments on RAC's draft report for Task 2, Computer Models were forwarded to the RFSALOP Co-Chairs. If this letter was sent, Laura Brooks will forward it to the RWG.

The Kaiser-Hill Team will conduct an independent check of the new RESRAD formulation by using a standard EPA Gaussian model that can simulate area sources, i.e., Industrial Source Complex (ISC) III. The Kaiser-Hill Team will run the ISC-III model and the latest version of RESRAD and compare results for year zero.

Other Information
A teleconference line is available for the NRC Workshop if the RWG, or other interested people, would like to hear the workshop. If anyone is interested, please contact Russell McCallister. The next workshop is scheduled for June 23 and 24, 1999, and will focus on groundwater modeling.

Russell McCallister suggested that the RESRAD training staff could be brought to Denver for a training session if the RWG, or others, were interested. If you are interested in attending a RESRAD training class, please contact Russell.

Russell McCallister provided an update on the possibility of having a complex wide meeting to discuss RSALs. Russell is trying to organize the meeting around July 11, 1999 in Las Vegas, NV. Several RWG members requested that the meeting be held in Denver so that all the RWG could attend or include arrangements to have interested parties who cannot attend in Las Vegas participate via teleconference. Russell agreed to look into having the meeting in Denver and teleconferencing capabilities and will provide updates, as information is available.

Richard Graham mentioned that there would be MARSSIM training available the week of September 20, 1999. If you are interested in attending the MARSSIM training session, please contact Richard.

Copies of the Peer Review Reports of the draft RAC Report for Task 2: Computer Models are available from Carla Sanda.

The next RFSALOP meeting is scheduled for May 13, 1999, from 4:00 to 7:00 at the Broomfield City Hall. Prior to the RFSALOP meeting, there will be a technical session from 2:30 to 3:30 at the Broomfield City Hall.

The next RWG meeting is scheduled for May 5, 1999, at 9:00 at CDPHE. The purpose of this meeting is to discuss the input parameters for the residential scenario. RWG members should come prepared to discuss the residential input parameters. RWG members that have been assigned a computer model must come prepared to discuss the specific input parameters associated with their model.

There will be a RWG meeting on May 26, 1999, at 9:00 at RFETS in Building 460, Room 122.

The proposed agenda for the May 26, 1999, meeting is:
Review of 3/17/99 and 4/13/99 Meeting Minutes
Update on Actions – 5 minutes
Review of Draft Comparison Table – 30 minutes
Discussion on the RAC Report on Computer Models - 30 minutes
Continue discussion on input parameters for the residential scenario – 30 minutes
Begin discussion on input parameters for the next scenario – 60 minutes
Other Items
Path Forward

446

RFCA RSAL Working Group Meeting Minutes
March 17, 1999

Mission Reminder
The Rocky Flats Cleanup Agreement (RFCA) Radionuclide Soil Action Level (RSAL) Working Group (RWG) is tasked with evaluating new information and determining its impact to the RSALs. (See, RFCA paragraph 5 and the Responsiveness Summary for Soil Action Levels released on November 6, 1996.) This includes developing an understanding of how the information impacts the RSALs. The RWG will evaluate the pluses and minuses of different approaches to developing RSALs.

Attendance
The RWG convened on March 17, 1999, at DOE. In attendance for DOE was Russell McCallister; attendees for EPA were Tim Rehder, Richard Graham, and Mark Aguilar; attendees for CDPHE were Steve Gunderson, Diane Niedzwiecki, Edd Kray, and Carl Spreng; attendees for the Kaiser Hill Team were Laura Brooks, Bob Nininger, and Rick Roberts. Also in attendance were the following members of the public: Brady Wilson and Victor Holm.

Agenda
Update on RWG Meeting Minutes-2/17/99
Update of actions
Review Draft Comparison Table
Discussion on Model Evaluation Information
Start RWG Action 3, Input Parameter – Residential Scenario
Other Items
Path Forward

Update on RWG Meeting Minutes-2/17/99
The RWG approved the draft Meeting Minutes from the 2/17/99 meeting.

Update of actions
A draft table that compares the NRC requirements with EPA/CERCLA/RFCA requirements was prepared and shared electronically with the RWG.

Section 151(b) of the National Waste Policy Act is cited in the preamble to the NRC rule that the RWG has reviewed. The preamble discussion focuses on Federal ownership of land where more stringent institutional controls are required due to the presence of long-lived nuclides at decommissioned sites. The RWG was not familiar with the National Waste Policy Act and an action was made to look into this Act. No reference has been found to a National Waste Policy Act; however, a reference has been found for a Nuclear Waste Policy Act. Section 151(b) of the Nuclear Waste Policy Act discusses Federal ownership and management of low-level radioactive waste sites where such ownership is necessary or desirable in order to protect the public health, safety, and the environment. It is believed that there is no National Waste Policy Act and that the reference in the NRC preamble is a mistake and the correct reference should be to the Nuclear Waste Policy Act. Copies of Section 151 of the Nuclear Waste Policy Act are available.

All other actions will be discussed under the appropriate agenda item.

Review Draft Comparison Table
The RWG discussed the draft table comparing the NRC requirements with EPA/CERCLA/RFCA requirements. The NRC requirements are summarized from 10 Code of Federal Regulations (CFR) Part 20, et al. The EPA/CERCLA requirements are summarized from 49 CFR Part 300 et al. The RFCA requirements are summarized from RFCA and the Rocky Flats Vision. The topics selected were based on topics that the RWG spent a great deal of time discussing and where the RWG felt there may be differences between the NRC approach and the EPA/CERCLA/RFCA approach. Since the development of the summary table is an ongoing effort, the table may be expanded as necessary in the future. One option may be to add a column for the 1996 RSALs so that any changes/differences between then and now could be

2447

easily identified. Some RWG members believe that it would be helpful to have the dose limits that have been used as ARARs added to the EPA/CERCLA column.

Some RWG members believe that it would be more useful to have the table summarizing the differences between the RWG than the laws themselves. The differences have been identified in previous meeting minutes.

A second table will be drafted which summarizes the meeting minutes. The RWG will review the existing draft table further and discuss the both draft tables at the next RWG meeting.

Discussion on Model Evaluation Information

Copies of various papers comparing computer models were distributed to the RWG, including a copy of the EPRI model comparison, at the February 17, 1999, RWG meeting. The RWG reviewed the material.

Victor Holm informed the RWG that the Rocky Flats Soil Action Level Oversight Panel (RFSALOP), not RAC, will try to obtain copies of MEPAS and GENII.

One potential difference identified between two of the models is the DandD model calculates an annualized dose and the RESRAD model calculates an instantaneous dose. Because the radionuclides at RFETS are long-lived, this may not be a critical difference, but something that the RWG agreed to evaluate further.

The dose conversion factors (DCF) in the DandD code are not hard wired into the program and can be changed. DandD was developed as a screening tool and uses the most conservative dose conversion factors.

At the March 11, 1999, RFSALOP meeting, RAC issued a draft report on a comparison of computer models that it has reviewed. It was suggested that all RWG members review the report. Some RWG members had reviewed the report and thought it was very concise and easy to read. Because not all RWG members had the opportunity to review the RAC draft report prior to this meeting, an agenda item for the next RWG meeting will be to discuss the RAC draft report.

The following key points from the EPRI model comparison draft report were discussed:

• The agricultural pathway in DandD tends to dominate the TEDE when the default plant mass loading factor is used. The default value for this parameter is 10% of the plant mass is contaminated soil (on a dry weight basis). Decreasing the value of this factor to 1% results in reasonable agreement between agricultural doses predicted by RESRAD and DandD for most isotopes. Many RWG members agree that the default parameter is conservative.

• RESRAD and DandD tend to agree well for doses resulting from direct irradiation, inhalation, soil ingestion provided that an effort is made to match input parameter values.

• Because RESRAD and DandD groundwater models differ in significant ways, the time dependence and magnitude of doses from groundwater pathways tended to be very different in this study. This affected the doses resulting from the irrigation pathways, the drinking pathway and the aquatic pathway. In general DandD results were higher for these pathways.

A primary difference in the water pathway calculations performed by DandD 1.0 and RESRAD 5.61 can be attributed to the method in which they model the unsaturated zone.

Some members of the public believe that DandD is more flexible than RESRAD, particularly with respect to how different variables can be set up for vegetables. Victor Holm has spoken with Dr. Ward Whicker. Dr. Whicker is trying to put better parameters together. This information may be shared with the RWG when it is available.

DandD parameters are selected to provide screening level radioactive doses to the critical group. DandD parameters may be changed to reflect site-specific conditions. The level of justification needed to change a parameter within the DandD code may be found in NUREG-1549, "Decision Methods for Dose Assessment to Comply with Radiological Criteria for License Termination."

The RFSALOP may not agree with RAC for declining further consideration to MEPAS at this time for application to the Rocky Flats site soil contamination. The MEPAS documentation that RAC received does not indicate an intrinsic Monte Carlo capability for uncertainty analysis. RACs decision to require the model source code in order to evaluate the model was made independent of the RFSALOP.

The RWG discussed whether it would stick with one model or continue to review several models and select a model(s) that are most appropriate for calculating an RSAL. The mission of the RWG for FY99 includes an evaluation of the pluses and minuses of different approaches to developing RSALs. The RWG does not need to reach a final decision this FY on which model(s) to select. In addition, the RWG is expecting information from the Actinide Migration Evaluation (AME) that may impact the RSALs.

The selection of input parameters and scenarios are also important. The uncertainty associated with the input parameter will always be there. This may also lead to different outputs between the models.

Models are not static; they continue to be developed and may change.

RESRAD resuspension model:
RESRAD 5.61 used a resuspension model that was based on area and dilution rate. Later, RESRAD was changed to a more complicated resuspension model. According to RAC, neither model fits well at RFETS.

Start RWG Action 3, Input Parameter – Residential Scenario
At the February 17, 1999, RWG meeting, the RWG agreed to review the following computer models: DandD, GENII, MEPAS, and RESRAD (versions 5.61 and 5.82). The RWG agreed to start developing input parameters for the residential scenario. The RWG agreed to review the following information: (1) input parameters that were selected for the original RSALS; (2) default parameters associated with each computer model; (3) recommendations from the 1998 PPRG Annual Review where recommendations were made to scenarios by the PPRG Working Group; and (4) approaches recommended by guidance associated with the computer model.

To date, GENII has not been received and there are concerns over the MEPAS model that has been downloaded from the web. Victor Holm has been working with the DandD and RESRAD models and offered to help any of the RWG members. Rick Roberts (who has agreed to review RESRAD) presented questions to the RWG for input and consideration. Following are the questions with a summary of the RWG discussion and proposed pathforward.

1. **Do we want to use RESRAD version 5.61 or version 5.82? The only difference between these is the air modeling routine. Should we have our air modelers look at the different resuspension routines and give us their views on which is more technically correct and/or applicable to RFETS? Then decide which to use.**

Several RWG members believe that RESRAD version 5.61 is very close to the GENII model. Version 5.82 may be less conservative than version 5.61. Without complete meterological data (e.g., wing speed), version 5.61 may provide a better result; however, if complete meterological data is available, then version 5.82 may provide a better result. The RWG is concerned that if wind speeds of 90 mph are used in the model as an average value, then the high winds, which can exist at the site, would be captured but it may not be realistic to assume that the average wind speed is 90 mph. On the other hand, if the average wind speed of 15 mph is used in the model, then the high winds may not be taken into consideration. Some RWG members believe that when doing long-term modeling, we need to be careful, and that looking at extreme episodes may not be a reasonable approach. Extremes may influence the loading averages. One question that was raised is whether there is any information from Industrial Source Complex II or III (air dispersion models) and how that information compares with the RESRAD code. When looking at air, the only solid numbers regarding air concentrations can be found in wind roses. Data on resuspension rates or factors are not available.

4449

Proposed Path Forward:
The agency and KH Team representatives have the action to discuss with their respective air experts the air resuspension factors used in RESRAD (versions 5.61 and 5.82).

Russell McCallister has the action to organize a conference call with the developers of RESRAD to coincide with the next RWG meeting. (The RWG goal is to discuss internally with the respective agency and KH Team air experts the issues and then have a conference call with the developers of RESRAD.)

2. Do we want to assess surface soils only or both subsurface and surface soils? If we are only going to assess surface soils, when will we assess subsurface soils?

Since 1996, the RSALs for surface soils have been applied as the action levels for subsurface soils. The RWG discussed whether this is still a valid approach. It is acknowledged that with time, the subsurface soils will probably be exposed to the surface. A soil erosion study, "Estimated Soil Erosion and Associated Actinide Transport for the South Interceptor Ditch Drainage," EG&G Rocky Flats, August 3, 1992, was completed at the site that considered water erosion in the Woman Creek area. This study concluded that the current erosion rate is approximately 7.5×10^{-5} m/y. If this rate is extrapolated over a 1000-year period, then 0.07 m of soil would be expected to erode over a 1000 years.

The difference between separate surface soil RSALs and subsurface soil RSALs could be significant. Preliminary Kd information from the AME team indicate that there is very little movement in the RFETS soils. Consequently, there may be an insignificant exposure pathway to actinides in subsurface soils. In the 1996 RSAL calculation, a low Kd value was selected as the input parameter. This Kd value was consistent with the OU2 RFI/RI Report. The RWG discussed whether this was an appropriate value. An alternative approach may be to recommend a conservative, but more realistic, Kd value for the input parameter based on the AME information.

Today, it is not clear whether there is a big subsurface soil contamination problem at the site. This information should be obtained during the industrial area characterization efforts.

The RWG needs to consider how the various models consider erosion rates.

Proposed Path Forward:
Initially, RSALS will be developed for surface soils only. The extrapolation of surface soil RSALs to subsurface soils will be addressed at a later date.

3. Do we want to reassess all exposure pathways evaluated? Do we want to add contaminated meat, eggs, and dairy products? How do we address water pathways?

Soil ingestion, external irradiation, plant ingestion, and inhalation account for more than 90% of the potential exposure in the 1996 RESRAD analysis; minor pathways were eliminated. The NRC Reg Guide states that all exposure pathways should be assessed. The NRC is open to eliminating exposure pathways with sufficient justification. CERLCA allows the elimination of exposure pathways with sufficient justification. An option to is to assess risk associated with each pathway. If the pathway contributes little risk, then explain why the pathway could be eliminated. Some RWG members believe that regardless of the risk contribution all pathways should be considered. Other RWG members believe that it is better to only assess the viable, realistic pathways.

The RWG agreed to assess meat, milk, and dairy ingestion pathways. One option is to do the assessment according to the 1989 EPA Exposures Factor Handbook. Another option is to assess the new EPA Exposure Factors Handbook (1997) for recommendations regarding the ingestion of contaminated meat, eggs, and dairy products.

The 1996 RSAL calculation did not include a groundwater pathway. This was based on an assumption that, in general, there is insufficient groundwater in the upper hydrostratigraphic unit to support a household. There is one well in the Arapahoe Sandstone that may be able to support a household. Today, there are questions regarding how much of the groundwater is attributable to site activities vs. natural recharge. Some RWG members believe that the RWG should assess a residential scenario where the residents get their water from surface water. Other RWG members question whether this is viable. Some RWG members would like proof that a future resident will not be able to use water on site.

Some RWG members are concerned that one of the problems with the RESRAD model is that it does not model overland flow. RESRAD can model vertical and horizontal movement of radionuclides in ground water only. RESRAD does not model the overland transport of radionuclides. For example, some members think it is doubtful that possible contamination to surface water is from the vertical leaching of contaminated subsurface soil to groundwater and then on to the surface water. It is more likely that contamination in surface water is caused by erosion of the soil into the surface water. The modeling efforts of the AME (WEPP model) may provide insight into how erosion is occurring on site. AME results are expected by the end of FY99.

Proposed Path Forward:
The RWG agreed to assess the groundwater pathway in the RESRAD analysis. If this pathway is included and the results show insignificant consequences due to this pathway, then the pathway has no impact. This could provide further justification that the pathway does not need to be considered. Some RWG members are concerned that including the pathway in the RESRAD analysis is inconsistent with RFCA and that a better approach would be to review the original data that supported the original assumption in ALF that the volume of groundwater is insufficient to sustain a household.

The RWG agreed to assess meat, eggs, and dairy products.

4. Do we split the residential exposure scenario into an adult and child receptor?

RAC is considering splitting the residential exposure scenario into adult and child receptors. A child receptor in a residential scenario may require a higher soil ingestion rate than for an adult; however, a child may breath less and eat less food than an adult. Normally, when assessing dose to a child, the assessor considers a five-year old child with in increased ventilation rate, but lower lung capacity over a lifetime of 70 years. Some members of the RFSALOP and the public may believe that an infant is more sensitive than an adult to dose exposure. A key factor is what DCF is selected for the model. The ICRP has age adjusted DCFs that could be assessed for use. Federal Guidance Report No. 13 is expected to propose risk based slope factors that take age into account. Richard Graham will find out if the FG 13 is final.

Proposed Path Forward:
The RWG decided to split out the child and adult receptors. The RWG will evaluate the differences and document its recommendation.

5. Do we want to set an institutional control period before it is assumed that a hypothetical resident would move onto the site (i.e., 50, 100, 200 years or more)?

The 1996 RSALs are based on a receptor being on site at year zero. Some RWG members are concerned that institutional controls may only be good until the next election. By examining the exposure at some future year, e.g., year 50, the assumption is that institutional controls are in place and fail at year 50. This analysis will provide insight into a potential receptors exposure in the event institutional controls fail.

Proposed Path Forward:
The RWG agreed to run RESRAD and look at the exposure to a receptor at year zero and at year 50. In these runs, the AME Kd values will be used.

451

6. **Do we want to examine each RESRAD parameter and justify the choice for each parameter? Do we instead want to perform a sensitivity analysis on each parameter and focus our energies on the most sensitive parameters?**

Proposed Path Forward:
The RWG agreed that initially, each RESRAD parameter should be reviewed. If the same input parameter that was used in 1996 is considered to still be valid, then the analysis and explanation in the 1996 document could be cross-referenced. If a change to an input parameter is recommended, then the RWG will document the proposed change. Each modeler should perform a sensitivity analysis on the parameters that they believe are sensitive.

7. **Do we want to reassess looking at other plutonium isotopes (Pu-238, Pu-241, & Pu-242)? This would also reexamine the ingrowth of Am-241 over time.**

The original assessment of Pu isotopes was documented in 1996.

Another important issue is the source of the uranium on site. RFETS is located in an area with natural uranium. When assessing uranium data, it is important to distinguish between background uranium levels from DOE altered uranium.

In calculating RSALs, understanding the isotope mix is important. The daughters of each isotope will also need to be calculated.

Proposed Path Forward:
The RWG agreed to review Appendix D, Analysis of Assessment Needs for Rocky Flats Plutonium, to the document titled "Action Levels for Radionuclides in Soils for the Rocky Flats Cleanup Agreement, Final, October 31, 1996," to determine if the RWG agrees that the conclusions in the appendix are still valid.

8. **Do we want to assess both forms of plutonium (soluble & insoluble)?**

Some RWG members would like to wait until the Actinide Migration Evaluation Team has completed its analysis on the form of Pu in the environment. The outcome of this analysis may be used in the calculation of RSALs. Other RWG members do not think that the AME results will provide information on whether Pu is soluble in lung fluid and that this is the important question. Other RWG members think the more important question is whether ingested Pu will move across the gut.

Proposed Path Forward:
The RWG agreed to use the insoluble plutonium DCFs since most evidence points to this. This assumption will be validated by the AME.

The following questions were raised, but the RWG did not have sufficient time to address them.

9. **Do we want to assess the correct form of uranium instead of the most conservative inhalation and ingestion dose conversion factors together?**

10. **Do we want to assess the non-cancer effects of uranium exposure?**

Old Actions
Prepare recommendations for input parameters for the residential scenario.

This action is ongoing.

New Actions
All RWG members have the action to provide comments on the draft comparison table to Laura Brooks.

Laura Brooks has the action to prepare a draft summary table identifying the specific regulatory differences discussed in previous working group meetings.

452

Rick Roberts and Tom Pentecost have the action to evaluate the distinction between DandD annualized dose and RESRAD instantaneous dose.

All RWG members have the action to review the RAC draft report on computer models and to be prepared to discuss the report at the next meeting.

The agency and KH Team representatives have the action to discuss with their respective air experts the air resuspension factors used in RESRAD (versions 5.61 and 5.82).

Russell McCallister has the action to organize a conference call with the developers of RESRAD to coincide with the next RWG meeting. (The RWG goal is to discuss internally with the respective agency and KH Team air experts the issues and then have a conference call with the developers of RESRAD.)

Rick Roberts will provide copies of "Rapid Assessment" to Victor Holm, Diane Niedzwiecki and Laura Brooks.

EPA will review the concept of substituting the air suspension model from "Rapid Assessment" into RESRAD.

RWG members working with models need to check what information is available on their model regarding verification/validation.

Laura Brooks has the action to send an electronic copy of the 1998 RFCA Annual Review report to Tom Pentecost.

Richard Graham has the action to determine if FRG-13 is final and to provide copies of FRG-13 to the RWG members.

All RWG members need to review Appendix D, Analysis of Assessment Needs for Rocky Flats Plutonium, in the October 31, 1996, "Final Action Levels for Radionuclides in Soils for the Rocky Flats Cleanup Agreement."

Other Information
The next RFSALOP meeting is scheduled for April 8, 1999, from 4:00 to 7:00 at the Broomfield City Hall. Prior to the RFSALOP meeting, there will be a technical session from 2:30 to 3:30 at the Broomfield City Hall.

The next RWG meeting is scheduled for April 13, 1999, at 9:00 at EPA, in the Downlink Room on the third floor. Since many RWG members may not know where the Downlink Room is located, Mark Aguilar will be outside of the conference center (second floor) and will guide members to the Downlink Room.

The proposed agenda for the next meeting is:
Review of 3/17/99 Meeting Minutes
Update on Actions – 5 minutes
Trip Report from the NRC Workshop held on March 18-19, 1999 – 10 minutes
Review of Draft Comparison Table – 15 minutes
Discussion on the RAC Report on Computer Models - 30 minutes
Discussion on the air resuspension factor with agency experts – 30 minutes
Conference call with RESRAD staff on air resuspension factor – 30 minutes
Continue discussion on input parameters for the residential scenario – 60 minutes
Other Items
Path Forward

453

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1947-1997

MEMORANDUM

4/20/99

FROM: Bobby R. Scott, Ph.D.

TO: Mr. Tom Marshall or current Chair
Rocky Flats Citizens Advisory Board
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Westminster, Colorado 80021

Ms. Norma Morin
Colorado Department of Public Health and Environment
DCEED-RFHS-A3
4300 Cherry Creek Drive South
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Golden, CO 80401

Ms. Anna Corbett
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5460 Ward Road, Suite 370
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Attached is a pre-publication copy of a manuscript that relates to Rock Flats plutonium entitled "Variability in PuO_2 intake by inhalation: implications for DOE-worker protection." Because of your interest in plutonium issues at Rocks Flats, I thought you and/or your colleagues may find the manuscript of use. The manuscript has been accepted for publication in *Radiation Protection Dosimetry*. Although the focus of the manuscript is on possible exposure of nuclear workers to airborne PuO_2, results presented suggest that similar analyses should be conducted for possible public exposure scenarios. We are initiating work on conducting similar calculations as presented in the paper but for PuO_2 contained in resuspended Rock Flats soil. Because the density of soil is much less than the density for PuO_2, deposition in the respiratory tract will be different for PuO_2 in resuspended soil than for airborne PuO_2. We hope to present our results that relate to public exposures to PuO_2 in resuspended soil in a poster at the American Chemical Society Meeting in New Orleans in August of this year and expect that those results will have important implications for selecting soil action levels for the different plutonium isotopes found at Rocky Flats.

I should point out that the variability in PuO_2 intake presented in the attached paper arises from variability in the sizes of the airborne PuO_2 particles. Additional variability and uncertainty should be considered when deriving radionuclide soil action levels. Variability and uncertainty were not adequately addressed in developing interim radionuclide soil action levels that were incorporated in October 1996 into the Rocky Flats Cleanup Agreement.

VARIABILITY IN PuO_2 INTAKE BY INHALATION: IMPLICATIONS FOR DOE-WORKER PROTECTION

Bobby R. Scott and Alice F. Fencl

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Running Title: Variability in PuO_2 Intake

456

VARIABILITY IN PuO_2 INTAKE BY INHALATION: IMPLICATIONS FOR DOE-WORKER PROTECTION

Bobby R. Scott and Alice F. Fencl

ABSTRACT

This paper relates to the stochastic exposure (SE) paradigm where, at most, small numbers of airborne toxic particles are presented for inhalation. The focus is on alpha-emitting plutonium dioxide (PuO_2) particles that may be inhaled by Department of Energy (DOE) workers. Consideration of the SE paradigm is important because intake of only a few highly radioactive PuO_2 particles, such as $^{238}PuO_2$, could greatly exceed the annual limit on intake (ALI) used to control worker exposure. For the SE paradigm, credible intake distributions evaluated over the population at risk are needed, rather than unreliable point estimates of intake. Credible distributions of radiation doses and health risks are also needed. Because of limited data on humans who inhaled PuO_2, these distributions must be calculated. Calculated distributions are presented in this paper that relate to the intake of radioactivity via inhaling polydisperse PuO_2 particles. The results presented indicate that large variability in radioactivity intake is expected when relatively small numbers of PuO_2 particles are inhaled. For the SE paradigm, one cannot know how many PuO_2 particles were inhaled by and individual involved in a given inhalation exposure scenario. Thus, rather than addressing questions such as "did the calculated worker's intake of $^{238}PuO_2$ exceed the ALI," it is better to address questions such as "what is the probability that $^{238}PuO_2$ intake by a given worker occurred and exceeded the ALI?" Mathematical tools for addressing the latter question are presented, and examples of their applications are provided with emphasis on possible DOE worker exposures at the Rocky Flats

facility near Denver, Colorado. The alpha-emitting isotopes ^{238}Pu, ^{239}Pu, ^{240}Pu, and ^{242}Pu are found at Rocky Flats. Although ^{238}Pu is thought to be present in relatively small amounts there, intake via inhalation of but a few $^{238}PuO_2$ particles could greatly exceed the ALI.

458

INTRODUCTION

Department of Energy (DOE) facilities have had a major role in the production of plutonium (Pu) and Pu components. This production has led to stockpiles of Pu and to Pu-contaminated environmental media. The Rocky Flats Plant has the largest stockpile of Pu in the U. S., over 14 tons[1]. The Pu is in different forms that include raw metal, machined parts, solutions, and wastes. Pu at Rocky Flats includes the alpha-emitting isotopes of ^{238}Pu, ^{239}Pu, ^{240}Pu, and ^{242}Pu, as well at the beta emitter ^{241}Pu[1,2]. Inhalation exposure to Pu in the PuO_2 form is considered highly plausible[1]. The radioactive contamination at Rocky Flats also includes the alpha-emitting radionuclide ^{241}Am[1].

Inhaled $^{239}PuO_2$ caused lung cancer in humans[3–8]. Inhaled $^{238}PuO_2$ and $^{239}PuO_2$ caused lung, bone, and liver cancers in animals[9]. The animal data indicate that bone and liver cancers could also arise in humans that inhale alpha-emitting PuO_2. Ongoing epidemiological studies may resolve this issue[4].

The nuclear-weapons-related mission of the Rocky Flats Plant involved shaping components from plutonium and other metals, which led to its current stockpile of Pu. Under its past mission, soil standards and action levels for Pu and other radionuclides were not an issue. However, the current mission of Rocky Flats is to manage toxic waste and materials, clean up the toxic waste, and convert the site to beneficial use in a manner that is safe and environmentally and socially responsible[1]. In carrying out this new mission, both worker and public exposures via inhaling Pu could arise. Thus, soil standards and action levels for Pu and other radionuclides are now an important consideration[1].

Action levels provide numerical criteria for determining what action must be taken to remove, treat, or otherwise contain soil that is contaminated with Pu and other radioactive materials. Recently proposed action levels for Pu and Am in Rocky Flats soil are controversial in that they allow a much higher residual radioactivity than some would have expected and are therefore under review for possible revision[1].

Several recent publications relate to potential future human exposures to Pu arising from the Rocky Flats Plant. Whicker *et al.*[10] discussed variability in continuos air monitor (CAM) measurements of Pu released in enclosed work areas and implications for of the variability for worker protection. A major observation was that the CAMs alarmed less than 30% of the time for integrated room plutonium air concentrations greater than 500 *derived air concentrations hours (DAC-h)*. Other publications relate to the following: (a) contributions of Rocky Flats releases to the total Pu (including Pu from nuclear testing fallout) in regional soils[11]; (b) a comparison of $^{239,240}Pu$ with ^{241}Am in soils around Rocky Flats[12]; and (c) development of a three-dimensional spatial model of Pu in soil near the Rocky Flats Plant[13].

For Rocky Flats workers, inhalation exposure to PuO_2 is considered a plausible exposure scenario. Previous fires at Rocky Flats have led to the release of PuO_2 and related inhalation exposure of workers. It is also important to consider inhaling PuO_2 contained in oily soil particles as a potential exposure scenario[10,14]. PuO_2-contaminated machining lubrication oils that leaked onto the ground from corroded storage drums at an outdoor storage area were dispersed during remediation[13]. Inhaling PuO_2 in oily soil particles will be addressed in subsequent research.

Future public exposures at or near the Rocky Flats site could involve PuO_2 contained in resuspended soil. The level of public exposure will depend on the post-remediation, use of the land (e.g., residential, industrial, recreational, etc.). Currently proposed soil action levels for Pu and Am for Rocky Flats are based on different future land-use scenarios[1]. The issue of public exposure to PuO_2 will be addressed in subsequent work.

460

To protect workers from airborne PuO_2 (e.g., through using the International Commission on Radiological Protection [ICRP] intake or dose limitation system), the intake of PuO_2 must be adequately characterized for inhalation exposure scenarios of interest. Respiratory tract dosimetry programs such as "LUDEP," which implements the ICRP Publication 66 Respiratory Tract model, and "LungMod," which implements the corresponding National Council on Radiation Protection and Measurements (NCRP) model, are usually relied on for radioactivity intake and dose evaluation. However, the ICRP and NCRP dosimetry programs were not intended to apply to the *stochastic exposure (SE) paradigm* where relatively small numbers of radioactive particles (e.g., hot particles) are presented for inhalation[15]. This is because the models relate expected intake to dose and were not designed to predict stochastic variation in intake.

Research results presented here relate to developing improved characterization of the intake via inhalation of airborne PuO_2 particles by workers with emphasis on the SE paradigm. Special emphasis is placed on evaluating variability over the population at risk in the intake of radioactivity. Because data on human exposure to airborne PuO_2 are limited, variability must be evaluated by calculation. The focus is on alpha-emitting Pu isotopes found at the DOE Rocky Flats Plant, but results presented apply to other DOE sites where workers can be at risk for inhaling airborne alpha-emitting Pu isotopes.

What are high-specific-activity PuO_2 particles?

High-specific-activity, alpha-emitting (HSA-αE) PuO_2 particles have specific activities $> 2.26 \times 10^3$ MBq/g; low-specific-activity, alpha-emitting (LSA-αE) particles have specific activities $< 2.26 \times 10^3$ MBq/g[15].

Why is it important to consider the SE paradigm?

As is shown later, inhaling only a few HSA-αE PuO_2 particles could greatly exceed the annual limit on intake (ALI). The SE paradigm applies to both the public and DOE workers for exposure scenarios involving sites contaminated with Pu. Accidental releases of $^{238}PuO_2$ from electric power sources (radioisotope thermoelectric generators [RTG]) used in space exploration could also lead to local, regional, and global stochastic exposure of the public[16,17]. Global exposure would involve billions of people. Because the SE exposure paradigm involves major uncertainties for particle intake as well as variability in the intake, special risk-assessment approaches are required to address the SE paradigm.

How is risk assessment for the SE paradigm different?

For the SE paradigm, probabilistic relationships govern intake via the respiratory tract and the intake of radioactivity can vary considerably. Further, health risks are not uniquely determined by the amount of radioactivity deposited in the respiratory tract as its spatial distribution is also important and can vary considerably. For example, a 37 KBq PuO_2 particle deposited in the nose is associated with a very different risk than for the same particle deposited in the lung.

For the SE paradigm and HSA-αE PuO_2 particles, many tidal volumes of air presented for inhalation may not contain any of the highly radioactive particles[15]. Furthermore, subsequent translocation from the respiratory tract of radioactivity from deposited particles to other organs (e.g., liver and skeleton) is governed by complex relationships that can relate to particle breakup characteristics. The breakup arises from alpha-decay energy deposited in the PuO_2 particle which damages the particle. Thus, cancer risk estimation requires special considerations for the SE exposure paradigm and HSA-αE particles.

For the SE paradigm, instead of generating the usual single (point) estimates of intake, dose, and risk, one must acknowledge that such single values are not credible. One then must replace unreliable point estimates with credible distributions that reflect variability, uncertainty, or both. As is shown later, distributions of intake will arise even when a fixed number of polydisperse PuO_2 particles are inhaled and deposited in the respiratory tract. For the SE paradigm, the question "what is the probability that intake of $^{238}PuO_2$ occurred and exceeded the ALI?" would be more appropriate than the question "did the intake of $^{238}PuO_2$ exceed the ALI?"

Thus, by using distributions rater than point estimates, each possible value for intake, dose, or risk is assigned a calculated probability. Zero intakes and zero added risk could occur with very high probability, even when the average intake (point estimate) is greater than zero[15]. Risk-based, site-remediation goals for Pu contaminated sites can therefore waste valuable resources when based on average risk evaluated for the SE paradigm.

Mathematical tools for characterizing the SE paradigm

Special mathematical tools (presentation, inhalability, and deposition probability) are used for characterizing particle intake via inhalation for the SE paradigm. These tools are discussed below.

Presentation

Poisson probability parameter, Ω, where Ω is the mean number of particles presented for inhalation. The notation $P(n|\Omega)$ is used to indicate the Poisson probability that exactly n particles are presented to an individual for inhalation, during the period of interest, when the number presented (averaged over the population at risk) is Ω. Thus,

$$P(n|\Omega) = \Omega^n \exp(-\Omega)/n!. \qquad (1)$$

4.6.3

The exclamation "!" represents the standard factorial notation. For example, 3! means $3 \times 2 \times 1 = 6$. Similarly $4! = 4 \times 3 \times 2 \times 1 = 24$, etc.

The function $P(\Omega) = 1 - \exp(-\Omega)$ gives the probability that one or more particles of interest are contained in the *total volume of air presented for inhalation*, for a given exposure scenario. The particle presentation is considered independent of particle size for airborne particles. For $\Omega << 1$, $P(\Omega) \approx \Omega$. Our earlier work[15] focused on PuO_2 inhalation exposure scenarios for which $\Omega << 1$. Here results are provided that are valid for all Ω.

The parameter Ω can be evaluated as $cV_T/(mE\{A\})$, where c is the radioactivity concentration (Bq/m^3) arising from airborne radioactive particles of interest; m is the number of persons inhaling the contaminated air; V_T equals $mE\{V\}$, where $E\{V\}$ is the volume of air inhaled, averaged over the m persons at risk; and $E\{A\}$ is the particle radioactivity, averaged over the airborne particles. Throughout this paper, $E\{\}$ is used to indicate an expectation (average) value.

Inhalability

Probability, P_I, that a particle *presented for inhalation* will enter the respiratory tract with the inhaled air[14]. Not all particles contained in the air about to be inhaled enter the respiratory tract with the air. The particle inhalability depends on particle aerodynamic size.

Deposition probability

Probability, P_{Dep}, that a *presented and inhaled particle* deposits in the respiratory tract. Not all inhaled particles deposit in the respiratory tract. The particle deposition probability depends on particle size, density, and shape[18–20].

2464

For the SE paradigm, the particle presentation is evaluated based on an assumed Poisson distribution, which is judged appropriate for the SE paradigm[15].

COMPUTATIONAL METHODS

General Approach

Here we describe how radioactivity intake distributions for inhaled PuO_2 were obtained for adult male nuclear workers. By radioactivity intake distribution we mean a plot (or other summary) of the different frequencies for which different amounts of radioactivity intake would be expected to occur in a specified population. Our intake distributions are conditional on PuO_2 particles being presented for inhalation. We therefore only consider particle inhalability, P_I, and deposition probability, P_{Dep}, when generating radioactivity intake distributions.

More specifically, the general approach used to obtain calculated radioactivity intake distributions (conditional distributions) for inhaled PuO_2 was as follows: (1) Intake evaluations were conditioned on particles being presented for inhalation [i.e., $P(\Omega) = 1$]. (2) Intakes of PuO_2 particles via inhalation were evaluated for adult males engaged in light exercise based on respiratory parameters for reference man, specified in 1994 ICRP Publication 66[20]. (3) Inhalability-adjusted, particle-size-specific, deposition efficiencies ($P_I P_{Dep}$) were based on the ICRP 66 model[20,21]. (4) The conditional intake distributions were generated with Crystal Ball[22], Monte Carlo software.

Conditional distributions for 1 to 10 particle intakes were first generated for $^{238}PuO_2$, then scaled to other PuO_2 particles based on particle relative specific activity (S_r) (see Table 1). Assumptions made are discussed in the next section.

4655

Assumptions for generating conditional $^{238}PuO_2$ intake distributions

Assumptions were as follows:

- For the adult male workers engaged in light, work-related exercise[20]:
  - Ventilation rate = 1.5 m^3/h.
  - Respiration frequency = 20 breaths/min.
  - Tidal volume = 1250 cc.
  - Volumetric flow rate = 833 cc/min.
  - Fraction of air breathed through the nose = 1.
- A particle shape factor of 1.5 for the non-spherical PuO_2[20].
- A lognormal, particle aerodynamic-diameter distribution[18]:
  - Activity median aerodynamic diameter (AMAD) of 5 μm[20].
  - Geometric standard deviation (σ_g) of 2.5[20].
  - Particles with aerodynamic diameter > 26 μm were judged not inhalable. The 26-μm size corresponds to a 10-μm real diameter for a spherical PuO_2 particle.
- A particle density of 10 g/cm^3[18,23].

These assumptions also apply to other PuO_2 particles. The 26-μm cutoff is subjective. However, such a cutoff is needed so that a small number of PuO_2 particles (e.g., a single, large, highly-radioactive particle), among the total airborne particles available, will not contain more radioactivity than the total airborne radioactivity being considered. This concern essentially relates to HSA aerosols.

2166

Calculation method for generating radioactivity intake distributions

A single-particle intake distribution (conditional on particle presentation) was constructed as follows. First, consecutive small aerodynamic-diameter intervals ($d_{ae,i}$ to $d_{ae,j}$) were constructed for i = 1, 2, ... 140 and j = i + 1. The variable d_{ae} represents the aerodynamic diameter, which relates to a unit density sphere with the same aerodynamic characteristics as the particle of interest. Particle size was constrained to the judgmental respirable size range $0 < d_{ae} \leq 26$ μm. For each small size interval $d_{ae,i}$ to $d_{ae,j}$, the corresponding particle-radioactivity intervals, A_i to A_j, were evaluated based on calculated equivalent volume diameters (d_{ev}) for spherical $^{238}PuO_2$ particles.

Particle radioactivity, A, was evaluated using the previously published equation[15]:

$$A = \rho S_r d_{ev}^3/845, \quad (2)$$

where A is in Bq and again the particle density, $\rho = 10$ g/cm^3. The particle relative specific activity, S_r, is provided in Table 1.

The particle aerodynamic size distribution was integrated over each size interval $d_{ae,i}$ to $d_{ae,j}$ to obtain the renormalized (because of use of a truncated distribution) fraction $f_{i,j}$ of particles in the interval-specific size range. Also, for the same size range, the inhalability-adjusted, particle-size-specific deposition probability, $P_I P_{Dep}$, was averaged over the small size-range interval yielding a value given by $E\{P_I P_{Dep}\}_{i,j}$. As before, $E\{\}_{i,j}$ represents the expectation value of the quantity within the brackets but here was evaluated over the size interval $d_{ae,i}$ to $d_{ae,j}$. The frequency, $Freq_{i,j}$, of single-particle intake events falling in the radioactivity interval A_i to A_j was then evaluated as

$$Freq_{i,j} = f_{i,j}E\{P_I P_{Dep}\}_{i,j}. \quad (3)$$

Both $Freq_{i,j}$ and the corresponding single-particle radioactivity interval A_i to A_j were entered into a custom distribution (nonparametric frequency distribution) to obtain a single-particle intake distribution for use in generating multiple-particle intake distributions. For very small particle sizes at the lower end of the lognormal size distribution, $Freq_{i,j}$ was found to be zero in a small number of adjacent size intervals. These essentially infinitesimal particle size intervals were excluded in setting up the custom distribution.

Fifty-five identical, custom distributions for single-particle intake were initially set up for use in generating radioactivity intake distribution associated with multiple particle intakes. The 55 distributions were numbered Par1, Par2, ... Par55. To regenerate the single particle intake distribution (to facilitate obtaining percentiles of the distribution and the mean and coefficients of variability, skewness, and kurtosis), Par1 was sampled 10,000 times. For a two-particle intake, the first particle's radioactivity was sampled from Par2 and the second particle's radioactivity from Par3, with the two values of radioactivity obtained added. This represents numerical folding (convolution) of single-particle intake distributions to obtain a two-particle-intake distribution. This was also repeated 10,000 times. Intake distributions for 3- to 10-particle intakes were generated in a similar manner using custom distributions Par4 through Par55. A similar approach was also use for 20- and 30-particle intakes but a separate computer program was developed to minimize the number of distributions used in a single program.

The indicated approach was used to avoid correlation over the multiple particle intake distributions. Results obtained for $^{238}PuO_2$ were then scaled based on S_r (see Table 1) to obtain results for $^{236}PuO_2$, $^{239}PuO_2$, $^{240}PuO_2$, $^{242}PuO_2$, and $^{244}PuO_2$.

4168

RESULTS

The conditional intake distributions for 1, 5, and 10 particles are plotted in Figures 1–3. Table 2 gives percentile levels (%) of the intake distribution for $^{238}PuO_2$ that correspond to 100 to 1000 Bq (in steps of 100 Bq), for 1 to 10 particle intakes. Footnotes c and d are provided to help to understand the numbers in Table 2.

Percentiles (2.5%, 5%, 50%, 95%, and 97.5%), in Bq, of the single- and multiple-$^{238}PuO_2$ particle intake distributions (conditional) are presented in Table 3 along with information on the coefficients of skewness, kurtosis, and variability. Footnotes c and d are provided to help understand the numbers in Table 3.

Mean conditional radioactivity intakes along with the coefficients of variability, skewness, and kurtosis are presented in Table 4 for $^{238}PuO_2$, along with results for other PuO_2 particles obtained by scaling based on S_r. Columns in Table 4 are arranged according to increasing values of S_r.

The changes in the shape of the $^{238}PuO_2$ conditional intake distribution in Figures 1–3, as one goes from single-particle intake to multiple-particle intake, are reflected in the values reported in Tables 3 and 4, for the coefficients of skewness and kurtosis. Like the coefficient of variability, these coefficients have no units.

DISCUSSION

For a single, $^{238}PuO_2$-particle intake, the conditional distribution in Figure 1 appears exponential. As more particles are inhaled (Figures 2 and 3), the distribution takes on lognormal appearances. For large numbers of particles, the distribution approaches a normal distribution. Coefficients of skewness and kurtosis presented in Table 3 reflect the conditional intake distributions generated. A value of the coefficient of skewness > 0 indicates a distribution with a longer tail to the right than to the left. The larger the value for the coefficient of kurtosis, the larger the deviation of the distribution from a normal distribution.

Note from results in Figures 1–3 that even when the number of particles inhaled and deposited in the respiratory tract is fixed, the radioactivity intake is predicted to vary considerably for polydisperse aerosols. However, large intakes are expected to occur with much smaller probabilities than for small intakes, for the polydisperse size distribution considered. Large intakes of radioactivity are indicated to occur with greater probability as the number of particles inhaled and deposited increases. However, large intakes associated with the upper tail of the intake distribution do not necessarily reflect a higher health risk as many of the high intake events are associated with deposition of large particles in the nose, which is a radioresistant site. In our future work, we will distinguish between deposition in different regions of the respiratory tract.

Even for a fixed number of particles inhaled, the simulated radioactivity intake varies widely (Figures 1–3). These results indicate that it is important to consider variability in the estimated radioactivity intake when evaluating worker exposure to airborne PuO_2. The variability indicated relates to that associated with the polydisperse particle size distribution considered.

The ALI for $^{238}PuO_2$ is 600 Bq based on ICRP Publication 30[24]. The results in Table 2 indicate that for a single-particle intake, the ALI corresponds to the 93.6 percentile of the conditional intake distribution. This means that 93.6% of the radioactivity arising from single-particle deposition in the respiratory tract is evaluated to be ≤ 600 Bq. It follows that the probability of exceeding the ALI via inhaling and depositing a single particle in the respiratory tract is $[(100–93.6)/100]P(1|\Omega)$ or $0.064P(1|\Omega)$. Note that 0.064 gives the conditional probability that a $^{238}PuO_2$ particle presented for inhalation is then inhaled and deposited in the respiratory

470

tract, and the particle radioactivity exceeds the ALI. $P(1|\Omega)$ gives the probability that a single particle is presented to an individual for inhalation during the period of interest.

Consider the example where on average 1 in 10 persons at risk has a $^{238}PuO_2$ particle presented for inhalation (i.e., $\Omega = 0.1$). Thus, the probability that a single particle is presented for inhalation (based on the assumed Poisson distribution) is

$$P(1|\Omega) = 0.1\exp(-0.1) = 0.0905. \quad (4)$$

Multiplying 0.064 by 0.0905 gives 5.79×10^{-3} for the probability that a single-particle intake both occurs and exceeds the ALI for the exposure scenario considered. The corresponding calculation for a two-particle intake relates to the joint probability $[(100-86)/100]P(2|\Omega)$ or $0.14*(0.1)^2\exp(-0.1)/2!$, which equals 6.33×10^{-4}. The corresponding calculation for three-particle intake relates to the joint probability $[(100-78.9)/100]P(3|\Omega)$ which equals $0.211*(0.1)^3\exp(-0.1)/3!$ or 3.18×10^{-5}. Intakes of higher particle numbers are essentially negligible for this case. The total probability of exceeding the ALI by inhaling $^{238}PuO_2$ particles when on average 1 in 10 persons has a particle presented for inhalation is therefore the sum $5.79 \times 10^{-3} + 6.33 \times 10^{-4} + 3.18 \times 10^{-5}$ or 6.46×10^{-3}. It follows that the probability of not exceeding the ALI is $1-6.46 \times 10^{-3}$ or 0.994 (rounded). Further, the probability of no intake of radioactivity is $\geq P(0|\Omega)$, where $P(0|\Omega) = \exp(-0.1)$ or 0.905.

When $\Omega << 1$, single-particle intake is expected to predominate[15]. Also in this case, the probability of no intake of radioactivity is essentially given by $P(0|\Omega) \approx 1-\Omega$. However, when Ω is not small in comparison to 1, the probability of no intake will exceed $P(0|\Omega)$ (as in the example above) because the fraction of the population that has particles presented but not inhaled

471

and the fraction of the population that has particle presented and inhaled but not deposited have not been accounted for. For monodisperse particles, these fractions are given by $[1-P(0|\Omega)](1-P_I)$ and $[1-P(0|\Omega)]P_I(1-P_{Dep})$, respectively. For both monodisperse and polydisperse particles, these fractions can be disregarded when $\Omega << 1$, because $P(0|\Omega)]$ will be very close to 1, so that $1-P(0|\Omega)$ will be very close to zero.

It should be clear that the conditional intake distribution generated applies to a range of values of the presentation Ω. This was the purpose of conditioning on $P(\Omega) = 1$ in constructing the distributions.

Results in Tables 3 and 4 show that the coefficient of variability (standard deviation divided by the mean) for radioactivity intake progressively decreases as the number of particles inhaled increases from 1 to 10. Further, for six or less PuO_2 particles inhaled and deposited in the respiratory tract, the standard deviation exceeds the mean intake. However, for seven or more particles, the standard deviation was less than the mean intake. Additional Monte Carlo calculations (Figure 4) revealed that when 30 particles are inhaled and deposited in the respiratory tract, the coefficient of variation is < 0.5. The coefficients of variation, skewness, and kurtosis were 0.47, 0.83, and 3.68, respectively. These results indicate that for inhaling many alpha-emitting, PuO_2 particles (deterministic exposure [DE] paradigm), a plausible upper bound for the intake of radioactivity by a relatively small group of male workers (e.g., few hundred workers or less) is 2.5 times the mean intake. It is suggested that this bound be increased to 3 times the mean to allow for variability associated with different respiratory tract geometry for different individuals. However, upper bounds obtained using this approach should be considered subjective and may be overly conservative for some exposure scenarios.

The results presented in Table 3 can be easily adapted to mixtures of PuO_2 particles involving different alpha-emitting Pu isotopes found at Rocky Flats, assuming the particle size

472

distribution is the same as used for Table 3. For example, suppose that 95% of the mass fraction of the Rocky Flats Pu sources for worker exposure is ^{239}Pu, 4% is ^{240}Pu, and approximately 1% is ^{238}Pu, with negligible fractions being represented by other alpha-emitting isotopes. Then, results for exposure to $^{238,239,240}PuO_2$ can be obtained using mass fractions 0.95, 0.4, and 0.1 as statistical weights for ^{239}Pu, ^{240}Pu, and ^{238}Pu, respectively. The 50th percentile (in Bq) for the conditional, single-particle intake distribution would, for example, be given by:

$$\text{50th Percentile (Bq)} = 0.95*(18.9\ \text{Bq} * 1/280) + 0.4(18.9\ \text{Bq} * 3.7/280) + 0.1(18.9\ \text{Bq} * 280/280)$$
$$= 0.064\ \text{Bq} + 0.1\ \text{Bq} + 1.89\ \text{Bq} = 2.05\ \text{Bq}.$$

The 18.9 Bq value is from Table 3. Note that relative specific activities (1, 3.7, and 280) from Table 1 are used in the above equation. Division by 280 arises because S_r is evaluated relative to ^{239}Pu rather than ^{238}Pu[15]. Note that 92% of the 2.05 Bq value is associated with $^{238}PuO_2$ even though ^{238}Pu makes up only 1% of the total Pu mass. Thus, a small mass fraction of ^{238}Pu could significantly impact the radioactivity intake distribution for mixtures of alpha-emitting Pu sources at Rocky Flats and other DOE facilities.

Results were presented only for alpha-emitting PuO_2 particles. At Rocky Flats, the beta-emitting ^{241}Pu is also present. Results presented here for the intake of $^{238}PuO_2$ can be adapted for $^{241}PuO_2$ via scaling by S_r. However, it is suggested that intakes of alpha and beta emitters be evaluated separately. The alpha-emitting isotope ^{241}Am is also present at Rocky Flats. Results presented here for $^{238}PuO_2$ can be adapted for $^{241}AmO_2$ by scaling by S_r and adjusting for differences in particle density (if found important).

It is also expected that a similar approach as presented for Pu workers would apply to public inhalation exposure to Rocky Flats soil containing PuO_2. However, respiratory tract deposition efficiencies for PuO_2 contained in soil is different than for PuO_2 because of the much lower soil density. Thus, it is important to have well-characterized PuO_2 sources for evaluating public exposure arising from PuO_2-contaminated soils at Rocky Flats. Reliable information is required on (1) top soil density and the associated uncertainty; (2) particle size distribution for resuspended top soil containing PuO_2; and (3) topsoil particle shapes (a shape factor is used in evaluating deposition in the respiratory tract). However, for the Rocky Flats Plant, this information is somewhat problematic in that PuO_2 in soil differs widely for different locations.

Current proposed soil action levels for Pu and Am in Rocky Flats soil are under review. It is strongly recommended that during that review, PuO_2 source characteristics be carefully evaluated. This includes careful evaluation of the mass fraction distributions for ^{241}A, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, and ^{242}Pu over exposure source material and different locations.

The variability in Figures 1–4 represents variability associated with the polydisperse size distribution considered. Variability associated with different respiratory tract geometry for different individuals will be addressed in subsequent work using the stochastic geometry approach introduced by Werner Hofmann and colleagues[25,26].

The variability reflected in Figures 1–4 has important implications for CAM alarm efficiencies for airborne PuO_2. Based on such variability, CAM alarms even for relatively high concentrations of radioactivity from PuO_2 should be expected to be quite inefficient for large particles. This could be problematic for worker protection for HSA-αE particles such as $^{236}PuO_2$, $^{238}PuO_2$, and $^{240}PuO_2$. While the focus of the presented work is on intake by workers of airborne PuO_2, a similar approach could be used for evaluating CAM intake and associated alarm efficiency and for developing better strategies for applications of CAMs at DOE and other facilities.

4.74

SUMMARY

For the SE paradigm and for HSA-αE particles, point estimates of intake by inhalation of PuO_2 can be quite unreliable. Rather than using point estimates, credible intake distributions over the population at risk are needed. Distributions of radiation doses and risks are also needed. Results presented in this paper related to the intake of radioactivity from inhaled PuO_2 represent a first step toward achieving these ends. The results presented clearly indicate that considerable variability in radioactivity intake is expected for the SE paradigm where at most only a relatively small number of particles are inhaled. Tools and approaches for dealing with this variability were presented and applied in examples relative to worker exposure at Rocky Flats.

A key finding was that the conditional intake distribution shifted from an exponential form to lognormal forms as one goes from single-particle inhalation to multiple-particle inhalation. In addition, coefficients of variability, skewness, and kurtosis progressively decrease as the number of particles inhaled and deposited in the respiratory tract increases. Also, for multiple particle inhalation, the upper tail region where large radioactivity intake is reflected, becomes more important. Because the mean radioactivity intake occurs in the upper tail of the skewed conditional distributions and because the coefficient of variability decreases to < 0.5 as the number of particles exceed 30, a reasonable upper bound to account for variability in radioactivity intake is 2.5 times the calculated mean intake. Increasing the bound to 3 times the mean is, however, recommended to allow for the additional variability associated with different respiratory tract geometry for different individuals. This subjective bound is recommended only for scenarios involving a few hundred persons or less so that very small probabilities in the upper tail regions of the radioactivity intake distributions are not important. For public exposure following the release of $^{238}PuO_2$ from atmospheric accidents during space exploration, it may be important to consider low-probability, large intakes associated with the upper tail of intake distributions, because billions of persons could be at risk. However, the particle size and radioactivity distribution is likely to be very different for such accidents than used in this paper. Further, high radioactivity deposition events in the upper tail of the intake distribution are expected to reflect deposition in the radioresistant nose (anterior and posterior nasal cavity), rather than in the lung. In our future research, we will look at deposition in the various regions of the respiratory tract.

476

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477

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481

Table 1. Relative specific activity and annual limit on intake for alpha-emitting PuO_2 particles.

Type of exposure	Specific activity class	Relative specific activity[a]	Annual limit on intake (Bq)[b]
$^{244}PuO_2$[c]	LSA-αE	2.9×10^{-4}	600
$^{242}PuO_2$	LSA-αE	6.4×10^{-2}	600
$^{239}PuO_2$	LSA-αE	1.0	500
$^{240}PuO_2$	HSA-αE	3.7	600
$^{238}PuO_2$	HSA-αE	280	600
$^{236}PuO_2$[c]	HSA-αE	8500	1000

[a]From Scott *et al.*[15]
[b]From ICRP publication 30[24].
[c]Not reported at Rocky Flats, but included for completeness.

480

Table 2. Percentile level of the conditional $^{238}PuO_2$ intake distribution associated with fixed amounts of radioactivity intake.[a]

Intake (Bq)[b]	Percent level by number of particles deposited in the respiratory tract									
	1 particle	2 particles	3 particles	4 particles	5 particles	6 particles	7 particles	8 particles	9 particles	10 particles
100	75.9[c]	53.1[d]	36.5	22.3	13.5	7.49	3.98	2.08	1.08	0.54
200	84.4	67.6	53.5	39.2	28.9	19.4	13.3	8.60	5.77	3.76
300	88.2	75.0	63.3	50.6	41.1	30.3	23.1	16.4	12.4	9.08
400	90.6	80.0	70.3	58.8	50.2	39.7	31.4	24.3	19.3	15.4
500	92.4	83.2	75.0	64.9	57.0	47.1	38.8	31.4	25.9	21.4
600	93.6	86.0	78.9	69.6	62.7	53.0	45.7	38.0	32.1	27.0
700	94.6	87.8	82.0	73.5	67.0	58.5	51.3	43.6	37.7	32.0
800	95.3	89.3	84.0	76.7	70.4	62.6	55.9	48.8	42.8	37.1
900	95.9	90.7	85.8	79.5	73.9	66.5	59.8	53.0	47.4	41.8
1000	96.5	91.5	87.2	81.6	76.9	69.6	63.2	57.0	51.5	46.3

[a]Based on 10,000 trials for each set (column) of percent-level values. Results conditional on $P(\Omega) = 1$ for male adults engaged in light, work-related exercise. Multiply column 1 by $S_r/280$ to obtain corresponding Bq for other PuO_2 particles.

[b]Intake amount in Bq.

[c]This number means that 75.9% of the intake via single-particle deposition is ≤ 100 Bq.

[d]This number means that 53.1% of the intake via two-particle deposition is ≤ 100 Bq.

Table 3. Percentiles (in Bq) for the $^{238}PuO_2$ conditional intake distribution.[a]

	Percentile (Bq) by number of particles inhaled and deposited[b]									
Level %	1 particle	2 particles	3 particles	4 particles	5 particles	6 particles	7 particles	8 particles	9 particles	10 particles
2.5	0.19[c]	2.46[d]	8.26	19.7	32.1	53.9	79.1	108	136	173
5.0	0.43	4.47	13.5	30.1	48.4	80.3	112	152	187	226
50.0	18.9	86.7	174	295	397	547	677	825	961	1097
95.0	746	1532	1911	2374	2588	2866	3156	3454	3619	3858
97.5	1244	2239	2523	2889	3150	3351	3729	3993	4252	4449
Other Statistics:										
Mean (Bq)	143	306	436	598	718	887	1040	1194	1332	1473
CV	2.55	1.82	1.49	1.27	1.15	1.03	0.97	0.91	0.85	0.81
Skewness	4.62	3.19	2.69	2.27	2.07	1.80	1.81	1.65	1.49	1.38
Kurtosis	28.2	14.6	11.4	9.55	7.93	6.60	7.23	6.23	5.53	5.14

[a]Based on 10,000 Monte Carlo trials per data set (row) evaluated for adult males engaged in light-work related exercise with $P(\Omega) = 1$; CV = coefficient of variability; skewness = coefficient of skewness; kurtosis = coefficient of kurtosis.

[b]Multiply results by $S_r/280$ to obtain corresponding results for other PuO_2 particles.

[c]This number means that 2.5% of the intake from single-particle deposition ≤ 0.19 Bq.

[d]This number means that 2.5% of the intake from two-particle deposition ≤ 2.46 Bq.

Table 4. Calculated conditional PuO_2 intake means (Bq) for adult males as a function of the number of particles inhaled and deposited in the respiratory tract.[a]

Particles inhaled[b]	$^{244}PuO_2$[c] (Bq)	$^{242}PuO_2$ (Bq)	$^{239}PuO_2$ (Bq)	$^{240}PuO_2$ (Bq)	$^{238}PuO_2$ (Bq)	$^{236}PuO_2$[c] (Bq)	CV[d]	Skewness[d]	Kurtosis[d]
1	0.00015	0.0327	0.511	1.89	143	4341	2.55	4.62	28.2
2	0.00032	0.0699	1.09	4.04	306	9289	1.82	3.19	14.6
3	0.00045	0.1	1.56	5.76	436	13236	1.49	2.69	11.4
4	0.00062	0.136	2.13	7.89	597	18123	1.27	2.27	9.55
5	0.00074	0.164	2.56	9.49	718	21796	1.15	2.07	7.93
6	0.00092	0.203	3.17	11.7	887	26927	1.03	1.80	6.60
7	0.00108	0.238	3.71	13.74	1040	31571	0.97	1.81	7.23
8	0.00124	0.273	4.26	15.78	1194	36246	0.91	1.65	6.23
9	0.00138	0.304	4.76	17.6	1332	40436	0.85	1.49	5.53
10	0.00153	0.337	5.261	19.5	1473	44719	0.81	1.38	5.14

[a]Results apply to young adult males engaged in light, exercise-related work and were obtained by multiplying results obtained for $^{238}PuO_2$ by $S_r/280$. Results are conditional on $P(\Omega) = 1$.
[b]Particles inhaled and deposited in the respiratory tract.
[c]Not reported as being present at Rock Flats but included for completeness.
[d]CV = coefficient of variability; skewness = coefficient of skewness; kurtosis = coefficient of kurtosis.

FIGURE LEGENDS

Figure 1. Simulated single $^{238}PuO_2$-particle intake distribution for adult males engaged in light, work-related exercise. The distribution is conditional on $P(\Omega) = 1$. Note the exponential form with a tail to the right.

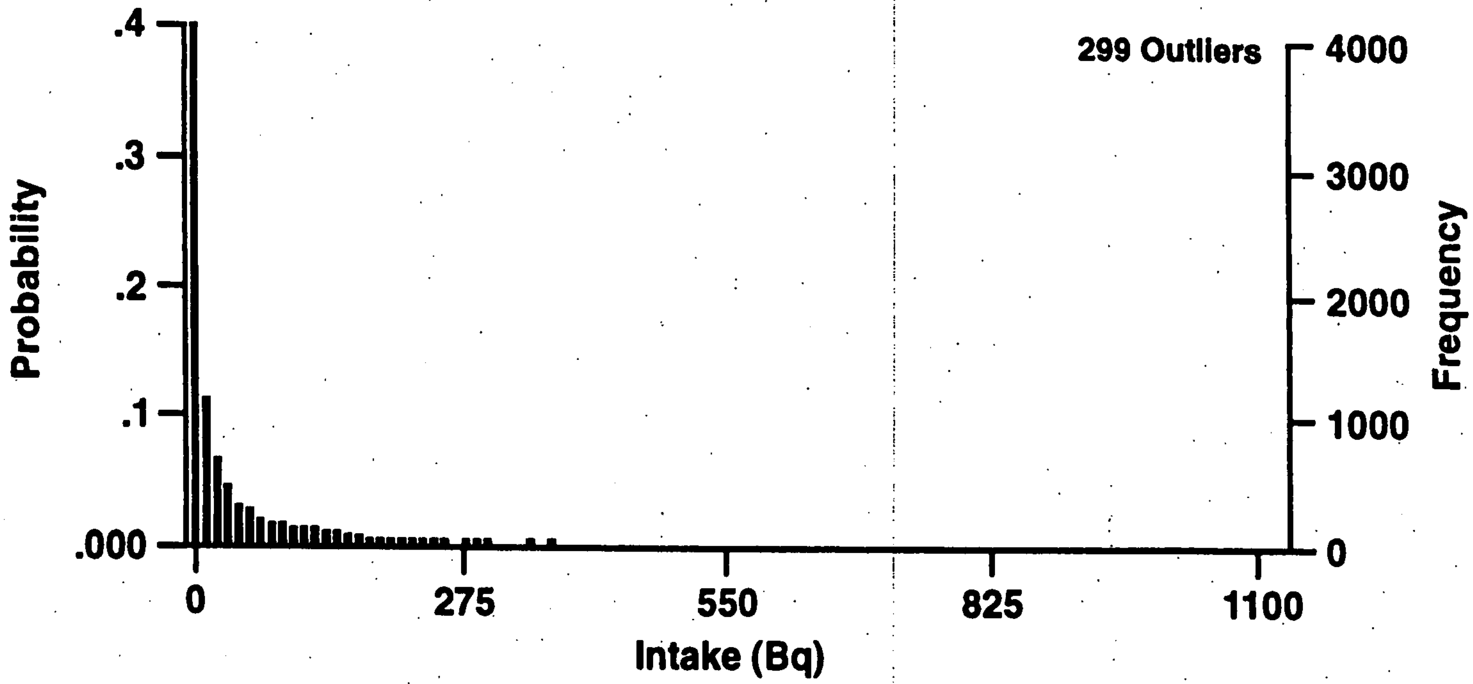
Figure 2. Simulated five $^{238}PuO_2$-particle intake distribution for adult males engaged in light, work-related exercise. The distribution is conditional on $P(\Omega) = 1$. Note the lognormal form in contrast to the exponential form for single particles.

Figure 3. Simulated ten $^{238}PuO_2$-particle intake distribution for adult males engaged in light, work-related exercise. The distribution is conditional on $P(\Omega) = 1$. Note the lognormal form in contrast to the exponential form for single particles.

Figure 4. Simulated thirty $^{238}PuO_2$-particle intake distribution for adult males engaged in light, work-related exercise. The distribution is conditional on $P(\Omega) = 1$.

486

Fig. 1

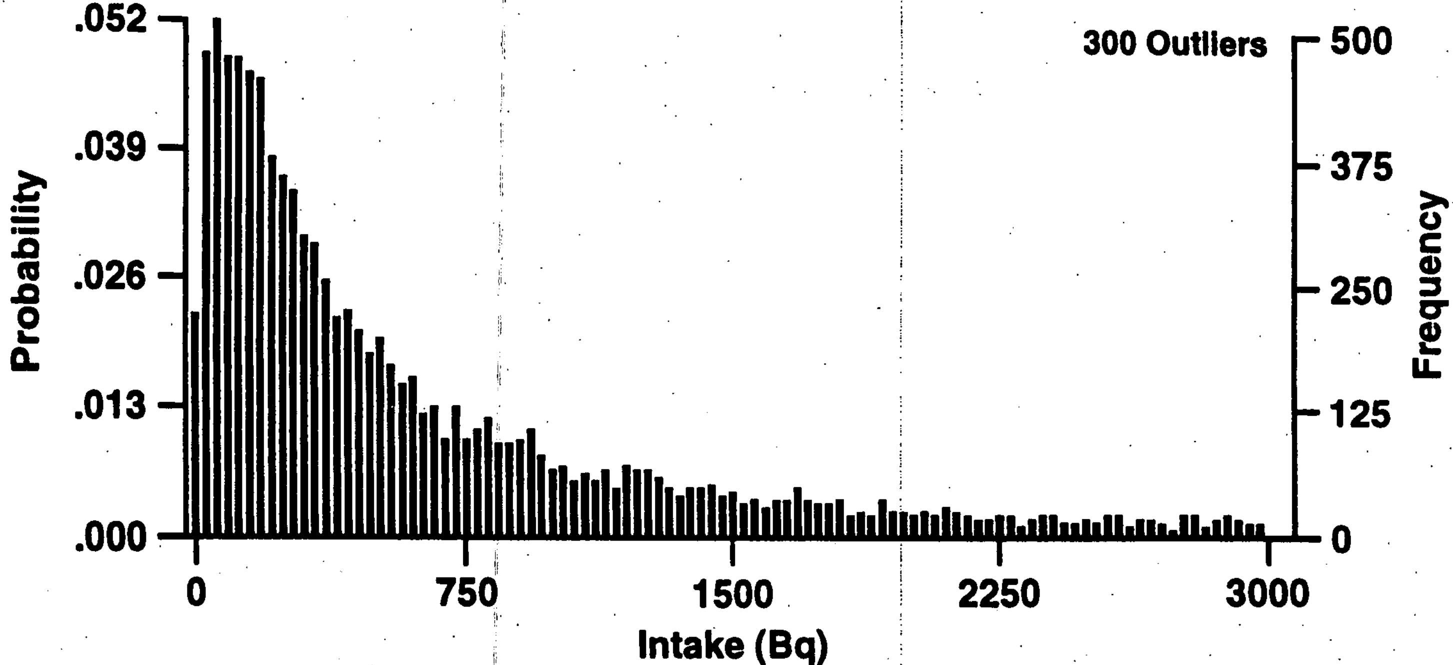


.4
.3
.2
.1
.000
Probability
0
275
550
825
1100
Intake (Bq)
299 Outliers
4000
3000
2000
1000
0
Frequency

3778-2

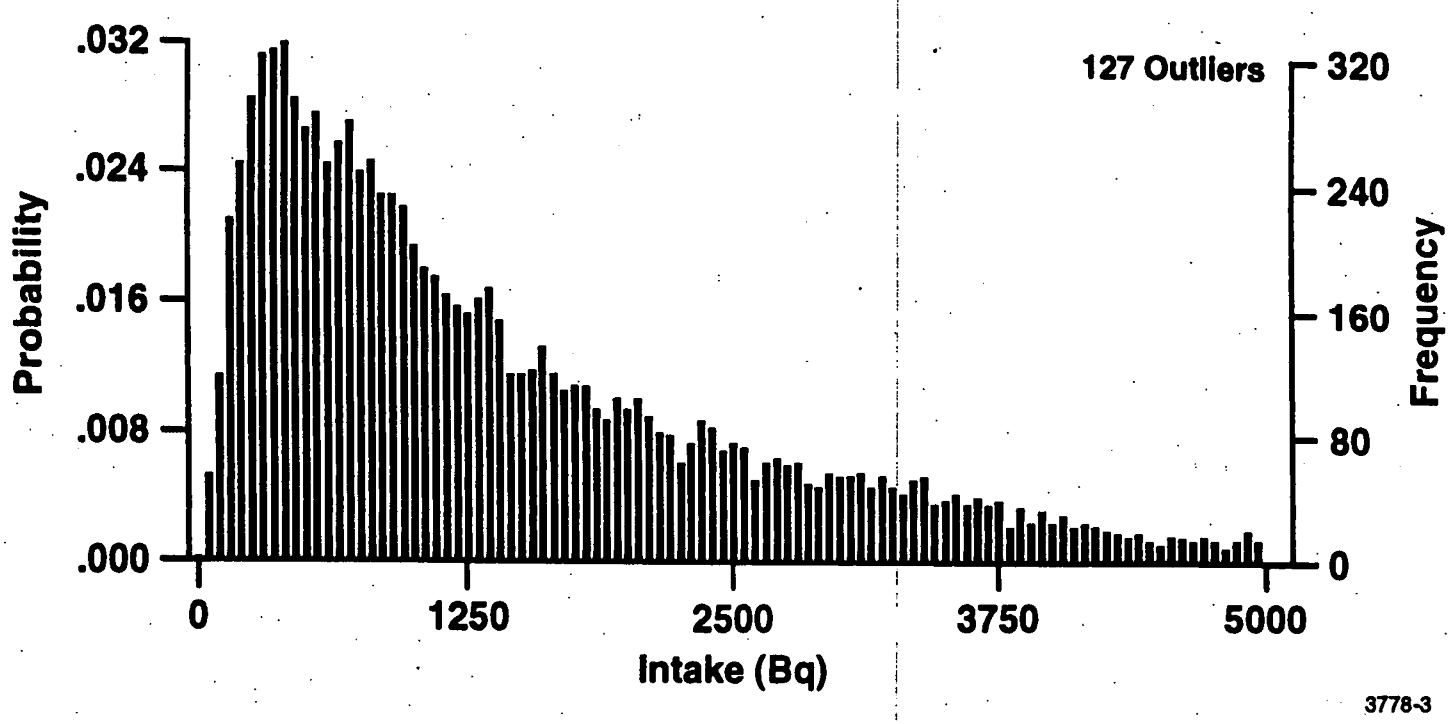
488

Fig. 2



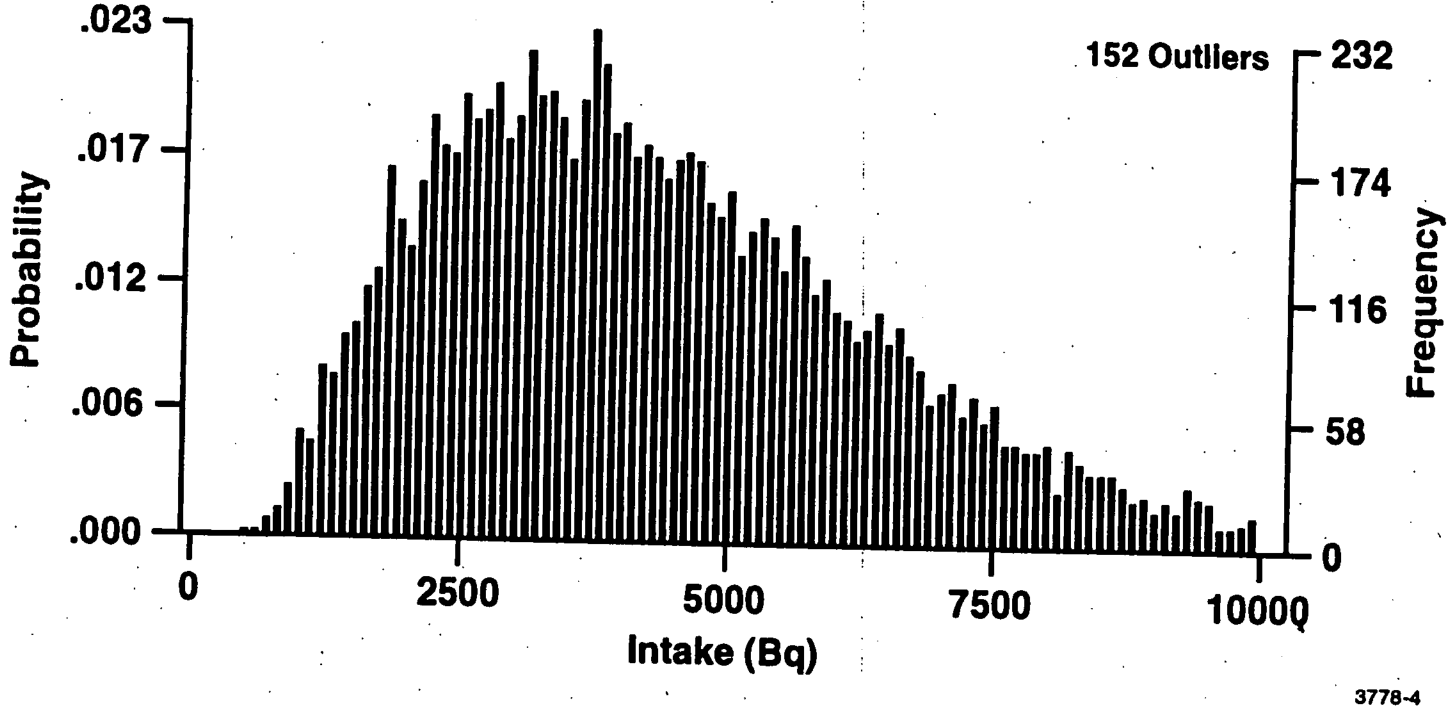
3778-1

Fig. 3



.032
.024
.016
.008
.000
Probability
0
1250
2500
3750
5000
Intake (Bq)
127 Outliers
320
240
160
80
0
Frequency
3778-3

Fig 4



.023
.017
.012
.006
.000
Probability
152 Outliers
232
174
116
58
0
Frequency
0
2500
5000
7500
10000
Intake (Bq)
3778-4

"A REVIEW OF THE RADIONUCLIDE SOIL ACTION LEVELS AT THE ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE"

PROJECT UPDATE

John E. Till

Risk Assessment Corporation

John Till
May 1999

OVERVIEW OF *RAC* UPDATE

- Review project tasks — John Till
- Comments on the Task 2 report — John Till
- Other issues — John Till
- Soil ingestion — Kathleen Meyer
- Actinide migration panel — Kathleen Meyer
- Task 6 report — David Thorne

John Till
May 1999

PROJECT TASKS

- Task 1: Cleanup levels at other sites (final report submitted)
- Task 2: Computer models to calculate soil action levels (draft report submitted)
- Task 3: Inputs and assumptions (draft report July 8)
- Task 4: Methodology for determining soil action levels (presented to the panel)

John Till
May 1999

492

PROJECT TASKS (Continued)

- Task 5: Independent calculation (draft report September 8)
- Task 6: Protocols (draft report completed)
- Task 7: Interaction with Actinide Migration Panel (ongoing)
- Task 8: Public Interaction (ongoing)

John Till
May 1999

OTHER ISSUES

- Budget status/milestone report
- Groundwater
- Comments from last RSALs meeting
- NCRP Report 129
- Task 3 outline
- RESRAD v5.61 vs. v5.82

John Till
May 1999

TASK 3 OUTLINE

I. Introduction

A. What is uncertainty and how do we handle it?

B. What parameters will be explored?

C. Difference between versions of RESRAD and impact on results of DOE scenario calculations

II. Scenarios applied in the analysis

John Till
May 1999

TASK 3 OUTLINE (contd.)

III. Sensitivity analysis - (RESRAD V5.82)
- A. Methodology
- B. Results
- C. What do we learn from this about input parameters

IV. Uncertainty distributions for selected input parameters
- A. Parameters selected from sensitivity analysis
- B. Discussion of high wind events at RF

John Till
May 1999

TASK 3 OUTLINE (contd.)

V. Monte Carlo Interface for RESRAD V5.82
- A. What is Monte Carlo?
- B. Brief code description

VI. Results of uncertainty runs - using v5.82 and DOE scenarios
- A. Results
- B. Sensitivity
- C. Comparison to deterministic calculations

John Till
May 1999

RESRAD v5.61 vs. v5.82

- Significant difference between the version of RESRAD used for the original DOE soil action level calculations and the one currently released is in the "area factor."
- The area factor is a value multiplied by the air concentration predicted for an infinite contaminated area to make it possible to determine the concentration in air resulting from a finite area.

John Till
May 1999

DIFFERENCE IN AREA FACTOR

- In the earlier calculations of soil action levels for Rocky Flats, the area factor, based on using a contaminated area of 40,000 m³ and a dilution length of 3 m, was 0.985
- Using the same area of contamination and a mean wind speed of 4 m/s (Denver mean), the area factor is calculated to be 0.104

John Till
May 1999

DIFFERENCE IN AREA FACTOR

- Since the area factor is multiplied by the air concentration calculated for an infinite contaminated area to produce air concentration for a finite contaminated area, the air concentration arrived at using RESRAD v5.82 can be nearly a factor of 10 less than that calculated with the old
- This results in LOWER dose and HIGHER allowable soil concentration (soil action level)

John Till
May 1999

Using Pu-239 as an example, the soil action levels predicted for the DOE scenarios based on different versions of RESRAD (wind speed = 4 m/s)

RESRAD v5.61	RESRAD v5.82
office worker (15 mrem) = 1088 pCi/g	office worker (15 mrem) = 7116 pCi/g
open space (15 mrem) = 9906 pCi/g	open space (15 mrem) = 53130 pCi/g
resident (15 mrem) = 252 pCi/g	resident (15 mrem) = 1474 pCi/g
resident (85 mrem) = 1429 pCi/g	resident (85 mrem) = 8351 pCi/g

John Till
May 1999

Radionuclide Soil Action Level Oversight Panel Meeting

Kathleen R. Meyer

- Actinide Migration Studies
- Soil Ingestion-Geophagia

K. Meyer May 1999 RAC

Actinide Migration Studies

- Researchers from Los Alamos National Laboratory are characterizing plutonium in soil samples from the 903 area
- Using state of the art techniques, they have shown that the Pu from soil under the 903 pad is insoluble PuO_2
- These new results provide solid proof for what many have assumed all along –that plutonium in the soil at Rocky Flats is insoluble PuO_2
- The AMS research that is underway has helped to define the potentially significant pathways and we still see inhalation as the major pathway for this work

K. Meyer May 1999 RAC

496

Soil Ingestion-Geophagia

- Geophagia "A condition in which the person eats inedible substances, as chalk, clay or earth"
- Both inadvertent and intentional soil consumption is seen world-wide, in all cultures
- Occurs at all ages and in many subpopulations including children, adolescents and pregnant women
- Soil ingestion is difficult to verify and quantify; some studies do not differentiate between inadvertent or intentional intake

K. Meyer May 1999 RAC

Soil Ingestion-Geophagia

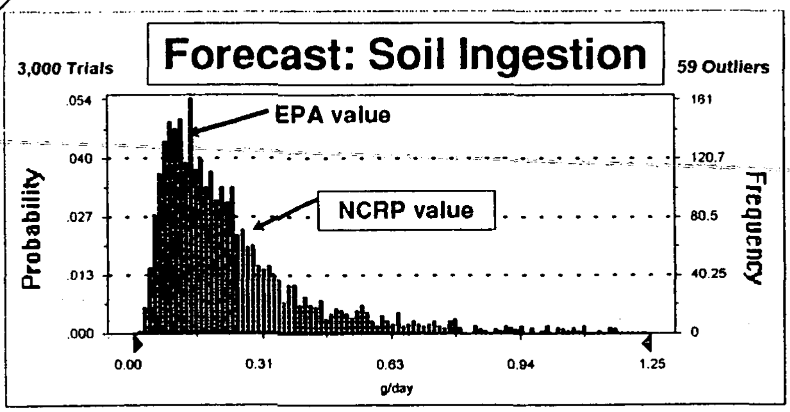
- Most studies conducted under fairly idealized conditions, or during more mild seasons of the year
- It is important to carefully consider the implications of translating a daily soil ingestion rate to an annual soil ingestion rate
- For these reasons, we will use the 50th percentile of our distribution for our daily soil ingestion rate

K. Meyer May 1999 RAC

Soil ingestion distribution

- Fit probability distribution to the data from various soil ingestion studies, including
  - NCRP 1999
  - Simon 1998
  - Stanek and Calabrese 1995
  - Thompson and Burmaster 1991
  - Calabrese et al. 1989
- Looked at how deterministic values from studies fit into distribution
  - Kimbrough et al. 1983
  - EPA 1994
  - NCRP 1996
  - Hawley 1985

K. Meyer May 1999 RAC



Geometric mean = 0.2 gram/day

Geo Standard Deviation = 2.17

5th percentile = 0.06 g/day

95th percentile = 0.73 g/day

K. Meyer May 1999 RAC

498

Recommended Scenarios

DOE/EPA/CDPHE	RAC Scenarios	
	Restrictive (Part-time)	Nonrestrictive (Full-time)
1. Residential	1. Current onsite worker	1. Rancher
2. Open space		2. Infant of rancher
3. Office worker		3. Child of rancher

K. Meyer May 1999

RAC

Comparison of Key Scenario Parameters

Parameter	Current DOE/EPA/CDPHE Scenarios: Residential	Current DOE/EPA/CDPHE Scenarios: Open space	Current DOE/EPA/CDPHE Scenarios: Office worker	*RAC* Recommended scenarios – Restrictive: Current site outdoor worker	*RAC* Recommended scenarios – Nonrestrictive: Resident rancher	*RAC* Recommended scenarios – Nonrestrictive: Infant of resident rancher (NB-2 yr)	*RAC* Recommended scenarios – Nonrestrictive: Child of resident rancher (5-17 yr)
Time on the site (hr/yr)	8400	125	2000	2100	8760	8760	8760
Breathing rate (m3 per year	7000	175	1660	3660	10800	1900	8600
Soil ingestion (grams)	0.2 for 350 d	0.1/ visit for 25 visits/yr	0.05 for 250 days	0.20 for 250 days	0.20 for 365 days	0.20 for 365 days	0.20 for 365 days
Soil ingestion (grams per yı	70	2.5	12.5	60	75	75	75
Irrigation water source	na	na	na	na	groundwater	na	na
Onsite drinkig water source	no	no	no	no	groundwater	no	no

K. Meyer May 1999

RAC

RSALOP

Radionuclide Soil Action Level Oversight Panel

April 27, 1999

Jessie M. Roberson, Manager
U.S. Department of Energy – Rocky Flats Field Office
PO Box 928
Golden, CO 80402

Dear Ms Roberson:

The Radionuclide Soil Action Level Oversight Panel is now approaching the midway point in its review of the Rocky Flats interim radionuclide soil action levels. We would like to provide you with a brief update on the status and progress of the review.

Risk Assessment Corporation (RAC), the consultant that is conducting the review of the interim radionuclide standards, is on schedule and on budget. The Oversight Panel and *RAC* are committed to an open review process. Representatives of *RAC* continue to meet with both Panel and interested parties one hour prior to each month's regularly scheduled meeting and after each meeting. These extra time periods provide an excellent opportunity for delving into technical issues and getting questions answered that pop up after meetings.

The Department of Energy has several representatives attending not only the monthly Panel meetings but the discussion periods as well. Additionally, DOE sends a written list of questions to be answered by the RAC team every month. The provision of time before and after the meetings to answer questions is an effort to provide for more efficient use of study funds and limit the time necessary to answer long detailed questions.

The Oversight Panel's focus is on using our limited funds to address the scope of work and provide a credible review process. Our goal is not to discredit the Department of Energy or any other entity that was involved in setting the original interim standard. Our goal is to ensure that the Radionuclide soil action level set for the Rocky Flats Environmental Site, is protective of human health and the environment for onsite users as well as off-site uses for both the immediate and long-term future.

Task 1: Cleanup Levels at Others Sites has been completed. The final report will be distributed at the May 13 Panel meeting. The draft ***Task 2: Computer Models*** has also been completed and reviewed by the Peer Review Team. Board members are in the process of sending in their comments on this task and the final report will be completed and distributed at the July 8 meeting.

501

Be assured that the Panel is working closely with *RAC* to ensure that all work items listed in the scope of work are accomplished as detailed in the RFP. We will provide you with periodic updates and personal copies of the final reports for each task listed under the scope of work.

We appreciate your support in this important review. Please feel free to contact either of us if you have any questions or would like additional information.

Sincerely,

Original Signed By
Hank Stovall, Co-Chair
Radionuclide Soil Action Level Oversight Panel
(303) 466-5986

Original Signed By
Mary Harlow, Co-Chair
Radionuclide Soil Action Level Oversight Panel
(303) 430-2400 - Ext. 2174

cc:

RSALOP

U.S. Department of Energy
Jeremy Karpatkin

502

To: **RAC**
From: **Victor Holm**
Date: April 20, 1999
CC: **RSALOP**
Subject: **Comments on the Part 2 Report**

While these comments are directed to the draft Task 2 Report, I will also be referring to the presentation on scenarios given by Kathleen Meyers and Jill Weber at the RSALOP meeting on April 8.

As I indicated in my letter to Kathleen Meyers on March 10, overall I believe RAC is on course and doing an excellent job. I particulary liked the discussion on Soil Action Levels (sec 2) and the Site Conceptual Model (sec 3). I am now familiar with the operation of three of the proposed computer models, RESRAD, GENII and D&D, and I concur that RESRAD is the best choice. I recently talked with Charlie Yu (April 13), developer of RESRAD, and I now have a much better understanding of the pitfalls with the air modeling. I look forward to your presentation on exactly how you will handle air modeling. In addition to the EPA Rapid Assessment Model you may also wish to look at the ICS-3 air dispersion model to see if it can be coded into RESRAD. In addition a beta version of RESRAD-OFFSITE is now available. This tool might be helpful in evaluating offsite exposure even if it can not be formally used because it not finalized.

Although the rest of this letter takes some exception with the scenarios suggested and the parameters used within them, I wish to assure you that the questions are asked in a constructive manner. I respect the work you are doing and realize that these are difficult questions. I also wish to assure the rest of the panel, although it may seem that I am always pressuring for a less conservative standard it is only because the other point of view is so ably represented. We are trying to obtain the best cleanup possible with the limited funds and time available. Whether we agree or not; when the money runs out DOE will build a fence around the site and we will have to live with the results. If this panel can not scientifically defend the results from what could be a concerted effort to discredit the work then we will have accomplished nothing.

The report discuses nine scenarios. At the last meeting the number was reduced to seven. Three of these are the RFCA scenarios which will not be modified. I do not consider the RFCA scenarios of much use to this study other than as points of reference. The current on-site worker scenario is interesting; but, I fail see how it can be used to set cleanup levels after closure of the plant and the current workers are gone. The infant and child scenarios are useful additions but are unlikely to be the controlling scenarios. We are then left with only one scenario, the rancher, which in my opinion will be difficult to defend because it not the best or most likely use of the land.

There is broad consensus both among stakeholders and local governments that the site should be used as open space. The EPA, under CERCLA, and the NRC, under the Licence Termination Regulations, both specify that regardless of the intended land use the site must be cleaned up to unrestricted standards unless it can be demonstrated that "complying with the unrestricted use

503

criterion would be prohibitively expensive, result in net public harm or not be technically feasible"(10CFR Part 20.1402(d)). The baseline scenarios must then address the unrestricted use standard of 15 mrem. The rancher scenario should be one of these. In my opinion the other should be a suburban resident since this is the most likely unrestricted scenario. These scenarios in no way interfere with the desire of the stakeholders and local government for open space. Since actual land use decisions made by local governments do not necessarily determine the scenario to be used in the cleanup. It is possible that an unrestricted cleanup will not be possible so we also need to consider restricted scenarios. I recommend that the current site worker be used for this purpose. This scenario could apply to an outdoor park worker maintaining vegetation, repairing trails and guiding visitors etc. Since he would work outside on site full time he would undoubtably have more exposure than the open space user.

My main confusion about the scenarios, which I believe is shared by others, is: Are they in fact standards? My reading of the applicable guidance is that this is how scenarios are normally considered in dose studies. If they are standards, then like any standard, the behavioral variables should be widely agreed upon and should not be site specific. There are many sources for this information; the EPA Exposure Factor Handbook, the NRC guidance, the default values given in the computer program documentation and the open literature. I question how much we should deviate from these sources. Another approach, which some panel members prefer, is to treat them as uncertainty values and use an appropriate probability distribution instead of considering them standards. It appears to me you trying to use both approaches at the same time. You call them standards; but, you derived them from probability distributions and then choose the 95th percentile. Perhaps I am being overly concerned about a trivial problem. In qualitative risk assessment the output distribution is supposed to be a measure of the uncertainty in the dose derived from a set contamination level. If the mean of the input distributions are already biased to include a large safety factor will we have an output distribution that is related to actual dose; or, one that is biased. How will we evaluate the extent of the bias ?

This bias is exhibited in nearly all the variables including: hours on site, breathing rate, vegetable ingestion and soil ingestion. From a practical point of view it is not a problem for breathing rate since the distribution used has little relative uncertainty, the mean and the 95th percentile vary by less than 10%. For the child soil ingestion rate the difference is significant. It can be argued that the distribution shown at the meeting represents two populations; a normal distribution and a near uniform distribution. The normal portion represents the uncertainty in ordinary children, while the uniform distribution is probably made up of children with a soil eating condition. The resulting joint distribution shown may not represents the uncertainty of soil ingestion at all. Moreover it is arbitrary and of debatable use to try to select the 95th percentile of a mixed population distribution such as this. One of the concerns some of us have had about this study from the beginning is that excessive safety factors would be introduced into the input parameters during the analysis and then another safety factor would be applied on the results. This was one reason that a probabilistic approach was adapted. If the input distributions are to be biased in favor of conservatism then the entire reason for this approach in questionable. I believe RAC needs to explain to the panel what it's approach to safety factors is going to be.

There are several other scenario variables that I recommend be reevaluated:

a. Time on site for the child of 8670 hr/yr does not consider time at school, play with other children or trips and vacations; is this reasonable? Why was the value of 5800 hr/yr in the draft report discarded ?

B. Time on site for the rancher of 8670 hr/yr does not consider time spent shopping or just socializing with neighbors or vacations. What was wrong with 8400 hr/yr which one reviewer already considered high.

C. Expecting the dry, rocky marginal land at Rocky Flats to provide all the plant food for the entire year is not defendable even at the 95^{th} percentile and it is not the custom on other ranches in Colorado or elsewhere for that matter. Would not 25% be more reasonable?

D. At the April meeting distributions for breathing rate and soil ingestion were shown for the child scenario. The breathing rate distribution is not just a distribution of uncertainty; but, has a strong positive correlation with age. The highest rates correspond to older children. The soil ingestion distribution presumably has a strong negative correlation with age. In fact my reading of the available papers indicates that most of the children with the soil eating condition are less than 5 years of age. I could find no example in the literature that suggested the condition is common in teenagers. It is likely that the joint probability of a child breathing more than 8600 cu m/yr and ingesting more than 1 gram of soil per day in much less than the 5% you indicated, in fact I would suggest that they are mutually exclusive.

I have one editorial comments: on p.23 second paragraph I believe the East Gate referred to is not the same as the present East Gate on Indiana St.

Again I wish to commend you on the generally good job you are doing. I look forward to a continuing dialog. I for one learning a great deal from this project.

Radionuclide Soil Action Level Project

Milestone Report 3

Risk Assessment Corporation

May 1999

The main deliverable for the Soil Action Levels Project between the Radionuclide Soil Action Level Oversight Panel (RSALOP) and *Risk Assessment Corporation* (*RAC*) will be a comprehensive report issued at the end of the project (November 1999). The main body of the report will be written for the public and will summarize *RAC*'s findings and recommendations. Appendices will provide the technical details of the work. The seven milestone reports will outline *RAC*'s progress in completing the Work Tasks and Deliverables, and the compensation requested according to the schedule provided in the contract. The purpose of this milestone report is to describe the activities that *RAC* has accomplished to date.

Milestone 3 (5/8/99) – 4 milestone items

- Final report of a review of soil action levels at other sites (Appendix A) will be submitted.
- Probability distribution for parameters identified in Task 3a will be provided.
- Evaluation of quality assurance procedures for soil sampling will be provided and a draft report of Appendix C will be submitted to the panel.
- *RAC* will provide a review of other potentially important pathways of exposure based on our interaction with the Actinide Migration Panel (part of Appendix D).

The first milestone item was met when *RAC* distributed the Draft Final Task 1 report, *Cleanup Levels at Other Sites*, to panel members in late April 1999. The next milestone item has been in progress as preliminary sensitivity analyses were carried out and a draft outline for the Task 3 report is prepared and presented at the May 1999 meeting. The third milestone is completed with the distribution of the draft Task 6 report, *Sampling Protocols*. This report will be finalized and incorporated into Appendix C of the final report. The final milestone for this period has been met with *RAC*'s attendance at the Actinide Migration Panel meetings and providing a written summary of the topics covered with this report.

- ***Final report of a review of soil action levels at other sites (Appendix A) will submitted to the panel.***

This milestone was completed when *RAC* revised and distributed the Draft Final Task 1 report, *Cleanup Levels at Other Sites*, to panel members in early May 1999. This report discusses our work comparing cleanup levels at other sites to those at Rocky Flats, and identifies information from other facilities that may be applicable in conducting the independent analysis at Rocky Flats. Comments were received on the draft Task 1 from a few members of the RSALOP. For the most part, these comments were considered beneficial to the Task 1 report, and they were

506

integrated into it. The primary comment from both reviewers indicated that a table showing the actual cleanup values and the doses associated with them might be instructive. An entire section devoted to this has been integrated into the front section of the report. *RAC* is continuing to seek more information on a number of sites, as requested by reviewers. Recently, we received dose assessment information completed for Enewetak Atoll but not in time to include it in the Draft Final version of Task 1. The data will be reviewed and applicable information will be incorporated into the Final version of Task 1, as Appendix A to the final report.

- ***Probability distribution for parameters identified in Task 3a will be provided***

The Task 3 report, *Inputs and Assumptions,* will be a working report to document the results of the sensitivity analysis, distributions for uncertain parameters, and Monte Carlo calculations. This report will focus mainly on parameter distributions for input values to the RESRAD calculation deemed significant through the help of the sensitivity analysis. *RAC* has developed an outline for the Task 3 report, which consists of an introduction, where the purpose of the report is described. Part of the introduction will contain a short description of the differences between RESRAD v5.61 (the version used for the DOE calculations) and RESRAD v5.82 (the most recent version under consideration, and the version *RAC* will use for the Monte Carlo analysis). We have done calculations using the DOE/EPA/CDPHE scenarios and will present the results of these calculations in this section.

The second part of the report will describe the scenarios developed for this project, both by DOE and by *RAC.* Section 3 will contain the results of the sensitivity analysis run using Version 5.82, including methodology and results, as well as the parameters that emerge from this analysis as significant parameters for which distributions will be created. The next section will include uncertainty distributions developed for different parameters. We will also include a discussion of high wind events as Rocky Flats, and the knowledge gained in the dose reconstruction about their impact on dose and risk. The report will conclude with a description of the Monte Carlo add-on created by *RAC* and the results of the calculations done using the DOE scenarios and the distributions of parameters created by *RAC.* Some parameters already identified through the initial stages of the sensitivity analysis as significant are mass loading, average annual wind speed, and the area of the contaminated field. These three parameters have an impact on the resuspension of contaminated soil in Version 5.82 of RESRAD. Additional parameters will undoubtedly emerge, and soil-to-plant transfer factors are also being considered.

- ***Evaluation of quality assurance procedures for soil sampling will be provided and a draft report of Appendix C will be submitted to the panel***

RAC distributed the Task 6 draft report, *Sampling Protocols*, to the Rocky Flats Soil Action Level Oversight Panel (RFSALOP) at the May 1999 meeting to complete this milestone. This draft report provides recommendations to the panel for consideration in developing a sampling protocol for the Rocky Flats Environmental Technology Site (RFETS) in support of the effort to conduct an independent assessment and calculate radionuclide soil action levels for Rocky Flats. *RAC* conducted a review of the available statistical methods and applications for assessing the soil action levels in the Rocky Flats environment and this report provides recommendations for sampling protocols applicable to the soil action level study. As part of this task, we conducted a review of the RFETS soil sampling program to determine the present status of soil sampling at the site. Several areas of the current RFETS soil sampling program were considered acceptable

509

for use in the RFETS soil sampling protocol for the soil action level study. for elements of a soil sampling protocol that are considered important to the study. These elements include (a) data quality objectives process, (b) multiple radionuclide considerations, (c) classification and identification of survey units, (d) soil sample depth, (e) sample spacing and methods, (f) small areas of elevated activity, (g) surrogate measurements, (h) number of required samples based on statistical methods, (i) independent confirmatory investigations, and (j) soil sample quality assurance. A number of specific recommendations are made in this report for the panel's consideration.

- ***RAC* will provide a review of other potentially important pathways of exposure based on our interaction with the Actinide Migration Panel (part of Appendix D).**

RAC has attended the Actinide Migration Studies (AMS) quarterly meetings, and continues to interact with study participants. The January 21, 1999 AMS meeting focused on studies of plutonium migration at Rocky Flats site. Dr. Greg Chopin from the University of Florida described his work with the use of oxidation state actinide analogs to observe effects of geochemical processes over long time periods. He and his colleagues have studied old uranium and thorium locations around the world to find analogs for plutonium, (e.g., Th^{4+} for Pu^{4+}, and U^{4+} for Pu^{4+}). The main message is that natural analog sites provide valuable information on actinide chemistry and fate and transport; to date these studies show very little movement of plutonium over long time periods. Their studies indicate that Rocky Flats plutonium is insoluble but they emphasize that solubility studies are complex. At that same meeting, Mike Murrell and Chris Brink from Los Alamos National Laboratory (LANL) explained how they are tracing uranium migration at the RF solar ponds using refined analytical techniques in ion counting to follow the transport of uranium and to differentiate between "Rocky Flats" uranium and "natural" uranium.

At the April 29, 1999 AMS meetings, researchers described progress on collecting borehole samples from the South Interceptor Ditch, runoff samples from a buffer zone area near Walnut Creek, and water samples from Pond B-5 discharge that will be used for suspended solid fractionation experiments. Jim Ranville from the Colorado School of Mines, described his work on soil aggregation at Rocky Flats and how it might affect solubility. Mary Neu from LANL then described results of current experiments done on characterizing plutonium in samples from the 903 area. Using powerful, new state-of-the-art analytical techniques, she and her colleagues have demonstrated that plutonium from under the asphalt pad at the 903 area is insoluble PuO_2. The Pu/Am ratio also indicates insoluble plutonium. These new results provide solid proof for what many have assumed all along –that plutonium in the soil at Rocky Flats is insoluble PuO_2, and thus may not get into the groundwater.

These studies are exciting and very relevant to the current soil project because they help to characterize the chemical and physical form of plutonium at the Rocky Flats site. The AMS research that is underway has helped to define the potentially significant pathways and we still see inhalation as the major pathway for this work. Recent work at LANL indicates that the plutonium from soil samples under the 903 pad is insoluble PuO_2. While results from some of the AMS studies indicate that this insoluble form of plutonium may not enter groundwater, we are examining a conservative calculation to address the question of whether or not the pathway can be ruled out of the current analysis. We understand the importance of groundwater and surface water pathways in the long term, and include the groundwater pathway in one of our scenarios. We do recognize, however, that our assessment of the groundwater pathway is limited by the complexity of the pathway.

512

Presentation of the Draft Report for Task 6: Sampling Protocols

Rocky Flats
Radionuclide Soil Action Level
Oversight Panel

RAC

D. J. Thorne May 1999

115

Review of the Current RFETS Sampling Program

- Quality Assurance Project Plan (QAPjP)
- Standard Operating Procedures
  - Administrative procedures
  - Operating procedures
- Quality Assurance Addenda (QAA)
- Work Plans
- The General Radiochemistry and Routine Analytical Services Protocol (GRRASP)
- Data Validation Guidelines

RAC

D. J. Thorne May 1999

515

RFETS Soil Sampling Methods

- **Four Methods of Sampling Radionuclides in the RFETS Environment**
  - Colorado Department of Health (CDH) Method
  - Rocky Flats (RF) Method
  - Grab Sampling Method (Spade and Scoop)
  - Vertical Soil Profile Method
- **Purpose of Different Sampling Methods**
  - The purpose of surface soil sampling at the RFP can be related to one or more specific objectives. These are as follows:
    - Resuspension availability, which determines if radionuclides are present in the top-soil that could be suspended in air and pose a migration pathway by inhalation
    - Deposit inventories, which determine the amount of accumulated radionuclides deposited on the ground
    - Distribution of contaminants, which defines the areal distribution of contaminants
    - Deposition increment, which defines the areal distribution with depth to verity HPGe surveys

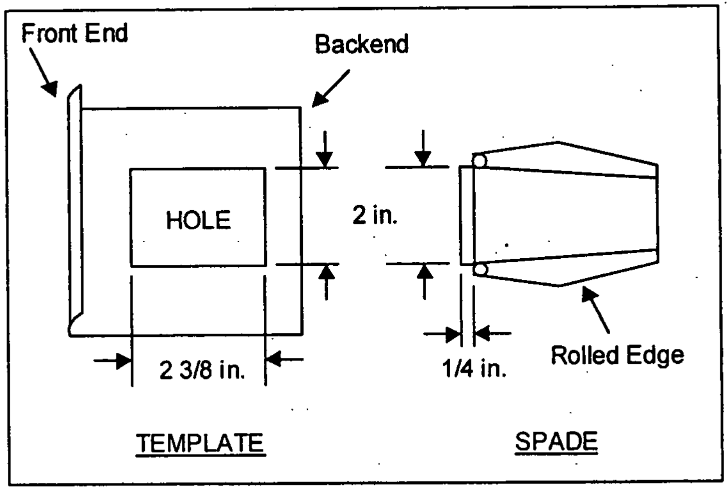
RAC

D. J. Thorne May 1999

513

CDH Soil Sampling Method

- **CDH sampler designed to sample upper soil surface 1/4 inch deep**
- **Vegetation and any undesirable top soil layer of surficial material are removed before sampling**
- **RFETS typically collects 25 evenly spaced samples and composites into one sample for each sampling location**



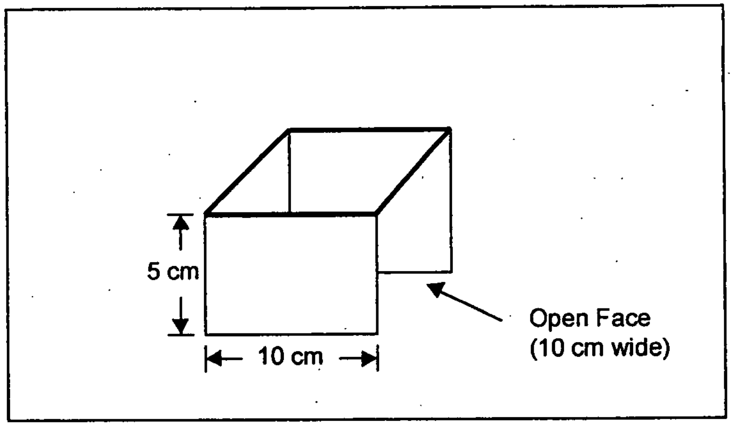
RAC

D. J. Thorne May 1999

5/4

Rocky Flats Soil Sampling Method

- Designed to collect soil sample 5 cm deep and a total volume of 5000 cm^3
- Soil is removed from outside of jig
- Scoop is used to finish cut on open face side and bottom surface



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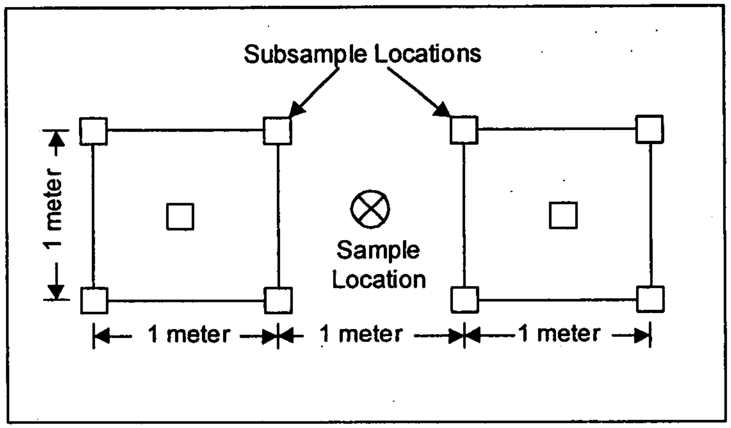
D. J. Thorne May 1999

RF Method Sample Layout

- Ten samples collected at each location and composited into one sample for analysis
- Ten samples obtained by collected one sample each from the center and corners of two - 1 m^2 areas spaced 1 m apart
- The soil samples are passed through a 10-mesh sieve to remove large particles



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D. J. Thorne May 1999

Grab Sampling Method

- Spade and Scoop are used to collect soil sample
- Vegetation and undesired surficial material are removed before sampling
- Soil sample collected to desired depth using stainless steel spoon or scoop
- Total number of samples are specified in the site-specific sampling plans

RAC

517

Vertical Soil Profile Method

- Designed to define the distribution of radionuclides in the top 6 inches of soil to verify the results of the HPGe surveys
- Discrete soil samples are collected at 2 inch depth intervals down to 6 inches.
- Total number of samples and their locations are specified in the site-specific sampling plans
- A sample of 500 g is typically obtained

RAC

518

Recommended Sampling Protocol Elements

Data Quality Objectives

- DQO process used
- Multiple radionuclide considerations
- Classification and identification of survey units
- Soil sampling depth
- Sample spacing and methods
- Small areas of elevated activity
- Surrogate measurements
- Number of samples based on statistical methods
- Soil sample quality assurance/quality control
- Independent confirmatory investigations

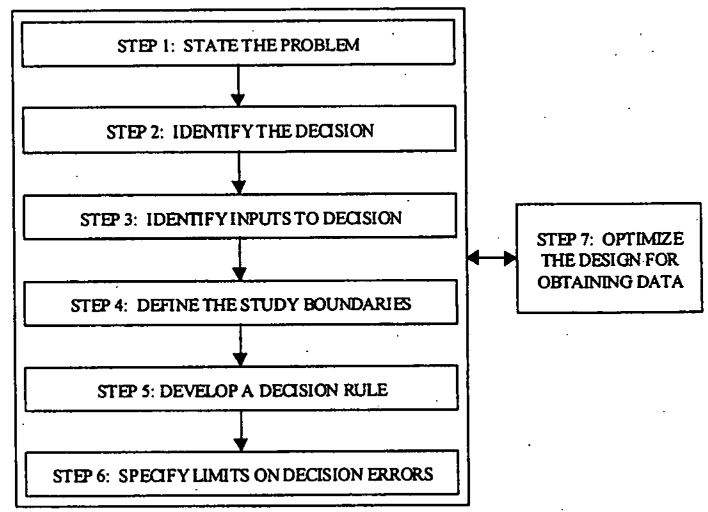
RAC

D. J. Thorne May 1999

519

Data Quality Objectives Process

- DQO process is iterative
- DQO process described by EPA - Guidance for the Data Quality Objectives Process
- DQO process recommended by MARSSIM
- DQO process consist of seven steps shown in figure
- *RAC* recommends the DQO process for soil sampling and the involvement of an Oversight Panel representative for RFETS



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0520

Multiple Radionuclide Considerations

$$\frac{C_1}{RSAL_1} + \frac{C_2}{RSAL_2} + \frac{C_3}{RSAL_3} + \ldots + \frac{C_n}{RSAL_n} \leq 1$$

- **Sum of ratios rule must be used for multiple contaminants**
- **Sum of ratios rule ensures that the total dose due to the sum of all radionuclides does not exceed the release criterion**
- **Two methods available for addressing problem:**
    - **Perform assessment using stochastic calculation of the sum of ratios - must have description of the radionuclide population distribution - acceptable probability level must be selected from the sum of ratios distribution**
    - **Select a point value from the RSAL distribution for each radionuclide - These values are then used as a comparison to the sample data such as the mean - then the sum of ratios is calculated deterministically**

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165

Identification of Survey Units

- MARSSIM provides classifications for areas based upon their potential for contamination exceeding the action levels
  - Class 1 Areas
  - Class 2 Areas
  - Class 3 Areas
- *RAC* recommends the Survey Unit concept for the RFETS soil sampling protocol

Survey unit suggested areas based on MARSSIM guidance.

Classification	MARSSIM Suggested Area
Class 1 - Land Areas	Up to 2,000 m^2
Class 2 - Land Areas	2,000 to 10,000 m^2
Class 3 - Land Areas	No limit

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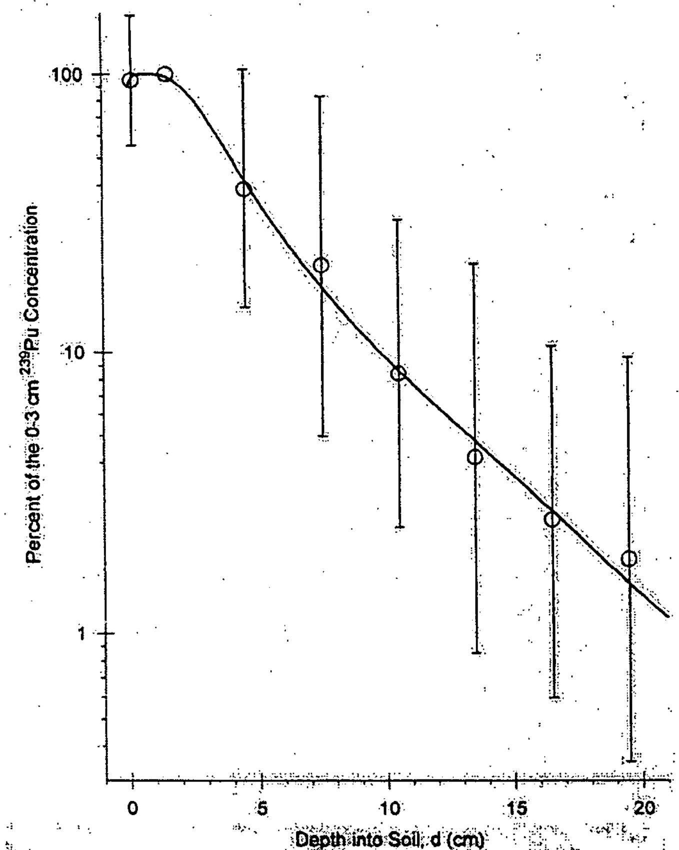
Soil Sample Depth

- Webb et al. (1997) found depth distribution of ^{239}Pu as shown in figure
- Webb et al., noted that the relatively uniform concentration of plutonium over first 2 cm is suggestive of some ongoing mixing process
- Litaor (1999) found that the top layer (0-3 cm) was most contaminated with 96% of plutonium in the top 12 cm of the soil



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525

Sampling Depth (continued)

- Litaor et al. (1995) used both the CDH and RF soil sampling methods and found no statistical difference
- Note that both methods involve composited samples
- The study noted that the CDH sampler exhibited a serious problem in locating the boundary between the soil surface and the litter layer
- Shierman (1994) found that the concentrations of americium and plutonium decreased exponentially as a function of depth
  - 90% of activity in top 9 cm of soil
  - 50% of activity in the top 3 cm of the soil
  - No difference was obsersed in ^{241}Am and ^{239}Pu movement vertically in the soil column

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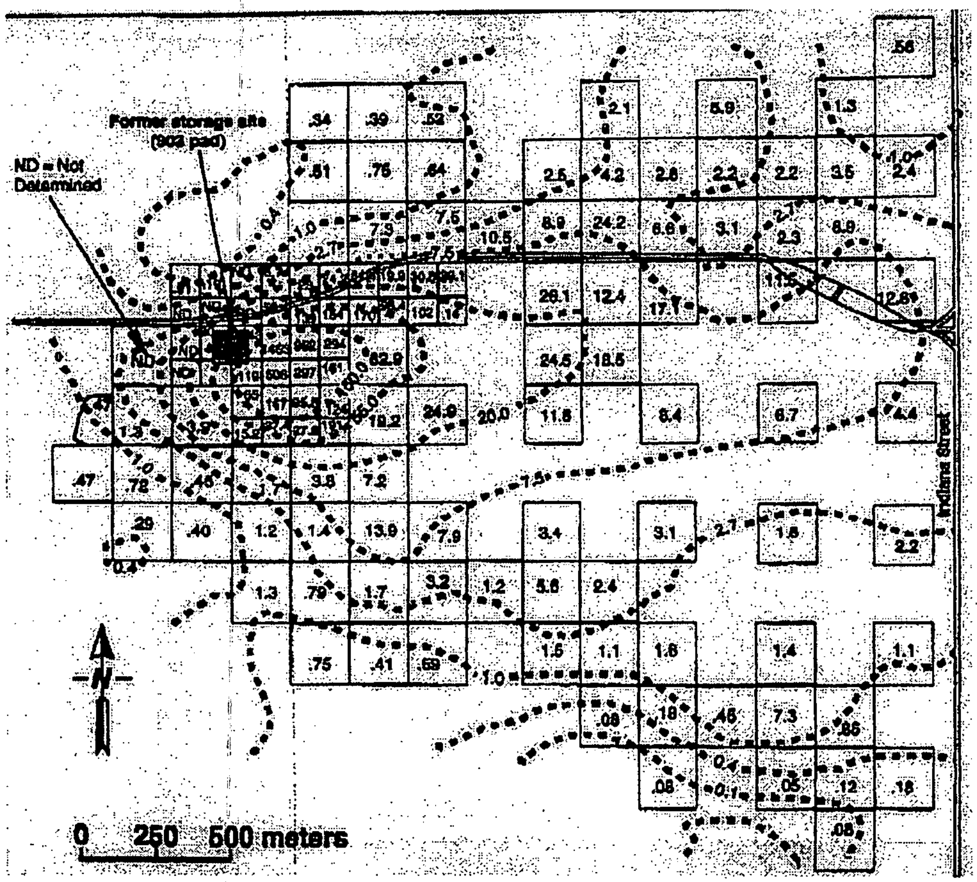
Litaor (1993) ^{239,240}Pu (pCi/g) in Soils Isopleth Map



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525

Recommended Depth and Methods

- Recommended method involves using profile sampling similar to Colorado State University
- 0-3 cm sampling intervals
- Method provides information on both the surface soil (resuspension) also all soil layers may be summed to find total inventory for other pathways such as groundwater or plant uptake
- Total depth of 15 cm to capture total inventory (undisturbed)
- The profile method also provides sufficient data to evaluate cleanup methods. It may be found that areas which have been remediated no longer require profile sampling (well mixed soil concentrations) such that a single 15 cm sample may be taken

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Sample Spacing and Methods

- Composite sampling, such as CDH and RF, are useful if:
  - the cost of analyzing individual grab samples for contaminants is high
  - the mixing process is thorough
  - information on the variability or extreme concentrations for samples is not needed
- Composite sampling presents a problem for action level project
  - no information on contaminant variance
  - no information on extreme values
  - small areas of elevated contamination not identified

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5297

Sample Spacing and Methods (continued)

- Random Sampling
  - Randomization is necessary to make probability or confidence statements
  - Involves assumption that the site is homogeneous with respect to the parameter being investigated
- Stratified Random Sampling
  - Strata defined according to factors such as depth, contaminant levels, and contaminant source areas or location
  - Use of survey unit classification is a type of stratification
- Systematic Sampling
  - Survey unit subdivided with a grid system with samples located at grid line intersections
  - Random location for grid start point

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Small Areas of Elevated Activity

- Use of a systematic grid with a random starting point will provide information on whether the residual radioactivity in a survey unit exceeds the soil action levels
- The systematic grid may not successfully identify small areas of elevated activity

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529

Small Areas of Elevated Activity (continued)

- Scanning with radiation detection equipment is used to identify small areas of elevated activity
- Systematic grid spacing may need to be modified based on the detection capabilities of the survey equipment
- Action levels are modified to account for smaller areas of activity - this can be evaluated using the same pathway model used to calculate the action levels
- Sum of ratios rule can be used to evaluate both the overall average contaminant levels and areas of elevated activity

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530

Surrogate Measurements

- A surrogate radionuclide is one that is easily measured and implies through correlation the concentration of other radionuclides
- Shierman (1994) and Hulse et al. (1999) have investigated surrogate measurements
- Shierman found the following relationship
  - » ^{239}Pu (pCi/g) = ^{241}Am (pCi/g) x 0.189^{-1}
- Hulse's relationship
  - » $^{239,240}Pu = 5.5\ (^{241}Am)^{1.1}$

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531

Statistical Analyses and the Number of Required Samples

- Statistical Analyses
  - Parametric (knowledge of distribution required)
  - Nonparametric (distribution-free)
    - Presented in MARSSIM
- Calculating the number of required samples
  - Estimated variability of the radionuclide concentrations
  - Null hypothesis
  - False positive and negative rates

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532

Independent Confirmatory Investigations

- An independent confirmatory investigation is performed by an independent third party, contracted by DOE, to provide data to substantiate the results of the final status survey
- *RAC* recommends that the Oversight Panel request that DOE implement a confirmatory survey process for the soil action levels project

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Soil Sampling Quality Assurance

- QA sampling requirements identified during the DQO process
- Six Data Quality Indicators (DQIs) must be addressed
  - Precision
  - Accuracy
  - Bias
  - Completeness
  - Representativeness
  - Comparability

Upper Confidence Limits for the True Variance as a Function of the Number of QC Measurements Used to Determine the Estimated Variance.

Number of QC Measurements	Level of Confidence (%)			
	90	95	97.5	99
2	9.49	19.49	39.21	99.50
5	3.10	6.01	6.02	9.02
10	2.05	2.54	3.08	3.91
15	1.76	2.07	2.40	2.87
20	1.61	1.84	2.08	2.42
25	1.52	1.71	1.91	2.17
30	1.46	1.62	1.78	2.01
40	1.38	1.51	1.64	1.80
50	1.33	1.44	1.61	1.68
100	1.21	1.28	1.35	1.43

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534

Summary

- The development of a sampling protocol is iterative in nature (DQO process)
- Determination of acceptable decision errors is also iterative - decision makers must weigh the risk for both false positive and negative errors
- All areas of the RFETS will not require the same sampling intensity using the concept of sampling units
- Several statistical techniques are available for evaluating whether the survey unit meets the soil action levels
- All sampling protocols contain common elements - *RAC* provides recommendations for these elements to the Oversight Panel in the Task 6 report

RAC

D. J. Thorne May 1999

May 4, 1999

Joe Goldfield
[redacted]

Carla [redacted]

Dear Carla,

I am enclosing two items--"Ode to a Pica Eater" and "Comparing Soil Cleanup Standards". I regard both documents as quite interesting and would like to forward them to both the members of our panel and to RAC. I have sent copies of both to Hank Stovall.

I am having some difficulty formulating my questions on breathing rates. If I get them done in time I will forward them to you.

Sincerely,

Joe Goldfield

Joe Goldfield

535

ODE TO A PICA EATER

J. Goldfield April 21, 1999

Prior to the April 8 meeting of the RFSALOP (Rocky Flats Soil Action Level Oversight Panel) a discussion developed concerning "pica eaters"--small children who have the distressing habit of eating dirt. Obviously such children living on plutonium contaminated soil at Rocky Flats after soil cleanup was completed would receive some degree of exposure to health effects from the plutonium intake. At the time I thought the discussion was somewhat unfeeling. How should we handle "pica eaters"? They are few in numbers. Should we disregard them in setting soil action levels (soil cleanup standards)?

After time for reflection, I felt that the sad little tykes needed a champion. So putting on my best Don Quixote outfit and mounting my trusty steed (accompanied, of course, by Sancha Panza) I rode forth to do battle with those who would write off these unfortunate critters.

How Much Soil Can a Pica Eater Eat at One Sitting?

After much thought I decided that a smidgen would be about right. I also concluded that a gram of soil could be considered a smidgen. But soil that has a specific gravity of about two would have a volume of one-half of a cubic centimeter to weigh one gram. That volume is a clump of soil about three-eighths inches by three-eighths inches by three sixteenths of an inch thick. I drew up a box with those dimensions. To be fair, it looked like two smidgens. I concluded that the little tyke would have to take two swipes to get one gram of soil. I further concluded that we would restrict our little pica eater to only one-half a gram at a time (one smidgen).

How Much Plutonium Could There Be in a Smidgen?

Well that's easy. If the little one lives at Rocky Flats after cleanup, on soil contaminated with 1429 pCi/g (picocuries per gram of soil) (assuming the DOE, the EPA and the Col. Health Dept. get their way) and a smidgen weighs half a gram, he would swallow 714.5 pCi of plutonium. Unless, of course, the little one is unfortunate enough to be set by its mother on a hot spot where the soil is contaminated with twice as much plutonium in which case his smidgen would contain 1429 pCi of plutonium. This last conclusion is not at all unlikely since the soil cleanup standard of 1429 is an average figure and finding spots with double the average will be likely.

How Bad Is That?

Well . . . "Closing the Circle on the Splitting of the Atom" dated January 1995, issued by the DOE Office of Environmental Management, on page 38, "The Evaluation of Standards for Nuclear Workers" gives the plutonium "tolerance limit" (maximum permissible) as a body burden of 1 μg (one microgram) of plutonium. How does that compare to the plutonium intake of our little pica eater?

Before we make the comparison we must face the question--do we believe that our small child pica eater should have the same maximum allowable body burden of plutonium as a full-grown, brawny nuclear plant worker? The plant worker is paid $40,000-$50,000 per year to take his chances. Our baby gets nothing. Our child is so small, helpless and vulnerable compared to the full-grown worker. The pica eater is part of our family--the human family. I feel an obligation to protect him. I would set the limit for the child at no more than one-tenth to one-twentieth of that of the worker--0.10-0.05 μg of plutonium.

The quantity of plutonium in the soil is given in pCi/g (picocuries of plutonium per gram of soil). The allowable body burden is given in micrograms. We must put them both in the same units in order to compare them. The attached page shows the calculations required to put both the concentration of plutonium in the soil (per smidgen) and the allowable body burden for the pica eater into nanocuries.

The calculations on the next page show that the quantity of plutonium 239 in a smidgen (one half a gram) is 1.429 nanocuries. The lifetime allowable body burden for our child pica eater is 0.10 to 0.050 micrograms equal to 6.3 to 3.2 nanocuries. We must conclude that the allowable plutonium 239 body burden for a lifetime is equal to the quantity of plutonium in 4.4 to 2.2 smidgens.

How can that be? How can our methods of calculation using computers, RESRAD, higher mathematics, Monte Carlo analysis overlook the threat to our little tyke? Shame on us ! Shame on us!

Conversion of Micrograms to Picocuries

Multiply the micrograms of plutonium allowed for pica eaters by 1000 to convert the micrograms to nanograms:

0.10 μg of Pu x 1,000 = 100 nanograms
0.05 μg of Pu x 1,000 = 50 nanograms

To convert nanograms to nanocuries, the nanograms must be multiplied by the "specific activity" of plutonium 239 which is 0.063 (nanocuries per nanogram).

100 nanograms x 0.063 = 6.3 nanocuries
50 nanograms x 0.063 = 3.2 nanocuries

Compare those results to the plutonium in a smidgen of Rocky Flats remediated soil (one half gram) which can contain 1429 picocuries of plutonium 239 (a plot containing double the average contamination of 1429 pCi/g). There are 1,000 picocuries in a nanocurie. Therefore the quantity of plutonium in a smidgen (one half gram) is equal to 1429 ÷ 1,000 = 1.429 nanocuries.

How many smidgens are we allowing the little tykes?

6.3 nanocuries (maximum permissible) ÷ 1.429 nanocuries per smidgen ≈ 4.4 smidgens

3.2 nanocuries (maximum permissible) ÷ 1.429 nanocuries per smidgen = 2.2 smidgens

Is our little pica eater only allowed 2.2-4.4 smidgens of Rocky Flats remediated soil before he is in danger of exceeding his lifetime allotment?

April 28, 1999

J. Goldfield

Comparing Soil Cleanup Standards

The attached document has recently come to my attention. It contains interesting information on calculating "Soil Screening Levels" and comparisons of the levels developed for cleaning soil at Johnston Atoll to those developed as "Soil Action Levels" by other facilities. As near as I can tell soil screening levels and soil action levels are synonomous.

This document is quite interesting because it was prepared at Oak Ridge National Laboratory and is dated 11/30/98. It describes calculations to develop soil cleanup standards. It basically tries to test the legitamacy of the soil cleanup standard for Johnston Atoll which is given as 500 Bq of TRU elements per kg of soil which is equal to 0.5 Bq/g or 13.6 pCi/g (picocuries per gram of soil). It discusses the value of several of the parameters that must be fed into RESRAD to calculate soil action levels.

The document is doubly interesting because Oak Ridge National Laboratory is a DOE facility and it is dated only few months ago.

ORNL/TM-1339

ornl

OAK RIDGE NATIONAL LABORATORY

LOCKHEED MARTIN

INDEPENDENT VERIFICATION OF PLUTONIUM DECONTAMINATION ON JOHNSTON ATOLL (1992 - 1996)

M. J. Wilson-Nichols

J. E. Wilson

L. M. McDowell-Boyer

J. R. Davidson

P. V. Egidi

R. L. Coleman

FYI

Grand Junction

8 pages

MANAGED AND OPERATED BY
LOCKHEED MARTIN ENERGY RESEARCH CORPORATION
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

ORNL-27 (3-96)

540

7.0 INDEPENDENT VERIFICATION OF THE SOIL SCREENING LIMIT

ORNL/ETS conducted a thorough evaluation of the SSL as part of the initial IV tasks. The established criteria are SSLs expressed as a soil concentration of 500 Bq of TRU elements per kilogram of soil or 5,000 Bq for a single particle. These levels are equivalent to the EPA value (U.S. EPA 1978) below which the risk of harm to people is trivial and corrective actions are not required (DNA 1989). The purpose of the verification was to ensure that no deficiencies or discrepancies exist within the derivation of the DSWA's selected SSL that might cast doubt on the quality of the soil the clean-up plant delivers for unrestricted use throughout the island.

This IV was accomplished by review of the rationale and calculations used to derive the SSL at JA. DSWA's rationale and a detailed explanation of the development of the SSL are presented in a letter from Edward T. Bramlitt, FCDSWA to John Eddy, DNA, on March 1, 1991, and is included as a reference to Appendix A. In addition, a literature search performed to gain access to recent developments in plutonium migration, uptake, and dose assessment provided information on several sites that have undergone similar experiences in the development of an SSL for plutonium. Clean-up levels from these sites were reviewed and compared to the JA SSL. The following paragraphs describe the evaluation of the SSL and the review of SSLs at other sites.

7.1 Evaluation of the SSL

The EPA's *Proposed Guidance on Dose Limits for Persons Exposed to Transuranium Elements in*

541

Soil Concentration = activity concentration of the transuranium elements in soil, Bq/kg.
$\sum f_i \eta_i$ = the contribution of the TRU elements from each particle-size fraction to the total resuspended material (also called the "enrichment factor").

In order to develop an SSL, Eq. (1) is rearranged to calculate a soil concentration based on a maximum acceptable air concentration at or below which clean-up would not be required. The rearranged form of Eq. (1) becomes

$$SSL = \frac{Acceptable\ Air\ Concentration}{Air\ Mass\ Loading \times \sum f_i \eta_i} \quad (2$$

In applying Eq. (2), conservative values were selected by EPA for the air mass-loading factor and the values for the enrichment factor, $\sum f_i \eta_i$ (U.S. EPA 1988). Selection of conservative values provides assurance that any area of soil contamination characterized by a TRU concentration less than or equal to the resulting SSL is highly unlikely to provide an exposure to airborne TRU elements that exceeds the acceptable exposure level.

An air mass-loading factor of 10^{-7} kg/m^3 (100 μg/m^3) was selected for the EPA development of an SSL; this value is higher than annual averages for any non-urban site in the U.S., according to 1965 National Air Sampling Network data (U.S.EPA 1988). Shinn et al. (1994) monitored mass loading at three work locations at JA, during a period of soil clean-up operations, and upwind of these locations, in an area of no measurable Pu contamination. During soil clean-up operations, when the soil was disturbed by the "mining" and "sorting" equipment, the median mass loading at the three work locations was 109 μg/m^3, and the average at the three sites were 1.78×10^{-7} kg/m^3 (178 μg/m^3), 9.3×10^{-8} kg/m^3 (93 μg/m^3), and 7.9×10^{-8} kg/m^3 (79 μg/m^3). However, the upwind "background" mass loading was measured at 4.1×10^{-8} kg/m^3 (41 μg/m^3), a value which likely overestimates the mass loading of soil because the contribution of sea salt to the sampled particulates was not evaluated. Therefore, the assumed mass-loading factor of 10^{-7} kg/m^3 is a conservatively high value for JA. From Eq. (2), the SSL is inversely proportional to the air mass-loading factor and, thus, selection of a high mass-loading factor leads to a conservatively low estimate of an SSL.

The term $\sum f_i \eta_i$ addresses how the activity concentration in the respirable-size range of soil particles might be enriched with respect to the activity concentration in the soil as a whole. A value of unity would indicate that the activity concentration in the respirable-size range is equivalent to that averaged over all sizes of soil particles. The parameter f_i represents the distribution of airborne soil mass as a function of particle size, and η_i accounts for the variability of soil activity and mass as a function of particle size. Data for f_i and η_i are available for five sites with plutonium contamination in the United States (U.S. EPA 1988). These sites include Mound in Ohio, NTS in Nevada, ORNL in Tennessee, the Rocky Flats Environmental Technology Site (RFETS) (formerly the Rocky Flats Plant) in Colorado, and the Trinity Site in New Mexico. According to EPA, the largest enrichment of activity within the fine particle-size range, which is more respirable, is documented for samples from the RFETS area. Therefore, in keeping with the objective of remaining conservative in the development of a SSL, an average enrichment factor of 1.5, derived from RFETS data, was selected.

Area size was not considered by EPA in development of the SSL. Area becomes a factor if the contaminated soil area is small enough that potential inhalation exposure is reduced by dilution of radioactive dust with uncontaminated dust from an upwind area. The amount of dilution is inversely proportional to the area of the contaminated zone. It is conservative to ignore this potential dilution, and thus, no correction for area size was made in development of the SSL.

Finally, the maximum activity concentration in air that corresponds to some maximum acceptable exposure level is specified to derive an SSL. The EPA guidance recommends a maximum absorbed dose rate to the lung of 0.01 mGy/year (1 mrad/year), and to bone of 0.03 mGy/year (3 mrad/year) after 70 years of chronic ingestion exposure. Dose to the bone and lung is a function of the lung clearance class. Dose to the lung is also a function of the size of inhaled particulate TRU elements. Clearance class refers to the pulmonary residence time and is a function of solubility. For insoluble compounds of TRU elements, a clearance Class Y corresponds to retention on the order of years. Although in the updated technical basis document (U.S. EPA 1990b) it is indicated that some plutonium oxides or other TRU elements may be cleared faster and, thus, result in doses to other organs that exceed the lung doses, the assumption of Class Y leads to lower allowable air concentrations based on dosimetric calculations and, thus, is conservative. Size of inhaled particulates with associated TRU activity is inversely proportional to dose received, although this is a rather weak relationship given that the dose decreases by only about a factor of five over the size range of 0.05 to 5.0 µm activity mean aerodynamic diameter (AMAD) (U.S. EPA 1990b). An AMAD of 1.0 µm was selected upon which to base the dosimetric relationship between suspended TRU activity and lung dose received. For a Class Y, alpha-emitting plutonium or americium compound of AMAD 1.0 µm, the atmospheric concentration corresponding to a 0.01 mGy/year (1 mrad/year) absorbed dose rate is approximately 9.6×10^{-5} Bq/m³ (2.6×10^{-15} Ci/m³) (U.S. EPA 1988, 1990b). Given a quality factor of 20 for alpha radiation, a concentration of 9.6×10^{-5} Bq/m³ corresponds to an annual committed dose equivalent of 0.2 mSv/year (20 mrem/year) to the pulmonary region.

Assuming the 0.01 mGy/year (1 mrad/year) pulmonary absorbed dose-rate limit, the SSL can be calculated from Eq. (2) as

$$SSL = \frac{9.6\times10^{-5}\ Bq/m^3}{100\ \mu g/m^3 \times 1.5 \times 10^{-9}\ kg/\mu g} \qquad (3)$$

resulting in an SSL of 640 Bq/kg (17 pCi/g) of soil. The SSL actually adopted for use at JA is 500 Bq/kg (approximately 13 pCi/g), based on the recommended SSL in the EPA proposed guidance of 7.4 kBq/m² (0.2 µCi/m²). Using Eq. (1), the soil concentration of 7.4 kBq/m² corresponds to an activity concentration in air of 7.4×10^{-5} Bq/m³ (2.0×10^{-15} Ci/m³), assuming a bulk soil density of 1.5 g/cm³ and considering only the top 1 cm of soil to convert soil concentration on a unit-mass basis to a unit-area basis. The 500 Bq/kg (13 pCi/g) JA SSL is, therefore, consistent with the 1977 EPA proposed guidance and corresponds to a 0.15 mSv/year (15 mrem/year) committed dose equivalent (7.5×10^{-3} mGy/year absorbed dose) to the pulmonary region based on dosimetry from the International Commission on Radiation Protection (ICRP) Report #19 (ICRP 1972).

The EPA proposed guidance indicates that this screening level should not be applied if contaminated soils contain americium and curium at activities that constitute more than 20% of the total TRU activity, due to the greater solubility of these radionuclides and, hence, greater possibility of larger doses via the ingestion pathway.

The SSL is based on air concentrations because inhalation of radioactive materials that have deposited on soils, and then are resuspended, is the more direct route of exposure. Ingestion of radionuclides like plutonium, which are poorly absorbed from the gastrointestinal tract before transport to the sensitive organ (i.e., bone), is a less significant hazard, according to EPA (U.S. EPA 1990a). An estimation of absorbed dose rate attributable to ingestion of crops, vegetables, beef, milk, and soil as a result of plutonium and americium soil contamination at RFETS (U.S. EPA 1990b), at levels of (0.25 μCi/m²) and (0.045 μCi/m²), respectively, was 0.65 mrad/ year to bone, based on a 70-year exposure duration. At the same soil contamination level for the top 20 cm of soil (the plow depth assumed in the ingestion dose calculations), the corresponding air concentration according to Eq. (1) would be 4.6×10^{-3} Bq/m³ (1.25×10^{-7} μCi/m³). This air concentration corresponds to an absorbed dose rate of approximately 48 mrad/year for a Class Y compound. Since the recommended dose limits for bone (the sensitive organ for the ingestion route) and lung are the same order of magnitude, and estimated inhalation doses to lung are significantly higher than ingestion doses to bone, for a given soil concentration, it is reasonable to base the SSL on inhalation doses.

More recent dosimetry (ICRP 1979), upon which DOE bases dose conversion factors, suggests that the 500 Bq/kg SSL (and related 7.4×10^{-5} Bq/m³ air activity concentration) corresponds to a 0.01 mGy/year dose rate, a 0.2 mSv/year annual committed dose to the lungs (ICRP 1979). The annual committed estimated dose equivalent (EDE) to the whole body is calculated by using tissue weighting factors, w_t, which represent the ratio of risk arising from each tissue (i.e., red marrow, lung, bone surfaces, and liver) to the total risk when the whole body is irradiated uniformly. Thus,

$$EDE = w_T H_{50,T} \quad (4)$$

where $H_{50,T}$ is the 50-year committed dose equivalent to tissue T, per unit intake of Pu-239. For inhalation of 1.0 μm AMAD particles of Class Y Pu-239, the weighted committed dose equivalents for each tissue per unit intake are:

Tissue	$\sum w_T H_{50,T}$
red marrow	9.1×10^{-6} Sv/Bq
lungs	3.9×10^{-5} Sv/Bq
bone surfaces	2.9×10^{-5} Sv/Bq
liver	1.2×10^{-5} Sv/Bq
Total	8.9×10^{-5} Sv/Bq

544

The total of these tissue-specific weighted committed dose equivalents represents a whole body committed EDE of 8.9×10^{-5} Sv/Bq intake of Pu-239. Multiplying the whole body EDE per unit intake by the air concentration of 7.4×10^{-5} Bq/m^3 (corresponding to the derived SSL), and an inhalation rate of 8400 m^3/year, give a whole body committed EDE of 5.5×10^{-5} mSv/year (5.5 mrem/year).

To compare the calculated committed doses to recommended dose limits other than EPA's, it is useful to consider the National Council on Radiation Protection and Measurements (NCRP) recommended limits on occupational exposure of 50 mSv/year committed EDE, a lifetime exposure to natural background radiation (excluding radon) of 1 mSv/year, and exposure of a maximally exposed individual at a power plant boundary of 0.1 mSv/year (NCRP 1987a, 1987b, 1989). The risk of fatal cancers associated with the above-recommended doses, according to NCRP, are 0.02, 0.001, and 0.0001 respectively. The SSL adopted by DSWA for JA corresponds to a committed EDE (0.055 mSv/year) that falls below the NCRP recommendations. Further evidence that suggests that EPA's SSL is appropriate for screening at JA comes from Garten (1980), who carried out a statistical analysis of the uncertainties in predicting dose to lung from plutonium using EPA's mass-loading model and concluded that the derived SSL is conservative because the likelihood of exceeding the proposed dose limits is small.

The EPA recommends that soil samples be taken to a depth of 1 cm and include all soil particles less than 2 mm in diameter, to obtain samples of soil that represent particles that may be resuspended (U.S. EPA 1990b). At JA, the SSL applies to dispersed activity in unscreened soil in an area not to exceed 0.1 m^3. Because "hot" particles are present in JA soils, a requirement also exists that activity of a 0.01 m^3 sample must be less than 5,000 Bq. However, conservative elements built into the sampling process include sample sizes of only 0.07 m^3, rather than 0.1 m^3, for comparison to the 500 Bq/kg limit, and sizes of only 0.0007 m^3, instead of 0.01 m^3, for comparison to the 5,000 Bq limit. This results in a 30% increase in conservatism and an associated reduction in the dose and risk limit achieved with the SSL.

7.2 SSLs at Other Facilities

Table 7-1 presents plutonium and americium clean-up criteria developed and used at various facilities. The clean-up guidelines at these sites range from 0.9 pCi/g to 200 pCi/g. The SSL of 13.5 pCi/g (500 Bq/kg), selected as the clean-up guideline by DSWA for the JAPRP, is well within this range. Indeed, it is lower than those at several similar sites.

The DOE has recommended using the RESRAD model to calculate risk-based soil clean-up guidelines at DOE sites. For comparison site-specific soil clean-up guidelines were calculated for JA using RESRAD. The resulting values were 40.8 pCi/g for a 30 mrem/year limit, and 136.0 pCi/g for a 100 mrem/year limit. These results are further evidence of the conservatism of the JA soil clean-up criteria.

545

Table 7-1. Plutonium and americium clean-up criteria developed and used at various facilities

Site	Responsible Agency	Pu/Am clean-up guideline		Comments
Enewetak Atoll	DNA/DOE	residential use: agriculture use: short-term visit:	40 pCi/g 80 pCi/g 160 pCi/g	
Hanford Reservation, Richland, Washington	DOE		30 mrem/year[a]	SSL based on dose rate clean-up to background reasonably achievable (ALARA standard)
Los Alamos National Laboratory, Los Alamos, New Mexico	DOE	^{238}Pu: ^{239}Pu:	27 pCi/g 24 pCi/g[b]	Weapons development (high levels in remote canyons)
Mound Facility, Miamisburg, Ohio	DOE	100 pCi/g, 25 pCi/g if reasonably achievable (ALARA standard)[c]		^{238}Pu in canal sediment
New Brunswick Laboratory New Jersey Site	DOE		200 pCi/g	^{239}Pu, ^{241}Am, and U (A 1985)
Boeing Michigan Aeronautical Research Center Missile Accident Site	USAF\EPA		8 pCi/g	Based on risk of 1 in 10,000 excess cancer r (USAF 1992)
Nevada Test Site	DOE		10 pCi/g	from U.S.DOE 1993a
Rocky Flats Environmental Technology Site	DOE	^{241}Am	209 pCi/g	Office worker exposu area, based on RESRA modeling (U.S.DOE 1
		^{239}Pu	1,088 pCi/g	
		^{241}Am	215 pCi/g	Open space exposure based on RESRAD modeling (U.S.DOE 1
		^{239}Pu	1,429 pCi/g	

[a] D. Stanton, U.S. Army Corps of Engineers, personal communication with D.S. Foster, ORNL, September 29, 1994.

[b] C. Mason, Los Alamos National Laboratory, personal communication with D.S. Foster, ORNL, September 30, 1994.

[c] C. Friedman, Mound Facility, personal communication with D.S. Foster, ORNL, September 30, 1994.

ALARA = as low as reasonably achievable
ANL = Argonne National Laboratory
CDH = Colorado Department of Health
DOE = U.S. Department of Energy
dpm = disintegrations per minute
EPA = U.S. Environmental Protection Agency
USAF = United States Air Force

546

7.3 Conclusion of SSL IV

DSWA developed SSLs for the TRU isotopes plutonium and americium at JA based on EPA SSLs. EPA SSLs result in estimated doses consistent with NCRP dose and risk recommendations. DSWA added additional conservatism by implementing their SSLs on a smaller soil volume. DSWA SSLs are within established regulatory guidelines and provide an adequate level of protection to the worker, the public, and the environment at JA. DSWA (formerly DNA) SSLs were verified through recalculation.

DSWA has opted to use the SSLs as their clean-up criteria. It is our opinion that this is an acceptable clean-up standard, based on comparison to clean-up guidelines used at similar sites. However, it would be valuable to the certification of the site to have written endorsement of this from EPA, as suggested in Number 34 of Appendix A. Other suggestions and concerns are listed in Sect. 10 of this report.

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548

Rocky Flats Coalition of Local Governments

City of Arvada | City of Boulder | Boulder County
City of Broomfield | Jefferson County | Town of Superior | City of Westminster

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May 11, 1999

Advanced Integrated Management Services, Inc.
5460 Ward Road, Suite 370
Arvada, CO 80002

Anna:

I am writing to request that your distribution fax sheet be updated to reflect the following changes:

1) DeAnne Butterfield is no longer the Executive Director; the new Director is David Abelson and he should replace her on the fax sheet.
2) The organization name has changed from RFLII (Rocky Flats Local Impacts Initiative) to RFCLOG (Rocky Flats Coalition of Local Governments).

Thank You!

Sincerely,

Katie Ewig
Office Manager

5460 Ward Road, Suite 205
Arvada, CO 80002
(303) 940-6090
FAX (303) 940-6088

549

KEN STARR

BOOZ · ALLEN & HAMILTON

5299 DTC BLVD, SUITE 410
ENGLEWOOD, CO 80111

FAX 303-694-7367
PHONE 303-694-4159 - GENERAL

IF POSSIBLE, PLEASE HOLD OFF FAXING INFORMATION UNTIL AFTER THE 19TH. THANKS

Ken -

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The following information confirms your: AUTOMATED DIAL IN RESERVATION ***NEW***

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Conference Date: 04/22/99 THU Start Time: 11:00 AM MDT
End Date: 04/22/99 End Time: 01:00 PM
Duration: 002 hr 00min 006 PORTS

Conference Host: CARLA STANDA
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PARTICIPANT CODE: 370737

04/20/99 01:48 PM EDT

Page 1 of 1 #225838

anna

From: [redacted]
Sent: [redacted]
To: [redacted]
Cc: [redacted]
Subject: Conf. Call

Mary, Hank, John;

The conference call you requested is scheduled for 11:00 am (Denver time) on Thursday, April 22. Carla or I will initiate the call, and you can join the call by dialing 1-888-422-7101. You will be asked your participant code, it is 370737. You can use any phone (John - cell phone is OK).

If others need to join in on the call, they can do so by using these same numbers. You can have 6 people on this call if you want to. If you need more, let me know & I will call & have them increase the reservation.

The call is ended when the host (Carla or I) hang up.

If you have questions, call me at 303-456-0884. Thanks, Anna.

552

ADVANCED INTEGRATED MANAGEMENT SERVICES, INC.

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COMPANY:	DATE: 4/20/99
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RE: Conf. Call

☐ URGENT ☑ FOR REVIEW ☐ PLEASE COMMENT ☐ PLEASE REPLY ☐ PLEASE SIGN

NOTES/COMMENTS:

553/553

5460 WARD ROAD, SUITE 370, ARVADA, COLORADO 80002
PHONE: 303-456-0884
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