Best Available
Copy

CORRES. CONTROL
OUTGOING LTR. NO.
DOE ORDER # _____

98-RF-02376

DIST	LTR	ENC
BENSUSSEN, S.		
BRAILSFORD, M		
BUHL		
CARD, R. G.		
HILL, J		
MANI, V		
MARTINEZ L		
NORTH K		
PARKER A		
TILLER R		
TUOR N		
VOORHEIS G		
Bormolini A	✓	
SHELTON D	✓	
NORTH K	✓	
CARR M		
Corsi J	✓	
file	4	
McCallister R	✓	
Karpatkin J	✓	
Chromec W	✓	
Law J	✓	
CORRES. CTRL	X	
TRAFFIC		
ADMIN REC		
PATS		

CLASSIFICATION:		
UCNI		
UNCLSSIFIED	x	x
CONFIDENTIAL		
SECRET		

AUTHORIZED CLASSIFIER SIGNATURE

Exempt from Class
Per CEX-266-95

IN REPLY TO RF CC NO.:

ACTION ITEM STATUS

___PARTIAL/OPEN
___CLOSED

LTR APPROVALS:

ORIG & TYPIST INITIALS

SKY :sel

RF-46469 (REV. 7/95)

1/61

KAISER•HILL
COMPANY

May 5, 1998 98RF-02376

Mr. LeRoy Moore
Rocky Mountain Peace and Justice Center
P.O. Box 1156
Boulder, CO 80306

RE: Proposal from Dr. Iggy Litaor to Complete Study Entitled "The Hydrogeochemistry of Plutonium in Soils of Rocky Flats, Colorado: A Case Study in Advanced Monitoring Program", CSD-005-98

Dear LeRoy:

I am in receipt of your letter dated April 6, 1998 in which you requested that Kaiser-Hill review a proposal from Dr. Iggy Litaor to complete a study titled "The Hydrogeochemistry of Plutonium in Soils of Rocky Flats, Colorado: A Case Study in Advanced Monitoring Program". Kaiser-Hill has given this proposal a thorough evaluation, and our estimate for funding Dr. Litaor's proposal (including site support) is about $40,000. As indicated in my letter to you dated April 13, 1998, Kaiser-Hill sent the proposal to the members of the Actinide Migration Studies Group for their evaluation. They have indicated to us that based upon the information provided, there is no clear benefit of the additional work to Rocky Flats Environmental Technology Site (Site) remediation. Also, they question how the additional two months at the Site would strengthen the conclusions made in the journal article.

This aside, Kaiser-Hill feels that since Dr. Iggy Litaor was a Kaiser-Hill Team contractor in FY96 and was paid to complete the work referenced above (which Kaiser-Hill believed was finished until we heard otherwise) that some additional effort and funds should be expended to allow Dr. Litaor to complete his work. However, Kaiser-Hill believes that Dr. Litaor does not need to return to the Site to complete the work referenced above since the task involves working with existing data. Our proposal is as follows:

- Kaiser-Hill will purchase the requested computer software (Visual MODFLOW, SPSS, Surfer, Grafer, and Microsoft Office) and send it to Dr. Litaor; and

- Based upon a detailed, specific inventory from Dr. Litaor of the RFEDS data and GIS mapping needed, Kaiser-Hill will send the data and maps on CD-ROM to Dr. Litaor (though besides ground water data for the 903 Pad area, Kaiser-Hill is uncertain as to what relevant data we may have that Dr. Litaor does not already have).

The cost for the purchasing the computer software and for the site support necessary to compile the RFEDS and GIS information is estimated at $10,000-$15,000 (depending on the amount of information requested). All activities (and associated data) funded by the Department of Energy (DOE) are the property of the DOE, and thus Kaiser-Hill requests the following: (1) all data

ADMIN RECORD

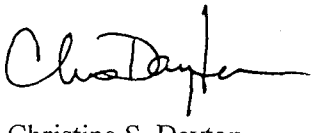
iser-Hill Company, L.L.C.
urier Address: Rocky Flats Environmental Technology Site, State Hwy. 93 and Cactus, Rocky Flats, CO 80007 • 303.966.7000
iling Address: P.O. Box 464, Golden, Colorado 80402-0464

associated with the hyrogeochemistry data (i.e., dissolved oxygen, rainfall simulation data, and other *insitu* measurements) that Dr. Litaor may have in his possession; (2) any data/calculations associated with the completion of Dr. Litaor's work; and (3) the software purchased for Dr. Litaor be returned to the Site upon completion of the work.

It is Kaiser-Hill's understanding that the cost of computer software and RFEDS and GIS information will complete Dr. Litaor's work, and thus no additional future funding for this work will be provided. The results of Dr. Litaor's work will be given to the Actinide Migration Studies Group for integration into the Actinide Migration Conceptual Model.

If this proposal is acceptable to Dr. Litaor, please have him forward his detailed, specific inventory of RFEDS data and GIS mapping requests. Please feel free to contact John Corsi at 966-6526 if you have any questions or require additional information.

Sincerely,



Christine S. Dayton
Regulatory Strategy
Kaiser-Hill, LLC.

cc:
Steve Gunderson, CDPHE
Russell McCallister, DOE-RFFO
Tim Rehder, EPA
Rocky Flats Citizen's Advisory Board

February 25, 1998

TO: Rocky Mountain Peace and Justice Center

RE: A Request for Additional Funding for the Completion of the Study Entitled: "The Hydrogeochemistry of Plutonium in Soils of Rocky Flats, Colorado: A Case Study in Advanced Monitoring Program"

The study of the hydrogeochemistry of Pu in the soils of Rocky Flats. Plant has started in 1992. The wet spring and summer of 1995 has challenged our working hypotheses and experimental results to date, especially in regard to Pu mobility in the soil environs. Unfortunately, the study was terminated in mid-course due to severe budget reduction and work-force reconstruction imposed on the Site by the Department of Energy (DOE). Several months later, limited funding was given to the principal investigator to write up the results of the geohydrological investigation. On July, 1996, I submitted a preliminary draft to DOE and K-H. The main findings of the study was the significant remobiliztion of Pu (up to 1 billion pCi) from the contaminated soils around the 903 area towards Woman Creek. On September 26, 1996, DOE provided me with a review of the draft which consisted on 34 comments and questions. I tried to answer most of these comments, however this effort was seriously hampered by the lack of the necessary software, no access to data base, and no technical support by the GIS facility, RFEDS personnel, and other experts on Site. During the summer of 1997, I spent 2 months rewriting the preliminary draft to a manuscript form and submitted it to Environmental Science & Technology. Early this year, I have received the review which recommends to divide the manuscript into two different papers: a groundwater modeling and a geochemistry paper (see attached review). Once again, I am facing with the dilemma of being away from the Site with its vast resources to perform the task. Hence, I am submitting this request for limited additional funding and *access* to the Site's resources to complete this important paper which should be the foundation for any future work such as recently attempted by the Actinides Migration Study.

The following are the resources I **must** have in order to successfully complete the paper:

1. Direct access to the following software (or equivalents) installed on a PC issued by DOE and/or its contractor: Visual Modflow, SPSS, Surfer, Grafer, & Miersoft Office. All these fairly expensive software packages (> $ 8,000) have been purchased by the Site over the years to support this project and others;
2. Direct and easy access to a GIS technical support; and
3. Easy access to groundwater and geochemical data from RFEDS.

The requirement for easy and direct access to software, database and technical support available on Site make the re-writing of the paper from a remote location difficult if not impossible. Hence, the bulk of my request for additional funding is for travel, lodging and living expenses while in Colorado. Because I am a college professor the best and the only time I am available for such a long period away from home is the summer months (July to September).

The following is a breakdown of the budget request:

Travel (Tel-Aviv to Denver and back)	$ 2,000
Rent (apartment in Boulder for two months)	$ 2,000
Living Expenses:	$ 3,000
Car Rental	$ 2,000
Miscellaneous	$ 1,000
Total:	$ 10,000

If you have more questions regarding this letter please contact me by phone, fax, or e-mail.

Sincerely,

M. Iggy Litaor
Associate Professor
Department of Biotechnology and Environmental Sciences
Tel-Hai College
Upper Galilee, 12210
Israel

OVER

Review of Manuscript No. ES970818T-26-a-0

Title: The Hydrogeochemistry of Plutonium in Soils of Rocky Flats, Colorado: A Case Study in Advanced Monitoring Program

Authors: Litaor, Litus, Barth, Zika, Moffitt, Daniels and Illangasekare

REVIEW

The article did not present a sound case for the conclusions made. It is clear that the mobility of plutonium is a key issue for contaminated sites such as Rocky Flats. However, the authors did not document the technical aspects of the work well before going on to a policy discussion on project funding.

The work presented in ES970818T-26-a-0 is a sound extension of previous site work, with the new material primarily centering around the hydrologic model and the plutonium flux calculations. As such, I would very much like to see a spatial calibration of the MODFLOW model, often shown using a residual map that subtracts the calibrated model heads from the measured heads. Maps of hydraulic conductivity and boundary conditions are appropriate. As described on pages 8 and 9, there is much more heterogeneity in the system than in the model. These data are fundamental to model verification. Typically, a transient simulation of a pumping or slug test is also often performed as model verification. Figures 1 & 2 need improvement. At a minimum, there should be a schematic illustration of the conceptual model being tested.

I'm not convinced that a model having a groundwater flux that is profoundly different from the observed flux is a calibrated model. The story isn't told in being conservative, but accurate. I also have a problem with altering boundary conditions on-the-fly, so to speak, as was described in the 1st full paragraph on Page 11. This paragraph defines boundary conditions for an "entire slope" conceptual model, a logical extension of the calibrated model, but with no documentation. Other questions: what's the uncertainty in Q? What is the impact of a 30% change in the head difference between the shallow and deep piezometers over the 65-day simulation period?

Regarding plutonium characteristics, the authors point to anaerobic conditions favoring the mobility of plutonium. I agree in principle, but I am not convinced by the work. A lot of emphasis is given to anaerobic conditions. Two data points, representing a 1.5 mg/L decrease in DO and a 0.6 pH units drop in pH does not provide a clear picture of anaerobic site conditions. The reader is not given eH measurements to work with. Three mechanisms for increased mobility are postulated, where do the author's stand? Both Tables 2 and 3 need work to better tell the story, more geochemical data would be great. Table 2 is confusing, better column headings and units are needed, and the caption launches into new ground with a statement concerning the correlation of soil water Pu activity to soil Pu activity. Table 3 is poorly organized. A better matrix of presentation is needed.

Finally, the environmental implications section should have some reference to risk. Without context, the Pu flux numbers don't have the needed barometer to understand the impacts.

RECOMMENDATION

I suggest that this submission be quickly turned into two separate articles. Article one should be a focused technical paper to a journal such as *Groundwater*. A second article focusing on the policy of Pu monitoring can then be put together succinctly. The second article has greater value as an editorial piece, based on well-documented fact.

Los Alamos

INSTITUTE FOR TRANSACTINIUM SCIENCE

April 15, 1998

Christine S. Dayton
Environmental Compliance and Management
Kaiser-Hill, LLC
P.O. Box 464
Golden, CO 80402-0464

April 15, 1998

Re: Letter from Mr. Leroy Moore, March 27, 1998

Dear Chris,

I would like to preface my comments with the fact that peer review of scientific data and interpretation of said data is an essential step in the scientific method. Every scientist has a professional obligation to perform their fair share of peer-reviewing, and their own scientific work must also withstand critical review by the scientific community. For my own part, I have published over 80 peer-reviewed publications, and in every case, I have had to subject my work to the criticism of my scientific peers. This is not always a pleasant exercise, but it is a necessary fact of life in scientific endeavors, and an important mechanism for getting at scientific truth.

During the past 10 years I have served in the capacity as a peer-reviewer for the *Journal of the American Chemical Society, Angewandte Chemie, Inorganic Chemistry, Polyhedron, Macromolecules, The Journal of Inclusion Phenomena and Molecular Recognition, Journal of the Chemical Society - Chemical Communications, Journal of the Chemical Society - Dalton Transactions, The New Journal of Chemistry, Chemistry - A European Journal, The Journal of Alloys and Compounds, Radiochimica Acta, Organometallics, Geochimica et Cosmochimica Acta*, and many others. I routinely perform peer-review of proposals for the National Science Foundation (US), the Office of Basic Energy Sciences (US), The Engineering Programs Science Research Council (EPSRC, Great Britain), the National Science and Engineering Research Council (NSERC, Canada), The Research Corporation (US), and others.

I was asked by Dr. Honeyman to examine a set of six documents provided by the Los Alamos Technical Office, and comment specifically on plutonium speciation, and whether, in my expert opinion, the fate and transport of plutonium at the RFETS had been adequately characterized and studied. I received NO funding for my participation in this review, and I treated the review like any other professional peer review activity. In addition to studying the six documents provided by LATO, I performed my own literature search on Dr. Litaor's work, and I looked into the history of the site to see what additional information I could glean. I submitted a seven page summary of my findings to the review team, and prefaced my remarks by stating "I do not have any experience in field work, groundwater monitoring, etc. Therefore, I will restrict my comments to those areas in

Mail Stop: D410 Los Alamos National Laboratory, Los Alamos, NM 87544 (505) 667-5054, fax (505) 667-7984

which I can make a knowledgeable assessment." In short, I found that an extensive monitoring program had been underway at the site for some time, that the data were undoubtedly valuable, but that the chemical form of plutonium and the mechanism of transport had not been adequately determined.

For my role in this peer review exercise, I acted totally independent of the other reviewers. I searched the literature for additional information, and I submitted my findings to the review team to be merged into a final document. As a reviewer I judged objectively the quality of the documents, the experimental and theoretical work, and the interpretations and expositions, with due regard to the maintenance of high scientific and literary standards. When the results of the review were questioned, the Site organized an opportunity for me to come hear Dr. Litaor present the full details of his work. Based on the above discussion, I applied the same scholarly and ethical standards employed in every peer review activity, and reiterate that I received no funding for my efforts. Based on the above, I find it hard to understand how Mr. Moore can possibly conclude that my reputation is somehow "tarnished" or that I acted in a "professionally questionable" manner.

Regards,

David L. Clark

David L. Clark

The Florida State University
Department of Chemistry
Tallahassee, Florida 32306-4390
Office: 850-644-3875
FAX: 850-644-8277
e-mail: choppin@chem.fsu.edu

April 14, 1998

Ms. Christine S. Dayton
Kaiser-Hill Company
PO Box 464
Golden, CO 80402-0464

Dear Ms. Dayton:

I have read the material you provided associated with the request by Dr. Iggy Litaor for additional funds to return to Rocky Flats to complete a report associated with his previous work at the site. I also appreciate your sending me a copy of Dr. Litaor's article in the Journal of Environmental Radioactivity published in 1997 which relates to this study.

Apparently, Dr. Litaor's request is based upon the recommendation in the quite critical review of a manuscript that he had submitted which suggested that the manuscript be divided into two separate articles, one a technical paper and the second on policy of Pu monitoring. Although I have not seen the manuscript in question, from Dr. Litaor's description in his request as well as in the review article of the manuscript, it would seem to have strong similarity to the reprint you provided which was published this year. Dr. Litaor notes that the study upon which the new manuscript is based was terminated in mid-course due to budget restrictions, but limited funding was provided to write a report on the results of the investigation prior to termination. Since the work was terminated in 1996 it must be assumed that it was not given a sufficiently high priority to compete with other studies. Also, as Dr. Litaor states, it was apparently terminated in mid-course which means that results can be viewed only as rather preliminary. As a consequence, it would seem that the resulting report would have quite limited value.

Dr. Litaor is requesting a rather significant budget to return for a two month period to revise his manuscript to meet concerns that were expressed on the preliminary draft. He states that the reason for such a extended stay is the necessity to have access to adequate software as well as to the data that had been obtained. He also notes that in addition to the $10,000 budget he will need an unspecified amount of GIS technical support which could easily double the budget. Given these conditions it would seem difficult to justify such an expense to complete a report on a study that was terminated "in mid-course" since it is unlikely that the results of that study would be sufficiently extensive to allow acceptable interpretation and prediction for future behavior. This is already apparent in the review of the manuscript provided in which it is stated that a sound case for the conclusions is not made. This is a very negative review and it seems very unlikely that revision alone is likely to make it more acceptable. Also the recommendation that it be focused into a technical paper requires that there be an adequate technical base. Such an adequate technical base is unlikely if this project was terminated in mid-course as stated unless additional technical work is

performed.

I conclude that the report would cover limited technical data. In view of that and the fact that it has already been questioned so strongly by the referees, use of such a report for the basis of a policy paper on plutonium monitoring does not seem acceptable. An additional question is where would such a policy paper be publishable? The referee states throughout the page of his review of the earlier report that more geochemical data is necessary but such data is not available due to the termination of the contract so acceptable revision seems unlikel and any further revision at present is probably a waste of funding.

If any research was continued after Dr. Litaor's departure, there should be technical personnel on site who would be capable of doing the necessary data calculations and modeling to revise the manuscript if it is of value to published. This would be a much less expensive procedure than bringing Dr. Litaor back.

In summary, based on the review of the manuscript and the fact the work was terminated in mid-course, there seems little value in spending the funds requested plus the funding that would be associated with the technical services associated with Dr. Litaor's two month stay. If DOE and Kaiser-Hill decide that the revision and publication of a final report would be of value, it would seem much more efficient and economical to have one of Dr. Litaor's associates such as Dr. Barth or someone else still on site to do the data revision and additional modeling and send it to Dr. Litaor for his final review. I recommend that the request by Dr. Litaor be rejected.

Sincerely,

Gregory R. Choppin

Gregory R. Choppin
R. O. Lawton Distinguished
Professor of Chemistry

GRC/kc

Los Alamos

NATIONAL LABORATORY

Chemical Science and Technology
Responsible Chemistry for America

Environmental Chemistry
and Waste Technology
CST-7, MS J514
Los Alamos, New Mexico 87545
(505) 665-0253, FAX 665-4955
Email: janecky@lanl.gov

May 3, 1998

Ms. Christine Dayton
Kaiser-Hill Company, L.L.C.
P.O. Box 464
Golden, Colorado 80402-0464
Fax: 303-966-5001

Dear Ms. Dayton,

RE: Review of "A Request for Additional Funding for the Completion of the Study Entitles: "The Hydrogeochemistry of Plutonium in Soils of Rocky Flats, Colorado: A Case Study in Advanced Monitoring Program"

Overall, this proposal to fund travel expenses and provide on site access to RFETS resources does not make a strong case. It is not clear how a hydrology modeling paper will be publishable, nor is it clear that such a paper can be the critical completion of Litaor's studies and underpinning of further work on the hydrogeochemistry of actinide migration.

Provision of a single technical review of the paper submitted to ES&T, without editor's comments and parallel reviews, gives a potentially skewed view of the peer review results. The draft paper would also, presumably, have provided a context for how publication can complete the study. Thus, key documents and referenced context to other documents reporting the findings of Litaor's team have not made available to those asked to review and potentially fund this proposal.

Within this incomplete presentation of the proposal, I perceive a different interpretation than Dr. Litaor in the direction suggested by the review. Rather than

> "a groundwater modeling and a geochemistry paper"

as proposed, the review states

> "...two separate articles. Article one should be a focused technical paper to a journal such as *Groundwater*. A second article focusing on policy of Pu monitoring...".

Technically, the reviewer's suggested approach focuses on actinide migration and avoids some of the limitations of a purely groundwater modeling paper. For example, application of Modflow to hydrologic modeling of the complex, heterogeneous system of local behavior within soils is not straight forward, as the reviewer points out. In addition, previous presentations and publications by Litaor on the complex structure of the soils, including root casts and animal burrows, indicates that continuum processes

(e.g. Darcy models embodied in Modflow) may not be appropriate at the scale of interest to evaluation and interpretation of Pu hydrogeochemical processes during the 1995 event.

In addition to my personal comments on the proposal, I solicited comments from Drs. Kirk Nordstrom and David L. Clark. Their responses (attached below) are similar in overall assessment, but provide different perspectives and detailed comments.

Sincerely,

Dr. David R. Janecky

cy: file

enc.

To: janecky@lanl.gov
From: "Darrell K Nordstrom, Hydrologist, Boulder, CO "<dkn@usgs.gov> (Kirk Nordstrom)
Subject: review comments

In regard to the proposal by Iggy Litaor:

In general, I find the justification inadequate to fund the travel expense proposal for Dr. Litaor because (a) it is not clear that 2 months of work with access to the site will make any difference to the data and the interpretation of the data, (b) the status of the manuscript "The hydrogeochemistry of plutonium in soils of Rocky flats, Colorado: A case study in advanced monitoring program" is not known at this time from the available information, and (c) it is not clear how site remediation will benefit from this expenditure.

Let me expand briefly on these points.

1. Dr. Litaor requests personal access to site data and computer software capabilities. I should like to know what data in particular he needs. There is data that he collected that no longer can be found at RFETS and if he doesn't have it then it must have permanently vanished. Clarification of data needs would help. Computer software needs are much easier to supply. I estimate that the software he requests could be purchased for about $2500 and with a small shipping charge it could be sent to him right away.

2. The main purpose of the travel grant would be to revise the manuscript submitted to ES&T according to a single reviewer's comments. ES&T does NOT solicit and reach a decision on the acceptability of manuscripts from only a single review. This action would constitute a breach of standard peer review procedures. ES&T always gets at least 2 reviews and more commonly it gets 3 reviews, sometimes 4 or 5 reviews. At this time we do not know what the decision was on the part of the ES&T editor who handled the manuscript, what the other review comments were, and whether the recommendations of the reviewer are sufficient to accept the manuscript. This information is, and should be kept confidential unless the senior author wishes to divulge it. If Dr. Litaor wishes to use the manuscript reviews as the main justification for the proposal, then he must provide the missing information regarding the other manuscript reviews and the editorial decision before DOE/KH/RFETS has a reasonable basis for making a decision on this proposal.

3. Although there is some indication as to the benefits to DOE, there really isn't an explicit description of how completion of this work will provide definite benefits for site remediation.

4. Much of the interpretive arguments in the manuscript are based on speculative statements regarding anaerobic conditions in the subsurface during the stormflow period of spring, 1995. What data will demonstrate the intensity and capacity of possible reducing conditions at that time?

Dissolved oxygen is not reliable for this task and a small drop in D.O. of 1.5 mg/L means nothing unless the final D.O. can be clearly shown to be less than 0.1 mg/L. Does he have other redox data or not? If not, I doubt there is any data at RFETS that shows this. Hence, this argument cannot be justified and the manuscript is not very denfensible.

5. The manuscript does not appear to be in good shape for publication and I find it hard to imagine that any amount of work is likely to change that situation very much. Supporting letters from the other authors pointing out how I may be wrong would go a long ways toward changing my opinion. Has Dr. Litaor talked to the other authors? Do they support his position? Since at least some of the other authors are working locally near the site, can't they access the necessary information? Wouldn't working through the co-authors be a more efficient way of getting the objective accomplished? If not, Dr. Litaor should explain.

6. With regard to MODFLOW modeling, I would insist that someone who uses MODFLOW (of which there are several people in the USGS) and who has applied it to real field situations, review the manuscript for scientific appropriateness. [Dave -- MODFLOW does not deal with vadose zone hydrology but during the spring of 1995 there was almost no vadose zone, so the model might give reasonable estimates if it was set up correctly] The MODFLOW analysis does not sound very carefully done to me.

Kirk Nordstrom

To: janecky@lanl.gov
From: Dave Clark <dlclark@lanl.gov>
Subject: Litaor review

Dave,

My reading of Dr. Litaor's proposal is that he needs access to data and software at the Site to revise a manuscript for ES&T. While revising the manuscript is of obvious interest to Dr. Litaor, I don't really see how RFETS will benefit. I do believe that Dr. Litaor should and will modify the manuscript to make it acceptable for publication in a peer-reviewed journal, but this could likely be done without spending $10,000. However, the only real benefit that Dr. Litaor will gain from Site access is to use computer software to refine his modelling, unless there is additional data available that the Site is not aware of. In the modern information age, it should be trivial to give Dr. Litaor access to the needed software via the internet, in the same way that we both run and monitor instrumentation over the internet at user sites like the EMSL or SSRL. Alternatively, why not just send the software to Dr. Litaor so that he can proceed with his data analysis in an unhurried fashion. From a technical perspective, I don't see any real scientific data that supports reducing conditions at the site. Its a reasonable hypothesis, but as yet unproven.

Regards,

Dave Clark

David L. Clark
Los Alamos National Lab
Los Alamos, NM 87545
(505) 665-6690 phone
(505) 667-7966 fax
dlclark@lanl.gov

RFP-1325.02 (REV. 3/98)
Previously RF-46522

CORRES. CONTROL
INCOMING LTR NO.

00537 RF 98

DUE DATE

ACTION

DIST.	LTR	ENC
BACON, R.F.		
BENSUSSEN, S.J.		
BORMOLINI, A.M.		
BOYTER, N.C.		
BRAILSFORD, M.D		
BURDGE, L		
CARD, R.G.		
COSGROVE, M.M.		
COULTER, W.L.		
CRAWFORD, A.C.		
DERBY, S.		
DIETERLE, S.E.		
FERRERA, D.W.		
FERRERA, K.P.		
GERMAIN, A.L.		
GILPIN, H.E.		
HARDING, W.A.		
HARROUN, W.P.		
HEDAHL, T.G.		
HILL, J.A.		
MARTINEZ, L.A.		
NORTH, K.		
PARKER, A.		
PHILLIPS, F.J.		
RHOADES, D.W.		
RODGERS, A.D.		
SANDLIN, N.B.		
SPEARS, M.S.		
TILLER, R.E.		
TUOR, N.R.		
VOORHEIS, G.M.		
Dayton, C	X	

COR CONTROL	X	X
ADMN RECORD		
PATS/T130G		

Reviewed for Addressee
Corres. Control RFP

4/9/98
Date By

Ref Ltr. #

DOE ORDER #

None

9 APR 98 2:39

RFETS-CC

States Government

Memorandum

Department of Energy

Rocky Flats Field Office

APR 8 1998

ELD:RJM:03342

Preliminary Evaluation of an Unsolicited Proposal from Peace Center on Behalf of Iggy Litaor Dated March 11, 1998

Hugh G. Miller, Contracts & Assets Management Division, RFFO

In response to your request dated March 23, 1998, asking for a preliminary evaluation of the unsolicited proposal from Iggy Litaor, the following is my evaluation:

I am following your guidance pursuant to FAR 15.503© on what a valid unsolicited proposal must have:

Be innovative and unique;

The proposal from Mr. Litaor is a continuation of his work that he was unable to finish under his previous contract. Therefore, it is not unique and innovative.

Be independently originated and developed by the offeror:

As far as I can tell, the proposal is his.

Be prepared without government supervision;

Again, as far as I know, no government assistant has been provided.

Include sufficient details to permit a determination that Government support could be worthwhile and the proposed would could benefit the agency's research and development or other mission responsibilities; and

The proposal is an continuation of his work previously generated under another contract. If Mr. Litaor provided all the necessary information, the Site could finish the study with expertise already under contract to assist in the Actinide Migration Workgroup.

Not be an advance proposal for a known agency requirement that can be acquired by competitive methods.

The Site currently is supporting an Actinide Migration Workgroup that has as its charter, to look at the very same things that Mr. Litaor is proposing to research.

Conclusion:

Based on the above set of criteria that you provided, the proposal does not meet all the criteria and therefore does not merit further evaluation.

Russell McCallister
Regulatory Liaison Division

cc:
J. Legare, AMEC, RFFO
J. Karpatkin, CED, RFFO
B. April, ELD, RFFO
C. Dayton, K-H

The Hydrogeochemistry of Plutonium in Soils of Rocky Flats, Colorado: A Case Study in Advanced Monitoring Program

by

M. Iggy Litaor[*†], G. Litus[‡], G. Barth[¶], E.M. Zika[§], J. Moffitt[§], H. Daniels[#], and T. Illangasekare[¶]

University of Colorado, Department of Civil and Environmental Engineering

Boulder CO 80409-0428

* Corresponding author telephone: 972-6-6900978; fax: 972-6-6900985; e-mail: litaori@telhai.ac.il

† Current Address: Tel-Hai Rodman College, Upper Galilee 12210 Israel

‡1264 Beaver Brook Canyon Rd. Evergreen, CO 80439

¶ University of Colorado, Department of Civil and Environmental Engineering

Boulder CO 80409-0428

§ Hydrosphere, 1002 Walnut St. Suite 200, Boulder CO 80302

PTI Environmental Services, 4940 Pearl East Circle, Suite 300, Boulder CO 80301

Summary

During the spring of 1995, more than 24.9 cm of precipitation fell on Pu-contaminated soils in Rocky Flats, Colorado. The resulting throughflow, which lasted for at least 65 days, saturated the soils, rendering them anaerobic. Using conservative assumptions, we calculated a minimum of 8.2 MBq of Pu was transported across a heavily instrumented toposequence. With less stringent assumptions, more than 50 MBq of Pu were transported across the entire contaminated slope. The observed Pu flux resulted partly from the dissolution of sesquioxides under anaerobic conditions, coupled with a shift in Pu fractionation from mainly particulate phase to increase in colloidal and dissolved Pu. This hydrogeochemically induced transport mechanism was not envisioned under any previous transport scenario, and it challenges the framework of remedial investigation/feasibility studies in hazardous waste site, in the sense that long-term advanced monitoring of the soil environs should be required.

Introduction

Plutonium contamination of soils at Rocky Flats Plant (RFP), located 25 km northwest of Denver, Colorado, originated primarily from a former storage area where steel drums were used to store plutonium-contaminated industrial oils from 1958 to 1968 (1,2). Many studies were conducted over the years to ascertain the influence of Pu on the ecosystem (3-5). More recently, an extensive characterization program was undertaken to study the physicochemical behavior, spatial distribution, and transport mechanisms of radionuclides in the soils of Rocky Flats (6-11). Small-scale (6 m^2) rain simulations did not transport significant amounts of Pu and Am from the contaminated soil to groundwater (12). Large-scale (180 m^2) rain simulations of 100-yr. recurrence interval, transported 1 to 3.3 % of the Pu and Am stored in these soils to groundwater (13). The general conclusion of this program was that Pu, Am, and U isotopes are fairly immobile in the soil environs.

The spring of 1995 was unseasonably wet. Total precipitation at Rocky Flats during the months of April and May exceeded 24.9 cm (a 25 to 50-year event), which is more than 200 % of the average precipitation for this period (14). A May 17 storm (a 15-yr event) produced significant overland flow, which remobilized at least 0.01 MBq of Pu-239+240 between the instrumented site and the southern interception ditch (Fig. 1)(15). Following the runoff, the soil became completely saturated and emanated strong decay odors; localized ponding and runoff episodes were also observed.

A thorough understanding of the fate and transport of Pu in soil, is essential for the selection of remedial alternatives, and potential litigation issues regarding the affected areas. Hence, the objectives of the present study are: 1) to assess the hydrogeochemical behavior of Pu in the soil environs during the spring and summer of 1995, and 2) to evaluate the impact of

Pu transport on the enivironment within the framework of the remedial investigation/feasibility studies (RI/FS) in hazardous waste site such as RFP.

Methods

Field Description

To assess the fate and transport of radionuclides in contaminated soils, an advanced monitoring system (MS) was installed during 1992 in five pits (TR 1 to 5) along a southeast-facing toposequence (Fig. 1). Pit 1 located at the toeslope was classified as fine-loamy, mixed (calcareous), mesic Cumulic Haplustoll. Pits 2 to 4 located along a colluvial footslope position were classified as fine-loamy, mixed, mesic Aridic Argiustoll. Pit 5 located at a steep backslope position was classified as loamy-skeletal, mixed mesic Aridic Argiustoll (12). Pit 8 located on the mesa above the toposequence (Fig. 1) was classified as loamy-skeletal, mixed mesic Aridic Haplustalfs. The toposequence exhibits a reclaimed mixed grassland transected by a wet meadow/marsh ecotone.

Monitoring System

The monitoring system (MS) consisted of ten major modules: (1) automated zero-tension samplers (ZTS) that collected water flowing gravitationally, mainly through macropores; (2) lateral zero-tension samplers that collected water flowing laterally through a cross section of 174 cm^2; (3) tension samplers (TS) (also known as tension lysimeters) that collected interstitial water at matric potential greater than -5 kPa; (4) time-domain reflectometry (TDR) probes, which measured in-situ volumetric water content; (5) automated piezometer network that monitored groundwater level; (6) temperature probes; (7) snowmelt monitoring system; (8) automated monolithic, weighing evapotranspiration lysimeter and evaporation pans; (9) micrometeorological tower, and (10) a telemetry communication

network coupled with a graphic user interface that processed and archived the data (see refs 12 & 13 for detailed description of the monitoring system).

General Analyses

The soil interstitial water collected from each ZTS and TS was measured to the nearest 1 mL using a graduated cylinder and briefly described for appearance (i.e., color, clarity, sediment content, and biota-i.e., earthworms). Specific conductance, temperature, pH, dissolved oxygen, and alkalinity were measured in the field, following approved standard operating procedures (16). The Pu-239+240 activity in unfiltered samples of the soil interstitial water were measured by alpha spectrometry in a commercial laboratory. Samples exhibiting biological components were ashed in an oven at 425-450 °C for 8 hours. The residue was transfer to a teflon beaker and was completely dissoved by repeated treatment of HF, 8N HNO_3, and saturated H_3BO_3. Once the solution was clear, it was then passed through an anion exchange column to separate the Pu from the solution. The Pu was eluted from the column with HCl-NH_4I solution, acidified with HNO_3, and heated to dryness. The sample was redissolved and electroplated onto stainless steel discs. Upon completion of the electroplating, NH_4OH was added to the solution to prevent redissolution of the deposit.

Fractionation of Pu in Soil Interstitial Water

Fractionation of radionuclides into suspended particles ($x > 0.45$ µm), colloidal (0.45 µm $> x >$ 10 kD), and dissolved (< 10 kD) was determined on six samples collected in June, and July 1995, using a fractionation scheme involving ultrafiltration and tangential flow filtration (17, 18). Particles larger than 0.45 µm were separated from solution using the Amicon TCF-10, thin channel ultrafiltration system. This system consisted of a peristaltic pump that circulated the solution through a spiral thin-channel, producing laminar flow over

the PCTE 90 mm diameter 0.45 μm membrane. Subsequent fractionations were achieved with the Minitan ultrafiltration system of Millipore Corp. The Minitan tangential flow filtration operates by pumping solution tangentially across a membrane. Particles and molecules smaller than the membrane pores are forced through the membrane by the pressure inside the manifold and are collected as filtrate. The Minitan system separated the sample into two size fractions: i. 0.45 μm ≥ x ≥ 10kD, and ii. x < 10kD. To achieve this particle size separation the Durapore PT series 10k Daltons membrane plates were used. The entire tangential flow filtration process was conducted under nitrogen atmosphere to prevent exposure to ambient air and minimize significant changes in the pH and redox potential of the soil solution.

Model Description

A single layer, three-dimensional numerical finite difference flow model was used to simulate head distribution along the toposequence (~ 17000 m^2), the entire slope (~ 85000 m^2) (see below for boundary definitions), and perform flow calculations across the seepage face. The computer code MODFLOW was selected because it is widely used and well documented (19). The water table remained at the surface for 65 days, thus, a steady-state model was used for that period. It should be noted, that the water table remained near the surface, at depth of 20 to 40 cm for at least 100 days, however to simplify computation and assumptions involved in water flux, only the complete saturation condition was used for head and flux calculations.

The spatial discretization of the slope was derived from the pit size (6 m long). A constant-head boundary was assigned between well 191 located at the northwest corner of the monitored area and well 13591 to the east, and well 1587 to the south (Fig. 1). The values for the constant head boundaries were derived from groundwater elevations measured in these observation wells during the saturation period.

A general-head boundary (GHB) was assigned between seep SW-053 and SW-051. This GHB represents a natural hydrologic boundary as can be seen from the seep vegetation, seeps' locations (Fig. 1), and observed surface flow during the saturation period. The conductance term in the GHB was computed from the measured saturated hydraulic conductivity (Ks) in TR-1, the thickness of the seep face in SW053, and the area of the seep face within the finite-difference cell.

The initial model parameters such as Ks (12), head distribution, and layer thickness were measured in the field (TR 1 to 5). The three meter depth of the single layer model was determined from the average depth to the subcropping sandstone across the toposequence. The bottom elevation of the single layer model was computed by kriging the 70 locations of surface elevation surveyed across the entire toposequence. The single layer model was divided into six different property zones which represent the hydrological properties measured at each pit along the slope and the mesa above the toposequence.

Pu Inventory and Flux

Plutonium inventories in the soils were calculated using 82 Pu analyses and 80 bulk density measurements taken across the study area (6, 9, 20). The spatial analysis was conducted using a pairwise relative variogram following by ordinary kriging using the Geostatistical Software Library (21).

The estimated Pu flux across the seepage boundary was performed by taking the various Pu activity statistics (e.g., mean and 75 % quartile) measured in the unfiltered interstital water multiply by the flux calculations adjusted to the appropriate sampling depth. For example, the water flux calculation through the three meter depth layer was adjusted to a

depth of 20 cm of the first sampling horizon times the Pu statistics of this layer. Similar computations were performed for the other sampling depths.

Results and Discussion

Water Flux Characteristics

During the May 17 runoff, the soil moisture content increased significantly in all sampling depths, and the water table rose to 80 cm below the ground surface (Fig. 2). Following the runoff, the soil began to dry, with a concurrent drop in groundwater elevation. On May 29, 1995 the soils (TR 1 to 4) became completely saturated because the groundwater rose to the soil surface. These conditions persisted for at least 65 days, with a distinct pattern of groundwater response: the shallow groundwater (0 to 4.5 m) that originated from a sandstone layer remained at the surface, while the deeper groundwater (> 4.5 m) contained within a mixed silt- and claystone that underlies the sandstone, quickly declined (Fig. 2).

In July of 1995, a flux test was performed using two lateral zero-tension samplers installed at 0.5-0.7 m, in TR 2 and 3 yielded a flow of 35 to 40 $m^3\ m^{-2}\ d^{-1}$. This sizable lateral flow was in striking contrast to the complete lack of lateral flow observed during the previous 3 years of monitoring and numerous rain simulations (12, 13). The two flux tests consisted of continuous sampling of soil solutions (~ 1L/min) during 3 hours period.

The nature of the water table surface (Fig. 2), the azimuth and magnitude of the measured lateral flux, and the geological data (22) suggested two concurrently operating recharge mechanisms. Paleochannels incised into the sandstone and claystone underlying the Rocky Flats Alluvium (22, see Figures 3.5-6 to 3.5-16) filled with recharge water, which eventually overtopped the southern paleoridge, and flowed southward, creating a group of ephemeral seeps (Fig. 1). Secondly, within the central and eastern portions of the toposequence, a subcropping sandstone

layer rests in hydrologic contact with the alluvium-filled paleostream above it and provides a conduit to drain the water-filled paleochannel. During the spring and summer of 1995, a hydraulic head of approximately 15 m developed between the paleostream (well 13591, see Fig. 1) and the toeslope position (TR 1 & 2), resulting in sizable lateral flow across the toposequence.

The comprehensive data set collected by the MS allowed the use of a numerical model to estimate the water flux across the toposequence. A trial-and-error calibration was used to match the calculated and observed heads (Table 1). The calculated piezometric surface at the toeslope was overestimated by 0.2 m, whereas the piezometric surface at the backslope position (TR 5) was underestimated by 0.6 m. These results are conservative because the total modeled head was lower than the observed, resulting in a smaller flux. The calculated flux varied between 0.23- to 0.97 $m^3 m^{-2} d^{-1}$, compared with the observed flux of 35- to 40 $m^3 m^{-2} d^{-1}$. The profound difference between the modeled and the observed flux is explained by the averaging of the calculated flux over the slope, whereas the observed flux was measured once, in two locations, at the toeslope where the hydraulic head difference was the greatest. The calculated flux should be considered as a conservative estimate to the true water flow ensued following the unseasonably wet spring and summer of 1995, especially because surface flow was also observed during most of the saturated period (65 d), but was not considered in the simulation due to difficulties in measuring reliable data across the entire toposequence (14).

Sensitivity analysis tested the uniqueness of the calibrated model using Ks as the most significant parameter in terms of flow. This selection is justified because the measured head was constant and extremely reliable, and the boundary conditions are grounded within the conceptual design of the toposequence. The most responsive section of the toposequence to change in Ks was the toeslope where the subcropping sandstone and the saturated soil are in

hydrological contact. Reducing Ks by half at the toeslope position produced the smallest error between the observed and the calculated head (Table 1). Under these calibration conditions the model results exhibited less than 0.06 % discrepancy in water balance.

Pu Flux Characteristics

Plutonium activity in the top soil (0 - 0.2 m) ranged from 2,200 Bq/kg at the toeslope position (TR 1), to 11,500 Bq/kg at the backslope position (TR 5), to 164,000 Bq/kg at the summit of the toposequence (TR 8). In soil interstitial water, Pu exhibited the highest activity in the top sampling depth of Pit 5, followed by a systematic decrease across the toposequence and with depth of sampling ($F = 45$, $P < 0.001$; $F = 140$, $P < 0.001$ respectively).

The Pu activity in soil solution exhibited an exponential decrease with depth of sampling, but showed a considerable increase in seep water at SW-53 (Fig. 3). The mean Pu activity in the seep water was higher than the mean activity in interstitial water collected from the 0.2-0.4 m sampling depth, attesting to the influence of more-contaminated water discharging from the top sampling depth (0 - 0.2 m) into the seep face.

To estimate the total amount of Pu transport across the toposequence, the Pu activities in the soil solution (Fig. 3) were multiplied by the calculated water flux (Table 2). Between 8.2 to 9.9 MBq of Pu were transported during the period of saturation. The depth to groundwater along the mesa above the toposequence varied between 2 m at the former storage area to 1.2 m at well 2684, located in the eastern section of the mesa (Fig. 1). Hence, it is highly probable that the hydrogeological conditions observed in the toposequence prevailed elsewhere across the 'entire slope' shown in Fig. 1. The 'entire slope' is defined as the area between the former storage site and the western edge of the seep vegetation, to the steep slope between well 2684 and seep SW053. The selection of the eastern bounds of the 'entire slope' conceptual design was

primarily based on field observations during the stauration period where considerable water flow was reported in an old drainage ditch which diverts groundwater flow originating from the slope east and above seep SW053 into the drainage system of seep SW053.

A constant-head boundary was assigned between well 191 and well 2687 to the east, whereas GHB was assigned between the western edge of the seep vegetation through seep SW053 to the eastern edge of the subcropping sandstone (Fig. 1). Using these boundary conditions for the 'entire slope' conceptual design (~ 85000 m^2) coupled with other model specifications as stated before, yielded a Pu flux of at least 50 MBq.

The Pu inventory across the toposequence ranged between 4,200 MBq in the top sampling depth to 10 MBq in the deeper sampling depth. The estimated flux of Pu suggested that less than 1% of the stored Pu in the top 0.2 m of soil was remobilized and left the slope during the spring and summer of 1995 (Table 2). However, a significant increase in the relative remobilization (~ 8 %) of Pu was observed with depth. The persistent throughflow transformed the generally aerobic soils of the toposequence to water-logged and anaerobic (< 2mg L^{-1} DO) soils. The anaerobic conditions probably facilitated enhanced dissolution of Fe and Mn oxides, to which as much as 40 % of Pu is adsorbed (11). Hence, the potential dissolution of iron and manganese oxides may result in release of Pu to the soil solutions.

There are two other auxiliary data sets that support the above proposed transport mechanism. First, a shift in Pu fractionation in soil interstitial water was observed probably due to decrease in DO and pH during the saturation period (Table 3). Samples collected at deeper depths (40 - 70 cm) exhibited higher percentages of dissolved and colloidal Pu. These sampling depths exhibited ~~more anaerobic~~ conditions compared with samples closer to the surface that displayed higher percentages of particulate Pu coupled with more aerobic

conditions (Table 3). This pattern supports the notion that increased Pu mobility in the soils was a function of reducing conditions that enhanced the dissolution of sesquioxides which in turn released adsorbed Pu in a dissolved or colloidal phase into the soil solution. Second, Pu in the soil of RFP, resides mainly in poorly defined discrete particles which contained up to 40% by weight Pu in a non-crystalline or organic substrate (23). If this poorly defined substrate is being destroyed by changing the redox potential, Pu will be released to the soil solution as was suggested above.

Additional important inference of the Pu fractionation experiments under anaerobic conditions (Table 3) and aerobic conditions (13) is the justification for our calculation approach to Pu flux in the soil environment. Considerable amount of the Pu is being transported in a particulate phase, irrespective to the redox conditions. Hence, the use of an advection-dispersion equation to compute Pu flux is inappropriate because the inherit requirement for a partition coefficient (Kd) that does not represent adequately the Pu mode of transport (mostly as particulate and colloidal) in this contaminated media.

Environmental Implications

The throughflow across the slope was collected by an interception ditch (SID) (Fig. 1), that drained into a holding pond. Flow data in the SID coupled with Pu measurements performed between May and July, 1995, yielded Pu flux estimate of at least 5.3 MBq. Similar calculations performed at the effluent of the holding pond yielded Pu flux estimate of 0.02 MBq that was released offsite. The difference between Pu inflow and outflow to the holding pond and Pu flux across the slope above the SID suggested that most of the transported Pu was retained by the soils across the slope and the pond sediments. However, the drainage efficiency of the SID has never been tested, thus it is plausible that some of the throughflow

bypassed the SID and flowed offsite, resulting in higher Pu release to the water supplies of the Greater Denver area.

Site investigation and remediation under the Superfund program follows the remedial investigation/feasibility study (RI/FS) process. The goal of the RI/FS is to reach a record of decision (ROD) regarding cleanup options in a timely manner. Studies performed during Phase II of the RI/FS suggested that Pu and other radionuclides remained largely immobile in soils (6-13). Therefore, a no-action remedial selection for Pu contaminated soils (< 60 MBq) was considered. Phase II studies were conducted from 1992 to 1994, during which time the groundwater elevation above the paleochannel was below average. Significantly higher groundwater levels had been observed between 1989 and 1991; hence, the need for long-term monitoring to ensure that the fate and transport of Pu and other radionuclides are better understood, and the risk to the public and the environment is minimal was also recommended. The hydrogeochemically induced transport mechanism described above was not envisioned under any previous environmental and hydrogeochemical modeling scenarios for Rocky Flats (24). Unfortunately, major reductions in funding for environmental restoration were implemented in mid-1995, with little regard for the RI/FS process. The MS was partially disabled and plans were in place for its removal. Had this removal been accomplished, the massive transport of Pu in soils would not have been recorded, and the ROD may have been signed by the regulatory agencies, without this knowledge.

Clearly, the situation described above represents a new challenge to the scientific community and DOE. The common wisdom that Pu in soils of a semi-arid environment is largely immobile has been shown to be an oversimplification. On the other hand, the widely accepted notion, that Pu in colloidal size has been transported over long distances in a shallow

aquifer near Los Alamos, New Mexico was recently seriously challenged (25). A call was made for shifting resources toward 'actual problems' and away from monitoring Pu in groundwater. The results presented here, clearly demonstrated that intensive monitoring of Pu contaminated sites which are in close proximity to a large urban area should be mandatory! If a similar event would occurred today at RFP, while the MS is completely disabled, it will be difficult, if not impossible to assess the magnitude and the ecological ramification of Pu transport in the watershed.

References

1. Krey, P.W. and E.P. Hardy, 1970. Plutonium in soil around the Rocky Flats Plant. HASL-235.

2. Seed, J.R., K.W. Calkins, C.T. Illsley, F.J. Miner, and J.B. Owen. 1971. DOW Chemical Company, RFP-INV-1.

3. Little, C.A. and F.W. Whicker. 1978. Health Phys. 34:451-457.

4. Little, C. A., F.W. Whicker, and T.F. Winsor. 1980. J. Environ. Qual. 9:350-354.

5. Martell, E.G. 1975. NCAR-TN/STR-110.

6. M.I. Litaor, M. L. Thompson, G. R. Barth, and P.C. Molzer. 1994. J. Environ. Qual. 23 1231-

7. Litaor, M.I. 1995b. J. Environ. Qual. 24:314-323.

8. Litaor, M.I. 1995a. J. Environ. Qual. 24 506-516.

9. Litaor, M.I., D. Ellerbroek, L. Allen, Erika Dovala. 1995. Health Physics. 69:923-935.

10. Litaor, M.I., and L. Allen. A. 1996. Health Physics. 70:1213-1223.

11. Litaor, M.I. and S. Ibrahim. 1996. J. Environ. Qual. 25: 1144-1152.

12. Litaor, M.I., G.R. Barth, E.M. Zika. 1996. J. Environ. Qual. 25 671 -

13. Litaor, M.I., G.R. Barth, E.M. Zika, G. Litus, J. Moffitt, & H. Daniels. J. Environ. Radio. in press.

14. Zika, E.M. 1996. Master Thesis, University of Colorado.

15. Litaor, M. I., unpublished information.

16. EG&G 1991. Environmental Management Department. Volume II. Manual No. 5-21000-OPS-GW. Rocky Flats Plant, Golden CO.

17. Harnish, R. A., D. M. McKnight, and J. M. Ranville. 1994. U.S. Geological Survey. Water-Resources Investigations Report 93-4175.

18. Litus, G.W. 1996. Unpublished Master Thesis, University of Colorado.

19. McDonald, M.G. and A.W. Harbaugh. 1988. U.S. Geological Survey, MODFLOW, Book 6 Modeling Techniques.

20. Webb, S.B., J.M. Stone, S.A. Ibrahim, and F. W. Whicker. 1994. Preliminary Draft, Colorado State University, Department of Radiological Health Sciences, Fort Collins, Colorado.

21. Deutsch, C.V. and A. G. Journel. 1992. GSLIB-Geostatistical Software Library and User's Guide. Oxford University Press, New York, 340p.

22. Final Phase II RFI/RI Report 903 Pad, Mound, and East Trenches area Operable Unit No. 2. RF/ER-95-0079.UN (1995).

23. McDowell, L.M. and F.W. Whicker. 1978. Health Physics, 35:293-299.

24. EG&G 1991. RF/ER-95-0079.UN (Rocky Flats Inc. Golden Colorado.

25. Marty, R.C., D. Bennett, and P. Thullen. 1997. Environ. Sci. Technol. 31:2020-2070.

Table 1.Calibration statistics before and after sensitivity analysis.

Piezometer /Pit/well*	Observed Head	Calculated Head (before)	Error	Calculated Head (After)	Error
		m			
TR-5	1806.9	1806.3	0.6	1806.7	0.2
TR-4	1804.6	1804.3	0.3	1804.6	0.02
TR-4	1803.1	1803.0	0.1	1803.0	0.1
TR-3	1802.9	1803.1	-0.2	1803.0	-0.1
TR-2	1801.0	1800.9	0.1	1800.8	-0.2
Well 11791	1800.4	1800.2	0.2	1800.0	0.4

*Ks in the toeslope multiplied by 0.5 exhibits the lowest reduced sum of squares. All the Ks were measured in the field (12).

Table 2. Statistics of Pu flux (activity and percentage) across the toposequence.

Depth	Mean	75 % Quartile	Inventory
m		MBq (%)	
0.0 - 0.2	5.7 (0.13)	6.8 (0.16)	4200
0.2 - 0.4	1.1 (0.45)	1.1 (0.45)	240
0.4 - 0.7	0.5 (5.0)	0.8 (8.0)	10
0.7 - 3.0	0.9 (ND)	1.2 (ND)	ND
Total	8.2	9.9	

The 75% quartile better represents the range of Pu flux because the soil solutions were mainly collected at the lower reaches of the toposequence, which exhibited the least amount of Pu (6,12). The mean activity of Pu in the soil interstitial water collected in the top sampling depth across the toposequence was highly correlated with Pu activity in the soil samples. This correlation exhibited a small standard error and was highly significant ($P < 0.001$).

Table 3. Mean concentrations of dissolved oxygen (DO), pH, and fractionation results (range) of Pu-239+240 in soil interstitial water collected from TR 2 & 3 in June and July 1995.

Depth of Sampling (cm)	n	0 - 40	40 - 70
DO (mg L^{-1})	3	3.96	2.46
pH	3	7.40	6.83
Temperature °C	3	12.2	11.2
Pu-239+240		%	
> 0.45μ	3	40 - 73	21 - 39
0.45μm > X > 10kD	3	28 - 60	39 - 64
< 10K Daltons	3	2 - 10	15 - 25

Figure 1. The toposequence is the area between well 191, 13591, ephemeral seep SW051 and SW053 (~ 17000 m^2). The 'entire slope' is the area between the former storage area, well 2687, the western edge of the seep vegetation, and the ephemeral seep SW053 (~ 85000 m^2).

Figure 2. The depth to water table from ground surface recorded in Pit 2. Similar hydrological conditions were observed across the toposequence.

Figure 3. Plutonium distribution in soil solutions and seep water (SW-53) sampled between May to July, 1995. Soil solutions were collected by zero-tension samplers (0 - 0.7 m), tension samplers (0.7- to 2.7 m), and wells (2.7- to 6.6 m). The boxplot depicts the limits, quartiles, mean, outliers (o) and extremes (*).

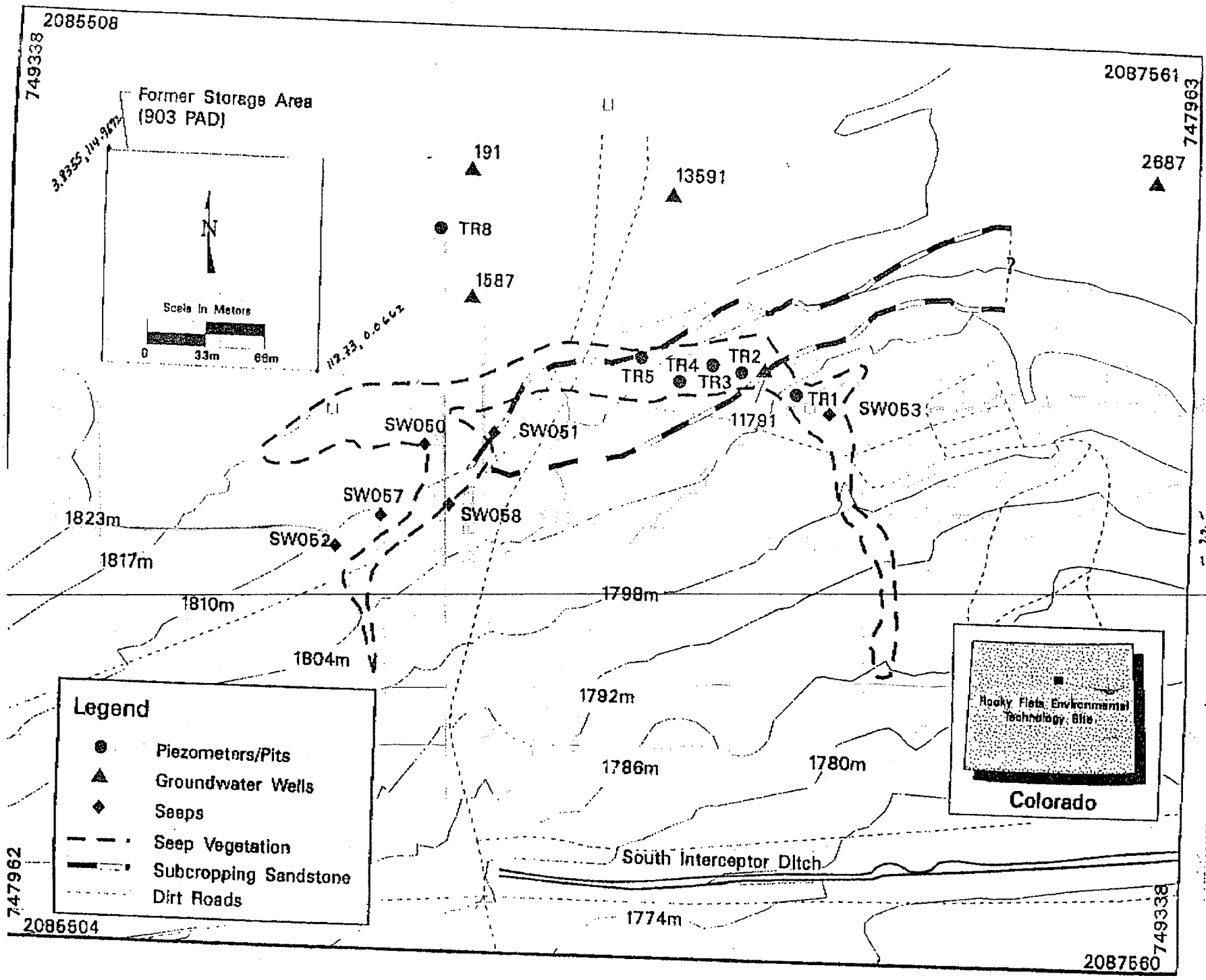
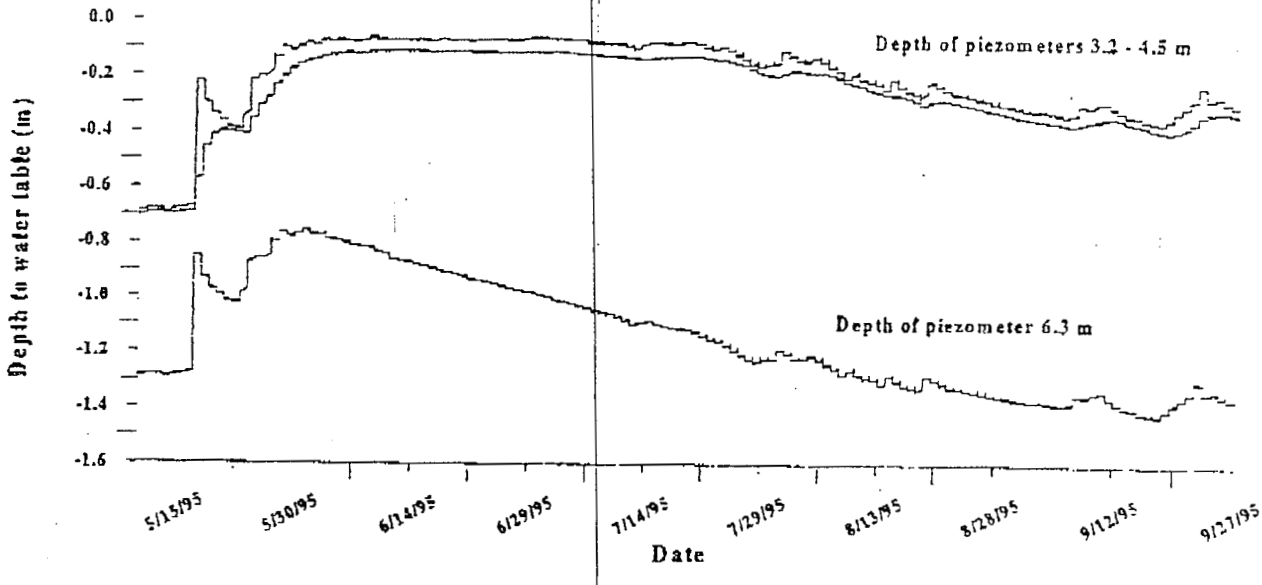

2085508
749338
2087561
747963
Former Storage Area
(903 PAD)
N
Scale in Meters
0
33m
66m
191
13591
2687
TR8
1587
TR5
TR4
TR3
TR2
TR1
11791
SW053
SW050
SW051
SW057
SW058
SW052
1823m
1817m
1810m
1804m
1798m
1792m
1786m
1780m
1774m
Legend
Piezometers/Pits
Groundwater Wells
Seeps
Seep Vegetation
Subcropping Sandstone
Dirt Roads
Rocky Flats Environmental Technology Site
Colorado
South Interceptor Ditch
747962
2086504
2087560
749338

Figure 2


Depth of piezometers 3.2 - 4.5 m
Depth of piezometer 6.3 m
Depth to water table (in)
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
5/15/95
5/30/95
6/14/95
6/29/95
7/14/95
7/29/95
8/13/95
8/28/95
9/12/95
9/27/95
Date

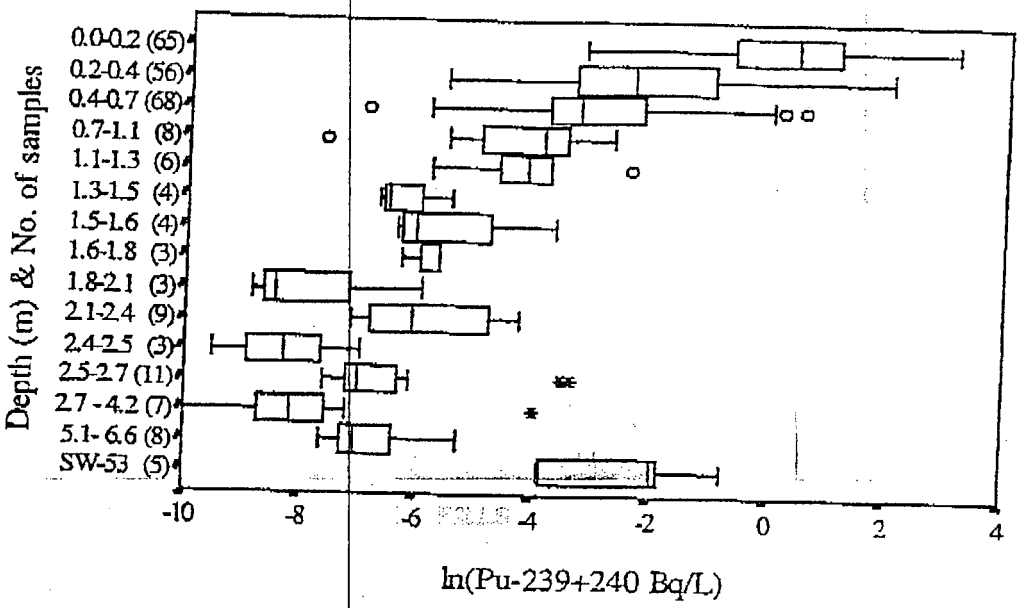

Depth (m) & No. of samples
0.0-0.2 (65)
0.2-0.4 (56)
0.4-0.7 (68)
0.7-1.1 (8)
1.1-1.3 (6)
1.3-1.5 (4)
1.5-1.6 (4)
1.6-1.8 (3)
1.8-2.1 (3)
2.1-2.4 (9)
2.4-2.5 (3)
2.5-2.7 (11)
2.7 - 4.2 (7)
5.1- 6.6 (8)
SW-53 (5)
-10
-8
-6
-4
-2
0
2
4
ln(Pu-239+240 Bq/L)

Figure 3