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PROCEEDINGS OF THE THIRD ANNUAL INFORMATION MEETING DOE LOW-LEVEL WASTE-MANAGEMENT PROGRAM

Convened by The DOE Low-Level Waste-Management Program

November 4–6, 1981 New Orleans, Louisiana

Compiled by:

D. E. Large, Oak Ridge Operations, Department of Energy
R. S. Lowrie, Oak Ridge National Laboratory
L. E. Stratton, Oak Ridge National Laboratory
D. G. Jacobs, Evaluation Research Corporation

DECEMBER 1981

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DOE LOW-LEVEL WASTE-MANAGEMENT PROGRAM
NUCLEAR-WASTE PROGRAMS
OAK RIDGE NATIONAL LABORATORY
Environmental Sciences Division

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SCOPE AND PURPOSE

The Third Annual Participants Information Meeting of the Low-Level Waste Management Program was held in New Orleans, Louisiana, November 4-6, 1981. The specific purpose was to bring together appropriate representatives of industry, USNRC, program management, participating field offices, and contractors to:

1. exchange information and analyze program needs, and

2. involve participants in planning, developing and implementing technology for low-level waste management.

One hundred seven registrants participated in the meeting. Presentation and workshop findings are included in these proceedings.

WELCOME AND OPENING REMARKS

D.E. Large
Program Manager
ORO Radioactive Waste Management Program
Nuclear Research and Development Division
USDOE, Oak Ridge Operations
Oak Ridge, Tennessee 37830

This is the third annual participants information meeting of the DOE Low-Level Waste Management Program. My name is Dewey Large and I am your associate in development of technology and engineering techniques for the DOE Low-Level Waste Management Program. Annually, the management team of the Low-Level Waste Program arranges a meeting for the program participants, so, welcome to your meeting. We welcome our visitors, our observers, and extend a special welcome and appreciation to the speakers and workshop leaders.

This meeting is designed to maximize the exchange of information and encourage the representation from participating field offices and their contractors to assist in identifying, planning, evaluating, and performing the technology development and demonstration needs being addressed by the program. Reports on the work being done by the participating contractors as well as presentation by the program staff are organized around individual major technology milestones. These reports are to be followed by workshops which also focus on each major milestone. This permits all attendees the opportunity to become familiar with the milestones, assess program needs, and take part in identifying activities necessary to meet each of the development milestones as they relate to the program objectives.

This is the participants meeting and, to meet our goal of maximizing the exchange of information, we need everyone's participation. There needs to be regular active input to permit the LLW management team to manage more effectively the low-level waste technology development activities.

I would like to call your attention to a few special program persons who have not been given agenda visibility. First, I would like to recognize the Queen of the Low-Level Waste Management Program, from the Headquarters standpoint, Betsy Jordan. She has been administratively restructured into the Commercial Waste portion of management. We have a new Prime Minister for the Low-Level Waste Program on the Defense side and that's Texas Chee. We have the IDO Associate Pro~ Manager, Ron Nelson. And, we will recognize the Director of EG&G w..ste management activities, Hank Beers. The old ship doesn't run real well unless it has all the crew onboard. We also have with us the Director of ORNL's Nuclear Waste Program, Tom Row. My new boss, Conner Matthews is here. He serves as Director of ORO's Nuclear Research & Development Division which has purview over Radioactive Waste Management for ORO. Also present is my associate in the ORO

Radioactive Waste Management Program, Doyle Brown. We are especially privileged in having representatives of the Program Review Committee here. These representatives will perhaps be identified later by Dr. Levin. Then, in absentia, we would like to recognize John Whitsett, the Chief of IDO Waste Management activities who, even though he is not here this year, is keenly interested in and very much aware of this Program.

I would like, not just to invite but please let me insist, that each of you complete your meeting evaluation form. You will find the meeting evaluation sheet among the materials which will be given to you. We would like that completed form returned to us before you depart from the meeting.

We are privileged in having for our Participants Meeting a group of very highly qualified and desired speakers. We have with us what might be considered a newcomer to the DOE Headquarters Management of Low-Level Waste. Let me emphasize that he is only new with respect to coming to low level waste management. He recently acquired under his purview the commercial portion of low level waste. But, let's not be mistaken, when we look at that youthful head of hair and only a few wrinkles in his face, which doesn't really reveal his long term interest in, and much experience in waste management as a member of our team. Bob Ramsey is not a novice in the waste management game.

COMMERCIAL LOW-LEVEL RADIOACTIVE WASTE MANAGEMENT

R.W. Ramsey
Nuclear Waste Management and Fuel Cycle Programs
Department of Energy
Washington, DC 20545

Thank you very much, Dewey. I appreciate the opportunity to be here with you this morning. My talk is listed on the agenda as the Message from Headquarters on Commercial Low-Level Waste. Now, that billing combined with my newness to the program makes me approach this task with trepidation.

The purpose of this paper is to review the goals, objectives, and activities of the Department of Energy's Low-Level Radioactive Waste Management Program. I will explain the new organizational structure of the Department, briefly cover the current low-level waste management situation, and outline the Department's role in providing state support. Institutional and technological needs will be identified, and I will discuss the Department's plan in meeting these needs. Finally, I wish to emphasize how our program priorities must be clearly understood and observed so as to accomplish our primary objective.

The goal of the program is to provide an acceptable near surface waste disposal system by 1986. Both commercial and interrelated defense objectives have been structured to meet this common goal. To be effective the system must provide for all low-level waste materials--whether defense or commercial--to be managed to protect public health and safety over the long-term. My remarks will address the commercial waste system; Dr. Oertel will discuss the comparable defense activities.

It is important to initially understand the recent reorganization of the Department of Energy. Beginning in FY 1982 the Congress, on recommendation of the House Armed Services Committee, has specified the separation of commercial and defense activities. To abide by Congressional intent, the Department has divided its programs--including Low-Level Waste Management--along source-of-funding lines. The defense activities fall under the Assistant Secretary for Defense Programs, H.E. Roser. Dr. Shelby Brewer, the Assistant Secretary for Nuclear Energy, administers the commercial part of the Program through the Office of Nuclear Waste and Fuel Cycle. Sheldon Meyers has remained on the commercial side as the Deputy Assistant Secretary and my office, the Waste Projects Office, reports directly to him. One lead field office has been retained for overall Program coordination and implementation of the Low-Level Programs in both defense and commercial sectors. In this manner, unnecessary duplication of research will be avoided, and benefits from each program side will be maximized. Technologies and procedures will be implemented according to the recognized needs of each program. The overall results will be distinct defense and commercial programs which utilize cooperatively-developed technologies and share information and results.

Past events and problems are evidence of the need for a reliable commercial waste management system. After nearly 20 years of technical and institutional experience with six commercial waste disposal sites, we still cannot assure sufficient disposal capacity beyond 1990. The attendant problems of increasing waste generation, increased number of shipments, and a rise in waste packaging violations reinforce the need for system reliability and a margin of safety. This is the goal of the technology programs augmented by a commitment to implementation.

Currently the states are responsible for the management of low-level radioactive waste generated from non-Department of Energy sources. The National Governors' Association, the National Conference of State Legislatures, and State Planning Council for Radioactive Waste Management concurrently recommended that a state approach was preferable in resolving the issues inherent in the management system. Regional sites, state regulation, waste classification, and waste reduction policies were recommended and endorsed by a broad base. The momentum culminated in the passage of the Low-Level Radioactive Waste Policy Act in December, 1980. States now are challenged with the responsibility for management of wastes generated within their borders--and the reality that states with waste disposal sites will be allowed to exclude out-of-region waste in 1986. States have a choice--either provide disposal space within the state, or negotiate with neighboring states to provide for common waste disposal.

The Department of Energy has a role in providing general support to the states in fulfilling the recent law. Prior to the Policy Act, the Department had assisted certain states in waste management planning. Tennessee, North Carolina, and Idaho received funds and/or direct staff assistance in completing state plans. In responding to increased requests for assistance, the Department has learned several things:

1. States need to know the extent of their low-level waste problem in order to make sound technical and political decisions. Improved methods are needed for states to determine their generation rates, degrees of waste hazard, and volume projections.

2. States want current information on the treatment processes available to them for reducing waste volumes and potential waste hazards.

3. States, as well as the defense operations, wish to improve handling procedures to decrease the amount of waste produced.

4. States, in a manner not unlike sovereign nations, desire to make their own management and organizational decisions within the framework of recognized technical approaches and sound regulations. While seeking assistance and sound advice, they do not want to be limited to one "expert" solution for every problem.

States have indicated a desire and need for assistance that is non-technical in nature. Processes for decision-making, methods for gathering data, skills in planning and coordination, and techniques in communication and information dissemination to the public need to be shared among the states. States also wish to choose among proven technologies in designing a waste management system that makes sense for them. The challenge to the Department of Energy is how to deliver the kind of state support that can efficiently satisfy these non-technical and technical needs, catalyze activity among the states, and help bring these two needs together into a functioning system.

The industry obviously has a key role in a low-level waste management system. The current situation of a State leasing to private enterprise for site operation has worked well. Also, the industry has shown that it is willing to work with States in the siting of new disposal facilities. Economic factors will come into play. Adequate volume provides the funds and economic flexibility to permit site operators to be conscientious. Site selection will be one of the thorniest issues. Therefore, industry and government must develop a workable site selection process. The technology for the safe disposal of low-level waste by shallow land burial is available; and performance objectives and siting processes are being set by the Nuclear Regulatory Commission in 10 CFR Part 61. A key to development of new sites is the relationship between private enterprise and government in the site selection and facility operation phases of the system.

The Low-Level Waste Management Program has been structured to provide general support, documentation, and demonstration. As a rule, assistance to one state or one institution should result in tangible products that can be shared with other states or defense programs. Likewise, technology results generated by defense funded activities will be shared and transferred to the commercial sectors.

In the area of general support, assistance has been provided to states in ongoing compact negotiations. Six regional groupings of states have evolved, and all are in various development stages. The Northwest has a compact among three core states and the Southeast is close to agreement on compact language. The Southwest and South Central regions are drafting initial compact language while the Midwest and Northeast have yet to resolve basic negotiating issues.

Exchange of information among states and regions is critical to achieving Program objectives. Therefore, the Department is heavily involved in producing and distributing information for various governmental and interest groups. Documentation of national generation data and quantities of waste disposed is a major Program activity. General public information has been published in brochure and "fact sheet" forms, especially designed for use as handouts and briefing material. "Directions" papers are being finalized to discuss those policy areas of greatest concern to state and local decision-makers.

For the past 2 years, the Program has worked on a national policy document, "Managing Low-Level Radioactive Wastes: A Proposed Approach" (LLWMP-1) to guide Federal efforts in resolving institutional and technical issues. Broad acceptance of the management philosophy, policy direction, and implementation strategy will be needed to successfully provide a reliable near surface disposal system by 1986. The strategy outlined in the final policy document (expected to be printed in January 1982) ties together the efforts in state assistance and technology development that I have just reviewed.

To summarize, the priorities for the Low-Level Waste Management Program have been established to meet one goal: an accepted management system by 1986. The highest priority will be given to supporting state efforts in forming the institutional structures needed to manage and regulate the system. A second priority will be the state role in demonstrating treatment and disposal technologies. Information from defense activities in areas such as environmental monitoring, siting criteria, and waste classification will also be of significant value to states. The Department of Energy is committed to providing support to the states, a role identified in the Low-Level Radioactive Waste Policy Act and one endorsed by the states.

Before summarizing, I would like to enunciate some of the steps I personally foresee in the government's role. First is what I will call compacting or promotion of mutually acceptable provisions in a pact among states seeking to participate in regional approach to provide low-level waste disposal. The government's response has been to render assistance in developing basic data and useful procedure and any other assistance we can provide to those states that are attempting to develop a compact and an approach to establishing disposal facilities.

The second step is the siting of disposal facilities. Here, the government can render assistance in development of criteria and guidelines, but it is evident to me that the compact of states and, to a significant extent, private industrial enterprise begin to take a dominant decision-making role in keeping with the provisions of the Low-Level Waste Policy Act. Hence, the government's role should be to help to catalyze the activity between the states or regions and the enterprises that would be called upon to operate such facilities.

Third is the licensing and the important inspection and enforcement of regulations which must be conducted to assure continuing public confidence and acceptance. This is an area of creative challenge in my estimation and such mechanisms as licensing of compacts, collaborative inspection and enforcement, and a broadening of NRC agreement licensing arrangements would seem to be practical and have merit.

Fourth is the transfer and implementation technology that addresses both near and long term aspects of disposal operations. Here, the federal government can provide real leadership in example as well as technical resources from its own operation.

Finally, there are the institutional, technical and economic issues posed by the post-closure situation. It is not clear to me how this issue will find its best resolution, however it is certain that specific mechanisms will have to be outlined well in advance and must not be ignored by any participant state, compact, enterprise, or the federal government, because this is and will always be the pivotal issue to the public.

To summarize, the priorities of the Low-Level Waste Management Program are established to meet one goal, an accepted management system by 1986. The highest priority will be given to supporting state efforts in forming the institutional structures needed to manage and regulate this system. The second priority will be the state role in demonstrating treatment and disposal technology. Information from defense activities and areas such as environmental monitoring, siting criteria and waste classification will also be of significant value to the states. The Department of Energy is committed therefore to providing support to the states, a role identified as part of the Low-Level Radioactive Waste Policy Act and one endorsed by the states. And, I might add, fully in concert with the mandates of the Atomic Energy Act under which we function. Thank you very much.

MESSAGE FROM HEADQUARTERS - DEFENSE PROGRAMS

Goetz K. Oertel
Acting Director
Defense Waste and Byproducts
Defense Programs
U. S. Department of Energy
Washington, DC

Thanks, Dewey. Well, at least unlike one other person here, I have not been administratively restructured. I don't really know what that means Dewey. I am afraid that it may be very painful. So, I am glad that I have been spared. But, it is a pleasure to be here. In fact, if Bob Ramsey is a newcomer to this, I just arrived, because Bob has been in this technology, low-level waste technology, much longer than I have with an occasional detour in environment and remedial actions and other fun things. Also, I must say this is the first time I have come to one of these meetings and I am impressed with the number of people here. I have looked at the agenda and I see you have really an excellent couple of days of briefing. So, I hope this will be as useful as it certainly can be from the looks of it.

I would like to welcome all of you to this Third Annual Department of Energy Low-Level Waste Information Meeting. I want to thank Oak Ridge, particularly Dewey and the Oak Ridge National Laboratory, for making the arrangements for this meeting.

I will be very brief in my remarks. As Bob said, there has been reorganization in Washington. Defense programs have been separated from commercial programs. I work for Chuck Gilbert who works for Herm Roser, the Assistant Secretary for Defense Programs. And, I have the defense waste management programs. Now, clearly, the technology is really very much the same for defense and for commercial applications. It does not make any sense to me for commercial and defense programs to establish their own independent technology programs. Shelly Meyers and I agree that the present lead field office structure should be maintained. We will both work to that. We are developing a memorandum of understanding between the two Assistant Secretaries which will maintain the lead field office structure and will document how we work together. We will try to make the job for Phil Hamric and his people as simple as possible. I would also like to apologize in advance to you. I am not going to be able to be with you through this entire meeting. In fact, it would have been fun to do so because it would have been an opportunity to learn about a whole lot of things I never get around to hearing. Instead, I will be needed in a possibly tough meeting and will probably have to leave you in the middle of the morning.

Right now, it is my special privilege to introduce Phil Hamric. Phil is one of our outstanding managers of technical programs in the Department. He has done some absolutely astounding things at the Idaho National

Engineering Laboratory. Certain improvements in the operation there have been just absolutely mind-boggling. Some of you know and have first hand experience with the problems that did develop through a series of years when we, the Department or the AEC, were thinking of phasing out the Idaho Operations. It is now a first class operation again, and I think Phil deserves much of the credit for that.

But, that's not why he is here. Phil has the low-level waste program, with Mike Barainca working for him, and, of course, the EG&G organization you all are familiar with. And, Phil will be your keynote speaker on low-level waste. Phil.

KEYNOTE: DOE'S LOW-LEVEL WASTE MANAGEMENT PROGRAM

J.P. Hamric, Director
Nuclear Fuel Cycle and Waste Management Division
Idaho Operations Office, U.S. Department of Energy
Idaho Falls, ID 83401

INTRODUCTION

Thank you, Goetz. As far as the split between defense and commercial waste is concerned, I have worked with Bob Ramsey and with Goetz before and we foresee absolutely no problem in that relationship. Dewey, at Oak Ridge, is right in hand with us on that. I think all of us, through the years, have worked where there have been dual funding and program sources for what we consider to be a specific integrated program. I don't know how many times the commercial and defense missions have been separated and put back together.

I am reminded by all this of Shelly Meyers who answered a pretty tough question at the public hearing held about a month ago in West Valley, New York for the demonstration project there. If you recall, at that time the President announced that DOE would be abolished, and so some people from rural New York asked the question: "Does that mean the West Valley project is gone?" Shelly said, "No, it is not gone. There is an act that established the West Valley program. A President has signed it into a Bill." We are separated from the political situation in what I still refer to as the Civil Service system. I don't think we have to worry about working together. Certainly, I don't.

I want to welcome some newcomers and repeat a little of what a couple of the previous speakers have said. I am very glad to have Mike Barainca join us from the Terminal Storage Operation of the Department of Energy program. He is working hard in Idaho to locate the field and the horse and get the saddle on and begin riding. We are very proud to have Mike join our staff and are already feeling the positive effects of his professional approach to the Low-Level Waste Program. I would also like to have you welcome Ron Nelson back to the program. He had a relatively serious illness and was out for about two months. He beat it and we are very glad to have him with us. In fact, at one time--with John Peel off helping the new folks in Washington, Mike Barainca not having yet arrived, and Ron Nelson being ill--we had no one individual assigned the fulltime responsibility for the low-level waste program. I apologize for whatever inefficiency and lack of communication occurred at that time.

We welcome Doyle Brown, who is going to be helping Dewey and Conner Matthews. Also we are very glad to see Tom Row's influence on the program. It has been very positive.

RELATIVE RISK

I have talked at the last two participants' information meetings on the subject of relative risk of the nuclear option versus other energy forms and I don't want to get into subjects I have touched on before. I think last year I felt more positive. It was in January in San Diego, and we had a new incoming administration. It clearly supported nuclear power as a source of energy to be investigated and utilized. Also last year, the Low-Level Waste Policy Act was passed and it was very significant. It's from that point I will begin to pick up and spend most of my time talking about the commercial waste program and trying to give you more information than perhaps we have in the past, so you can understand why we place a lot of emphasis on the commercial program. I won't be talking about the relative risk of burning wood and having flue fires and smoke in your house as I did last year.

On the subject of relative risk I will only say that by this time next year I will have completed a very small project to collect facts, data, issues, and perspectives on the health effects of radiation. Dr. Ed Shaw, a professor of radiobiology at the University of Kansas, is doing this work for us in Idaho. He has worked two summers for us and I plan for him to spend one more summer to get the information on radiation health effects pulled together and published. We now have a very, very rough draft which we intend to send out for comments from recognized and credible institutions and people. The format is a compendium of what is known about radiation health effects. What little opinion is in it will be confined to Dr. Shaw's summary. After he has finished his work, we intend to have one of our operating contractors at the Idaho National Engineering Laboratory put the document into language for people who are not experts in the field. The understanding level and audience that we are shooting for is people with an administrative background. By this time next year I hope to have a million copies of this study to provide an overview of the health effects of radiation.

The material will include analyses of issues such as the Portsmouth Naval Shipyard study which made front page news in many newspapers and which was subsequently shown to be false by the National Institute of Occupational Safety and Health (NIOSH). Shaw's material will also discuss radiation damage to tissue and health effects. But enough said about that.

PROGRAM STATUS

This year our strategic position is stronger than last year and last year was, of course, a big improvement for nuclear over the year before. I will just mention two examples. The President's policy on nuclear energy is very supportive. He supports reprocessing and also believes it should be essentially a commercial endeavor. He has a committee looking at what kind of a transition we need to make it work. Another item is relatively current. Idaho Senators James McClure and Steve Sims, along with Senator

Robert Stafford from Vermont, have introduced a comprehensive piece of legislation called the National Nuclear Waste Policy Act of 1981. It is very comprehensive. It includes interim storage, geological disposal, retrievable monitored storage, cost recovery, and state participation in these endeavors. We will be watching to see how that bill fares in the near future.

Now let me follow up on discussions I have had with you over the last couple of years, with some positive developments. There aren't many negative ones. Perhaps the most negative thing is the budget for the low-level waste program. I don't think the budget situation is hopeless. It is not going to disable our effort. We have a lot of support from Goetz and Bob with respect to the budget. I am going to show you a half dozen or so viewgraphs. They contain information on the commercial waste program, what we are doing, and a little bit about why we are doing it.

Program Objectives

The Low-Level Waste Policy Act says that every state must have a solution for disposing of the commercial waste generated in their states by 1986. And that is not all that far away. Let me talk about 1986. Five years is none too long for all that states must do: conduct siting search, make a specific site study, obtain site acceptance, get industry involved, open a low-level waste disposal facility, get SAR's written, get them approved, form a company--which industry would have to do--and really be in a position of having things rolling (Figure 1). So, 1986 is not that far away, and we need to hustle. These are not all of our objectives, but certainly ones worth talking about at this meeting. I would like to point out that working with the states is a very broad, encompassing activity, and one that needs a lot of coordination and good direction. I want to applaud George Levin and his staff at EG&G who have been carrying out these objectives in the commercial area for DOE. We also have objectives in the defense area that relate to the commercial area. There is a lot of work which you participants are doing which is applicable to both defense and commercial waste. The waste, in most respects, is technically the same material.

Figure 2 shows the projected annual generation of commercial low-level waste up to the year 1990 in cubic meters per year. It is not cumulative but annual projections. In 1990 about a half--at least no more than two thirds--would be from power reactors. So, there are lots of other interests aside from the production of electrical energy. Figure 3 shows the capacity of the three commercial burial grounds now operating. The remaining capacity is shown in the clear area. Barnwell, of course, has the most reserve capacity and Beatty has the least. In Nevada right now the prospect for expansion of that burial ground is certainly not positive. So, there is great pressure for a solution to be in hand on the 1986 end date.

Figure 1.

Commercial and Defense Objectives Support the Program Goal

Commercial

- To assist states in development of state plans, demonstrations, and site characterization
- To ensure that commercial waste responsibility is maintained in the private sector
- To maintain a DOE program of consensus development

Defense

- To continue to support defense technology demonstrations
- To provide documentation to support technology transfer

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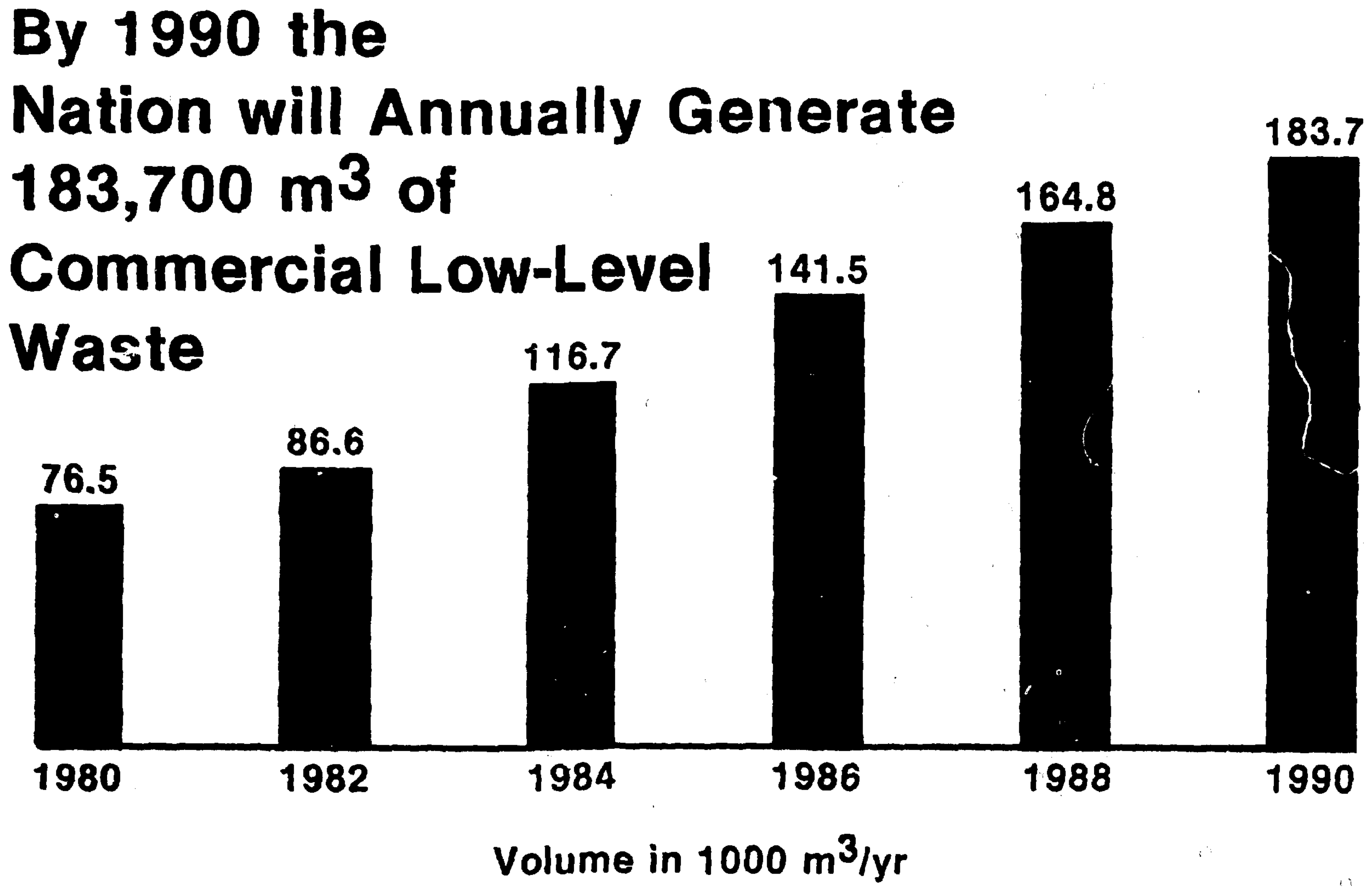

Figure 2. Projected Annual Generation of Commercial Low-Level Waste

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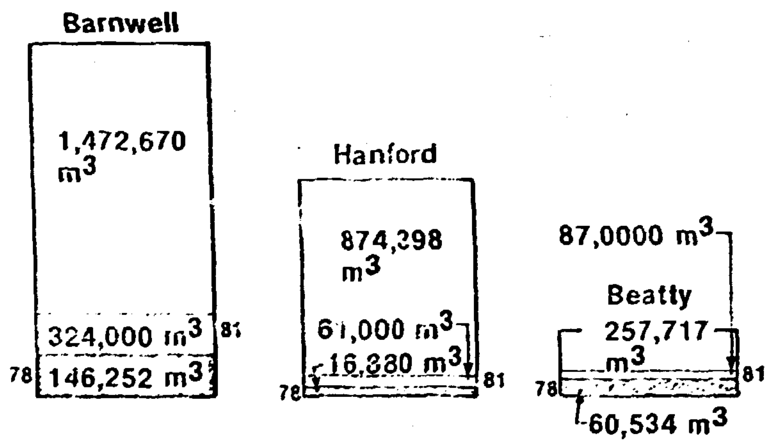
Figure 3.

Commercial Low Level Waste Disposal Site Capacity (Data as of January 1, 1978) (Volume as Cubic Meters)



78 Total volume remaining = 2,604,785 cubic
81 Total volume remaining = 2,319,785 cubic meters
78 Total volume utilized = 223,666 cubic meters
81 Total volume utilized = 305,666 cubic meters

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Program Strategy

The strategy must involve consensus, generically and in every way (Figure 4). That's very simply stated but perhaps not so simply obtained. I feel that we can get technical consensus. We--and I mean those of us here--can agree technically on what we think is the correct answer for low-level waste disposal sites as far as siting, operating a site, closure, post closure requirements, migration studies, migration monitoring, and other technical items. I think we can arrive at a consensus here, and in many respects that's one big purpose of this meeting.

Institutional consensus is more difficult because it involves a number of institutions which do not always have the same motivations. The fact is the system can complicate reaching a political consensus. However, the technical consensus is coordinated through our office by Mike and Ron. We are using George Levin and EG&G to a very large extent in communicating with various institutions in the country, for instance, each of the states. I do not want to say any more about this point than that it represents one area of needed consensus. Getting a solution by 1986 will require states to get together, find a site, agree to use that site, and then comply with the compact which restricts use of the site to member states. In other words, each state will be part of a region which has its own compact.

Status of Regional Compacts

Figure 5 shows the status of the progress in regional compact efforts which Bob Ramsey discussed earlier. This is evolving because consensus and a lot of communication are required. We need to get a good data base on commercial low-level waste. We think the states and the regions can do that a lot better than the Department of Energy. There is really no obligation for waste generators to tell us, DOE, how much waste they are generating. But, we think that the states can get the information and they are beginning to do so. We are trying to help the states, as appropriate. So, it is an evolving situation. As Bob said, the Northwest has the first compact. The double cross hatch lines show states which haven't decided which compact to join. There are some indications that both California and Texas may have enough waste to establish a disposal site in their own states.

Program Budget

Figures 6 and 7 show the budget breakdown and there are a couple of major points I need to make. The whole pie includes the defense as well as the commercial waste programs. The major portion (Figure 6) is the National Laboratories' or participants' share of the overall low-level waste budget. The portions labelled institutional grants and commercial contracts are mostly work with the states and with organizations working for the states. As you see, the institutional grants and commercial contracts got relatively larger from fiscal year 1980 to fiscal year 1981. But the budget for the work you are doing also increased between 1980 and 1981. In

Figure 4.

The Strategy

- To achieve a technical consensus

- To establish an institutional consensus

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Figure 5.

Progress in Regional Compact Efforts

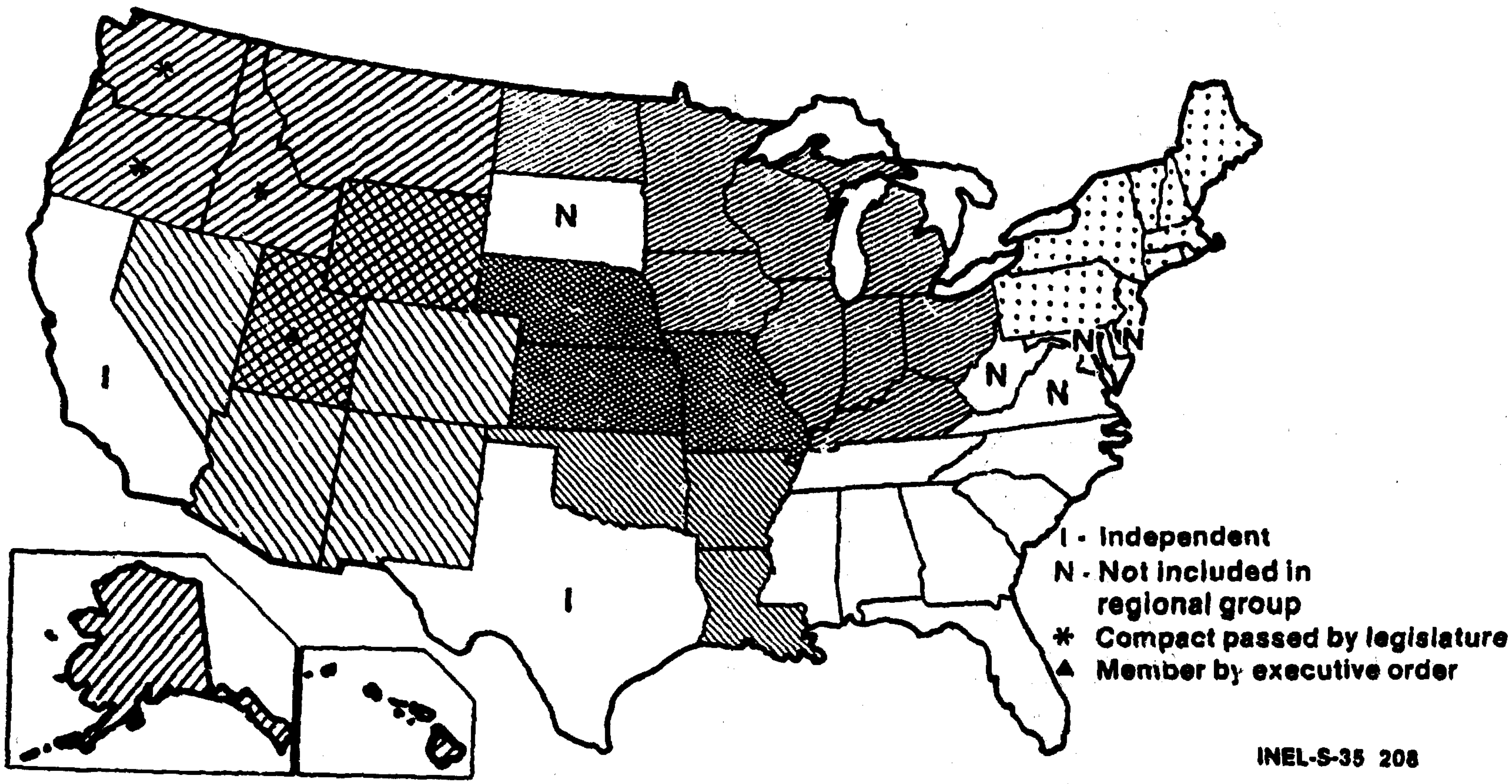
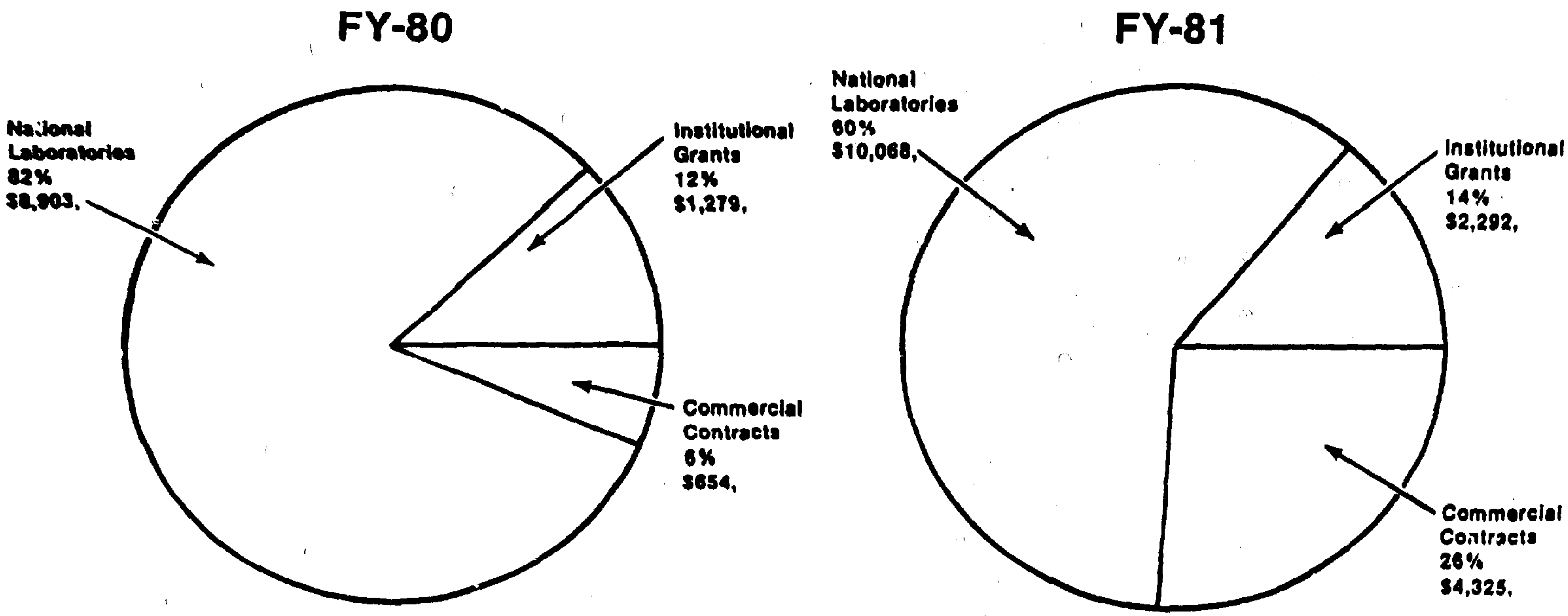


Figure 6.

Distribution of Funding Low-Level Waste Management Program



FY-80		FY-81
$ 548,	Commercial funding	$ 3,845,
$10,288	Defense funding	$12,840
$10,836	Total funding	$16,685,

$ = (000's)

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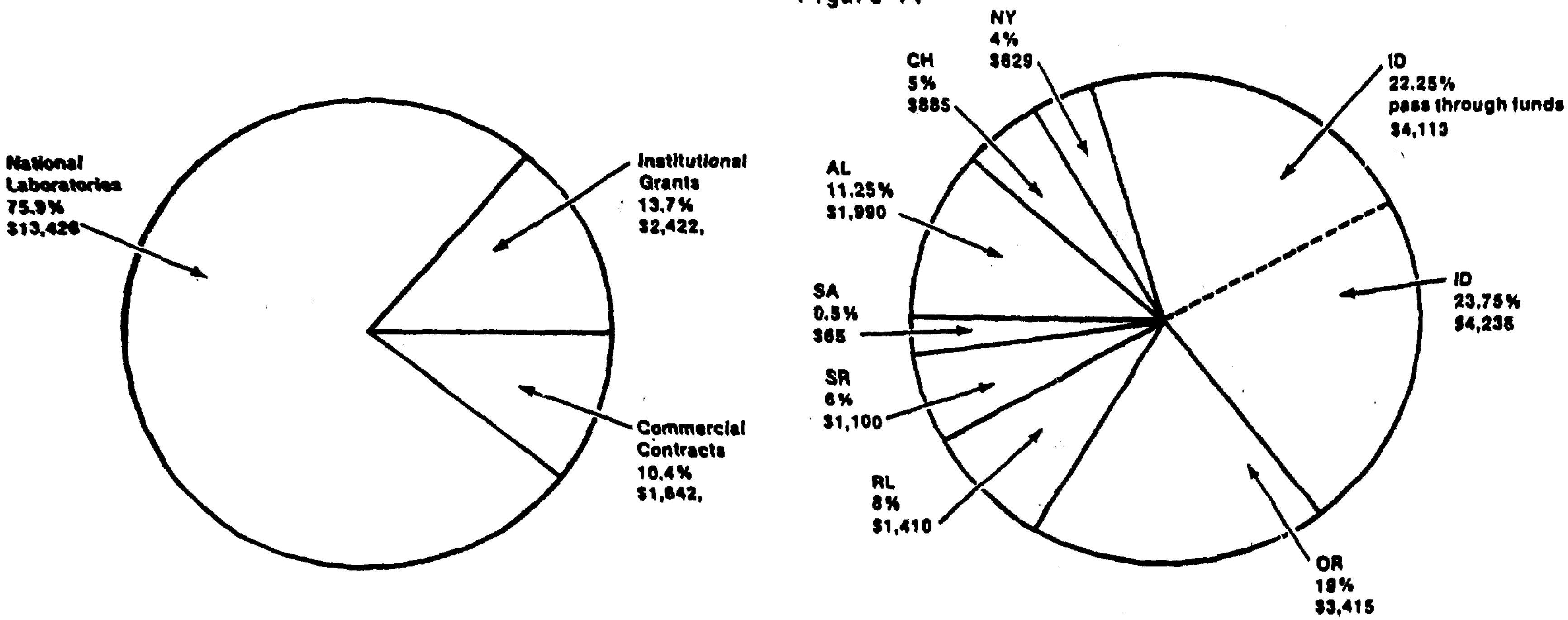
Distribution of FY-82 Funding Low-Level Waste Management Program

Figure 7.



*Commercial funding BA	$ 6,390,
Defense funding BA	$11,300,
Total funding	$17,690,

$ = (000's)

INEL-S-35 196

* Expected budget as of Oct, 1981

fiscal year 1982, there is more growth in funding for both the defense and the commercial areas. There is no shrinkage. But, I do want you to note that we have a fairly significant effort in commercial waste.

Now for the budget breakdown --- Figure 7 shows where the money is going--Chicago, Albuquerque, Savannah River, and so on. Let me point out the Idaho money. About twenty-four percent stays in Idaho for management and for some technnical work and twenty-two percent of the Idaho budget is pass through funds which are not spent by us in Idaho.

Figure 8 shows our budget projection through 1985. The reason we indicate a tailing off is that one of the program objectives is to solve the problem and terminate the program. I am not saying the program will completely terminate. Some technical problems will probably evolve in the later years that will need to be addressed. But, we do see a downward trend after 1984. We hopefully will have solved the problem by 1984 or 1985, and certainly in the commercial waste area by 1986. Some follow-on work will probably be required in the post 1986 time frame.

WORKING WITH THE STATES

Now I would like to note that the states are doing a good job in addressing their responsibility under the low-level waste act. I believe that the Department of Energy by itself would, in fact, be unable to solve the commercial waste problem in the way that it needs to be solved. Commercial organizations--industry--should open the sites, operate them, and invest the capital required to make a profit. I don't think DOE could do that. I don't think DOE alone could be the sole driving force to accomplish regionalization, compacting, and the like. So, I feel that the law is a good one. The low-level waste management problem is in the hands of the people who can solve it and they are moving to do that. In the commercial area, DOE works pretty much in the back out of the spotlight behind the curtain. Through you we work in the background to support efforts the states are carrying on. There are some positive results to DOE and to you, as our technical arm that carries out the work. One positive thing is that the states can find out there are reasons that we work in funny ways. In working with the states we may improve our image and credibility--and that is important: to have an organization think it can do something and it is wanted and needed.

When the commercial burial grounds were closed about three years ago, the reaction was: we will give the waste to the federal government. For our defense sites, in particular, that is a problem. For very good reasons, in my opinion, those sites are not regulated by NRC. If we used defense sites for commercial waste we would have to divide our burial grounds, into one part that NRC would regulate and one that DOE would regulate. But, the way things are going, the waste is not coming to the Department of Energy burial grounds. I think that is a plus. It is a plus because the states are going to solve their own problems, and that will have an overall positive effect on the nuclear industry in general. Certainly nuclear

Figure 8.

Low Level Waste Management Program BA (In Thousands)

	FY 1981 Actual	FY 1982 Revised	FY 1983 OMB	FY 1984 Projected	FY 1985 Projected
Commercial funding	$ 3,845	$ 5,385	$ 7,375	$ 7,523	$ 7,592
Defense funding	13,890	11,280	12,141	10,325	7,670
Total funding	$17,735	$16,665	$19,516	$17,848	$15,262

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waste is no more difficult to handle technically or with respect to health effects than other waste which does not decay away and which is quite lethal to humans. The states are handling those wastes.

One thing we need to get word to the states and to organizations outside of DOE and its contractors, regarding procurement and contracting with us. Many state officials have no experience with federal grants or contracts. So they don't know how to get something done. It does take a long time and the reason is that Congress has established, and the administration has implemented, a set of regulations to protect both industry and the government from mismanagement of procurements and contracts. As a program officer, I want to get grants and procurements out as quickly as possible to get the work done sooner and meet milestones with more assurance. But, our contract people have a set of gates that they have to study, unlock, open, and then pass through, close, and lock again. A procurement package goes through that kind of extensive review. It is required. The Federal Procurement Regulations tend to be anti what I want, what the states want, and what organizations that are contracting with us want. The regulations slow us down. While I think the regulations are too detailed and contain too many checks and not enough balances, they are law, and we have to carry them out. John Whitsett has been working with our procurement people to draft a plan to expedite things through our office--to find the quickest way of getting contracts out. For example, if something qualifies as a grant there is less to do than if it were a sole source contract. We are trying to improve the strategies for specific procurements and contracts and that has been a major problem.

SUMMARY

Finally, in the commercial area, we can all benefit from the work you people are doing for us. In fact, your help is essential to meeting the 1986 goal for solving the commercial problem. We want your participation and your feedback on what we are doing and how the program is being run. Please, give it to us.

PROBLEM AREAS FOR INCREASED EMPHASIS

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INTRODUCTION

In my talk I would like to cover four areas. The overall program schedules, technical program emphasis, institutional program emphasis, and the administrative program emphasis.

This is a participants' meeting and I view it as an interactive process. I hope to get feedback from each and every one of you. I am going to outline my preliminary perceptions of the areas that I think need emphasis. I would like to talk to representatives of all organizations. I have asked Dewey to set aside the Waikiki Room this afternoon and tomorrow from 5:00 until 6:00. I will be there and I would like to meet with the DOE representatives and the senior DOE contractor representatives today to discuss their perspective of the areas that need emphasis.

Tomorrow, I would like to meet with institutional, commercial, and state people to discuss methods to improve the program.

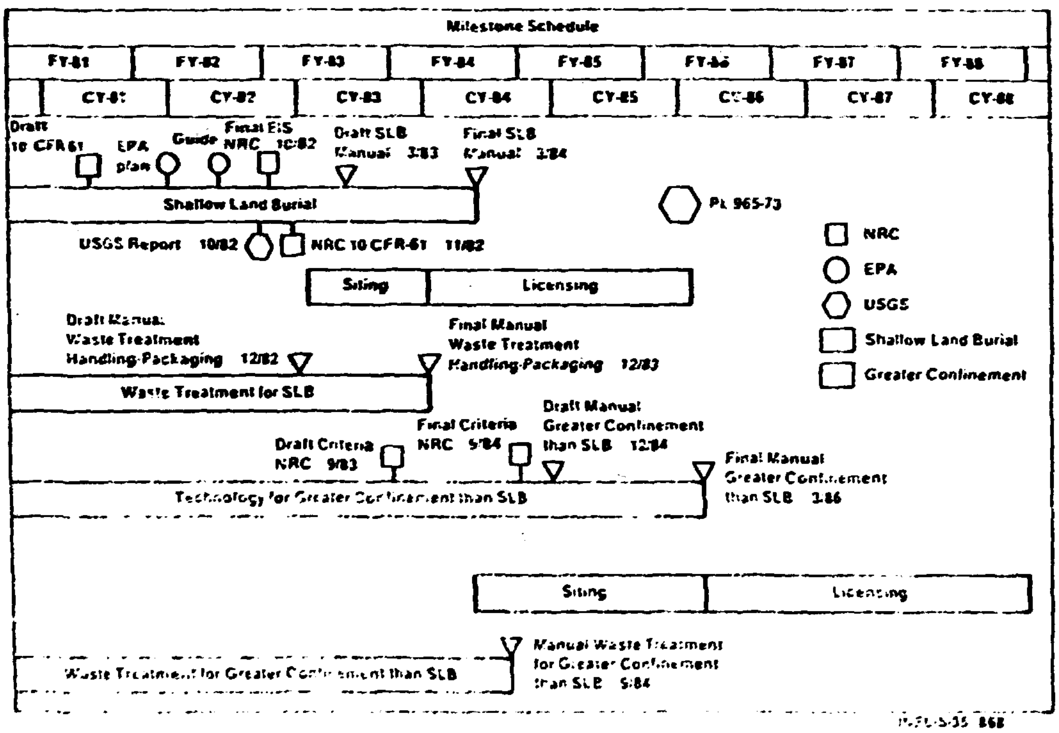
THE LOW-LEVEL WASTE MANAGEMENT PROGRAM

Figure 1 portrays the two major elements of a low-level system: shallow land burial and greater confinement. Both of these areas have two subsystems; waste treatment and engineered burial. Waste treatment should reduce the volume of waste and provide an acceptable waste form. Engineered burial in qualified geologic settings will provide effective isolation of the waste form from the accessible biosphere.

Shallow Land Burial

The shallow land burial concept is the first part of the system and is the activity of the greatest emphasis in the program today. Public Law 965-73 indicates that by 1986 each state is required to provide the availability of capacity for burial of the wastes that are generated within that state. The Department of Energy, along with the NRC and other federal agencies, is directed to assist the state in accomplishing this objective. I have tried to identify on Figure 1 the major documents that are being prepared by supporting agencies.

Figure 1. Major Elements of the
Low-Level Waste Program



The question marks over the EPA Guidelines indicate the uncertainty of these milestones. The EPA was unable to attend this meeting. On Monday I talked to the EPA to obtain information for this meeting, and learned that their budget has been cut back. The EPA was originally intending to issue some guides or standards in the 1983-84 time frame. They are now revising their approach, in view of the U.S. Nuclear Regulatory proposed rule 10 CFR Part 61. By the end of this calendar year they expect to issue a plan outlining their proposed activities for the LLW program. They tentatively indicated that they are going to prepare a guidance document during the middle of calendar year 1982. This will provide an umbrella to assist the NRC in the preparation of 10 CFR Part 61.

As you know, the NRC has issued 10 CFR Part 61 for comment. They recently issued a notice in the Federal Register extending the comment period to January 14, 1982 to provide the opportunity to review the EIS which has been written to support 10 CFR Part 61.

I consider documentation of 10 CFR Part 61 as a very critical element to the DOE program. It clearly is the driving force for the commercial aspects of the program. But, it will also influence the defense side of the program. Since it provides information and guidelines on public acceptability, the defense programs will have to look very carefully at these NRC documents and understand what, if any, differences exist between what the NRC rules and the criteria DOE is proposing to use. I have asked EG&G to assist my office in compiling and analyzing the comments that we obtained from the field offices. We are going to go back again to the field offices for additional comments because most of them indicated that they wanted to review the EIS before they finalized their comments on 10 CFR Part 61.

As you look at Figure 1, you see that the driving elements are going to be the siting and licensing processes. I see this really as a two year question mark. For those of you that have not read the EIS, the NRC states that the siting process is a one to two year process and that the licensing process also is a one to two year process. That is, the time for these two activities' combined ranges - from two to four years. In view of the 1986 schedule established by Public Law 965-73, these two ranges represent a substantial uncertainty. The degree of complexity of the siting process and the schedule will depend on the site. It is apparent that it would be much easier to site a burial ground at an arid site with simple geology than it would be at a humid site with complex geology. So, I can understand the reason for the range on the time estimate. It may also be possible during the licensing phase for an Agreement State to cut the licensing from a two year period to a one year period. So there are two years of uncertainty in the time it will take a state to qualify and license a burial site. I expect that by the end of calendar year 1983 the states are going to be aggressively implementing a screening process and considering a qualification process that will allow them to have a burial site during 1986.

The siting process can be divided into two phases. The first phase is a screening phase where the states evaluate broad areas with coarse screening criteria, such as population density, flood plains, and depth to the water table, etc. These preliminary screenings will probably lead to a host state and a candidate location or locations. Once that state has decided to become a host state, they will initiate a very intensive site qualification process, either by themselves or through a commercial firm. The NRC has indicated in the EIS that they believe at least one year of environmental information is required. However, NRC has not precisely defined the information required. I believe the Department of Energy can assist the states by identifying and documenting the methods of conducting these evaluations, by documenting existing technology, and providing the information as soon as possible.

There have been several reviews of the program. One of the most recent reviews, by the Conservation Foundation, indicated that with proper implementation, technology exists today to dispose of the waste. If some technology exists, a lot of the people ask "Why are you spending the money that you are on technology programs?" and the answer is "because each and every one of us wants to do what we can to improve the system in those areas where we can." The Department of Energy has been taking the lead to provide new tools to the commercial sector, but we are going to have to accelerate our effort if we are going to effectively assist the states. We are trying to accelerate our effort in the site qualification area. Our major milestone is to document the status of technology, as it existed at the end of fiscal year 1981, in a manual which will be available to the public in March of 1983. This schedule provides for an internal peer review by the Department on an earlier schedule. We will then document the information from our technology programs and update that manual into a final form in March 1984. We will continue to assist the states by providing available information and by assisting them in their development or criteria and methodology for screening. Oak Ridge National Laboratory will be the technology integrator for the development of a technical manual and will be working with the various DOE laboratories to obtain this information. I ask each of you for your cooperation in this effort.

Additionally, I know that many of the commercial operators of burial grounds have procedures and standards which they utilize and I would appreciate it if they would share those non-proprietary elements of their programs with the states.

Greater Confinement

The second part of the system is to provide the technology for greater confinement. At the present time we are conducting an assessment and feasibility study of the greater confinement concept, i.e. burying the waste at depths greater than 20 meters. We expect that there may be some cost savings by reducing the packaging requirement if waste were buried at greater depth. This cost savings should be possible without a decrease in safety objective of effectively isolating the waste if it were sent to a greater confinement facility instead of a shallow land burial facility. Additionally, the necessary isolation may be achieved for certain wastes more cost effectively by greater confinement than in a mined high-level repository.

But the task is primarily in support of the Department of Energy's defense program, and we are evaluating the use of a confinement facility for defense waste applications. While we consider that a greater confinement demonstration will provide the technology transfer to the commercial sector, we have not yet made any judgements related to the need for a similar facility for the commercial sector. Specifically, when the NRC issues 10 CFR Part 61 for implementation, the commercial sector will not be able to dispose of waste which exceeds category C until there is a facility for disposal of these wastes, either a greater confinement facility or a repository. Since a repository is not expected until the latter part of the century, I would expect that the generators would have some concern relating to the storage and disposal of these wastes. But, I haven't heard any concerns expressed by the utilities or any of the working groups with whom we have discussed the program. So, I wonder if there is a need for a greater confinement facility for commercial waste at this time. I think we need to look at this issue quite critically before the government gets in position of putting up with another type of facility. We are looking to the Nevada Operations Office and their contractor for a thorough evaluation of this issue. Preston Hunter, a Nevada contractor, will give a presentation tomorrow on the greater confinement technology.

TECHNICAL PROGRAM EMPHASIS

We need to concentrate on technology transfer. The consensus of people is that technology exists; but in reviewing the documentation, my preliminary assessment was that a great deal of documentation was being developed for site specific needs. That is, if someone at Idaho is developing a test, they are developing it for an application at Idaho rather than for an application at Hanford and other sites. We need to come up with standard procedures and standard methods that can be used at several sites. Many of these procedures currently exist. The American Petroleum Institute has standards, and there are several existing standards or procedures used by other industries. We need to look at the existing standards and make sure that they are adequate for our program or refine them for use by our program.

Figure 2 outlines a process for accomplishing the technology objective. This is an iterative process and one can start at any point. Our objective is to establish criteria and demonstrate that our process meets its criteria. The NRC has established a draft criteria for the commercial program and DOE is establishing criteria for the DOE program. Hopefully, all criteria will be available by the end of next calendar year. But, in order to establish these criteria, we need to understand the total system. We need to understand the geology, the engineering facility, the waste form, the waste treatment, closure and post-closure, and remedial action technology. We have to understand the total system. There are some synergisms. In developing the criteria you develop the system and

Figure 2.

Technical Program Emphasis

- Establish near surface disposal criteria
- Conduct system analysis to identify areas for technology development
- Specify technology development objectives in test plans
- Conduct peer review of test plans and test results
- Issue manual defining status of technology

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vice-versa. You must test the components system and that is what we want to do in test plans. Many of the National Laboratories already require test plans and use them as a method of formalizing the scientific method, by establishing objectives and formulating hypotheses before the tests are conducted. If one establishes objectives properly, I think one can design a test to help another site. Then as the test is conducted the technique developed can be more readily transferred.

Additionally, I see a need for greater detail in terms of supporting milestones to defend my program. We have been going through an exercise on the budget that is referred to as "the twelve percent cut." We may go through additional exercises for the next few months. I am sending a letter to most of the field offices within the next couple of weeks with a list of possible program funding reductions. I have had difficulty in trying to quantify the impacts from possible budget cuts. That is, if there is an upper tier milestone that requires some subtier activity to support it, that lower tier activity should show up in the impacts. I need your support to demonstrate the impact of possible budget cuts. I believe we will be better able to defend our funding if the activities and issues we are trying to resolve are quantified and documented.

Some of these plans have been developed, and there appear to be several that the Idaho Operations Office has not seen. We are going to be working closer with Oak Ridge this next year to improve communications in this area. For activities involving large scale tests, I would like to have test planning documents reviewed by an independent group of qualified peers to assure that information is transferable and that these test plans are sound. After we have completed conducting these tests according to the plans, or an update of these plans--we don't view these plans as being static, but living, documents that would be updated--the information would be documented. This will provide a verification and validation of the hypothesis. Those of you that have quality assurance backgrounds recognize the need to validate our methodology. It is this element of validation that we need to stress this year.

10 CFR Part 61

Another area of technical program emphasis is our review of 10 CFR Part 61. As I indicated earlier, the NRC has issued 10 CFR Part 61 and an accompanying EIS for comment. Everyone here needs to review this document critically. My preliminary assessment of the EIS and 10 CFR Part 61 is that they are very good documents. I think that the NRC has put a lot of thought into them. My major concern is the waste classification system. That is, I don't understand the impacts of implementing this system. I am not sure that all limits established can be supported by the Department. DOE has also been developing a waste classification system. One of the things that I am considering is, rather than coming up with a totally unique waste classification for DOE waste, to try to utilize a similar waste classification system to that developed by the NRC, and I need to understand the impacts of implementing an approach similar to the NRC. We need to understand what impacts of this type of an approach would be on the defense programs. I am not saying you license defense LLW programs. What I am saying is that we have to understand the DOE safety performance objectives and be able to defend them as you do in a commercial program. We are developing criteria for DOE programs and a waste classification system is an integral element of our approach.

Another area that the commercial sites will have to develop and understand is institutional control and what systems might be utilized. This concern applies to high-level waste as well as the low-level waste and we need to carefully consider our approach to this issue. I am going to be asking all the DOE participants and DOE contractors to assist the LLW Program Office in working cooperatively with the NRC in the 10 CFR Part 61 exercise.

INSTITUTIONAL PROGRAM EMPHASIS

The next area that I would just like to touch upon is the institutional program emphasis. Bob Ramsey and Phil Hamric discussed some of the cooperative efforts of the Department of Energy and our contractors in working with the states. When the states have asked, we have provided information. Additionally, we have provided financial support to the states for certain efforts. Some of the states have indicated that the DOE financial assistance program is slower than they would like. And, there has been considerable discussion of the scope of activities in which the Department should assist the states. Headquarters is trying to reach an agreement on the scope of work the Department is willing to support and methods for evaluating proposals from the states. One method of doing this is a Notice of Program Interest and this method is specified in the Federal Procurement Regulations. We intend to issue a notice to the states which says what our intent is, and it is our hope to publish this by January. This vehicle will assist the states in targeting proposals into areas which the Department is willing to provide assistance.

Another issue in state assistance is funding. With the program cutbacks, fewer dollars will be available for state assistance. So, Mr. Ramsey and I have to explore the most efficient method of providing the necessary support for both technology transfer and financial assistance.

The other area where everyone here can contribute is participating in your community activities by explaining the waste problem. The program responsibility for public outreach rests with the Idaho Operations Office, but I know that many of you will have opportunities to speak at various forums and I would appreciate your continuing to do so. Call Ron Nelson or myself and let us know what the request is so we can assist you, if necessary. Additionally, I would appreciate it if you avoid issues which involve policy. The Department must maintain a consistent policy position and since policy is developed at Headquarters, any possible policy involvement should be cleared through Headquarters.

ADMINISTRATIVE PROGRAM EMPHASIS

Finally, there is emphasis in the administrative area. This meeting today is fulfilling a major need in the communications area by providing an opportunity of understanding the DOE LLW program. We are looking for feedback. I have asked Dewey Large to prepare a questionnaire and provide one to each of you to complete. We want your opinions of this type of forum. We want to improve our communications. I feel there may be a need to have some workshops directed at specific issues to accomplish specific objectives. I would like to have feedback from you on these issues and look forward to the two sessions that I set up today and tomorrow. I will also look at your comments during my review of the questionnaires. I really think that lateral communication such as an information meeting is a very valuable process. But you can get miscommunication if you try to provide direction in this manner. We need to strive to maintain communications related to program directives through the established communications channel.

SUMMARY

In concluding, I think I have covered the thrust of the program on technology transfer, the review of the NRC regulations, and my desire to try to validate the program through the development of test plans, procedures, standards, etc. We recognize the need for good milestones to manage programs, and the need for a proactive approach in working with the states and improving communication between the participants. Thank you all for participating in this workshop.

NATIONAL ACTIVITIES IN LOW-LEVEL WASTE

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BASIS OF THE DOE PROGRAM

Let me start by telling you where we come from as a program. We have two basic customers, the states and the DOE facilities. To some extent they have very different needs. The states need to get their act together; they need to develop the capability that doesn't exist today. Many of their problems are nontechnical. They are "how do we make the system work?" kind of questions. They are called institutional or political --- soft stuff. The DOE facilities on the other hand are of a different situation. With the possible exception of Oak Ridge, everybody has enough space, the system works, and most of the sites are in pretty good shape. So, they are in a lot better condition than the commercial sector and some of the things in the past have reflected that perspective.

The basic premises that we have been working under are very simple. First, and foremost, is that the basic technology for the management of low-level waste exists today and, if you do it right, it works. There are some improvements needed, probably in the area of volume reduction, maybe some monitoring and predictive capability, or maybe some burial work for some Northeast sites and places like that. But, they are refinements. We also use the idea that waste management technology ought to make economic sense; whatever we do ought to make sense economically - an appropriate return on investment or positive cost benefit - depending on what you have to do. But, you ought not to throw money away. And, lastly, for dealing with some special situations, like Three Mile Island where they generate some special waste, you may need some special requirements. Possibly, in the area of waste form.

STATUS OF REGIONAL COMPACTS

I have been asked to review for you what is going on around the country, and I am going to try and do that for you. I can't do it in great detail. If you have some questions about a particular area when I get through, give me a wave. I think, first and foremost, you ought to realize that, in the last two years, the problem has gone from a federal problem to a state problem. Whether any of us like it or not, the states believe they own the problem today. There are people in many states committed to solving the problem. That's something that must be recognized.

In terms of the compacts, the first area to get a compact was the Northwestern part of the United States. In fact, the first state to sign off and pass the law was the State of Idaho, which had absolutely nothing to do with the fact that we happen to be in Idaho. They had a lot of good things going for them and some bad ones. They had a disposal site that has about 95 unused acres, which means it will service them for a long time. The State of Washington, at that time, had Initiative 383 which basically said that, after last July 1st, they couldn't take any waste from outside the State if it was generated by power plants. There was a lot of political pressure in Washington to assume control over the destiny of that site - what comes in and what goes out. They had one more thing going for them - a lawyer on Governor Evans' staff in Idaho was capable of writing the compact. So, they were really able to put together very fast a very special purpose compact, probably of little use to any other region because it is made for the Northwest. It should be introduced this month or next month in Congress by Senator McClure. They don't expect action on it this time around but they do expect action the next time.

The Southwestern part of the United States has responded to the leadership of Colorado. This region has a simple rule of thumb. The state that generates the most waste will host the disposal site, if it wants to be in that compact. California chose not to be in the compact and Arizona is wavering. They are saying, well, let us be in for a while and we will see what happens. Both California and Arizona will generate more waste than Colorado. Colorado is third. Governor Lamm is prepared to accept the site. They are meeting in Scottsdale tomorrow in the throes of negotiating the final price of the compact.

Working our way East, to what we call the South Central Region (Texas, Oklahoma, Louisiana, Arkansas, and other states), there is a weird situation. They don't have a lot of waste. Texas has chosen not to participate and to develop a Texas-only site. They have some legislation to support that end, and about 2 million dollars in funding. Representatives from states in this region meet once a month in Oklahoma City, because Oklahoma is the only state in the region without a sunshine law, so they can have private meetings there. They are pushing it around without much success.

The first meeting was in February of 1980, started at the faculty club at Michigan State University, when the Midwest got together. Bill Taylor and Governor Milliken's office put the meeting together. They didn't get anywhere with that one. About ten days ago, they completed, they feel successfully, negotiating all the principles involved in a compact and they feel they are prepared to give it to some lawyer, who they hope the Department of Energy will hire for them, to write the compact. So, they seem to have, in the last few months, reached the point where they are proceeding forward. They are trying to set up a whole system in the Midwest, and have the compact deal with a broader perspective than most other places. It would deal with processing centers and various disposal options and they are trying to put it all together for a systems approach.

The Southeastern part of the United States has Barnwell, South Carolina as a disposal site and that gives them an advantage. They worked out a compact and presented it to the governors last September 24th, in Puerto Rico. They seemed to have reached agreement on all the provisions. However, they have one problem left - that's what states are in and what states are out. Those that are clearly in are Florida, Georgia, Alabama, Mississippi, North and South Carolina, and Tennessee. There are some others like Virginia and Maryland that might like to be in. It is not clear how that's going to work itself out.

The Northeastern United States includes New England, Pennsylvania, New York, and New Jersey at this point. They have been meeting since about mid-April. they have had a couple of meetings and, I guess in September, admitted Pennsylvania, New York, and New Jersey to full partnership from observer status. I think Maryland is going to go to the next meeting, which I believe is this Thursday. Thursday is a big day for a meeting. New England seems to have evolved toward getting some of their staff support from an organization called CONEG, Counsel of Northeast Governors. Their position, in my perspective, is one of either of poised reaction or poised to circle the wagons and do nothing for a while. In the next month or two, I think it will sort itself out. They have a couple of things going for them, one of which is Three Mile Island which generates a lot of waste, and not too many states are going to accept it. So, that does give them an impetus to get some kind of site in that part of the country.

Then, there is one group of states left. We refer to them as the SOL group. And, it kind of grows in strength; Maryland, Delaware, West Virginia. Virginia seems to be getting in there lately. It is not clear where South Dakota stands. They are not having a piece of the action at this point. It's an awkward situation that needs to be dealt with over the next six months to a year and it is our hope that cooperatively, the National Governors Association, the National Counsel of State Legislatures, the Southern States Energy Board, the Western Interstate Energy Board, and the Department of Energy can work out a deal so everybody will have a home.

SUMMARY

That's about where we are now. My personal perspective - do I think that every region is going to have a disposal site by 1986? Oh, probably not. Do I think they are going to need to have one? I don't think so either. The Northwest compact, the Southeast compact, and most compacts include a loophole that allow the compact commission to accept out-of-region waste if it so chooses. I think it is necessary that every region be really moving towards getting a disposal site, that every region have acted in good faith such that one can really believe that they are committed to getting a disposal site. If that situation obtains, then one can expect that the Northwestern states, and the Southeastern states, through their compact commissions, will probably create some more room for them to be successful. All of this has been described as a soft technique --- it's very imprecise whatever it is. It is very difficult to describe the behind-the-scenes activity. Bob called it a catalyst and I think that's as good a word as any. Where we are most useful is to bring the right people together at the right time, and hopefully in the right setting, so that they can talk about and resolve their problems. It is very difficult for us to figure what kind of deal Kentucky and Illinois need so that they can get together and solve a disposal site problem or reopen Maxey Flats and put Chuck there back in business or whatever. That's not the thing that we can do very effectively. But, we can bring the people from Kentucky and Illinois together, and we can provide them with information and staff support.

Now, as a more selfish point of interest, I think you have to be aware of the approach we try to take when states ask for help. When a region or state comes and asks us for help, we do try to offer them your services. Sometimes, they accept and often they don't accept. They don't accept mine anymore than yours, either. Don't feel singled out. But, our first approach is to try to provide support through the local DOE laboratory. There is one case where Oak Ridge is providing some support to Tennessee. But, most of the time right now the Department isn't very credible and they are not interested in our support. But, we are continuing to do that, and you are welcome to participate and help in that effort.

I think that about covers roughly what is going on around the country. Unless, someone is interested in a particular item, I would like to leave it at that. I would just like to leave you with a few words about this meeting. One, I would like to encourage you all to speak up and if you don't understand something, or you don't like something, or it doesn't make sense, say so, nicely, but don't be shy. The purpose is to try to promote some good interaction on what's going on. We are interested to find if we have bad rocks, and to find out where the good rocks are and put them in the program.

LOW-LEVEL WASTE MANAGEMENT PROGRAM: TECHNICAL PROGRAM OVERVIEW

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Thank you, Dewey. My purpose this morning is to refocus your thinking on the technology aspects of the Low-Level Waste Management Program (LLWMP) which we are going to be discussing for the next two and one-half days. In order to do that, a recapitulation of the missions that we are interested in, some of the programs history, and a brief discussion of where we are going are needed. I don't intend to get into a detailed program overview, as the title of the talk might indicate, because you are going to get all of that information during this meeting. So, let's first look at the mission. The overall mission of the program, as you heard several speakers discuss this morning, is the disposal of materials that have been designated as low-level waste in a manner that will protect the public health and safety, in both the short and the long terms, and to establish a low-level waste management system no later than 1986.

The mission of the technical program (Figure 1) is to develop the technology component of the Department of Energy's Low-Level Waste Management Program and to manage research and development, demonstration, and documentation of the technical aspects of the program. We will talk a little more about this shortly.

Now, I would like to review just a little history. The current technology development program is based on four distinct activities (Figure 2). First, was the shallow land burial steering committee, which started about 1975 and went on to 1979. It developed the document called "Unresolved Technical Issues in Land Burial of Low-Level Radioactive Waste." I know most of you have seen it, and have certainly heard us talk about the technical issues and gaps described therein. There have been general state-of-the-art reviews prepared to describe the currently available technology. In Des Moines, we established major alpha program milestones. At the San Diego annual meeting we discussed extensively the handbooks and how they supported the milestones. Basically, what we are interested in is technology transfer.

What we have attempted to show in Figure 3 are some of the major technology objectives because these are the things that we are going to be addressing for the next two and one-half days. They are: develop and demonstrate techniques for waste generation reduction, develop and demonstrate waste treatment, handling and packaging techniques, develop and demonstrate the technology for greater confinement, and develop the technology for remedial action at existing sites. In addition, we have another objective of equal importance, the technology transfer objective which is to compile, and

Figure 1.

LOW LEVEL WASTE MANAGEMENT PROGRAM

MISSION: TO DISPOSE OF MATERIALS THAT HAVE BEEN DESIGNATED AS LOW LEVEL WASTE IN A MANNER THAT WILL PROTECT PUBLIC HEALTH AND SAFETY IN THE SHORT AND LONG TERMS.

- ESTABLISH A LOW LEVEL WASTE MANAGEMENT SYSTEM NO LATER THAN 1986.

TECHNOLOGY DEVELOPMENT MISSION: DEVELOP THE TECHNOLOGY COMPONENT OF THE DEPARTMENT OF ENERGY'S LOW LEVEL WASTE MANAGEMENT PROGRAM. MANAGE THE RESEARCH, DEVELOPMENT, DEMONSTRATION, AND DOCUMENTATION OF THE TECHNOLOGICAL ASPECTS OF THE PROGRAM.

Figure 2.

THE BASIS FOR THE CURRENT TECHNOLOGY

DEVELOPMENT PROGRAM IN SHALLOW LAND BURIAL

COMPRISES FOUR COMPONENTS

SHALLOW LAND BURIAL STEERING COMMITTEE RECOMMENDATIONS
- 1975-1977 AEC-ERDA-DOE FOR HQ MANAGEMENT
- 1979 "TECHNICAL ISSUES" DOCUMENT FOR LLWMP

. STATE-OF-THE-ART REVIEW
- 1980

. DES MOINES LLWMP MANAGEMENT MEETING
- 1980 ESTABLISH MAJOR "ALPHA" MILESTONES

. SAN DIEGO PARTICIPANTS MEETING
- 1981 "HANDBOOK" STRUCTURING OF MILESTONES

Figure 3.

TECHNOLOGY OBJECTIVES

- DEVELOP AND DEMONSTRATE TECHNIQUES FOR WASTE GENERATION REDUCTION.
- DEVELOP AND DEMONSTRATE WASTE TREATMENT, HANDLING AND PACKAGING TECHNIQUES.
- DEVELOP AND DEMONSTRATE THE TECHNOLOGY FOR SHALLOW LAND BURIAL.
- DEVELOP AND DEMONSTRATE THE TECHNOLOGY FOR GREATER CONFINEMENT.
- DEVELOP AND DEMONSTRATE THE TECHNOLOGY FOR REMEDIAL ACTION AT EXISTING SITES.

TECHNOLOGY TRANSFER OBJECTIVES

- COMPILE AND ISSUE A HANDBOOK DOCUMENTING THE TECHNOLOGY FOR EACH OF THE ABOVE TECHNOLOGY OBJECTIVES.

issue a handbook or handbooks, as the case may be, documenting the technology for each of the above technical objectives. And, as Dr. Levin has mentioned, we intend to use these documents as vehicles for giving technology information to the ultimate users, be they states, commercial vendors, or whoever. So, there is somewhat of a duality of the program. We have work going on, which you will hear about in the next day or so, on pure technical aspects on improving shallow land burial, and other areas. You will also hear something about handbooks -- the technology transfer is the other part of the program.

Let's now look at the alpha milestones which were developed to meet the technical objectives (Figure 4). The alpha milestones are the planning devices that we use in the program to designate where areas of work are ongoing. Please note the absence of any completion dates. You will be hearing about the detail during the rest of this meeting. I do want to call your attention to what these milestones are. Milestone A is to develop and demonstrate technology for waste generation reduction, (notice the parallel technology transfer milestone) and to issue a waste generation waste reduction handbook. Milestone B is to develop technology for waste treatment, handling, and packaging and to issue the Technology Transfer Document. Milestone C, which is the flagship of the program because shallow land burial is the principal way of disposing of waste today and we feel will continue to be so, is to develop and demonstrate technology for improved shallow land burial and issue the handbook. Milestone D is to develop and demonstrate remedial actions technology for existing burial sites. We have need for remedial action in both the defense and commercial area. Let's now look at Milestone E. You heard Dr. Barainca talk earlier about greater confinement; this is the milestone which is aimed at answering such questions as, "Is a greater confinement capability really needed?" Milestone G is aimed at developing waste treatment, handling, and packaging technology needed for greater confinement disposal. Notice, that the Milestone B and G fall together in a pair as do C and E and you will hear some of them discussed together.

As you know the stated purpose of the program is the exchange of information and the analysis of the program needs for the low level waste management program. We hope that you will take full advantage of the program that you see on the agenda. We also hope that you will talk with your fellow workers in the corridors and express your opinions and ideas to them. Further, we would welcome input to any of the people who are on the staff. Certainly, Dr. Levin and I would be more than happy to have any recommendations as to needs, gaps, and issues that you feel are important to us.

Now, I would like to focus your attention a little bit on the format of the meeting as it will be from now on. We will start the technical program by discussing technical development programs in our sister federal agency, the Nuclear Regulatory Commission. We will then discuss programs of interest to us in the commercial area, and finally, finish with some DOE-type information on interim operations by John Deichman.

Figure 4.

THE LLWM PROGRAM HAS ESTABLISHED A SET OF "ALPHA" MILESTONES TO MEET THE OBJECTIVES

MILESTONE A

- DEVELOP AND DEMONSTRATE TECHNOLOGY FOR WASTE GENERATION REDUCTION.
- ISSUE WASTE GENERATION REDUCTION HANDBOOK.

MILESTONE B

- DEVELOP AND DEMONSTRATE TECHNOLOGY FOR WASTE TREATMENT, HANDLING AND PACKAGING OF LLW FOR SHALLOW LAND BURIAL DISPOSAL.
- ISSUE WASTE TREATMENT, HANDLING AND PACKAGING HANDBOOK FOR SHALLOW LAND BURIAL.

MILESTONE C

- DEVELOP AND DEMONSTRATE THE TECHNOLOGY FOR SHALLOW LAND BURIAL DISPOSAL.
- ISSUE HANDBOOK FOR SHALLOW LAND BURIAL DISPOSAL.

MILESTONE D

- DEVELOP AND DEMONSTRATE REMEDIAL ACTION TECHNOLOGY FOR BURIAL SITES.
- ISSUE REMEDIAL ACTION HANDBOOK.

Figure 4. (Cont.)

MILESTONE E

- DEVELOP AND DEMONSTRATE THE TECHNOLOGY FOR GREATER CONFINEMENT DISPOSAL FACILITY.
- ISSUE GREATER CONFINEMENT DISPOSAL HANDBOOK.

MILESTONE G

- DEVELOP AND DEMONSTRATE THE WASTE TREATMENT, HANDLING AND PACKAGING TECHNOLOGY FOR GREATER CONFINEMENT DISPOSAL.
- ISSUE HANDBOOK FOR WASTE TREATMENT, HANDLING AND PACKAGING FOR GREATER CONFINEMENT DISPOSAL.

We will then move into the afternoon session to discuss the activities and studies which are currently underway within the low level waste management program. Basically, we have structured this part of the program to be subject-oriented rather than contractor-oriented. So, you will find continuity by subjects, i.e. we will discuss Milestone A in its entirety and all contractors who are working in that area will be talking about that. We have also attempted to set the format of the talks so that you will first hear studies and activities which deal with fundamentals, the generic studies, if you please. We will then move to application of these fundamentals, and finally cover demonstrations.

We intend to utilize the last day for workshops on the milestones. I would like to emphasize to you that the workshops are your meetings. This is where you can discuss the work going on in the areas of the various workshops. I would like to point out to you that the workshops are led by contractors. The worksheets which you have seen in your handout have been developed by contractors. The people from the management part of the program are serving only as resources, and as the scribes for the workshops.

So, again, I would like to welcome you to this meeting. I would like to suggest that you take full advantage of the fact that we have assembled many of the people who are involved and have knowledge of the many aspects of the low level waste program, to circulate and discuss topics of interest. However, please pay particular attention to those papers that cover the workshop area you have signed up for. And, then, by all means participate in the workshop. Thank you.

NRC ACTIVITIES RELATED TO 10 CFR PART 61

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INTRODUCTION

Thank you, Dewey It's a real pleasure to be here and meet with you folks. First of all, I want to convey Bob Browning's regrets at not being able to attend. If you look at the program you see Bob listed as the principal speaker. Bob is our deputy director. Our director chose this week and next to take a trip and Bob is unable to attend.

What we do want to do today is to go over several aspects of our program at NRC. John Stewart will review some of the things we're doing other than the program activities related to 10 CFR Part 61. That's the thing that's been on my mind and a lot of people's mind for the last months -- years, really. We want to show some of the other activities that we have underway and expose you very briefly to some of the technical work that we have under contract to support these various objectives and planned accomplishments. It's not intended to be a detailed discussion of what the researchers are doing for us but simply to show you the kind of work that's going on.

I think it's extremely important that DOE and NRC join together and share in the technical work that both of our agencies are doing. In that respect, I would like to report that we have made some very good progress in the last few months in sharing information. We've looked at the low-level waste management plans of both NRC and DOE and we see areas where it looks like you are doing the same things we're doing; at least by titles there's a lot of similarity. It is not unusual that there would be similarity. I think we all recognize the same kinds of problems.

We have focused in on at least two technical areas and have brought together, at Brookhaven and then Oak Ridge and Los Alamos, not only the program managers, but more importantly, the scientists and the technical people who are actually doing the work, around the same table to compare notes on what was being done. Surprisingly enough the work tasks complemented each other very well. We saw very few areas of overlap and duplication. I want to emphasize that it is very important to our program to share knowledge and I look forward to the next few days of learning more about the technical work that is going on in low-level waste within DOE.

I've asked John Stewart, who is one of our staff members in the Waste Management Division, to go through some of the aspects of our program plan and give you a feel for what goes on at NRC, a lot of which isn't directly visible to the outside world yet. I would like to go through some of the aspects of 10 CFR Part 61, give you a little background and a status report.

HISTORICAL DEVELOPMENT OF 10 CFR PART 61

At this point I want to give you a little bit of background of the events that have led up to where we are now in the development of 10 CFR Part 61 and the Environmental Impact Statement. The whole process started a little over three years ago when NRC published an advanced notice of proposed rule-making which told the public, "We want to do something about low-level waste regulation", and asked the public to advise us what to do. We received a number of comments in response to the notice of rule making and this provided guidance to us in terms of what we wanted to do and where we wanted to go.

The next milestone came about a year later, November 5, 1979. At that time, if you recall, the Governors of the States of Washington, Nevada and South Carolina were a bit unhappy, to put it mildly, over the way low-level waste was being handled and shipped into their states. They came in and asked then-Chairman Hendrie what NRC was going to do about it. Fortunately, we had a preliminary draft of 10 CFR Part 61 so that the chairman could tell them that we were developing guidelines and regulations.

In retrospect, that preliminary draft was a little bit rough around the edges, and some of the things in it haven't held up. But, it was our first attempt to put down on paper all of the things that we were thinking about that ought to be in a regulation. It was very fortuitous that this happened because this draft got very wide distribution. A preliminary staff draft within the Commission doesn't usually get out onto the street; this one did. We mailed out four or five thousand copies to all kinds of people, and it provided something to talk about on an informal and a formal basis. We received a number of comments on this preliminary draft and we structured a series of workshops in the summer and fall of 1980. We held workshops in Boston, Atlanta, Denver, and Chicago, at which we brought together government, industry, academic representatives, and public interest groups, to examine some of the key issues in 10 CFR Part 61. We derived a great deal of benefit and a great deal of information from these workshops. All of this culminated in July when we published proposed 10 CFR Part 61 in the Federal Register. We followed that up in October with the draft Environmental Impact Statement (EIS) that gives the rationale and explains the rule.

The EIS represents a tremendous amount of effort, largely on our own staff's part. Dames and Moore, as a contractor to us, provided much of the technical derivations and the technical basis that you find in some of the appendices and in the EIS. The actual writing of the statement and the preparation was strictly an in-house staff effort. We intend to keep it in-house, to the extent that we can, during the comment period and the preparation of the final statement. Not that we have anything against contractors, but the document had to look like an NRC document and contractor reports have a tendency to look like contractor reports -- there's a difference beetween the two. So we had to take the information and translate it into the kind of format and language that's necessary.

That's where we're at now. We have extended the comment period, as Mike indicated earlier, to correspond with the comment period on the EIS, January 14, 1982.

I want to interject one point at this time, and that is, we're very anxious to talk with people about their comments on the rule. Some of the comments that we've seen so far reflect a misunderstanding of what we intended to do, which tells us we'd better clean up our language and make it more understandable. Some of the comments are difficult for us to understand; we're not quite sure what the commenter is driving at. So, I'd like to encourage that if you have any comments, or if you're thinking about writing us a comment, please give us a call. I'll be around for the next two or three days here in the meeting. We want to understand your comments and we want you to understand what it was we tried to say, so that when we do get the comments they are things we can deal with and deal with to your satisfaction.

BASIC FEATURES OF 10 CFR PART 61

I'd like to move into some of the basic features of 10 CFR Part 61. I presume most of you have read it in great detail and are at least halfway through the EIS by now, but I will kind of skim through some of the features. There are essentially three aspects to 10 CFR Part 61. There's a procedural aspect, a technical aspect, and a handful of miscellaneous things, perhaps the most important of which are the financial assurance requirements.

Procedural Aspects

I'd like to first of all walk through the procedural aspects. There are five phases in the licensing of a low-level waste disposal site. I want to make a point that 10 CFR Part 61 is a Federal regulation to govern the licensing of low-level waste disposal sites in Nonagreement States. It's a tool to be used by the NRC. More than half of the states are Agreement States. What do they do with this rule? We see 10 CFR Part 61 as being the model against which state regulations will be compared for compatibility. Any Agreement State that intends to license a low-level waste disposal site will have to create its own regulations which we hope look exactly like 10 CFR Part 61, but they at least have to be compatible.

I'm really talking about NRC's regulation, but you can also visualize state regulations looking very much like this.

Five phases in licensing a facility begin with the pre-operational phase, go through to the actual operation of the facility, which may continue for twenty, thirty, or forty years. There's a site closure phase, at which time the facility is prepared for the final long-term institutional care. The site closure phase is followed up by a five year period, or whatever it takes to make sure that the things that were done to close the site are effective and continue to be effective. Then begins a period of institutional control where the site owner maintains the responsibility for the custody of the site.

Preoperational Phase

I only want to touch on several things that go on in the pre-operational phase. First on the list, of course, is the actual selection of the site itself. If you look through 10 CFR Part 61 you find essentially nothing that tells you what the site selection process is, except that you must conform to the environmental requirements that are reflected in 10 CFR Part 51 which are the NEPA requirements. NEPA requirements simply say that you must consider alternatives. We've taken the position in our guidance to licensees that it is not necessary to come to NRC with a number of fully characterized sites. We do want to see how you arrived at the site you chose. We want to see what the site selection process was so that it is clear that alternative sites were considered on the basis of reconnaissance level information, and that a considerable judgment was made in choosing the site for which a license is being requested. The site selected does have to be fully characterized. The hydrologic, geologic, topographical, and all the features that are essential to the judging of the site must be presented to us for the site of choice.

There's a whole series of procedures that we go through at this point which involve many opportunities for public hearing. We also offer opportunity for not only public participation, but participation by states and Indian tribes that might be affected by the selection of the disposal site in their area.

Operational Phase

After we have completed our evaluation of the license application and prepared a safety evaluation and an environmental impact statement for that site, assuming everything is satisfactory, we issue a license and operations begin. During the operational phase the facility is constructed in accordance with the preliminary plans that were laid out in the application. Waste is received and disposal operations begin.

One feature of the operating phase is periodic review and renewal of the license. When we issue the license, we're making a commitment of a hundred years, a hundred and fifty years, or maybe even longer; we're making a very long-term commitment. To renew that license every five years may seem a little absurd on the surface, but it does serve a very worthwhile purpose. Every five years or so we feel that it's important to review the operations, review the operating history, review the operating data that's been accumulated, reconsider the financial arrangements that have been made, look at the development of technology that occurred during this period of time to make sure it's being applied properly, and essentially up-date the operation and improve it on a five-year basis. I hope there aren't too many licensees in here who will translate that into ratcheting, but we do want to keep the operations apace with the technology.

Site Closure and Post Closure

Following the operational period, as the site becomes filled the licensee will submit to us his final version of the site closure plan that has been under periodic review during the operating period. He tells us how he's going to finally prepare the site for closure. After we're reviewed and approved that, he proceeds to do it. After having conducted the final activities at the site, usually consisting of grading and the final vegetative cover preparation, and whatever is involved in controlling surface activities at the site, the licensee is then obliged to remain on site for a period of time. Five years or so is what we're proposing in the regulations, to assure that things like subsidence, surface drainage, and erosion control that were put into effect are actually working. The best analogy I can think of is those of us who have bought new houses with all kinds of assurances from the contractor, but as soon as the warranty is up the foundation back-fill starts to sink and the plaster comes off and things like that. So this is kind of an extended warranty period, if you will.

Institutional Control Phase

At the conclusion of that period the site owner takes possession of the site. I think you can translate that as some state, not the Federal government. Ownership by the State or Federal government is a requirement. Now, of the six sites, one is owned by the Federal government, the one at Hanford. The other five are owned by the states in which they're located. My off-the-wall prediction is that there probably won't be any more sites located on Federal land, particularly with these kind of institutional requirements. The emphasis is shifting to the states, the responsibility is shifting to the states, the development of sites is shifting to the states. I think that the states will be the ultimate owners of new sites.

During this hundred year period -- and I'll explain the significance of a hundred years in a few minutes -- we expect that the site owner will only have to carry out routine monitoring and surveillance, perhaps minor maintenance, such as fence-fixing and grass-planting and things like that. One of our design objectives is that all that the site owner has to do during this institutional period is to keep people out and keep the fences up and take samples and monitor to make sure that all the things that were done prior are working.

Technical Aspects

In laying out the technical part of 10 CFR Part 61, we debated at great length as to whether or not to have a rule that was based on performance objectives or whether we should go into specifics with a prescriptive type of regulation. We ended up with a little bit of both, quite frankly. We did feel it was very important to set performance objectives. We set performance objectives in four areas, three of which are related to protection of people from the effects of radiation, the fourth one has to do with the long term institutional care of the site.

As you heard earlier, there isn't any EPA standard for low-level waste. EPA low-level waste guidance criteria may be out in 1983. One thing that I think is worth stating is that NRC has the statutory responsibility and authority, and has had even since 1954 with the Atomic Energy Act, to license low-level waste disposal facilities, with or without EPA standards. We'd like to have EPA standards, but in their absence, we've developed a sort of surrogate for an EPA standard and proposed it in the rule.

In the EIS, we go through a discussion as to the range of values that we considered and why we chose this value. Those of you that have had anything to do with the nuclear fuel cycle will recognize the numbers as coming out of the fuel cycle standard that EPA put out as 40 CFR 190. To us, it was a touchstone; it was a standard that was reasonably well accepted. It was considerably lower than the 500 millirem individual population doses permitted by the International Commission on Radiological Protection (ICRP) and 10 CFR Part 20. While we chose a value that was considerably below that, we picked one that was not unduly restrictive, like one millirem per year exposure.

We also backed it up to the EPA primary drinking water standard that says that any drinking water supply nearby should meet primary drinking water standards.

We also set another performance objective dealing with protection of individuals from inadvertent intrusion. This is a concept that is perhaps unique to our business. The hundred year institutional period that we propose is a necessary part of the system. One of the primary things that happens during this period is that people keep people out. At the end of that period of time we made some assumptions that people gain access to the site. We think this is an unlikely event, that people will maintain institutional control, and that they're not going to forget the next day. Nevertheless, we performed evaluations to determine what happens under differing sets of scenarios to individuals who might intrude on the site and carry out reasonably normal activities. We chose a performance objective for this scenario of 500 millirem per year dose.

During operation performance objectives are fairly simple. People comply with 10 CFR Part 20, the standard for protection against radiation. We considered it important enough to call out as a performance objective that the site and the waste that is buried in that site needs to remain stable, because stability is the keystone for the whole operation in terms of water control, penetration of water, and potential migration. Stability of the waste and stability of the site are both important.

The goal during the long term institutional period is that active maintenance is not required. By active maintenance I'm referring to things like the pumping of trench water at Maxey Flats and running it through an evaporator.

So much for performance objectives. It would be nice to say that's the end of the regulation, now go out and devise systems that will meet these objectives. It's a good idea; however, the problem is that nobody is in charge of the complete system. We view the system as consisting of four major components. First, the site itself -- that is, the hydrological, geological, physical characteristics of the site are very important factors in the disposal of low-level waste. Second, the way the site is designed and operated, the way that trenches are prepared, the way that waste is emplaced, the way the trenches are closed -- this is a very important aspect. Third, the waste itself -- that is, the physical and radiological characteristics of the waste are a very important factors. The fourth factor is the insitituional requirement. These four things in combination -- and there are probably an infinite number of combinations that would work -- we think can meet the performance objectives. In 10 CFR Part 61 we have established certain minimum requirements for each of them.

The requirements for site suitability are largely avoidance criteria; that is, stay away from this, stay away from that problem. You can also call them lessons learned. I think for almost all of these you can recognize situations at existing sites that have promoted a siting requirement. They represent, to a large extent, things that we've learned, things that have caused us problems. They don't tell you what's an ideal site, but they perhaps tell you what bad sites look like. We're going to have a workshop in December, at which we will go beyond these proposed criteria to discuss what are some of the good characteristics that we should start looking for in sites. We've laid out a series of requirements on the site design -- the way that the site should be laid out, and the way that it should be operated and closed.

The Low-Level Waste Task Force recommended in their draft document that we should classify by total hazard -- consider all the hazards. We have not attempted such a task in 10 CFR Part 61. We set out to classify just on the radiological hazard alone and found it to be an extremely difficult job and something that is a very difficult thing to understand.

The Class A, Class B and Class C waste classification scheme that is in 10 CFR Part 61 represents particular combinations of those four factors that I talked about before, all of which are normalized to a 500 millirem exposure to an intruder and which also the guarantee that we meet the off-site migration. Given the combination of 100 years institutional control, an acceptable site, and disposal of waste without any particular regard to its waste form, we calculated what the upper concentrations of certain isotopes would be such that if, at the end of the hundred year institutional period, an intruder came into the site, engaged in construction and agricultural activities, (he excavates for a basement, plants some crops, raises a garden, lives on the site,) he would not receive more than a 500 millirem exposure.

We assumed that the waste by then looks like dirt, and that the intruder doesn't recognize that it's low-level waste. From this scenario we derived those values that you see in Column A of Table 1 of 10 CFR Part 61. These are the maximum concentrations for isotopes that are acceptable under that combination of conditions. There is a point at which any higher concentration would exceed the 500 millirem limit. That's the point at which waste becomes Class B waste.

The Class B waste has as its particular characteristic that it must be in a stable waste form. We try to define stability. What we're looking for is a waste that will last a long time and won't change its size and shape during that period of time. The scenario at the end of the hundred years assumes that upon intruding on the site, and attempting to carry out the construction and agricultural activities, the waste doesn't look like dirt, but looks like chunks of concrete or vinyl esterstyrene. It looks like waste. It's not the kind of condition that allows the intruder to carry out the construction and agriculture scenario. The intruder gets out upon discovering the waste. Thus, we call this the discovery scenario. The intruder gets out with 500 millirem exposure or less. There comes a point at which even that scenario would cause him to exceed the 500 millirem limit. One way to prevent that from happening is to take the waste that has higher activity, and bury it down deep, put it down at the bottom of the trench, cover it up with a lot of this lower activity waste. We call that Class C intruder waste. Intruder barriers, by and large, mean just burying waste deeper or where you can't go deep, construction of some sort of artificial barrier. We've decided that 500 years is as long as you want to allow any credit for that kind of thing. The values in Column C represent the maximum values that are acceptable for disposal under these conditions. At the end of 500 years if you assume that the Column C values look like dirt, if somebody intrudes with the construction and agriculture scenarios, they will not exceed the 500 millirem exposure.

Waste classification represents a combination of waste form, radioisotope characteristics, radioisotope concentrations, the method of emplacement, and to some extent the site characteristics.

Of all low-level wastes there are some that are exempted by 10 CFR Part 20 that never make it to the low-level waste disposal site or the wastes that are subject to 10 CFR Part 61, Class A at the present rate of generation is about 60 percent of the total, Class B would be somewhere in the neighborhood of 30 percent, and roughly 10 percent would be Class C intruder protected waste. At the present time we visualize less than one percent of the waste that we project over the next twenty years would need to go someplace other than shallow land or near surface disposal.

This doesn't include decommissioning wastes from power plants. We don't see, within the time frame we looked at in the EIS, large reactor components with very high levels of activation products or similar wastes being a problem. Some day they will. The waste unsuited for near surface disposal includes transuranics (TRU) above ten nanocuries per gram. In the commercial sector the volume of waste that's being currently generated as transuranic waste is very small. There is less than one hundred thousand cubic feet of waste that is currently in storage because there's no place to put it. This will have to remain in storage until something is resolved for TRU disposal. This all can change as we enter into a reprocessing economy where more and more transuranics are generated. This is one of the things that we intend to look at as follow-on to 10 CFR Part 61.

Miscellaneous Requirements

The institutional requirements are that the land must be owned by the Federal or state government and control must be maintained over the site for about a hundred years.

With regard to financial assurances, there are three phases that must be protected. We require financial assurances to assure there is money to carry the operations through the normal operating life. We also require surety arrangements to make sure there's money set aside for the site closure. The third thing we require is that the licensee demonstrates to us that he's made arranagements with the site owner satisfactory to both of them to assure that there will be money during the post-closure period.

I briefly mentioned the state and tribal participation and that's all I'll give it here. We offer the opportunity for states and Indian tribes to assist us in the evaluation of an application to license a low-level waste disposal facility.

We have some provisions in 10 CFR Part 20 that establish a manifest system. This is in response to some Government Accounting Office (GAO) requests that such a system be established. It's somewhat comparable to the EPA system. We're not instituting new forms, we're simply piggybacking on Department of Transportation (DOT) shipping documents and disposal sites shipping records. We're asking that these documents be used as a vehicle for tracking and controlling shipments.

And finally, we have a requirement that waste generators will have to prepare their waste to comply with the waste form requirements.

SUMMARY

Where do we go from here? We plan to have 10 CFR Part 61 and the EIS in final form just about a year from now. We're targeting to have the final rule presented to the Commission for their approval and to have the final environmental statement published sometime in October 1982. Then we're going to start on the next phase, which is to look at all those things that aren't included in 10 CFR Part 61 and perhaps draft amendments to 10 CFR Part 61 to deal with criteria that would be appropriate for such things as intermediate depth burial. This may provide the basis for disposing of some of the wastes that can cause excessive exposure with the existing 10 CFR Part 61 scenarios.

We're also looking at the bottom end of the spectrum in terms of those wastes that are included, but maybe shouldn't be. Maybe alternative disposal methods would be more suitable. One of the dominant comments we received so far on the rule concerns de minimis values, that is, a level that you can throw away in the trash dump and not worry about it. We're sensitive to that. We've been handling this problem on a waste stream by waste stream basis. We're going to see if we can expand the list of exempted wastes.

We're preparing technical positions, which are the precursors of regulatory guides. Over the next year we expect to issue a number of them. In addition, we will be issuing standard format and content guides to tell how to prepare applications and environmental reports.

I would like to conclude by saying we're anxious to get your input on 10 CFR Part 61. I can't emphasize that too much. Any of you who have questions, comments, or whatever, see me during the next few days. I'll be around through all of the meeting. Thank you.

OVERVIEW OF NRC'S LOW-LEVEL WASTE ACTIVITIES

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INTRODUCTION

This presentation describes the major objectives of the NRC Low-Level Waste Program today, gives an overview of our major accomplishments for FY81 and what our major goals are for FY 82. Also included is a brief discussion of our contractual support. This presentation also provides dollars and the type of projects we're doing but does not go into any detail due to time limitations.

ORGANIZATIONAL STRUCTURE

Within NRC, the Office of Nuclear Materials' Safety and Safeguards (NMSS) is the lead office in terms of low-level waste disposal (See Figure 1). This Office is headed up by Mr. John G. Davis and the Division of Waste Management is headed up by Mr. Jack Martin, who is the program area manager for low-level waste management. The program area manager plays a very important role in NRC. In this case, Mr. Jack Martin is responsible for the coordination of all the low-level waste management activities throughout the entire agency. He is responsible for the development of the goals and objectives of the program, making sure we are all tracking along the same direction in terms of program management.

There are three major supporting Offices - Research; Inspection and Enforcement; and State Programs. The Office of Nuclear Regulatory Research, which last spring combined with the Office of Standards Development now has both Research and Standards activities and handles a lot of contractual support for the lead office. The Office of Inspection and Enforcement, has people who go on-site on a periodic basis and inspect the NRC license facilities. The Office of State Programs handles NRC's agreement state programs and also interfaces with the states and looks at the progress that's being made in forming regional compacts.

THE NRC PROGRAM

Figure 2 provides the FY82 Low-Level Waste Management Program Area budget. NMSS, the lead Office, has thirty people who have been assigned to the Low-Level Program area. However, the Office of Research has the largest

Figure 1.

NRC LEAD OFFICE AND SUPPORTING OFFICES

- LEAD OFFICE: OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS (NMSS) JOHN G. DAVIS
  DIVISION OF WASTE MANAGEMENT - JOHN B. MARTIN (PROGRAM AREA MANAGER)

- SUPPORTING OFFICES: OFFICE OF NUCLEAR REGULATORY RESEARCH (RES)

  OFFICE OF INSPECTION AND ENFORCEMENT (IE)

  OFFICE OF STATE PROGRAMS (SP)

Figure 2.

LLW PROGRAM BUDGET FOR NRC

OFFICE	FY82-STAFF-YEARS	FY82-PROGRAM SUPPORT ($K)
NMSS	30	2400
RES	9	4800
IE	1	0
SP	1	55
TOTAL	41	7255

commitment in terms of support ($4,800 K). It is important to mention that program support includes only dollars and does not include staff at NRC.

There are three major objectives in our program (see Figure 3). The first is to perform the safety and environmental reviews for low-level waste disposal facilities. This includes our licensing actions. This also involves our renewals of existing licenses, new applications when they come in, and includes site closure activities. This major objective also includes NRC's agreement state activities. With agreement states we provide the same assistance as we do for the NRC licensed facilities. However, we will provide technical assistance to the agreement states only upon request.

The second major objective is to develop regulations and regulatory guidance for Low-Level Disposal Facilities. This includes the draft rule (10 CFR Part 61) which is described in detail in the following NRC presentation by R. D. Smith.

The last major objective is to assess ongoing low-level waste management activities and includes all other activities beside licensing activities and the rule. This includes Three Mile Island waste generation, and a whole array of different activities that will be discussed in more detail later in this presentation.

Safety and Environmental Reviews

The following is an overview of NRC's low-level waste management program as based on our major objectives. As Figure 4 indicates, the first planned accomplishment under the first objective is to perform NRC's safety and environmental reviews. This is for the NRC licensed facilities, as mentioned previously. This includes applications for new licenses, the renewal of existing licenses, minor administrative matters, and site closure activities. As far as FY81 was concerned, our major accomplishment for this planned accomplishment was to complete the review of the Special Nuclear Materials license for the Barnwell Low-Level Waste Disposal Facility in South Carolina. We also completed a preliminary Draft Environmental Assessment for the Sheffield Low-Level Waste Disposal Facility in Illinois. During FY82 we'll be doing more work related to the closure of the Sheffield site and for the renewal of the Special Nuclear Materials license for the Hanford site. The second planned accomplishment involves the agreement states. Again we'll provide technical assistance for agreement states as we do for the NRC licenses, when so requested. For example, at the request of South Carolina, we performed an environmental assessment of the Barnqwell facility. This was for the South Carolina state license, and was completed last year.

The next planned accomplishment is licensing review procedures and modeling capability. The low-level branch is developing modeling capability in-house. We're not reinventing the wheel; we looked at existing models and are applying them to selected problems to assist us in our licensing actions. Basically what we're going to be doing in licensing review

Figure 3.
MAJOR OBJECTIVES OF THE NRC LLW PROGRAM

- PERFORM SAFETY AND ENVIRONMENTAL REVIEWS FOR LLW DISPOSAL FACILITIES
- DEVELOP REGULATIONS AND REGULATORY GUIDANCE FOR LLW DISPOSAL FACILITIES
- ASSESS ONGOING LLW MANAGEMENT ACTIVITIES

Figure 4.

NRC SAFETY AND ENVIRONMENTAL REVIEW ACTIVITIES FOR LLW DISPOSAL FACILITIES

PERFORM SAFETY AND ENVIRONMENTAL REVIEWS FOR LLW DISPOSAL FACILITIES

PERFORM SAFETY AND ENVIRONMENTAL REVIEWS FOR NRC LICENSED FACILITIES

- EVALUATE APPLICATIONS FOR NEW LICENSE
- EVALUATE APPLICATIONS FOR RENEWAL OF LICENSE
- EVALUATE MINOR AND ADMINISTRATIVE AMENDMENTS
- EVALUATE SITE CLOSURE ACTIVITIES

PROVIDE SAFETY AND ENVIRONMENTAL REVIEWS FOR AGREEMENT STATES

- EVALUATE APPLICATIONS FOR NEW LICENSE
- PROVIDE OTHER REQUESTED ASSISTANCE
- PROVIDE ASSISTANCE TO SP

DEVELOP LICENSING REVIEW PROCEDURES AND MODELING CAPABILITY

- DEVELOP LICENSING REVIEW PROCEDURES
- DEVELOP MODELING CAPABILITY FOR PERFORMANCE ASSESSMENT

procedures is to develop a road map, i.e., the layout of exactly how we will respond to the applications as they are received by NRC.

The contractual effort to support NRC licensing activities are described in Figure 5. The contractual support for this planned accomplishment includes four projects for a total of $175 K. Figure 6 indicates that a total of $825 K for five projects (including 3 research projects for the Maxey Flats site closure activity) are budgeted for FY82.

Figure 7 describes the contracted support effort for modeling capability. This includes the various models we're working with as well as the contracts in support of our modeling efforts. The first models, FEMWATER and FEMWASTE, are in-house models that we're going to be using. The first one, FEMWATER, predicts radionuclides transport. Another model we will be using in-house is the method of characteristics for transport model. This model will be applied in assessing the potential for radionuclide transport at the Barnwell Low-Level Waste Disposal Facility (perhaps for Sheffield also).

Regulations and Regulatory Guidance

As previously mentioned, the second major objective concerns the rule and is described in detail in the following paper by R. D. Smith (see Figure 8). However, it should be mentioned here that the development of the draft rule and EIS are very significant to the low-level program area. The two major FY81 accomplishments for the program area were to publish the draft regulation (10 CFR Part 61) almost a year ahead of schedule and to complete the draft EIS for the low-level regulation.

The next planned accomplishment is to provide technical support for and publish regulatory guidance on near surface disposal. NRC is developing a series of technical positions for regulatory guides. Last year we completed the draft technical position on waste form. For FY82 we've scheduled draft technical positions on site suitability and characterization, facility design, monitoring, and funding for site closure activities.

The next planned accomplishment concerns other than near surface disposal. Work on this planned accomplishment will be initiated in FY82 and will continue into FY83 and beyond.

Figure 9 shows the contractual efforts to support the rule. This includes 2 contracts for a total of $267 K. Figure 10 indicates the contractual effort for regulatory guidance on near surface disposal. This includes a total of eleven contracts for a total of $1535 K for FY82. Examples of work efforts to be accomplished are the Trench Cap Study, the field investigations at Beatty and Hanford which are on-site investigations and the decommissioning and stabilization study for SLB facilities. Currently there is one contract (Engineered Disposal) for $300 K for other than near surface disposal.

Figure 5.

CONTRACTUAL SUPPORT - FY82

- PERFORM SAFETY AND ENVIRONMENTAL REVIEWS FOR NRC LICENSED FACILITIES - 175K

CONTRACTOR	DESCRIPTION	NRC OFFICE
ORNL	ENVIRONMENTAL ASSESSMENT FOR LLW DISPOSAL	NMSS
BOA	ENVIRONMENTAL ASSESSMENT FOR LLW DISPOSAL	NMSS
USGS	GROUND WATER DISCHARGE	NMSS
ISGS	RADIOHYDROLOGY TUNNEL-SHEFFIELD	RES

Figure 6.

CONTRACTUAL SUPPORT - FY82

- PERFORM SAFETY AND ENVIRONMENTAL REVIEW FOR AGREEMENT STATES - 825K

CONTRACTOR	DESCRIPTION	NRC OFFICE
ORNL	ENVIRONMENTAL ASSESSMENT FOR LLW DISPOSAL	NMSS
BOA	ENVIRONMENTAL ASSESSMENT FOR LLW DISPOSAL	NMSS
PNL	RADIONUCLIDE DISTRIBUTION - KY	RES
STATE OF KY.	BURIAL GROUND SITE SURVEY - KY	RES
GEO CENTERS, INC	MAXEY FLATS - SUBSURFACE RADAR	RES

Figure 7.

CONTRACTUAL SUPPORT - FY82

° DEVELOP LICENSING REVIEW PROCEDURES AND PERFORMANCE ASSESSMENT CAPABILITY - 1200K

CONTRACTOR	DESCRIPTION	NRC OFFICE
ORNL	FEMWATER AND FEMWASTE MODELS	NMSS
PNL	UNSATURATED ZONE HYDROLOGY	NMSS
ERTEC	METHOD OF CHARACTERISTICS TRANS MODEL	NMSS
LASL	WASTE TRANSPORT IN SOIL	RES
PNL	RADIONUCLIDE MIGRATION - GROUNDWATER	RES
BNL	SOURCE TERM OF RADIONUCLIDES IN SLB	RES
PNL	BIOENVIRONMENTAL PATHWAY	RES
UNDES	LLW RISK METHODOLOGY	RES

Figure 8.

DEVELOP REGULATIONS, AND REGULATORY GUIDANCE FOR LLW DISPOSAL FACILITIES

PROVIDE TECHNICAL SUPPORT FOR AND PUBLISH REGULATION 10 CFR 61

- DEVELOP DRAFT REGULATION AND DRAFT EIS FOR NEAR SURFACE DISPOSAL
- DEVELOP FINAL REGULATION AND FINAL EIS FOR NEAR SURFACE DISPOSAL
- DEVELOP DRAFT AMENDMENTS TO REGULATION AND DRAFT SUPPLEMENT TO EIS FOR OTHER THAN NEAR SURFACE DISPOSAL
- DEVELOP FINAL AMENDMENTS TO REGULATIONS AND FINAL SUPPLEMENT TO EIS FOR OTHER THAN NEAR SURFACE DISPOSAL

PROVIDE TECHNICAL SUPPORT FOR REGULATORY GUIDANCE ON NEAR SURFACE DISPOSAL

- PROVIDE TECHNICAL SUPPORT FOR AND PREPARE TECHNICAL POSITIONS
- PROVIDE TECHNICAL SUPPORT FOR REGULATORY GUIDES

PROVIDE TECHNICAL SUPPORT FOR REGULATORY GUIDANCE FOR OTHER THAN NEAR SURFACE DISPOSAL

- PROVIDE TECHNICAL SUPPORT FOR AND PREPARE TECHNICAL POSITIONS
- PROVIDE TECHNICAL SUPPORT FOR REGULATORY GUIDES

Figure 9.

CONTRACTUAL SUPPORT - FY82

° PROVIDE TECHNICAL SUPPORT FOR AND PUBLISH REGULATIONS AND EIS - 267K

CONTRACTOR	DESCRIPTION	NRC OFFICE
DAMES AND MOORE	EIS/10 CFR PART 61	NMSS
RFP	CRITERIA FOR ALTERNATIVES TO NSD	NMSS

Figure 10.

CONTRACTUAL SUPPORT - FY82

° PROVIDE TECHNICAL SUPPORT FOR REGULATORY GUIDANCE ON NEAR SURFACE DISPOSAL - 1535K

CONTRACTOR	DESCRIPTION	NRC OFFICE
PNL	ALARA LLW SITE	NMSS
IGS	SHEFFIELD TRENCH CAP	NMSS
ORNL	WORKSHOPS ON SITE SUITABILITY	NMSS
COE	TRENCH DESIGN/CONSTRUCTION TECH.	NMSS
COE	SITE CHARACTERIZATION AND MONITORING	NMSS
COE	GEOTECHNICAL QA/QC	NMSS
UC-LNM	UNSATURATED ZONE SOIL HYDROLOGY	RES
UNDES	FIELD INVESTIGATION - BEATTY AND HANFORD	RES
UNDES	DECOMMISSIONING - STABILIZATION	RES
U. OF AZ.	BURIAL GROUND DESIGN, CONSTRUCTION AND OPS	RES
UNDES	SURVEY AND MONITORING INSTRUMENTATION	RES

Assessment of Ongoing LLW Management Activities

The last major objective, Assess Ongoing Low-Level Waste Management Activities, includes several significant planned accomplishments (see Figure 11). The first is to assess unique and significant low-level waste problems. This includes the characterization and evaluation of TMI, West Valley, and also to assist other NRC divisions and offices as requested. A major accomplishment last year was to evaluate the TMI Epicor II waste forms. It is important to mention that our efforts will be decreasing somewhat for TMI in FY82 as DOE increases their activities in this area.

The next planned accomplishment is waste storage processing, generation processing and storage. A major accomplishment for FY81 was to evaluate the key waste generators. We made on-site visits and we did evaluations of their operations. Another significant item we completed in FY81 was the policy statement for volume reduction. The Commission issued a policy statement (not a regulation) that provides guidance on the problem of volume reduction.

The last planned accomplishment is program area management. Interagency low-level management activities are important. We've had several meetings with DOE in FY81. We had the meetings on burial trenches and trench caps and waste form. We've found these meetings to be very productive. We've received a number of responses from the questionnaires we sent to the participants of the NRC/DOE meeting. The participants of the meetings generally found them to be productive and found that NRC and DOE weren't duplicating efforts in these areas of low-level management. We will hopefully continue to meet in the future.

The last program item to discuss is the program control document. For FY81 we completed a draft program control document which maps out what we'll be doing in the next five years. This document will require frequent revisions as programs and budgets change. However, the program control document will provide a guide as to what direction we're going in the future as far as the area of low-level waste management is concerned.

Figure 12 indicates the contractual efforts to analyze unique and significant waste problems. The major effort will be oriented towards the TMI clean-up and will total nearly $1000 K. Figure 13 shows the contractual effort for waste generation, processing and storage. This will include 10 contracts for a total of nearly $1000 K.

SUMMARY

In conclusion, this presentation provides an overview of the NRC low-level program and our goals and objectives. This includes our major accomplishments for FY81 and a discussion of what NRC will be doing in FY82. An overview of NRC's contractual efforts in low-level is also provided.

Figure 11.

ASSESS ONGOING LOW-LEVEL WASTE MANAGEMENT ACTIVITIES

ANALYZE UNIQUE AND SIGNIFICANT LLW PROBLEMS

- CHARACTERIZE AND EVALUATE TMI WASTE MANAGEMENT ALTERNATIVES
- CHARACTERIZE AND EVALUATE WEST VALLEY LLW MANAGEMENT ALTERNATIVES
- ASSIST OTHER NRC DIVISIONS AS REQUESTED

EVALUATE WASTE GENERATION, PROCESSING, AND STORAGE

- IDENTIFY SOURCES OF LLW
- ASSESS PROCESSING CHARACTERISTICS OF LLW
- ASSESS EFFECTS OF STORAGE ON LLW DISPOSAL

PROVIDE LLW PROGRAM AREA MANAGEMENT

PARTICIPATE IN INTERAGENCY LLW MANAGEMENT ACTIVITIES
REVIEW NATIONAL PLAN
UPDATE LLW MANAGEMENT PROGRAM CONTROL DOCUMENT

Figure 12.

CONTRACTUAL SUPPORT - FY82

° ANALYZE UNIQUE AND SIGNIFICANT LLW PROBLEMS 968K

CONTRACTOR	DESCRIPTION	NRC OFFICE
BNL	TMI RESIN SOLIDIFICATION	NMSS
BNL	CHARACTERIZATION OF TMI - TYPE WASTES	RES
UNDES	PROPERTIES OF SOLIDIFIED DECON WASTES	RES

Figure 13.

CONTRACTUAL SUPPORT - FY82

° EVALUATE WASTE GENERATION PROCESSING AND STORAGE - 1930K

CONTRACTOR	DESCRIPTION	NRC OFFICE
BNL	DEVELOP LLW FORM CRITERIA	NMSS
CNSI + USE	LLW RAD WASTE RECORDS (2)	NMSS
CNSI + USE	LLW RECORDS (2)	NMSS
BNL	STUDY OF NON-FC WASTES	NMSS
BNL	PROPERTIES OF RADWASTES AND CONTAINERS	RES
INEL	PRAIRIE ISLAND IN-PLANT SOLID STUDY	RES
PNL	CHARACTERIZATION OF VOLUME REDUCED WASTES	RES
UNDES	CHARACTERIZATION OF NON-FC WASTES	RES

EPRI'S PROGRAMS IN LOW-LEVEL WASTE MANAGEMENT

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Palo Alto, CA 94303

It's my pleasure to be here today to highlight the technical programs of the U.S. utility industries that are concentrated or focused at the Electric Power Research Institute. I regret I won't have time to go into many of the programmatic activities of various U.S. power companies that are conducted individually on their own internal R&D funding. This is the first year that EPRI or its contractors have participated in the low-level waste participants meeting. I think this is perhaps a reflection of three items. First, the passage of the 1980 Low-Level Waste Management Act which moved this issue to the front burner if it was not perceived as such by some. Secondly, a renewed commitment by the Department of Energy to work cooperatively with industry. I would hasten to add that people like Goetz Oertel, Bob Ramsey, and many others, have always worked cooperatively with the utility industry even under the past administration. But we notice in the past year a renewed dedication to cooperative industry programs and we're very appreciative of that. Finally, about a year ago the Electric Power Research Institute initiated an increased level of effort on low-level waste disposal.

The programs at the institute reside in two departments. Those related to low-level waste siting technology and safety analysis are within the Systems and Materials Department, generally under my direction. Those that relate to process technology for low-level waste disposal, equipment that would be at a power plant, are in the Engineering and Operations Department and are under Bob Shaw and his people. Our activities are also coordinated with the Utility Nuclear Waste Management group under Russ Stanford who will follow me as a speaker today.

Within the limitations of our budget we have tried to develop a comprehensive program. Because of the constraints imposed on our various sponsors by the public utility commissions, we have only $60 million a year to spend on all elements of nuclear technology research and development, from fuel to all of the safety issues. As a result of resource limitations, the issue of low-level waste management receives only about one to one and a half million dollars per year of effort, and this is a substantial increase from previous years.

The objective of Electric Power Research Institute and its programs in low-level waste siting is as follows: To serve as a source of reliable technical data for parties who are interested in opening and operating a new low-level waste site in one of the regions of the country. This could include both a state agency, including their state regulatory authorities, and a commercial company interested in operating such a facility. We hope to function as a source of reliable technical data for such a group because it's in the interest of the utilities to make sure that the waste effluents from the power plants are handled correctly so they don't become a public health and safety or public acceptance problem.

With respect to processing technology, given the limitations of our funding, we can perhaps spend only a half a million to one million per year in this area while demonstration of even one system is a $10 million item. Thus, our focus has been on technical assessments of various systems developed by private companies in the marketplace. So later in this presentation I will discuss how we have conducted some technical assessments to help utilities understand the readiness of various technologies to be implemented in the volume reduction area.

The EPRI program objectives in waste disposal are described in Figure 1. Figure 2 shows how the budget in the nuclear fuel cycle program is broken down. This year we're planning to spend about $600,000 on matters related to spent fuel storage technology, another $100,000 keeping technically abreast of fuel reprocessing systems, and approximately $400,000 on matters related to high-level and low-level waste disposal.

In the area of low-level waste disposal our objective is to provide a technology package, including the analysis of tradeoffs between waste form package and site characteristics tc open a new low-level waste disposal site (Figure 3). We note in this figure that the process equipment development is covered by the Engineering and Operations Department. To accomplish the low-level waste siting technology objective we are focusing on preparing a handbook illustrating the necessary analysis to license a new low-level waste disposal site.

If there is a simple way to characterize this program objective, it's to indicate that we're very concerned about the timing of Milestone C in the present DOE program and we feel that a package to describe the siting of a new shallow land burial site is required as early as we can possibly get it (Figure 4). We plan to have such a package available in preliminary form by the first quarter of 1982 and we welcome the opportunity to interact with members of the DOE program who are contributing to Milestone C in order to make the preliminary EPRI package as technically useful and as technically sound as possible.

Figure 5 summarizes the status of our accomplishments and our emphasis for the coming year. Much of our activity in low-level waste disposal grew out of analyses we were performing on the high-level waste program which we recognized for several years at EPRI as a matter of paramount importance for technical and public acceptance. In the course of that program we developed a methodology that we have called the retention quotient methodology for high-level waste. This is basically a systems analysis approach, and early in 1981 we began efforts to extend this to low-level waste.

Our approach has been to have a multi-contract team with one of the contractors effectively simulating the functions of the NRC and the EPA and

Figure 1.

EPRI PROGRAM OBJECTIVES

- HELP ESTABLISH TECHNICALLY SOUND DISPOSAL REGULATIONS AND LICENSING PROCEDURES
- FOCUS R&D PROGRAMS ON DEVELOPING ESSENTIAL INFORMATION
- HELP IMPLEMENT SAFE DISPOSAL IN A REASONABLE TIME FRAME
- PROVIDE INPUT TO NEEDED LEGISLATION
- PROVIDE INPUT TO BETTER PUBLIC UNDERSTANDING

Figure 2. External Fuel Cycle Budget

SUBPROGRAM	APPROACH		TECHNOLOGY
EXTERNAL FUEL CYCLE	ASSESSMENT OF LONG-TERM FUEL STORAGE SYSTEMS	$600K	ZIRCALOY/AIR CORROSION CASK INTEGRITY FUEL ROD/ASSEMBLY CORROSION
	ASSESSMENT OF FUEL REPROCESSING SYSTEMS	$400K	
	DEVELOPMENT OF NUCLEAR WASTE DISPOSAL METHODOLOGY	$400K-HLW $400K-LLW	WASTE FORMS BARRIER MATERIALS LEACHING CRITERIA
	STAFF STUDIES		ENRICHMENT REPROCESSING SPENT FUEL STORAGE

Figure 3.

LOW LEVEL WASTE DISPOSAL

OBJECTIVE:

- PROVIDE TECHNOLOGY PACKAGE INCLUDING ANALYSIS OF TRADEOFFS WITH WASTE FORM, PACKAGE, AND SITE CHARACTERISTICS TO OPEN A NEW LLW DISPOSAL SITE

  NOTE: IN PLANT PROCESS EQUIPMENT DEVELOPMENT COVERED BY ENGINEERING AND OPERATIONS DEPARTMENT

APPROACH:

- PREPARE A HANDBOOK ILLUSTRATING THE NECESSARY ANALYSIS TO LICENSE A NEW LOW LEVEL WASTE DISPOSAL SITE

Figure 4. Technical Implementation Plan Milestones

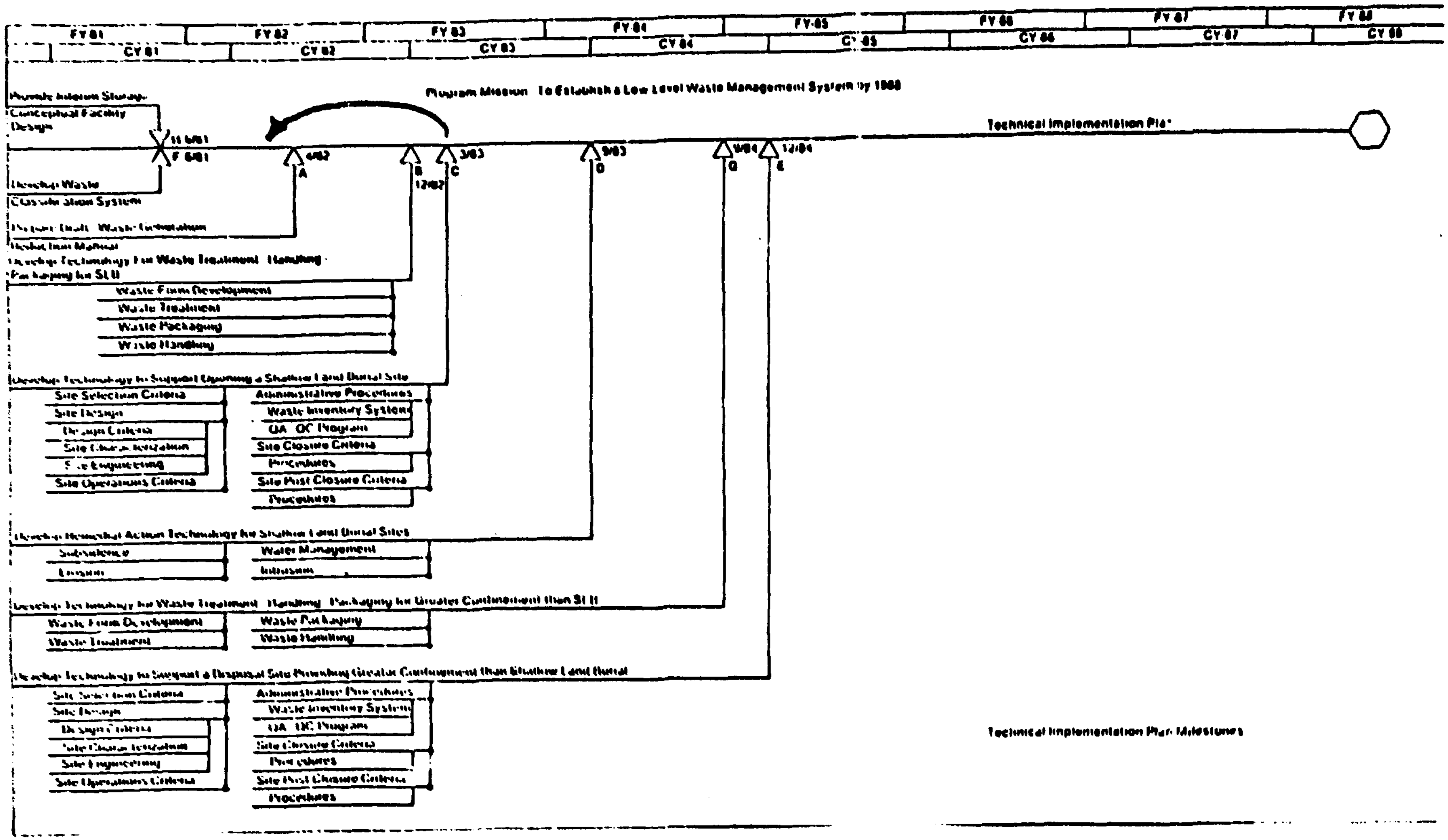


Figure 5. EPRI's Accomplishments and Emphasis in 1982

STATUS/ACCOMPLISHMENTS

- RETENTION QUOTIENT METHODOLOGY FOR HLW EXTENDED TO LOW LEVEL WASTE
- DEVELOPMENT OF LOW LEVEL WASTE SITING TECHNOLOGY

1982 EMPHASIS:

- COMPLETE SITING TECHNOLOGY DEVELOPMENT AND COMMUNICATE TO INTERESTED UTILITIES AND STATE AGENCIES another attempting to simulate the functions of the Department of Energy or the applicant and operator of a low-level waste site.

We've been very pleasantly surprised, in the area of low-level waste management, to see what an excellent job appears to be included in the environmental impact statement (EIS) that supports 10 CFR Part 61. We've had approximately one month to review the draft EIS and I can say without equivocation that, for the first time, an EIS looks like it's going to be a very useful element to the industry and to those of us who are interested in opening low-level waste sites.

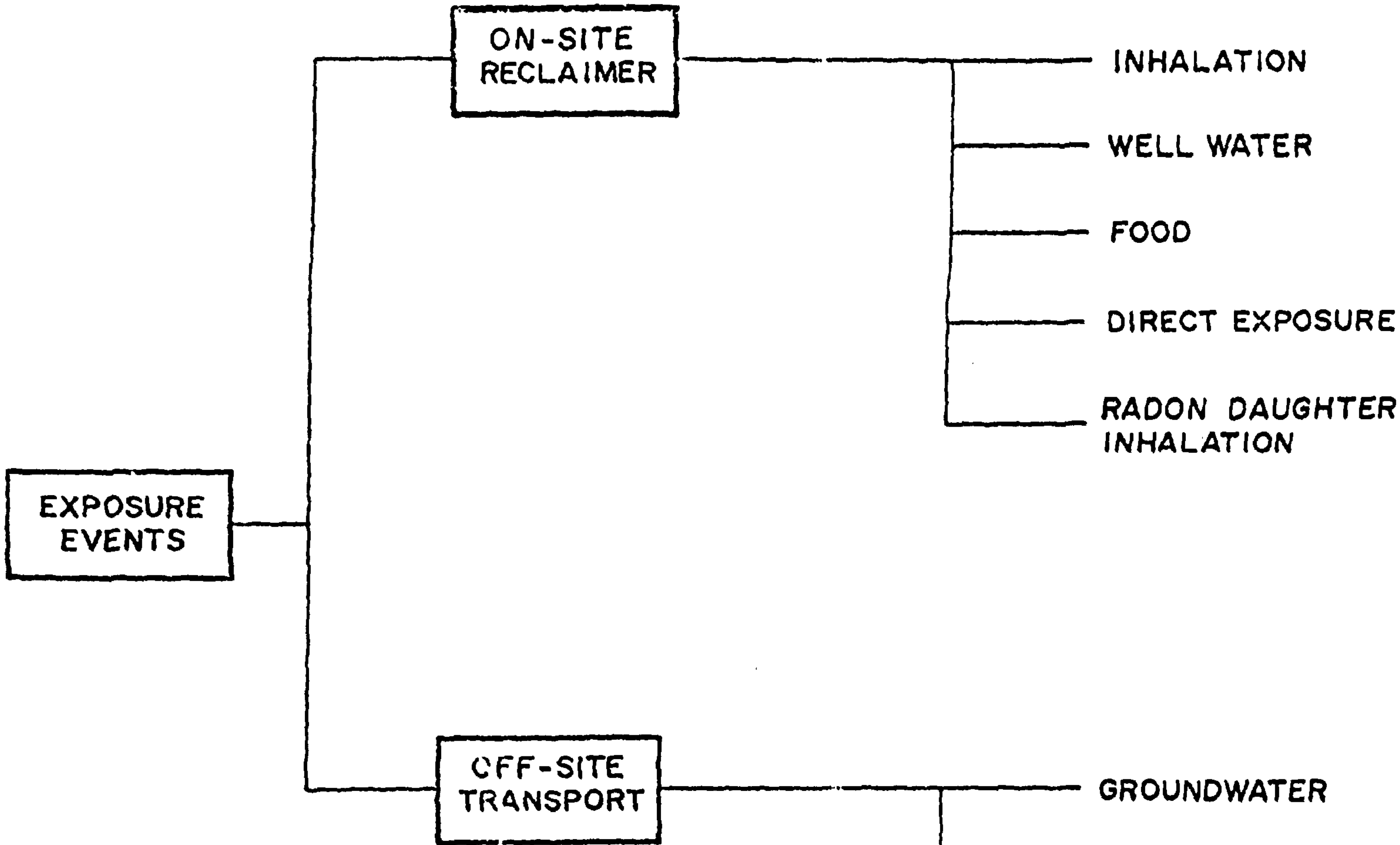
For those of you who haven't had a chance to review that document yet, let me commend it to you. We are in the process now of reviewing our program to avoid re-inventing the wheel as it has been documented in the EIS for low-level waste disposal.

Both our DOE surrogate and our NRC surrogate have developed a nuclide migration model which is not much different than that described by the NRC. We cover various reclaimer exposure scenarios or intruder exposure scenarios and various off-site transport mechanisms (Figure 6). In the case of low-level waste these are primarily ground water and surface erosion. We were surprised to discover that analysis of low-level waste scenarios were more difficult and more complicated than for high-level waste.

Figure 7 displays in our methodology, the "retention quotient" that is required for the low-level waste disposal site and the performance quotient. The retention quotient is the reciprocal of the decontamination factor that is required for the waste inventory in the repository to be released and just meet the selected radiation dose limit. The performance quotient is a measure of the required hold-up of the geologic barriers in that particular siting location. Shown in this figure is the performance quotient for a site with only one meter of cover and a site with greater than three meters of cover. You notice that for about the first 500 or 1,000 years the site with only a one meter cap has a negative safety margin of about an order of magnitude.

Figure 8 summarizes some of the insights that we have derived from our analysis. This was undertaken in part to support the industry's comments on 10 CFR Part 61 and to provide basis for action in case the NRC and the people pursuing regulations didn't do as well as they appear to have done in their EIS. It's generally recognized that inadvertent intrusion is very important. Second, in order to perform the required safety analysis, it is necessary to have simple geology and hydrology. We're starting to quantify the benefits from deeper burial and we're identifying some mobile radioisotopes whose control is critical in cutting down the exposure pathways. These include technetium-99, iodine-129, carbon-14, and the like. The high integrity containers, at least in our analysis, did not have major impact on the ground water pathway unless they restricted the leach rate after failure. However, I would add that we do support the considerations documented in the EIS with respect to maintaining the site stability by preventing subsidence.

Figure 6.



MAJOR PATHWAYS FOR DISPOSED LOW-LEVEL WASTE

Figure 7. RQ and PQ for the Recaimer Food Event, and PW for Two Cover Thicknesses

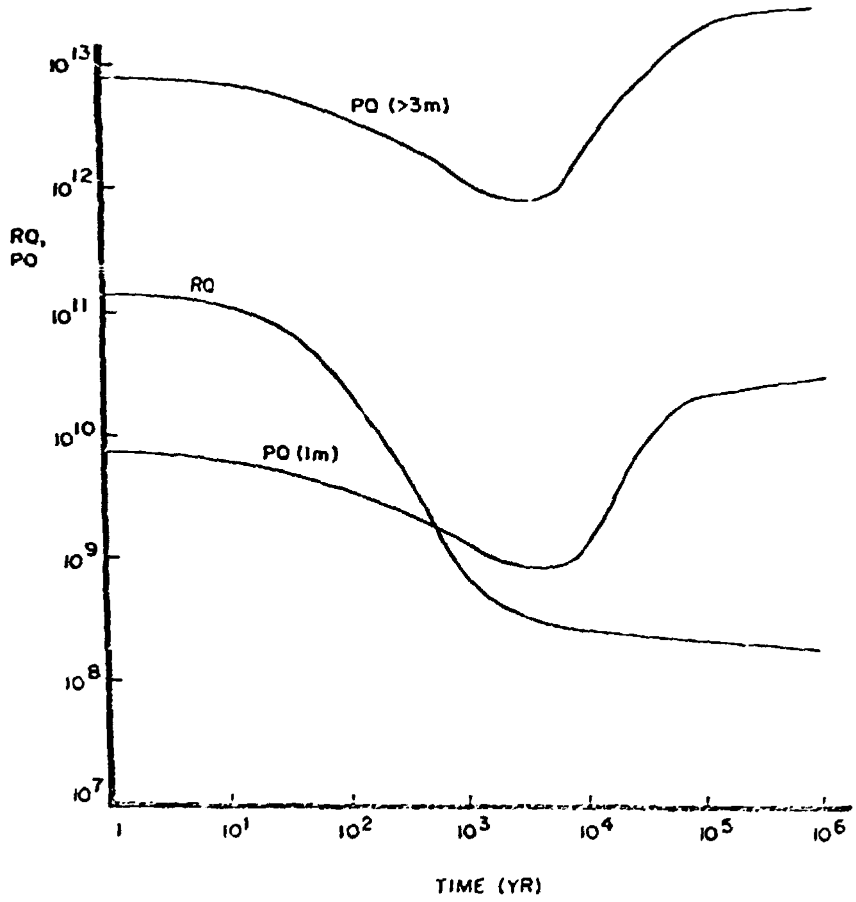


Figure 8.

INSIGHTS FROM RQ-PQ ANALYSIS OF LLW

- IMPORTANCE OF INADVERTENT INTRUSION
- NEED FOR SIMPLE GEOLOGY AND HYDROLOGY
- BENEFITS FROM DEEPER BURIAL
- MOBILE, LONG-LIVED ISOTOPES ARE DOMINANT IN GROUND AND WELL WATER PATHWAYS
- HIGH INTEGRITY CONTAINERS DO NOT HAVE A MAJOR IMPACT ON GROUNDWATER PATHWAY IMPACTS UNLESS THEY RESTRICT THE LEACH RATE AFTER FAILURE

Figure 9 summarizes the criteria that we have selected in the absence of the NRC criteria or the EPA criteria. These were set by the on-site reclaimer dose rate pathway which was required to be less than 500 mrem per year and potential doses from off-site transport of less than 10 mrem per year. We're pleased to note that the NRC has used 25 mrem as its criteria in 10 CFR Part 61.

As part of putting together a technology transfer package, our siting handbook will illustrate how to locate low-level waste disposal sites. The next series of figures attempt to show this in illustrative form. We have a series of exclusion criteria and a series of site identification criteria which are similar to those of the NRC (Figure 10).

We have also proposed steps for site selection and qualification. These include defining the region of interest, eliminating large areas with exclusion criteria, collecting site data and performing initial modeling, selecting a site for license application, conducting additional site characterization and modeling, and finally, continuing the site characterization process through the necessary steps for approval by the NRC.

I have included a number of figures that illustrate locating a site in the state of Washington (Figure 11). We excluded areas that are major cities, severe winter areas, or contain special restricted areas such as parks or what have you (Figure 12), and regions that are near rivers or lakes or flood plains or near surface aquifer recharge zones (Figure 13). And Figure 14 shows one potential area, coincidentally the Hanford site. I don't think that's too big a surprise but we picked that site because we had available data to use in the analytical modeling which we intend to illustrate in the site selection handbook.

We have been through a process that I think many applicants will find agonizing in terms of finding reliable nuclide migration models and models that give calculated results within a few orders of magnitude of the NRC model. We expect the results of the project to make the modeling and safety analysis tasks easier and to identify what site data is particularly relevant.

Figure 15 provides a little bit of technical background on the input parameters to a facility characterization. This includes the trench volumes or assumptions on the mixture of fuel cycle and institutional waste.

Figure 16 compares the calculated releases compared to the current 10 CFR Part 61 limits. The major area where we see a difference is in the well scenario where some of our computations are still exceeding the four mrem per year limit suggested by NRC based upon the EPA drinking water limit. I think part of the difference in values is due to problems related to a difference in dose conversion factors. We have used the ICRP 30 and INREM dose conversion factors, while we understand the NRC is still using Regulatory Guide 1.109. In addition, there are other conservatisms in the modeling. We hope to have worked this out in the next few months in time

Figure 9.

ILLUSTRATIVE HEALTH CRITERIA

(PERFORMANCE OBJECTIVES:)

- POTENTIAL ON-SITE RECLAIMER DOSE RATES LESS THAN 500 MREM/YR.
- POTENTIAL DOSES FROM OFF-SITE TRANSPORT LESS THAN 10 MREM/YR.

Figure 10.

ILLUSTRATIVE SITE SELECTION CRITERIA

AREA EXCLUSION

POPULATED AREAS

FLOOD PLAINS

HIGH EROSION

NEAR MAJOR WATER BODY

ABOVE SOLE SOURCE AQUIFER

ABOVE MINERAL RESOURCES

SITE IDENTIFICATION

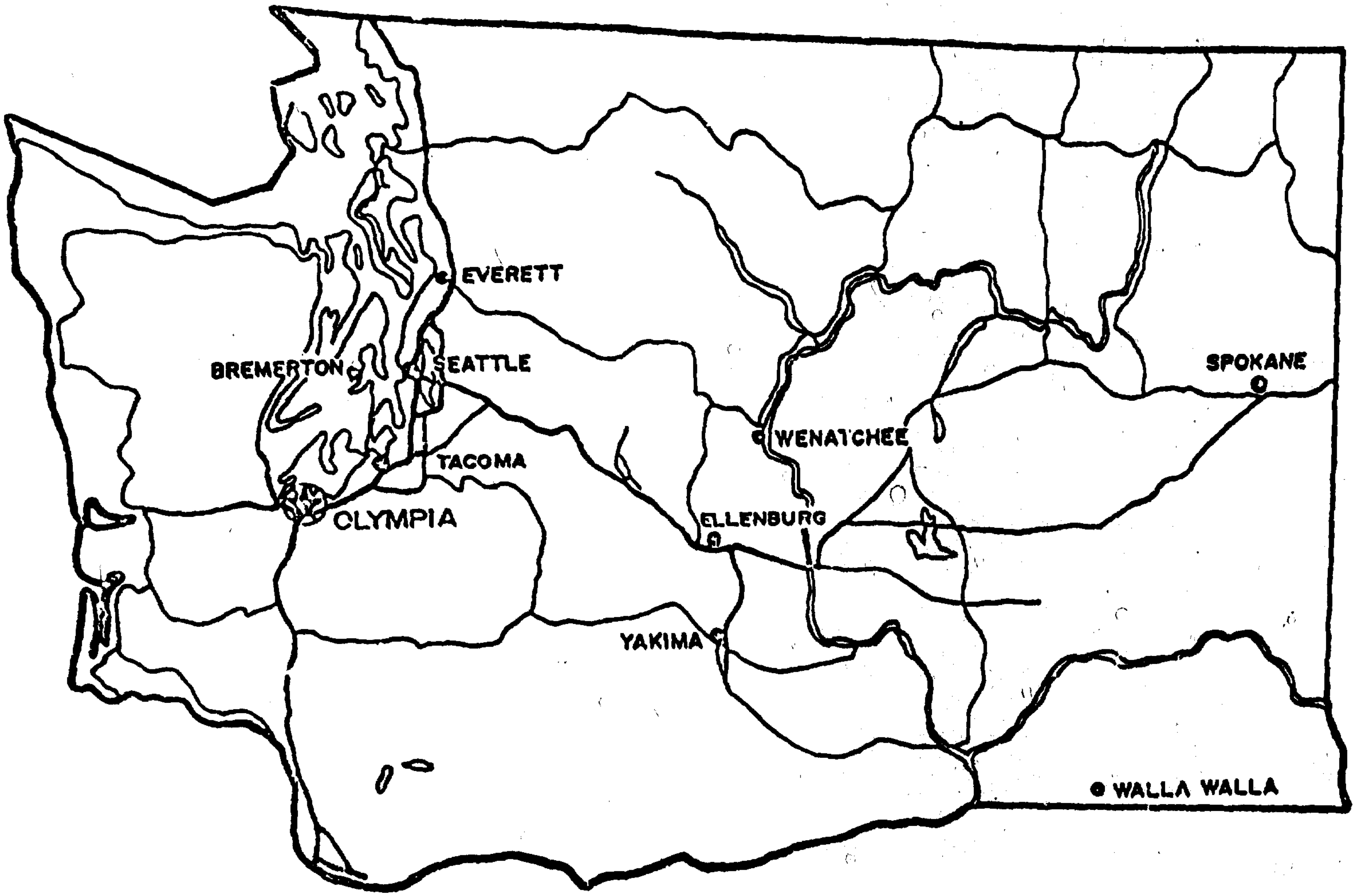
SIMPLE GEOHYDROLOGY

ADEQUATE AREA

HIGH RETARDATION SOIL

SUFFICIENT DEPTH TO AQUIFER

Figure 11.



EXAMPLE AREA FOR LOW-LEVEL WASTE DIPOSAL SITE SELECTION

Figure 12.
Exclusion Areas

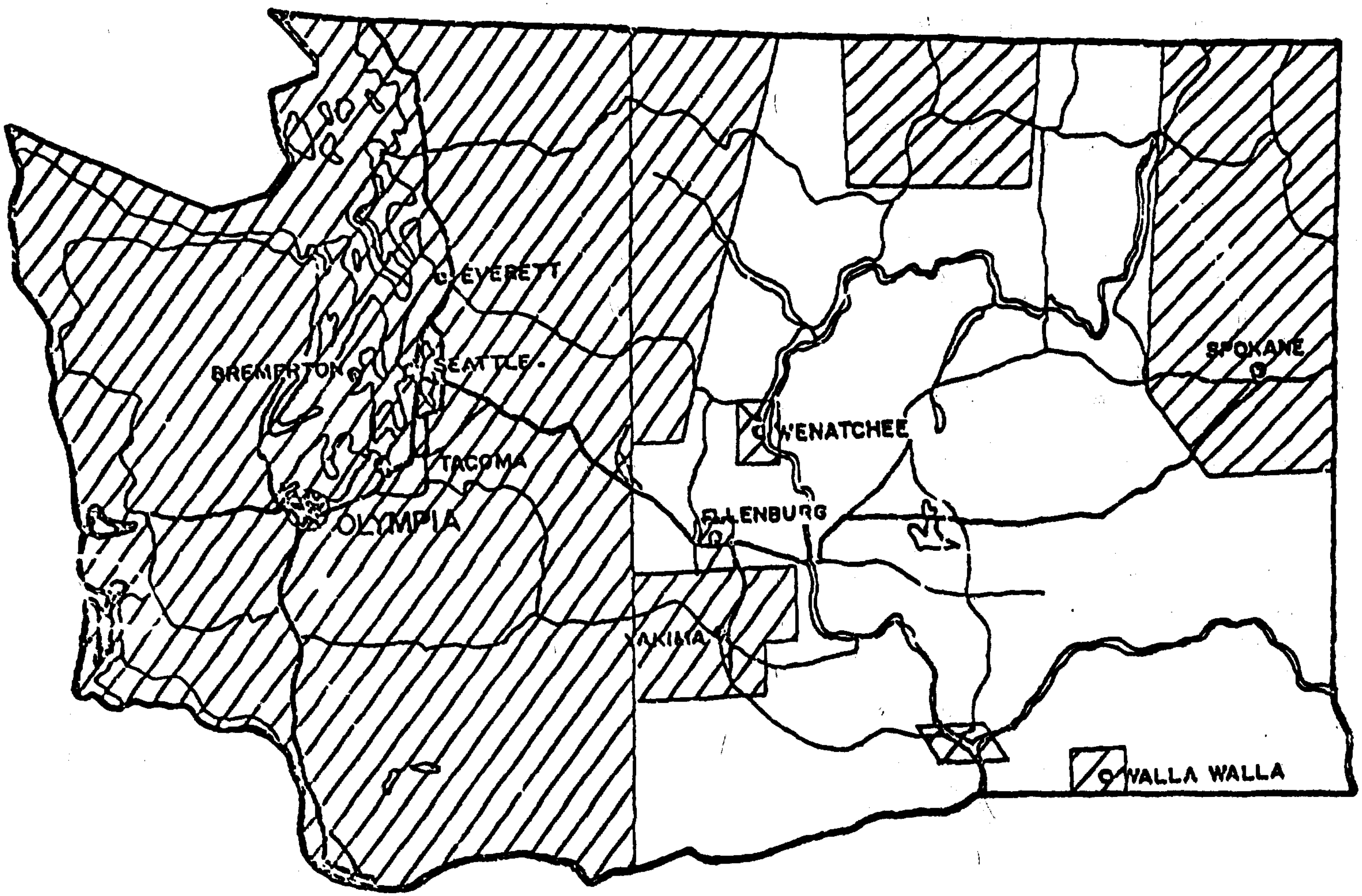


Figure 13.
Additional Exclusion Areas

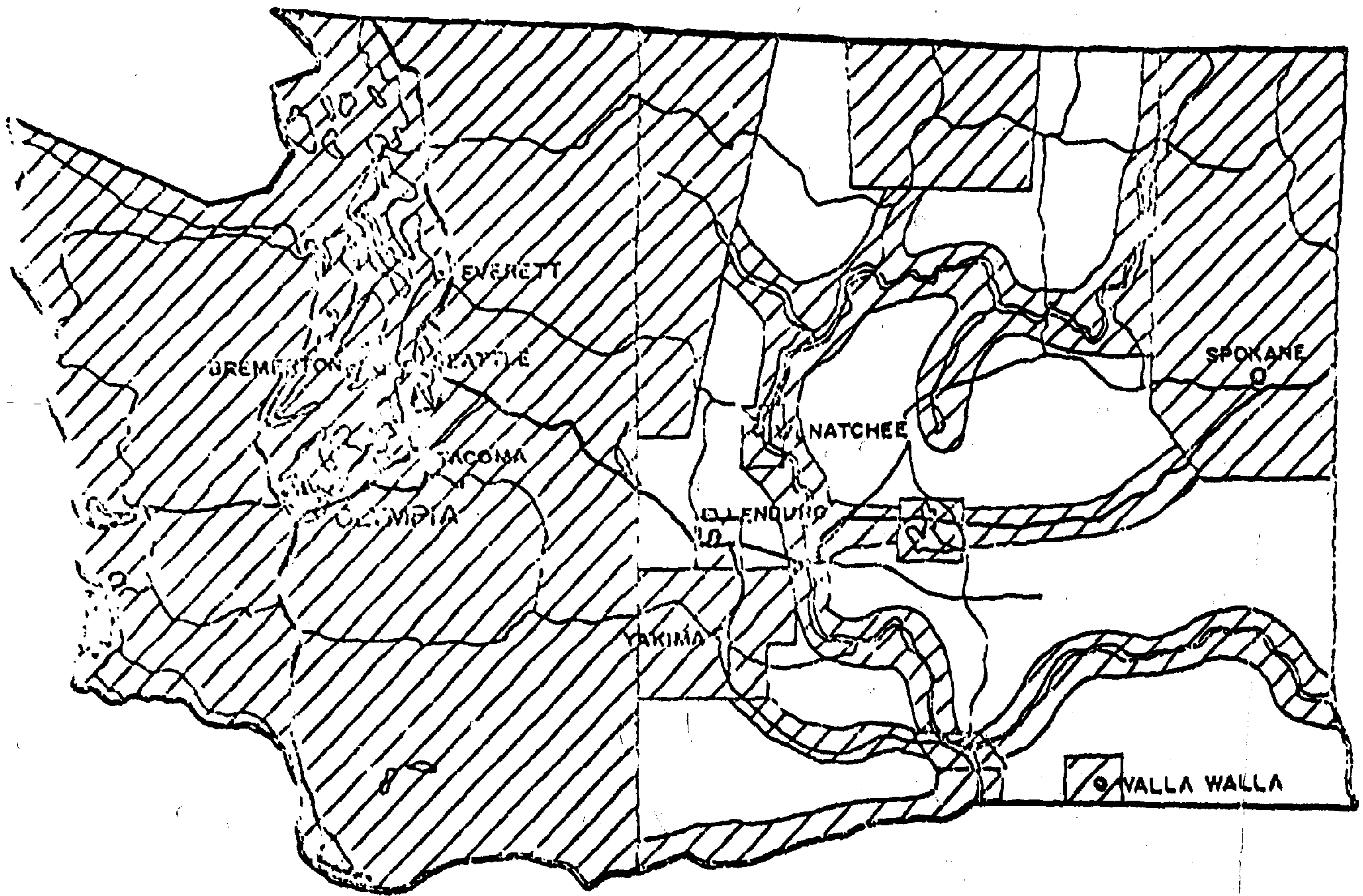
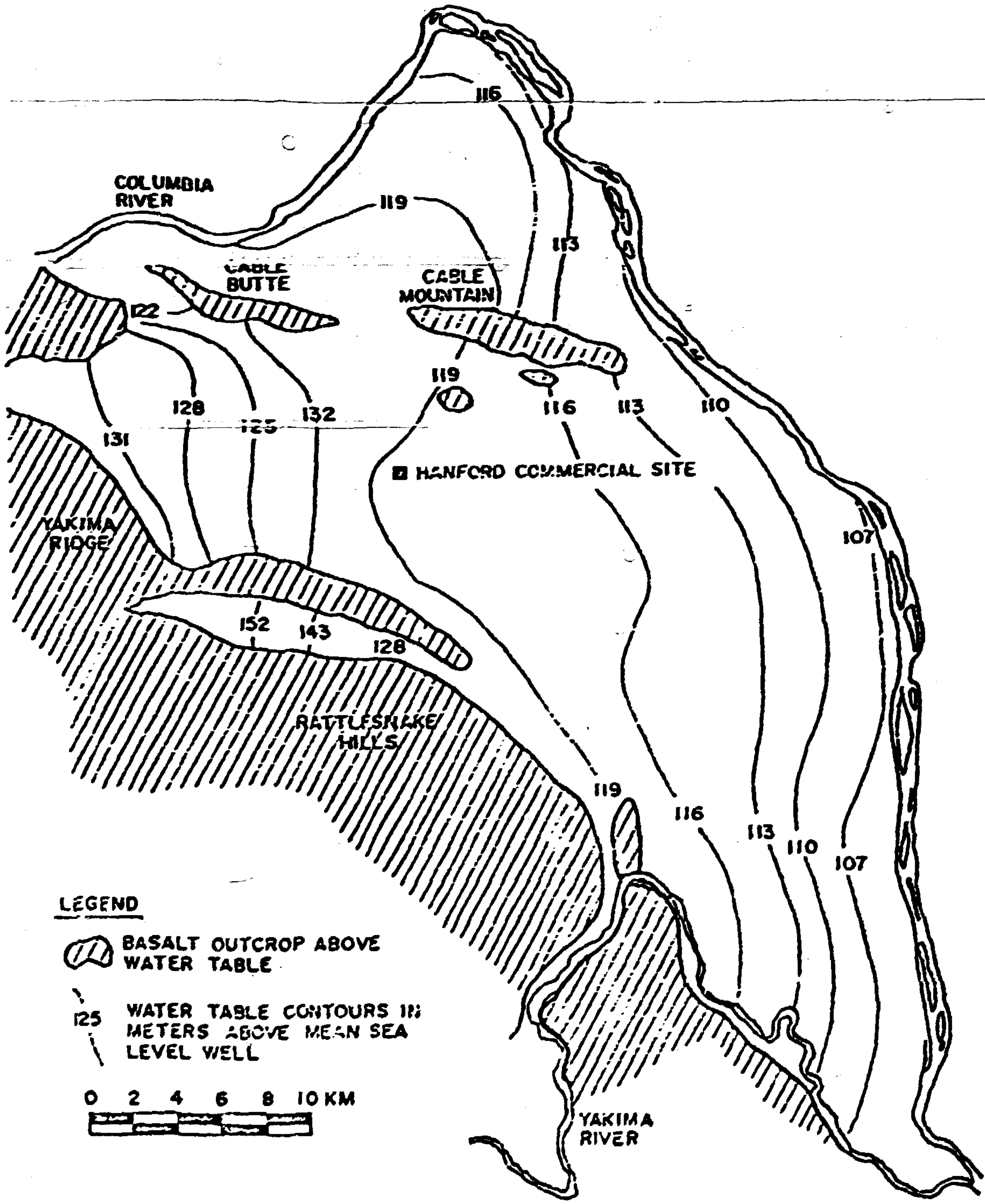


Figure 14.



WATER TABLE MAP FOR HANFORD RESERVATION AREA

Figure 15.

REFERENCE DESIGN FACILITY SITE CHARACTERIZATION

- 120 15m × 150m TRENCHES, 6m DEEP
- INVENTORY 50% INSTITUTIONAL, 50% FUEL-CYCLE (BY VOLUME)
- ALL RELEASE PATHWAYS APPLICABLE
- NOMINAL LEACH RATES (10^{-2} to 10^{-3} PER YR)
- CONSERVATIVELY LOW RETARDATION FACTORS
- MODERATELY HIGH DILUTION IN SURFACE WATER SYSTEM
- HUMID SITE -- 1 m/yr RAINFALL

Figure 16.

REFERENCE DESIGN FACILITY-COMPARISON OF PEAK DOSE WITH ILLUSTRATIVE PERFORMANCE CRITERIA

PATHWAY	PEAK DOSE OR RELEASE RATE	TASC LIMIT	10 CFR 61 LIMIT
WELL	9.3×10^3 mrem/yr*	500 mrem/yr*	4 mrem/yr*
	0.094 Ci/yr (Tc-99)	4.9 Ci/yr	
	0.032 Ci/yr (I-129)	0.11 Ci/yr	
RIVER	8.8×10^{-3} mrem/yr	10 mrem/yr	25 mrem/yr
EROSION	0.015 mrem/yr	10 mrem/yr	25 mrem/yr
RECLAIMER FOOD	191 mrem/yr	500 mrem/yr	500 mrem/yr
RECLAIMER DIRECT EXPOSURE	19.5 mrem/yr	500 mrem/yr	500 mrem/yr
RECLAIMER DUST INHALATION	0.14 mrem/yr	500 mrem/yr	500 mrem/yr
RECLAIMER RADON INHALATION	1.1 mrem/yr	500 mrem/yr	500 mrem/yr
RUNOFF TO FARMLAND	5.0 mrem/yr	10 mrem/yr	25 mrem/yr

*50-yr COMMITTED DOSE EQUIVALENT

for workshops early next spring, 1982, in which we will have a benchmarked set of analytical models ready for use by interested parties in preparing safety analyses that could be used for screening sites and selecting the site for a repository.

Figure 17 indicates some of the areas of sensitivity analyses that are underway where we both hope to assure that we are calculating in a manner consistent with the NRC, and that indeed the NRC calculations are consistent. And finally, we have identified, I think, an important research need that the people at Oak Ridge, Battelle Pacific Northwest Laboratory, or Savannah River can contribute to very significantly, and that is, of course, the carbon-14 uptake factors. This seems to be a critical nuclide in many of the analyses and we're not sure that the dose conversions being used are precisely correct.

Moving on to the next area I want to highlight the programs that are under way in the areas of process technology and activities that would be going on in a power plant. These programs are being conducted under the direction of Bob Shaw, with Mike Naughton his principal colleague in performing this research. The first program is an assessment of volume reduction technologies which was begun about two years ago, under Research Project 1557. This was conducted by Sargent and Lundy and assessed volume reduction technology. Our objective was to assess the systems in a manner that would be useful to the utility industry as a planning aid for those planning to install volume reduction systems (Figure 18).

Figure 19 highlights the commitments that have been made by various power companies to different types of volume reduction systems. These commitments have been underway since 1976 or 1977. Regretably, the schedules of many of the power plants have slipped, the cost of the volume reduction systems have in some cases increased, and the start-up schedule of the volume reduction systems have been delayed in some cases. Also shown in this figure are the facilities that are considering some type of incineration.

Figure 20 highlights the incentive that the operating power companies see for volume reduction systems. There appears to be a levelized annual saving of a $1.2 to $1.9 million per year, which can justify a capital investment approaching $9 million. It can also be significant in reducing the number of shipments through the countryside, such as to Barnwell, where there is a very restricted limit of 100,000 cubic feet per year, if my memory serves me.

As a follow on to the volume reduction technology assessments, we're now initiating an assessment of incinerator performance. Gilbert Associates has been selected as the contractor for this activity based on their experience at Philadelphia Electric and Kiushu Electric. The experience that they will be reviewing will come primarily from foreign utilities in Japan, Canada, Germany and Sweden.

In addition, there is another project in the same general group which is looking at radwaste source; identification, and reduction. In some

Figure 17.

SENSITIVITY ANALYSIS

- SENSITIVITY OF CONSERVATIVE BASE CASE TO IMPORTANT PARAMETERS
  - ECOSYSTEM
  - WASTE FORM AND LEACH RATE
  - CANISTER FAILURE TIME
  - BURIAL DEPTH
- SENSITIVITY OF WELL AND RECLAIMER SCENARIOS
  - CARBON-14 UPTAKE

Figure 18.

Purpose of EPRI VR Study

Identify advanced low-level radwaste treatment systems that are commercially available or are expected to be in the near future;

Collect engineering and performance data on these systems; and

Assess these systems in a manner that will be useful as a planning aid to the electric power generating industry.

Figure 19.

U.S. VOLUME REDUCTION COMMITMENTS BY UTILITIES -
(Excluding Crystallizers)

Utility	Station	VR Suppliers	Comments
Carolina Power & Light	Shearon Harris	AECC	Dryer purchased; incinerator later
Cincinnati Gas & Electric Company	Wm. H. Zimmer	Not Awarded	Dryers bid; incinerator optional
Commonwealth Edison Company	Braidwood*	AECC	VR equipment on site; VR solidification not determined
Commonwealth Edison Company	Byron*	AECC	VR equipment on site; VR solidification not determined
Consumers Power Co.	Midland	WPC	Equipment on site
Consumers Power Co.	Palisades	WPC	Scheduled operation late 1981
Detroit Edison Co.	Fermi-2	WPC	
Duke Power Company	Oconee*	AECC/SECO	Total new radwaste facility
Georgia Power Co.	Vogtle	AECC/SECO	
Houston Lighting & Power	Allens Creek	WPC	
Niagara Mohawk Power Company	Nine Mile Point-1*	NNI	Cancelled
Niagara Mohawk Power Company	Nine Mile Point-2	WPC	
Public Service Indiana	Marble Hill*	AECC	VR solidification not determined
Puget Sound Power & Light	Skagit	WPC	Station cancelled
Tennessee Valley Authority	Browns Ferry*	Not Awarded	
Tennessee Valley Authority	Sequoyah*	AECC/SECO	
Tennessee Valley Authority	Watts Bar*	AECC/SECO	
Tennessee Valley Authority	Yellow Creek*	NNI	
(To be determined)	________*	Koch (formerly Helix)	DOE Incinerator demonstration

Figure 20.
Cost Summary for Volume Reduction Systems

		BASE CASE	VR CASE
DRUMS			
DAW		900	92
CONCENTRATES		1585	295
RESINS & SLUDGES		500	165
		2985	552
PACKAGING	$	204,000	69,000
SHIPPING	$	1,080,000	460,000
BURIAL	$	230,000	69,000
		$ 1,514,000	592,000

LEVELIZED ANNUAL SAVING (10 YR) 1,984,000

EQUIVALENT CAPITAL INVESTMENT (10 YR) 9,018,000 respects this is parallel to Milestone A in the DOE program. The objective is to provide utilities with a method for assessing the sources of low-level wastes and suggestions and case studies on how other companies have been successful in reducing the quantities. Gilbert Associates was the successful bidder under this task based on their PWR experience at Palisades, Crystal River, and their BWR experience at Oyster Creek, Monticello, etc. The first task, which was initiated at a workshop held last week, is to approach utilities to define the manner in which they are controlling their sources of radwaste, so that we can share the learning experience of various utilities. The results of this project will be shared at a workshop a year from now to be conducted by the contractor.

The next project has looked at the use of microwave technology as an approach to solidifying resins. Dr. Harry Lawroski, in conjunction with Chem Nuclear Systems, have been the contractors of this system. This project has been underway for approximately a year and we're expecting a final report within the next month or two. In fact, the reason that Bob Shaw and Mike Naughton are not here today is there has been a workshop scheduled for some period of time to review the chemistry, radiation monitoring, and volume reduction programs in San Jose yesterday and today.

The final two projects attempt to characterize the performance of hydroclones with respect to removal of sludges and solids, and we are performing an assessment of the methods used to assay nuclear power plant solid radioactive wastes.

We hope that this will shed some light on the capabilities of utilities to screen their waste with respect to the NRC Category A, Category B and Category C. I'd like to thank you for the opportunity of briefly highlighting these programs. We have two of our contractors with us here today, Vern Rogers of Rogers & Associates Engineering Company and Tom Kabele and Mike Giuffre of the Analytic Sciences Corporation. We hope that some interaction at the detailed technical level can go on in the course of this meeting. We very much appreciate the opportunity to participate.

THE ROLE OF UTILITY NUCLEAR WASTE MANAGEMENT GROUP

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Thank you. The Utility Nuclear Waste Management Group (UNWMG) is a group of 39 nuclear utilities which support a general program which is under the administration of Edison Electric Institute (EEI), but which actually operates quite separately. The function of the group is primarily to interact with Congress in the development of desired legislation, interact with NRC and EPA in the development of regulations, and interact with DOE in the carrying out of programs in which we are interested. We are interested in anything in the waste management field.

The group is organized with a steering committee made up of 39 members, one member from each supporting organization plus a member from the National Rural Electric Cooperative Association and one from the American Public Power Association. The EEI organization is made up of investor-owned utilities only. UNWMG is also supported by non-investor owned utilities -- Sacramento Municipal District and Nebraska Public Power District, for example, are members of UNWMG and support its program but they are not members of EEI. In fact, I tried to get TVA in as a member, but didn't quite make it.

The group is organized into four working groups. One devotes its efforts to high-level waste activities, one to low-level waste interests, one to spent fuel storage and reprocessing, and a fourth to public information. Each of these working groups has a number of task forces that are organized to respond to a particular need at the time. In the area of high-level wastes there is a continuing effort on the NRC's waste conference rule making that has been going on now for about eighteen months. UNWMG was a principal participant in this hearing process, mostly in a role which was supportive to DOE.

Our second major activity is in the promotion of desired legislation. I think somebody mentioned the bill in the senate, Senate 1662. We are quite active in developing testimony before Senate hearings. We get an industry spokesman to present an industry point of view. We work at the staff level, suggesting rewording. We take a very active role in this type of activity. EEI has a legislative affairs group -- you can call that the lobbyists. We have one individual in that group who is assigned to waste management legislation. This person works quite closely with the industry lobbying group, the American Nuclear Energy Council (ANEC). We also work quite closely with other industry groups such as the Atomic Industrial Forum (AIF), the Committee for Energy Awareness (CEA), and even individuals.

We have been quite active in trying to get our input into the DOE's high-level waste program, and we have been somewhat critical of this program. We think it has been too research oriented. We're trying to get it turned around to a more project oriented program. The technology is known. Both DOE and ourselves have presented testimony to that effect, so the tone of our actions in this area is let's get on with the job.

In the area of spent fuel storage, this group was primarily put together to interact with the DOE on their AFR program -- which now is no longer in the picture. But part of their program was a contract under which the DOE would take title to spent fuel. That contract and that act of taking title to spent fuel is still a very important aspect of waste management. You will see various parts of this reflected in draft legislation. In this draft legislation, by the way, there are comparable efforts going on in the House and we expect something to come out in this Congress, but in the next session.

The low-level waste group has a number of activities. One of them, an obvious one, is a task group addressing 10 CFR Part 61 and the development of comments on 10 CFR Part 61. There is another one addressing what we call contingency plans -- the "What if" scenario. What if we don't get repositories available? What will new power plants that are coming on stream now that do not have a Barnwell allocation do with their low-level waste? In other words, what this all boils down to is on-site storage. In that regard we have interacted with NRC in what's required in the licensing of these facilities and NRC has just recently published their position on interim contingency storage on site, under procedures of 50.59 in certain cases.

We have another group that's active in promoting state compacts. It's an activity which is complementary to DOE's activities. The utilities don't wear a white hat either, by the way -- their hats are just about as black as DOE -- but there are some places where we find that we could interact in the political arena maybe somewhat more effectively than DOE. So here is an effort that we try to make complementary. One of the kind of things we're doing is we've conducted a survey which we'll publish shortly, which tells who to contact in the various states and who is active in promotion of state compacts by name and telephone number.

The fourth general area of activity is in the area of public information. I had a professional anti-nuclear character tell me not very long ago that the anti-nuclear people had given up on the safety issue -- they really weren't getting anywhere -- and now they're concentrating their big guns on the waste issue. We, representatives of industry, are becoming very aware of the importance of being able to field questions and relate to the public on the subject of waste management. So we've got quite an active program just starting up now, an industry sponsored program, on the public information issue. This is not strictly a UNWMG activity. DOE public information people are involved, as are ANEC and AIF -- there's as much involvement as we can get.

I think maybe in the interest of cutting down time I would like to make just two comments on my impression of the DOE program and a couple of concerns I have. One of them is that 1986 is not that far away -- it's almost upon us. We don't have the luxury of drawn-out schedules and refined reports. I would like to make a plea for the issuance for use of whatever we can put together now. There are all sorts of people out there, particularly in the state government areas, people trying to promote state compacts, that are hungry for information. And when I see a manual for site operations being published in 1984, let's have a draft of it by next March, 1982, that's when it's needed. 1984 will be too late.

Now I think I can draw a parallel. I know that I'm talking to scientists and engineers who like perfection in their work. But I think this is a case where we just plain don't have that luxury. Dale Smith talked about the publication of a crude draft of 10 CFR Part 61, and it was very helpful. I, myself, had the experience of a situation a few years ago where there was a panic situation on how to license spent fuel storage. I published a draft of regulatory guidance -- some of you may remember it, Regulatory Guide 3.24 -- and I purposely left typos, and garbled English in it, so that it was recognized as a draft. But it did give the guidance that was needed at the time. So I make a plea for publication of all the material you can, as soon as you can, even in draft form. I think there is a very urgent need. I don't know what the status is, but I think there has been some sort of a hold-up on publication of DOE reports. Somehow, I hope that bottleneck can be broken.

I think my last observation is on a little lighter vein, on the subject of the report on radiation. This is obviously a very, very important subject. It is still the subject of greatest public concern, and I think that I'd like to suggest a title that "Radiation is Good for You" and I hope that when whoever is doing this, they at least get input into it from T.D. Luckey of the University of Missouri, too.

On the subject of public perception, let me make one more point. Throughout the presentation of DOE programs, no matter who's talking, we talk about the need to develop the technology and demonstrate the technology. For God sakes we have the technology developed, it is demonstrated, we have low-level waste burial sites in operation, they are licensable, they may not be the ultimate in perfection, but let's not give the public the perception that we don't know how to handle this job. We do. And somehow or other I wish that the language, the presentation that we all use, could convey the message to the public that we have confidence the job can be done, we know how to do it, let's get on with it.

I think that's enough out of me.

INTERIM OPERATIONS TECHNOLOGY

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Thank you, Dewey. One thing about being last: I managed to cut down sixty percent of what I had written down to say, because it's already been said very well by others.

I'd like to work with this chart (Figure 1) which shows waste generation classifications at Hanford, because I think it tells us something about the magnitude of the waste we have. Let's go to the vertical axis labeled "Waste, No Scale." There is no scale. I don't care whether you want to call it curies, or whether you want to call it cubic feet, or what. Coming across the bottom is time up to the year 2000. Until 1970, nuclear waste management operations -- and I'm going to talk to you from an operator's viewpoint right now -- were pretty simple. We had only two kinds of waste: high-level and low-level. In 1970, we came up with a definition for TRU waste and this caused us to now split into a third channel, in the middle of the chart, and we stored TRU waste. But I think this also implied to us that there was some TRU material mixed in our high-level, waste-storage tanks, which was accumulated prior to 1970, and some TRU waste which had already been put into the low-level sites prior to 1970. These "mixed situations" are shown adjacent to the TRU. So, in 1970, Waste Management became a little more complicated.

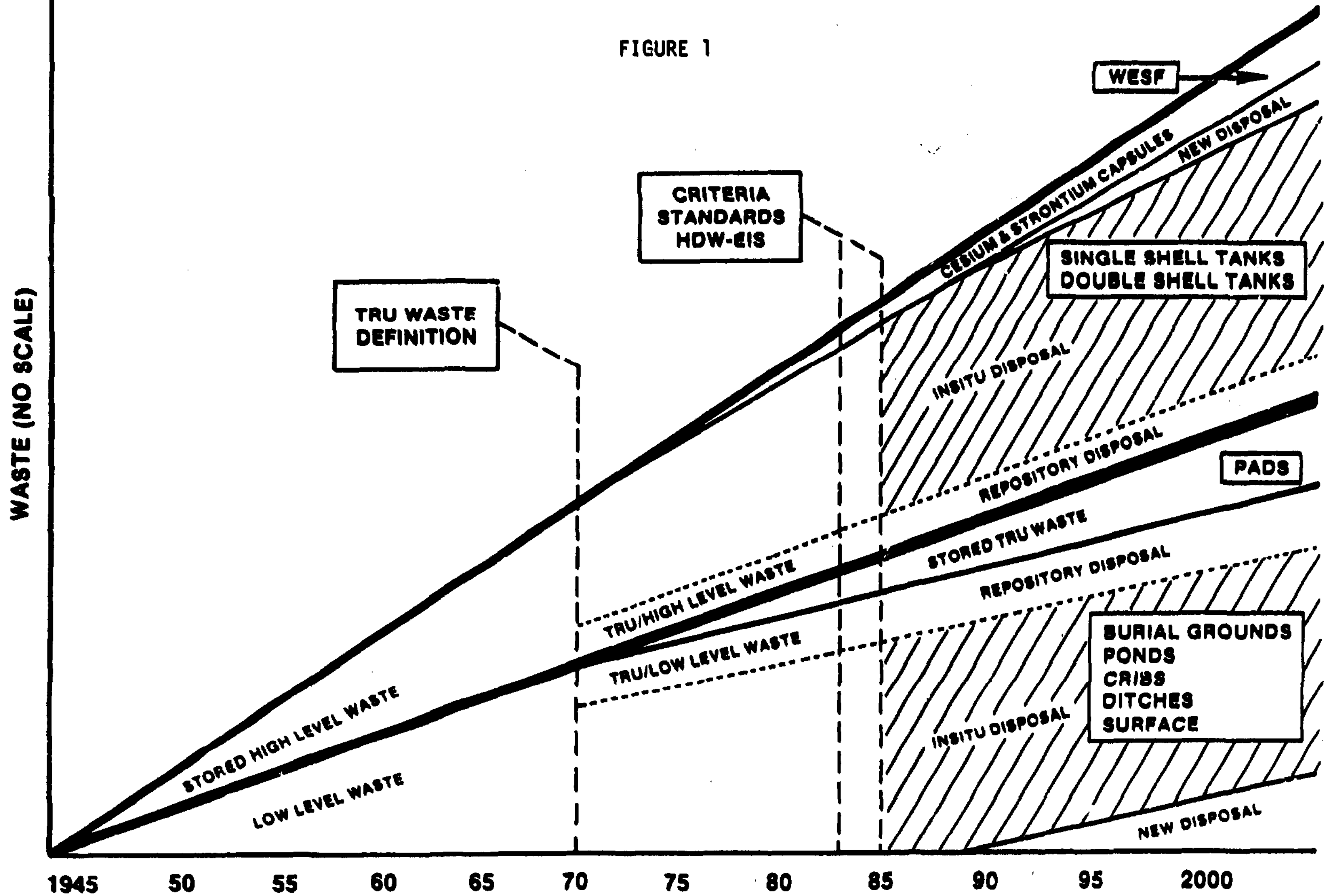
We've been talking about criteria and standards, 10 CFR 61, and other things this morning. At Hanford we're preparing an Environmental Impact Statement to help us to define future operations for disposal. We're anticipating that there will be information forthcoming within the next few years which will guide us. This information is anticipated in 1982 through 1985 time frame. If we look at the chart we can project that the anticipated criteria and standards will direct that we will probably ship the TRU to a repository from the storage pads. The major portion of the remaining waste can then be disposed of insitu with proper barriers per criteria and standards. These insitu-techniques are yet to be defined or developed.

Such a chart can be developed from any site and would look very similar to this chart. Hanford has something a little bit unusual to the other sites; the high-level waste has had the cesium and strontium removed, encapsulated and stored.

Projecting ahead, we know that in 1986 the DOE sites are going to be implementing the new low-level waste criteria. We will have new

HANFORD WASTE FORMS

FIGURE 1



operating methods which we'll start at that time, and so when I start counting up the various waste catagories in 1986, I find eight different major forms that we're going to have to deal with. Originally, we started out with two, in the 1940's. So I think this is kind of an interesting perspective when you look at developing new things and how you follow them through into the operation of an existing site.

One other point: we started operations in the 1940's; we made a major change in definitions in 1970; we are anticipating change in the mid-1980's -- what changes can we anticipate 15 years from now, in 1995?

These are the kinds of things that influence an operator. Let me go on a little bit. Criteria are probably the most important items that we need in guiding our technology efforts into future operations. Criteria are always first in any plan that we have.

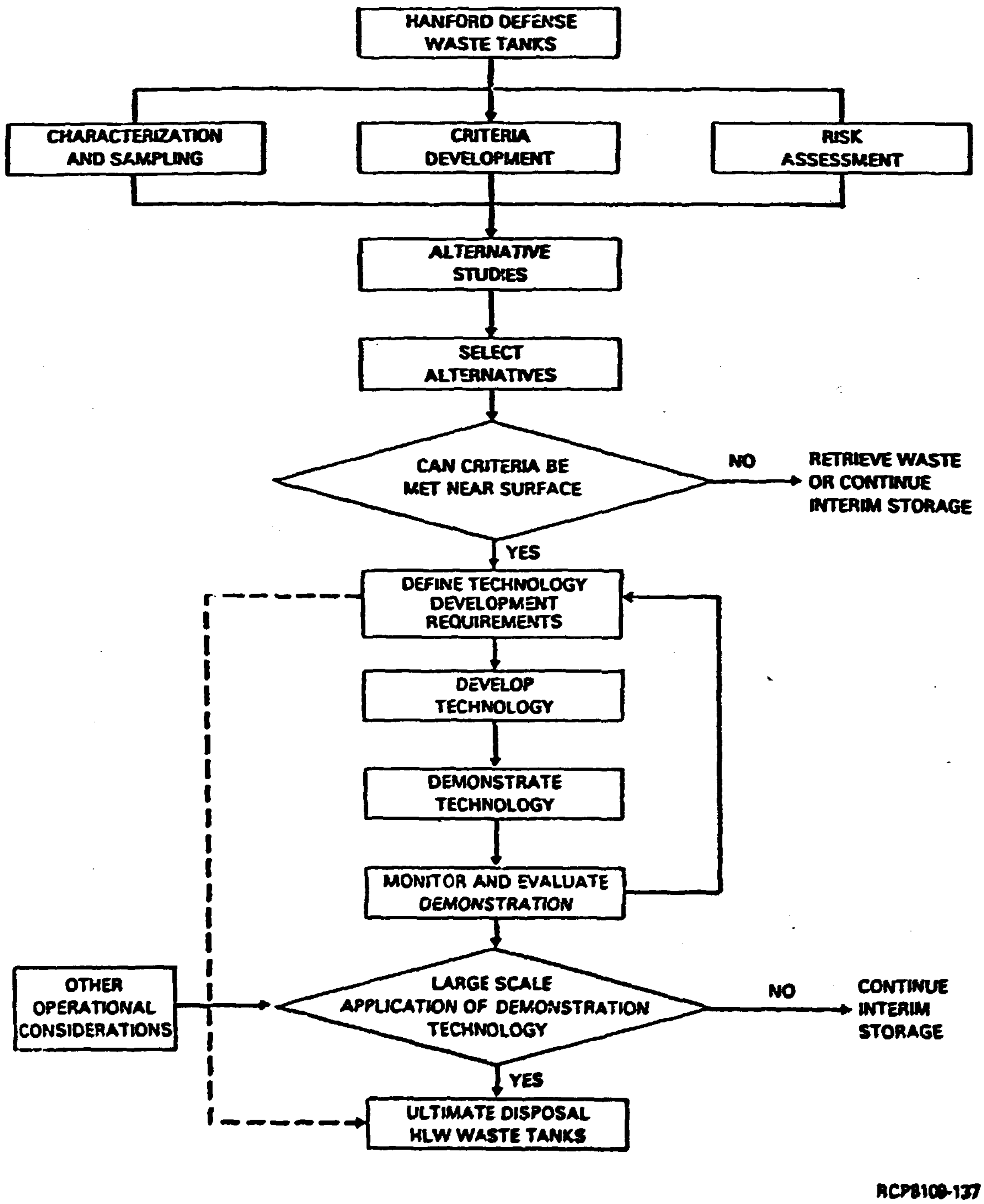
Anything that we do must start with criteria. The initial effort in the example (Figure 2) of a High Level Waste Program shows criteria, Waste characterization and risk assessment, before we begin to progress down through the program. I want to applaud the Low-Level Waste Program for progressing in these criteria areas early in the overall program schedule. But, I applaud it with mixed emotions since I really would like to see criteria development move a little bit faster than the schedule we need the criteria now to make decisions at the operating sites. We need it to plan, schedule, and to budget.

There have been many significant, low-level, waste technology achievements that have been benefiting our operations today. I'd like to recite only a few. There are many significant activities that I personally don't know about. Some of the migration studies at Oak Ridge and Savannah River have contributed greatly to the overall operations and understanding of the burial grounds at those sites. Trench capping at Oak Ridge and subsidence work at Hanford have improved the contamination control at those sites, and I think we'll hear more specifics about these efforts during the course of the program.

Most sites have developed some significant, geo-hydrological data and understanding of migration, which have led to the establishment of site ground monitoring systems. Significant trench design work has been done at Oak Ridge to solve the water problems of "bath tubbing." The Nevada site has some trench design work and some waste stacking that really should be "food for thought" for all sites. Idaho has certainly come a long way in waste-handling efforts.

These are items which I think are very significant; that have helped us manage the daily operations and maintain the daily environmental controls at each site. I certainly applaud the continuance of technology to support us "guys" in the field.

FIGURE 2



HANFORD DEFENSE WASTE TANKS
CHARACTERIZATION AND SAMPLING
CRITERIA DEVELOPMENT
RISK ASSESSMENT
ALTERNATIVE STUDIES
SELECT ALTERNATIVES
CAN CRITERIA BE MET NEAR SURFACE
NO
RETRIEVE WASTE OR CONTINUE INTERIM STORAGE
YES
DEFINE TECHNOLOGY DEVELOPMENT REQUIREMENTS
DEVELOP TECHNOLOGY
DEMONSTRATE TECHNOLOGY
MONITOR AND EVALUATE DEMONSTRATION
OTHER OPERATIONAL CONSIDERATIONS
LARGE SCALE APPLICATION OF DEMONSTRATION TECHNOLOGY
NO
CONTINUE INTERIM STORAGE
YES
ULTIMATE DISPOSAL HLW WASTE TANKS
RCP8109-137

There are still needs. For example, I think we need to do something about some of the free aqueous liquids and the organic compounds. These are compounds that will tend to migrate. The incinerators that are now under development certainly will help to change this waste to an acceptable waste form. But I'd like to pose a question for your thought. If we look back at some of the capital expenditures that we've been able to achieve in the 1970's and project forward, I think that we need to be able to begin to pool some of our efforts in looking at the overall waste forms at our sites. Let me suggest something to you: where we have high-level facilities and where we have TRU waste, we should talk about shipping these all to repositories. It may be cheaper to process and combine these waste forms in one facility and process them as high level or TRU waste and then ship to a repository, as opposed to having special-purpose incinerators at all sites. This objective needs exploring in order to minimize capital requirements.

Up to now I've talked only about emplacing wastes. What about the old wastes? What about the waste that has been emplaced since the 1940's. These old sites will eventually need the same degree of stabilization per the criteria as the new sites that we're talking about today. The old sites will probably be even more difficult to stabilize because the burial records are not as extensive as our today's records.

This stabilization, I imagine, is going to be very site-specific as far as doing the technology work, the background to understand the problem. It may even get down to the point that it is trench-specific within a site. But in any case the common technological issues will be:

- o determining the migration rates, determining what the waste inventory is from the records or from surveying techniques.
- o determining what monitoring is required to verify the inventory and the migration rate,
- o determining what the subsidence controls need to be before implementing stabilizations,
- o determining what water controls will be required,
- o and finally, determining what intrusion barriers and erosion barriers and erosion barriers are needed.

I think that you see the overall low-level waste management program is designed around answering these important questions.

I'd like to conclude with several observations:

- o First, the sites really need some site-specific work and I think we need a balance between some of the generic work and the site-specific needs. And certainly the lead site is very much set up to be the conduit for coordination and I applaud this kind of a meeting for passing on and exchanging information.

- o Second, I think standard packaging is very important so packages will not cause subsidence. I'll talk to you about subsidence tomorrow. We find that subsidence is a definite remedial problem that we have to address. In fact, at Hanford we ran a big, fully-loaded earth scraper through the burial ground trying to compact an old burial ground. In one particular area we almost lost the entire scraper in a hole where we were trying to cause subsidence. I rather suspect that you all have similar problems so I applaud the NRC statements earlier which acknowledge that this activity needs to be looked at.

Simple compaction of waste before emplacment may be enough to solve this problem. In the case where the scraper fell in, it happened to be a very large but not completely full box containing equipment, I think that we need to be able to address these type packages because we may be able to handle more cheaply at the burial site. I suggest we bring the non-full box to the site but then fill it with sand, or something equivalent, so that it can't compress at a later point.

- Third, at the time of trench closure, careful covering must be done to assure that there are no void spaces which will cause subsidence. I think that the trench closure is probably the most important activity that we can do. We need to close the trench with all environmental, biological, and erosion control barriers in place at closing. Returning to do this work at a later date is costly, not in proper budget year, and simply gets put off.

- Fourth, I think we need to use site-specific information that is already known to look at equivalent natural soil cover or a combined natural soil cover and barrier materials that can be laid down to prevent root or animal penetration when the burial trenches are closed. We have found roots of natural growing vegetation twenty feet deep on the Hanford site. This says we need twenty feet plus a little safety marginal, for natural cover. We can change and control the natural vegetation to shallow rooted species (i.e., a few inches) however, something could happen in the future which could upset the shallow-rooted species and return to deeper varieties.

  The subject of greater confinement came up this morning and quite frankly, that one scares me a little bit for existing burial grounds. I think that we need to look at this closely, because I think greater confinement is not only important, but it also can be very costly when we start talking retrofitting at places like Hanford that already have 450 acres of low-level waste sites. We need to be careful with criteria and standards for waste already buried.

- Fifth, I think we need to do some work on trench design. Many of us use some old draglines that we've had for years and I think that we can dig much more effectively with the new, more efficient equipment available today. Some of us have done it already. I think Nevada is using some good equipment techniques. There are more efficient, large backhoes. They were tried on a lease-basis at Hanford and proved capable of moving earth ten times faster.

- Sixth, I think we've got to examine the engineering barriers and get them in place, especially in the wetter sites. This is going to be a continuing work; perhaps even site-specific. I think that perhaps we need to emphasize barriers more from a remedial action standpoint.

In closing, I'd just like to make this comment - I think we have the proper people here in this room, and I think that we are solving a lot of our problems. I would really like to have everyone speak up, especially the operators, like myself, that have very specific problems that we can identify and get these issues before our technical experts. I would like nothing better than to really load up our good friends with the lead sites with excellent ideas. So, in the next couple of days, I know for one, that I'm looking forward to participating and I hope you will too.

Dup

OVERVIEW OF LLWMP MILESTONES
A. REDUCTION OF WASTE GENERATION
AND
B. AND G. WASTE TREATMENT

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LLWM Program Office
Oak Ridge National Laboratory*
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OBJECTIVES OF MILESTONES A, B, and G

Three dependent milestones have been grouped together in this technology development session on Waste Treatment. The objectives of these milestones are as follows:

- The objective of Milestone A is "To Develop Technology for Waste Generation Reduction" by September 1984.
- The objective of Milestone B is "To Develop Technology for Waste Treatment, Handling, and Packaging for Shallow Land Burial" by March 1984.
- The objective of Milestone G is "To Develop Technology for Waste Treatment, Handling, and Packaging for Greater Confinement than Shallow Land Burial" by September 1985.

MILESTONE A

The development of technology for waste generation reduction is focused on methods and technology to assist in reducing generation of low-level waste. The major components of this effort, performed by Pacific Northwest Laboratory, included the preparation of a waste generation reduction handbook that included a state-of-the-art review, cost-benefit assessment, and an identification of problems, gaps, and issues.

The draft of the document was delivered to the LLWMP in September 1981. After sufficient review, revisions, and any other changes that may be required, the document titled, "Handbook of Methods to Decrease Low-Level Waste Generation" will be published. The milestone for publication is April 1982. After the handbook is distributed, problems in the reduction of waste generation or gaps in the technology may be observed. We have provided for a resolution of these issues and a reissue of the handbook by September 1984.

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*Operated by Union Carbide Corporation under contract W-7405-eng-26 with the U.S. Department of Energy.

MILESTONES B and G

The development and demonstration of waste treatment technology is focused on technology applicable to the entire low-level waste stream from generation to disposal. The portion designated Milestone B is in support of shallow land burial, while the portion designated Milestone G is in support of greater confinement than shallow land disposal. The major components of this effort include waste treatment, waste packaging, waste handling, and waste testing.

These components have been subdivided as follows:

Waste Treatment Studies
- General Treatment Guidelines
- Mechanical Treatment
- Incineration
- Chemical Treatment
- Metal Volume Reduction
- Waste Form Development

Waste packaging Studies
- General Packaging Guidelines
- Transport Package
- Disposal Package

Waste Handling Studies
- General Handling Guidelines
- Generator Site Handling
- Transport Handling
- Disposal Site Handling

Waste Testing
- General Testing Guidelines
- Define Treatment Methods
- Select Standardized Test Procedures
- Establish Testing Centers (For QA)

Each of the components starts with general guidelines. These guidelines have not been fully developed at this time but are expected to guide the waste generator in the selection and application of technology to specific waste streams. The five other divisions are process-oriented as mechanical treatment technologies like compaction, incineration of combustible liquids or solids, chemical treatment of primarily liquid effluents, the reduction in volume of metallic waste, and the development of waste forms for disposal.

The next component involves waste packaging for transport and disposal. The LLWMP has assumed that since LLW packages or shipping containers are available to meet current DOT/NRC regulations, that development effort would be minimized. Further, if higher integrity packages/shipping containers are required to meet 10CFR61 Class C waste regulations that industry would undertake their design, testing, and certification. This component is therefore expected to only summarize information about the existing containers and their usage.

The waste handling component of the waste treatment technology covers the procedures, equipment, and requirements involved in the movement of waste packages at the generating site, over-the-road, and at the disposal site. The emphasis of this effort is a brief review and critique of existing practices and recommendations for further improvements.

The waste testing component of waste treatment technology involves the necessary quality assurance measures of the final waste product for disposal. The development of testing guidelines and standardized test procedures is underway by several groups outside the LLWMP, e.g., ANS, IAEA, and DOE's MCC. There is considerable international interest in waste testing since the performance of the waste packages are not always the same as indicated by the laboratory test samples. The need to support the establishment of testing centers, either for product development or as a referee, has yet to be determined.

The basis or guidance for the selection of LLWMP technology projects has been three state-of-the-art reports. These reports provide a comprehensive overview of the waste arisings, current treatment practices, an identification of problems, gaps and issues.

The areas of technology that have been supported to complete Milestones A, B, and G are as follows:

- Waste Generation Reduction
- Incineration of Organic Liquids
- Incineration of Combustible Solids
- Concentration and Destruction of Liquid Contaminants
- Metal Waste Volume Reduction
- Waste Solidification (Testing)
- Waste Handling and Segregation
- Treatment of Solids for Disposal

These areas of technology have been matched with program participants as shown in Table 1. It may be noted that work prior to FY 1982 has been indicated by a "c" while current work is indicated by an "o". To the extent possible, these are indicators of directly funded LLWMP tasks.

Table 1.

SUMMARY
TECHNOLOGY STATUS

	ANL-W	BNL	EG&G	MOUND	ORNL	PNL	RFO	RHO	SRL
WASTE GENERATION REDUCTION					C	O		C	
INCINERATION LIQUIDS			O					O	O
INCINERATION SOLIDS			O	O					O
CONCENTRATION AND TREATMENT LIQUIDS				O	C				
METAL VOLUME REDUCTION			O		O			O	
SOLIDIFICATION (TESTING)		O							
HANDLING		C			O				
TREATMENT OF SOLIDS FOR DISPOSAL	O						O		

KEY C = COMPLETED PRIOR TO FY 1982
O = ONGOING IN FY 1982

The FY 1982 program controlled technology milestones for this part of the LLWMP are listed in Table 2. These milestones are subdivided into those controlled by DOE Headquarters and those controlled by the LLWMP Technology Program. The method of meeting a milestone, its timing, and other aspects of this nature will be discussed in detail on Friday by R. S. Lowrie.

The outstanding requirements for waste treatment technology are as follows:

- Completion of General Treatment, Packaging, Handling, and Testing Guidelines
- Evaluation of Mechanical Treatment Technology
- Characterization and Qualification of Waste Streams
- Development and Acceptance of Waste Form Test Methods
- Determination of Need for Waste Form Test Centers
- Preliminary Documentation of Results by September 1982 as a Draft Handbook

TABLE 2

FY 1982 DOE LOW LEVEL WASTE MANAGEMENT
PROGRAM CONTROLLED TECHNOLOGY MILESTONES

MILESTONES A, B, and G

DOE LLWMP Headquarters Controlled Milestones	
Demonstrate an incinerator for treatment of institutional waste and issue report (3/82)	ID/EG&G
Issue waste generation reduction manual (4/82)	RL/PNL
LLWMP Technology Program Controlled Milestones	
Complete Mound membrane plant design (3/82)	AL/Mound
Status report on application studies of microwave plasma torch incinerator (9/82)	RL/RHO
Report on volume reduction and product acceptability attained in Mound glass melter project (9/82)	AL/Mound
Report on ion exchange resin and nitrate salt solidification investigations (9/82)	CH/BNL
Issue final report on the evaluation of scrap metal decontamination effectiveness (9/82)	OR/ORNL
Report on process evaluation studies of nitrate decomposition by carbon, urea, and thermal methods (9/82)	AL/RFO

SUMMARY

- The objective of Milestones A, B, and G is to provide documentation of the best available technology for waste volume reduction, treatment, handling, packaging and solidification to meet the needs of shallow land burial disposal and for greater confinement than shallow land burial.
- Many of the hardware options for waste treatment have been reviewed for appropriate usage with low-level waste, some of the more promising options remain to be evaluated.
- Testing of treatment technologies with real industrial wastes at appropriate levels of radioactivity has been initiated, considerable work remains to be completed.
- Analysis of the interaction of treatment, solidification, and disposal needs to be completed.

MILESTONE A: HANDBOOK OF METHODS TO DECREASE LOW-LEVEL WASTE GENERATION--FY-1981 STATUS

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PROJECT OBJECTIVE AND STATUS

A major objective of this milestone is to produce a handbook on approaches and methods that help minimize the generation of low-level waste (LLW), thus providing waste generators the necessary technology to assist in the reduction of LLW generation. A working draft, Handbook of Methods to Decrease Low-Level Waste Generation, was completed and released for review and comment, thereby fulfilling FY-81 project milestone commitments. Comment on and review of the draft handbook is to be completed by mid-November 1981. The final draft will be issued by the end of FY-1982. In addition, recommendations for development of methodologies for decreasing LLW generation will be conveyed to ORNL.

STUDY EMPHASIS

The amount of LLW that requires disposal can be reduced by both 1) decreasing the rate of generation, and 2) reducing the volume of the waste after generation. Decreasing the rate of LLW generation is the subject of the handbook. Although reducing the volume of LLW after generation is important, this method is generally accepted and relatively well documented, and thus is not specifically addressed. The handbook contains information intended to assist these generators of LLW:

- commercial nuclear fuel-cycle facilities related to electrical generation;
- installations engaged in government-related activities that involve nuclear materials;
- institutions such as hospitals, universities, and research foundations that use nuclear materials for research;
- industrial processors and users of radioactive materials.

The handbook is based on information obtained from generators of radioactive waste. Pertinent data were collected through interviews and site visits. Approximately 80 persons were contacted who represented 35 to 40 organizations. Available literature on waste generation reduction was also studied.

OUTLINE OF HANDBOOK

The handbook is divided into four chapters: Design and Engineering, Operation and Maintenance, Decontamination, and Administrative Methods. These chapters reflect distinct areas where waste management can be potentially improved to reduce LLW generation. Each chapter includes an approach to reduce waste generation and a description of waste-reduction methods. The approach provides direction for the user in terms of contamination control, reuse, materials and equipment, and processes. These four considerations have possible application in the user's overall waste management scheme. The methods in each chapter parallel the considerations discussed in the approach. Cost/benefit relationships and examples are discussed at the end of each chapter.

This organization is intended to allow convenient identification of pertinent methods to help reduce waste generation. For example, if a new facility or process is being considered, the user should refer to those methods for decreasing waste generation in the Design and Engineering chapter. However, a pertinent concern, such as contamination control, may require a review of all four chapters.

Examples and cost/benefit "tradeoffs" are included to illustrate the application of the waste generation reduction methods.

STUDY RESULTS

Few unique developments or technological breakthroughs were identified for decreasing LLW generation, while the most popular methods suggested, or already in use, dealt with common sense waste management practices. Growing economic incentives influenced by increasing transportation and disposal costs provide a stimulating force to develop new methods to reduce waste generation. However, these incentives are not totally effective since waste generators can often pass on additional waste disposal costs by increasing customer charges, such as increased medical costs or higher utility rates.

Results of the study indicate that waste generation can be controlled and ultimately reduced if a systematic plan is followed. Although it would be beneficial to reduce wastes in areas of greatest waste generation, the most significant waste-generation reduction results from systematic evaluation of waste generation factors and application of methods throughout the facility. Thus, the handbook offers methods to decrease waste generation in terms of facility and equipment design, operation and maintenance, decontamination, and administrative controls. Although proper training of personnel and modification of equipment and facilities can significantly reduce waste generation, a reduction in LLW generation requires conscious and continuous effort by all involved personnel.

Of the many potential advantages for decreasing the generation of LLW, the major advantages are prolonged life of existing LLW disposal sites and reduced overall costs of waste management activities. These factors provide real incentives for pursuing methods for decreasing the generation of LLW.

WASTE SEGREGATION

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ABSTRACT

A scoping study has been undertaken to determine the state-of-the-art of waste segregation technology as applied to the management of low-level waste (LLW). Present-day waste segregation practices were surveyed through a review of the recent literature and by means of personal interviews with personnel at selected facilities. Among the nuclear establishments surveyed were Department of Energy (DOE) laboratories and plants, nuclear fuel cycle plants, public and private laboratories, institutions, industrial plants, and DOE and commercially operated shallow land burial sites. These survey data were used to analyze the relationship between waste segregation practices and waste treatment/disposal processes, to assess the developmental needs for improved segregation technology, and to evaluate the costs and benefits associated with the implementation of waste segregation controls.

This task was planned for completion in FY 1981. It should be noted that LLW management practices are now undergoing rapid change such that the technology and requirements for waste segregation in the near future may differ significantly from those of the present day.

OBJECTIVES AND PROCEDURE

Currently, little or no waste segregation is practiced at shallow land burial sites used for the disposal of LLW. In some cases, the resultant intermixing of various waste types in the burial trenches has resulted in disposal site problems such as subsidence, trench cap deterioration, and migration of radioactivity. For example, organic chelating materials have been disposed of in the same trenches as solidified wastes, providing a mode for affecting radionuclide sorption capacity

(K_d) of the disposal site geology. Corrosive compounds, frequently present, promote a rapid loss of integrity of metallic waste containers and enhance radioactivity release from the waste forms. Other chemical interactions also occur when diverse waste types are disposed of without regard to segregation. Some wastes in shallow land burial may primarily be chemical or toxic hazards (rather than radioactive hazards) and, as such, benefits may result from more waste-specific disposal practices. Subsidence and trench cap deterioration problems may be minimized by segregation of organic wastes susceptible to microbial decomposition and compaction under the weight of the overburden.

This study was undertaken with the goal of achieving several objectives as shown in Figure 1. Completion of this task and achievement of these objectives has yielded the following: (1) determination of the state-of-the-art of LLW segregation technology, (2) the ascertaining of current waste segregation practices for both DOE and commercial LLW, (3) analysis of the relationship between segregation practices and waste/treatment disposal processes, (4) recommendations regarding changes and developmental needs for the establishment of improved segregation controls, and (5) a limited assessment of the associated costs and benefits of implementing waste segregation procedures.

The types of facilities for which waste segregation practices were investigated are shown in Figure 2. These facilities included major DOE laboratories and plants, nuclear fuel cycle installations (fuel fabrication plants, nuclear power plants), institutions (universities, hospitals, medical research centers), industrial concerns (producers of radioisotopes or radiopharmaceuticals), waste brokers, and shallow land burial sites (both DOE and commercial).

Information relevant to the evaluation of waste segregation practices at each of these facilities was also obtained on the characteristics of as-generated LLW (see Figure 3). This included data on waste types and corresponding radionuclide content as follows: liquid wastes (organic liquids and oils, decontamination solutions, aqueous concentrates, etc.); wet solid wastes (spent ion exchange resins, evaporator bottoms, sludges, etc.); dry solid wastes (combustible and non-combustible trash containing plastics, cellulosics, rubbers, filters, metals, etc.; discarded equipment consisting of decommissioning and renovation items, etc.); and the corresponding radionuclide type(s) and specific activity range(s).

The annual generation rates for LLW produced in the U.S.A. are shown in Figure 4. Appoximately one-third of the domestically-produced LLW volume is from government sources, and two-thirds is commercially generated.[1] Of the commercial wastes, approximately 60% by volume is attributable to nuclear fuel cycle operations. Government wastes, for the most part, have been disposed of by shallow land burial at what are now DOE sites. Much lesser amounts have been disposed of by ocean dumping (during the period of 1946-1970) and by shallow land burial at commercial sites. Since 1979, the small percentage of DOE waste that formerly was disposed of at commercial facilities has been shipped to

WASTE SEGREGATION

Objectives of the LLW Segregation Task

- DETERMINE STATE-OF-THE-ART
- ASCERTAIN CURRENT PRACTICES
- ANALYZE RELATIONSHIP BETWEEN SEGREGATION PRACTICES AND WASTE TREATMENT/DISPOSAL PROCESSES
- SUGGEST CHANGES AND DEVELOPMENTAL NEEDS FOR IMPROVED SEGREGATION PRACTICES
- ASSESS ASSOCIATED COSTS AND BENEFITS

FIG. 1. OBJECTIVES OF THE LLW SEGREGATION TASK.

WASTE SEGREGATION

Types of Facilities for Which Waste Segregation Practices Were Investigated

- DOE LABORATORIES AND PLANTS
- NUCLEAR FUEL CYCLE INSTALLATIONS (FUEL FABRICATION, POWER PLANTS)
- INSTITUTIONS (UNIVERSITIES, HOSPITALS, MEDICAL RESEARCH)
- INDUSTRIAL CONCERNS (RADIOISOTOPE/RADIOPHARMACEUTICAL PRODUCERS)
- WASTE BROKERS
- DISPOSAL SITES (DOE, COMMERCIAL)

FIG. 2. TYPES OF FACILITIES FOR WHICH WASTE SEGREGATION PRACTICES WERE INVESTIGATED.

WASTE SEGREGATION

Waste Characteristics Important to the Evaluation of Segregation Practices for LLW

WASTE TYPES

- LIQUID WASTES (ORGANIC LIQUIDS, DECONTAMINATION SOLUTIONS, AQUEOUS CONCENTRATES, OILS, ETC.)

- WET SOLID WASTES (SPENT ION EXCHANGE RESINS, EVAPORATOR BOTTOMS, SLUDGES)

- DRY SOLID WASTES

  COMBUSTIBLE AND NON-COMBUSTIBLE TRASH (PLASTICS, CELLULOSICS, RUBBERS, FILTERS, METALS, ETC.)

  DISCARDED EQUIPMENT (DECOMMISSIONING AND RENOVATION ITEMS)

RADIONUCLIDE CONTENT

- RADIONUCLIDE TYPE(S)

- SPECIFIC ACTIVITY RANGE(S)

FIG. 3. WASTE CHARACTERISTICS IMPORTANT TO THE EVALUATION OF SEGREGATION PRACTICES FOR LLW.

WASTE SEGREGATION

Annual Rates of LLW Generation in the U.S.A.

SOURCE	ESTIMATED VOLUME OF LLW GENERATED IN 1981 (FT^3)	PER CENT OF TOTAL LLW VOLUME
GOVERNMENT	$\sim 1 \times 10^6$	33.
COMMERCIAL	2×10^6	67.
FUEL CYCLE	1.2×10^6	41.
NON-FUEL CYCLE	8×10^5	26.

FIG. 4. ANNUAL RATES OF LLW GENERATION IN THE U.S.A.

DOE burial sites to avoid reducing the limited capacity of existing commercial sites. However, a small percentage of LLW from government sources (e.g., Department of Defense wastes from the Navy and from veterans hospitals) continues to be disposed of at commercial burial sites.

The distribution of LLW disposed of at commercial burial sites in 1979 (based on data in Reference 2) is shown in Figure 5. Except for the wastes from nuclear power plants, fuel cycle LLWs from fuel fabrication, etc. are included in the industry classification. With the continued growth of nuclear power, an increasing percentage of LLW can be expected to be attributable to nuclear power plants in the future.

The management of LLW involves a series of unit operations as shown in Figure 6. To a varying degree, waste segregation may be applied at any of the stages indicated in Figure 6. However, segregation is best accomplished early on and as close to the point of generation as is technically feasible. It then will serve as a key determinant of all subsequent operations (i.e., waste treatment and processing, interim storage, transportation and final disposition of LLW).

It is recognized that specific benefits are derived from the application of segregation controls by the LLW generator (see Figure 7). Efficient segregation of non-radioactive waste from radioactive wastes at the point of generation can drastically reduce the volume and cost of waste requiring treatment and disposal. Segregation of wastes can also lead to more efficient waste processing by which, for example, personnel exposures can be reduced and solidification can be directed towards certain "problem" wastes. Other benefits include an enhanced ability to discriminate between wastes and to maintain accurate records, and overall improved operations and radionuclide retention at burial sites.

The investigative approach used in this task included the conduction of both literature and field surveys. Very little information has been published concerning waste segregation technology, and the literature search disclosed only a few current examples of its application to LLW management. It was therefore necessary to rely upon extensive personal contacts and field visits for most of the data obtained in this study. This was very time-consuming and only a limited number of site visits could be completed during this period. However, a representative sampling of relevant practices was obtained during this scoping study.

The accomplishments for the Waste Segregation Task in FY 1981 are shown in Figure 8. These have included the following: (1) a literature survey of LLW generation rates and segregation practices, (2) a survey of the current state of LLW segregation technology at selected facilities, involving both personal contact and site visits to representative facilities, (3) a determination of need for new or improved segregation techniques based on information obtained in the segregation technology

WASTE SEGREGATION

Distribution of LLW Disposed of at Commercial Burial Sites in 1979 (Data from Reference 2)

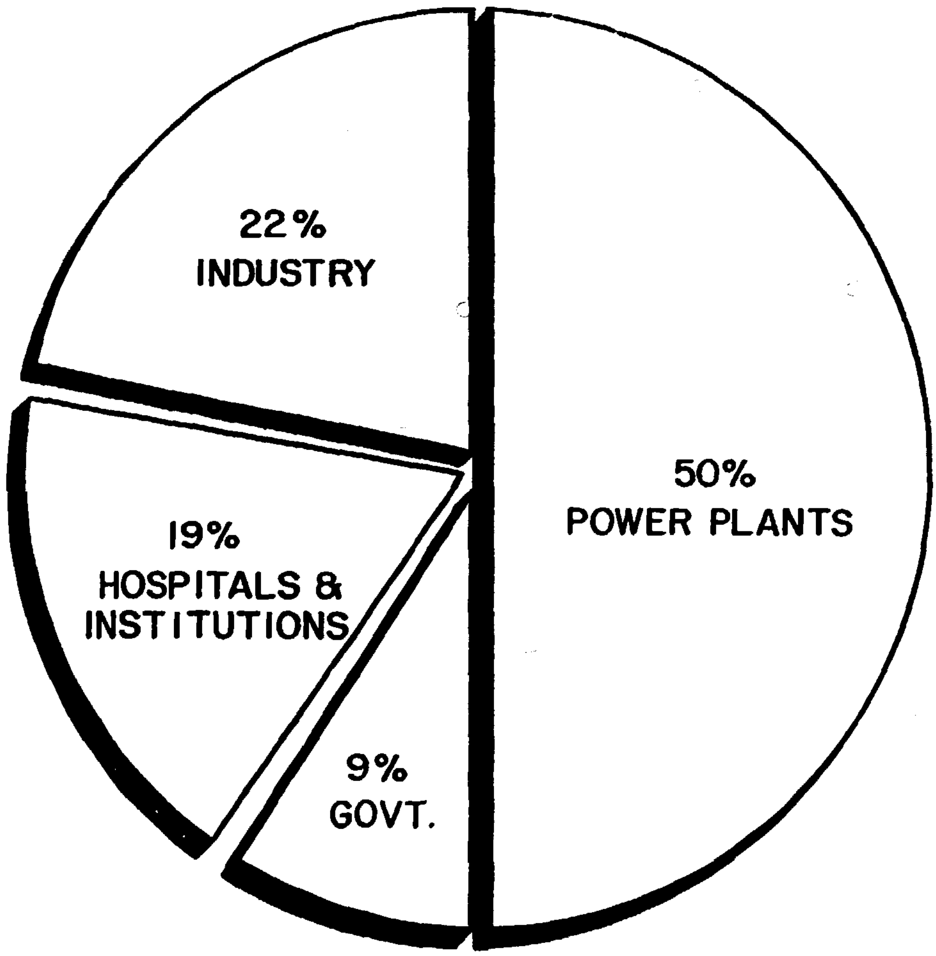

FIG. 5. DISTRIBUTION OF LLW DISPOSED OF AT COMMERCIAL BURIAL SITES IN 1979 (DATA FROM REFERENCE 2).

WASTE SEGREGATION

Management of Low-Level Waste (LLW)

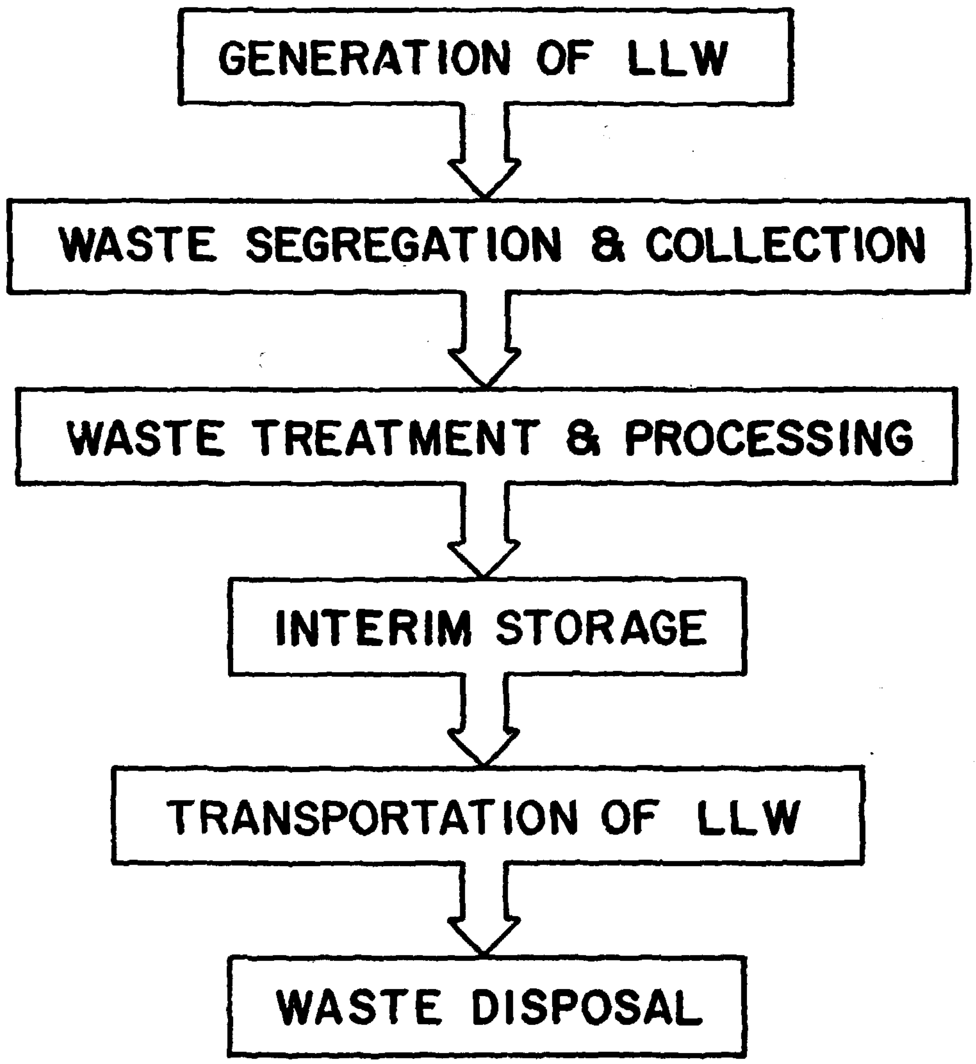

FIG. 6. MANAGEMENT OF LOW-LEVEL WASTE (LLW).

WASTE SEGREGATION

Potential Benefits of Waste Segregation

- NET REDUCTION IN WASTE VOLUMES REQUIRING COSTLY TREATMENT AND DISPOSAL
- IMPROVED CAPABILITY FOR MORE EFFICIENT WASTE PROCESSING
- ENHANCED ABILITY TO DISCRIMINATE BETWEEN WASTES AND TO MAINTAIN ACCURATE RECORDS
- REDUCTION IN PERSONNEL RADIATION EXPOSURES
- IMPROVED OPERATIONS AND RADIONUCLIDE RETENTION AT BURIAL SITES

FIG. 7. POTENTIAL BENEFITS OF WASTE SEGREGATION.

WASTE SEGREGATION

Waste Segregation Task FY 1981 Accomplishments

- LITERATURE SURVEY OF LLW GENERATION RATES AND SEGREGATION PRACTICES
- SURVEY OF CURRENT STATE OF LLW SEGREGATION TECHNOLOGY (PERSONAL CONTACT/SITE VISITS)
- DETERMINATION OF NEED FOR NEW OR IMPROVED SEGREGATION TECHNIQUES
- INTERIM REPORT (PRELIMINARY RECOMMENDATIONS CONCERNING LLW SEGREGATION TECHNOLOGIES)
- END-OF-YEAR ANNUAL SUMMARY REPORT AND TECHNOLOGY TRANSFER DOCUMENT

FIG. 8. WASTE SEGREGATION TASK FY 1981 ACCOMPLISHMENTS.

survey, (4) the issuance of an interim report with preliminary recommendations concerning LLW segregation technologies, and (5) the completion of the end-of-year annual summary report and technology transfer document.

The information obtained in this study and presented in the final summary report should be useful for the future planning and development of treatment options leading to improved management of LLW. This information provides input to the milestones of the National Low-Level Waste Management Program (NLLWMP), and in particular to Milestone B (the development of technology for waste treatment-handling-packaging to support shallow land burial).

STATUS OF LLW SEGREGATION

All waste generators practice some degree of segregation of their various waste streams (although the terminology "waste segregation" is not in common usage).* Because of the rapidly increasing costs of LLW disposal and restrictions which have been imposed over the past two years at commercially operated shallow land burial sites, there has been an increasing concern among waste producers to reduce the volumes of LLW which must be shipped for disposal. Volume-reduction treatments are specific to certain waste types and therefore require segregation as a pretreatment. Thus, the technology and requirements for waste segregation are undergoing rapid development at the present time.

Waste segregation is now recognized as being an essential element of the LLW management system if the problems attendant to shallow land burial are to be either solved or alleviated. As they are currently being proposed for application to commercial sites, future regulations can be expected to mandate the implementation of disposal site segregation controls which will permit the application of specific disposal methods or specific site locations of LLW on the basis of its type, form, chemical composition and radionuclide content. Only by means of segregation can there be established a capability of discriminating among wastes based on their physical, chemical and radiological properties, thus permitting selection of a disposal method related to the hazard of the waste.

*It should be noted that the proposed 10 CFR Part 61 recently issued by the NRC uses the term "segregation" in a different context.

Waste segregation can be utilized for the exercise of different disposal options. The recent NRC changes in 10 CFR Parts 20.301, 20.303, 20.305 and 20.306 (Federal Register/Vol. 46, No. 47, March 11, 1981, pp. 16230-16234), which allow for the disposal of certain biomedical waste "without regard to its radioactivity," have already resulted in a significant reduction in volume of LLW shipped from several institutions. While the alternate disposition of these wastes is in some cases uncertain, this deregulation by the NRC is generally considered to have been a significant improvement in the management of LLW.

ASSESSMENT OF CURRENT LLW SEGREGATION PRACTICES

Although recently there has been a growing interest in waste segregation technology, the generators and processors of LLW have received little guidance or encouragement for the adoption of segregation practices aside from the general speculation as to future regulatory requirements. Very little dissemination of information concerning waste segregation practices has occurred, and few personnel are aware of the technology being used at other than their own sites.

Significant savings have been reported by some sites that have implemented waste segregation. At New England Nuclear, for example, segregation of wastes is practiced to a high degree and has been shown to be very cost-effective. Segregation has been accomplished there largely through the establishment of institutional controls and increasing employee awareness of the need for waste segregation. For the most part, New England Nuclear's program involves segregation at the point of generation, this having been clearly designated as a responsibility of the individual waste generator. An important feature is the careful documentation and accountability for each discrete package. The program at New England Nuclear could serve as a model for other generators of similar types of LLW.

Experience at DOE facilities has also indicated that significant savings and reduction of volumes can be achieved through waste segregation. At ORNL, for example, a comprehensive waste segregation policy was instituted and shown to be successful, largely due to dedicated efforts for increasing worker awareness of the need to segregate all solid wastes. The effort included the coordinated use of seminars and training sessions, publication of articles in the laboratory paper, and dissemination of attractive and effective posters throughout the laboratory. This program could likewise serve as a model for similar sites.

At nuclear power plants, where the LLW streams are large and of reasonable consistency, the concept of on-site storage of all LLW is being seriously considered. It may be that the deployment of properly engineered on-site treatment/storage facilities will be accepted and become an attractive option for nuclear-based utilities in the future. If so, it can be presumed that the on-site treatment and storage of the wastes generated at nuclear power plants will require the adoption of advanced methods for collecting, handling, processing and packaging radwastes. Associated with these developments will be increasing demands for the segregation of radwastes for both treatment and storage purposes.

Many of the persons contacted in the LLW generation and segregation surveys have expressed opinions favoring improved segregation of the wastes if it can be demonstrated that the adoption of these practices would not require unreasonable operational adjustments or large cost outlays. (Disposal costs have increased dramatically within the past several years, such that the small user cannot afford much more outlay without curtailing the use of radioisotopes.)

Waste segregation is widely perceived as contributing to a more acceptable mode of waste management and disposal. However, the relative ease with which a given facility or LLW generator is able to adopt segregation technology will vary greatly depending on the diversity of the site, available personnel, and so on. At some LLW generating sites, a reasonably consistent waste stream is produced which may be amenable to the applied segregation technology, while at other sites the waste stream characteristics may present special problems or resist a straightforward application of segregation technology.

For improved processing and disposal of LLW, waste segregation should be practiced wherever it is technically feasible and cost-effective to do so.

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DEVELOPMENT OF CRITERIA FOR THE SHALLOW LAND BURIAL OF SODIUM-CONTAMINATED WASTE

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The Liquid Metal Fast Breeder Reactor (LMFBR) experimental program has produced and will continue to produce radioactive scrap and waste materials, some of which contain elemental sodium in small or bulk quantities. These sodium-bearing materials must presently go into special temporary storage facilities because the present criterion for shallow land burial is "no sodium" (PR-W-78-0'+ EG&G Document - no alkaline metals).

Much of this material is in storage at Argonne National Laboratory-West (ANL-W) located on the Idaho National Engineering Laboratory (INEL) in Idaho where the Experimental Breeder Reactor II (EBR-II) has been operating since 1963. Initially the INEL's Radioactive Waste Management Complex (RWMC) requirements indicated that material containing elemental sodium would be considered on a case basis. The absence of a qualified transport cask (most material in high Rem range) precluded the disposal of this material until about 1975 when the first ANL-W waste cask was qualified for over-the-road use. At that time a safety evaluation was performed to support the burial of specific waste items containing up to 170 g of elemental sodium since a significant portion of the sodium contaminated waste contained quantities up to this number. This evaluation was not approved by the operators of the RWMC for safety considerations and the RWMC's criteria were changed to "no sodium" (no alkaline metals). Since "no sodium" is not practical and requires a definition, a better criterion is needed, if the LMFBR program is to dispose of this type of radioactive waste.

The Sodium Waste Technology (SWT) Program, managed by DOE-CH with assistance from ANL, was established as part of the TRU Waste Management Program at DOE-AL. The objectives of the program are to develop methods and processes for removing sodium from scrap and waste materials and converting the sodium into a disposable form. Inherent in these objectives is the development of standards necessary for safe handling of the waste from generation to disposal. Any sodium removal process, whether water wash, alcohol wash, steam-moist nitrogen, evaporation, etc., leaves some amount of elemental sodium in cracks, crevices or other hard to reach areas of the waste component. Therefore, "no sodium" needs further definition if disposal of the waste is to be achieved.

Criteria may be established either based on some finite value of elemental sodium present in a waste package or based on the material having been subjected to some process known to reduce the sodium content to acceptable levels. To take the latter approach requires that the acceptable level be determined prior to the identification of the process or processes since some of the processes are much less efficient at removing sodium than others. ANL-W is presently preparing to test the Melt-Drain-Evaporation Calcine (MEDEC) process. This process was selected because all information to date indicates that this process is the only one with the ability to remove elemental sodium from small cracks and crevices and, therefore, the process which most closely approaches the criterion "no sodium." Establishment of new, acceptable criteria for shallow land burial could, however, allow the use of other, less rigorous processes. In view of this concept, the SWT Program, in FY81, contracted with Atomics International-Rockwell International Energy Systems Group (AI) to begin the development of shallow land burial criteria for sodium-bearing waste.

The objective of the contract with AI was to provide the technology base required for making a safety analysis of the consequences of leaving some quantity of residual sodium on radioactive waste destined for shallow land burial. From the safety analysis based on empirical data, burial criteria could then be developed. Three areas of study were scheduled for the FY81 time frame.

1. Analytical Safety Study

Data and information were gathered on the type of radioactive waste and scrap containing residual sodium, the condition and behaviour of residual sodium, safety related incidents on disposing sodium containing components, and presently applicable criteria for burial of such wastes. The information was obtained from four waste generators (Atomics International, Argonne-West, FFTF and Fermi-1) and six burial sites (U.S. Ecology, Beatty and Richland Sites; Chem-Nuclear; EG&G Idaho; Rockwell-Hanford; and duPont). Information from sodium cleaning and removal experiments conducted at AI were also reviewed. Finally, licensing requirements (NRC) for burial of radioactive scrap and waste with residual sodium were reviewed. Major conclusions resulting from this effort were:

(a) reactor vessel, and components such as primary and secondary piping, cold and hot traps, and valves constituted the bulk of the articles used in sodium service that required sodium removal and disposal.

(b) Principal cleaning processes used for removal of residual sodium are i) alcohol, alcohol-water, ii) steam, steam-inert gas, iii) carbon-dioxide, nitrogen (passivation only), and iv) evaporative methods. Numerical data on residual sodium are available only from the evaporative cleaning tests.

(c) Safety related incidents have occurred either during the cleaning process or during handling of components prior to cleaning. No reported incidents have occurred after these components were buried.

(d) The licenses now issued to burial sites by state agencies or DOE require that waste or scrap having hazardous properties (such as violent reactions with moisture) or pyrophoric properties be not buried at these sites. Operators of the burial sites interpret this to include any quantity of sodium that may remain in components. They contend that the 'burden of proof' as to what constitutes a safe amount of residual sodium is a task that must be addressed by waste generators. Therefore, sodium-contaminated waste similar to those in (c) above as well as others are not being shipped to disposal sites.

2. Experimental Studies on Reactions of Residual Sodium with Water

The purpose of these tests were to obtain data on changes in pressure, temperature, and hydrogen concentration that would result in the event residual sodium-water reactions were to occur in a buried waste container. The results of the tests will be used to evaluate the amounts of residual sodium that may be tolerated in buried sodium wastes without adverse safety consequences if ground water were to inadvertently enter a ruptured container.

Initial tests were run using small quantities of elemental sodium (up to 7.5 grams) in a closed container and varying the water addition rates. Additional tests were then carried out by distributing known quantities of sodium up to 4 grams on specimens (i.e., sodium wetted components). There were three variables in these tests: (1) quantity of sodium, (2) rate of water input, and (3) weight of components contaminated with sodium. Initial data have been plotted and additional data are required. There was in a few cases a violent reaction.

3. Experimental Studies of Hydrogen Permeation of Soil

In addition to the safety aspects of sodium burial, it was decided that in the area of radiological concerns, the only unique aspect of sodium burial would be the tritium that may be released from a ruptured container. The tritium could be released as the water entered the container and reacted with the sodium. Tests were conducted to determine how much hydrogen (tritium) would be converted to water when it is allowed to permeate through a column of soil. The results of the tests disclosed that little, if any, of the hydrogen is converted to water; however, the hydrogen is physically trapped in the 12 ft column of sand which was used. Whether the situation has an adverse impact compared to water has yet to be determined.

Work projected for FY82 will continue the sodium-water reaction testing using sodium-wetted components to obtain sufficient data to determine the amount of sodium which can be safely buried as part of other waste. The tests will also investigate the difference when the container contains an inert gas instead of air. The hydrogen permeation tests will continue using actual soils from Idaho, Nevada and Washington to determine if the results obtained from the sand column originally used are representative of the actual conditions. The preliminary diffusion model prepared by AI will be improved with these additional data. Field tests will be performed if the results obtained appear to be beneficial to the overall program.

FY82 work will also include closed container studies on sodium compounds such as the MEDEC process product as well as determining a method for certification (QA) of the amounts of elemental sodium which are present in a waste package.

The final objective will be to establish criteria, for the Low Level Program for the shallow land burial of sodium-contaminated waste and sodium compounds which may result from the various sodium removal processes. It is expected that this would be completed in early FY83.

Costs for the FY81 work totaled $98K of which $50K was funded by the Low Level Waste Program. The remaining $48K was funded from the operating budget of the SWT Program. FY82 work is expected to cost $100K with an additional cost of $50K in FY83 for development of the actual criteria.

In summary, it is necessary to establish criteria for the safe shallow land burial of waste material containing small quantities of elemental sodium. The present criterion of "no sodium" is not realistic and probably can not be achieved. In FY81, work was begun on providing a technological base for the establishment of these criteria by conducting experiments on the safety aspects (sodium-water reactions in a closed vessel) and on the radiological aspects (tritium permeation). Additional work is required in FY82 to complete the base with additional empirical data. Using these data, criteria will be established in FY83 which will allow the safe disposal of sodium-contaminated wastes from the LMFBR program in shallow land burial.

Dup

RFP 3283

THE LOW-LEVEL WASTE NITRATE CHALLENGE

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ABSTRACT

Accomplishments of work planned in fiscal 1981 to deal with low-level radioactive waste nitrate are presented. The quantities of waste nitrate from commercial and defense nuclear activities which are environmentally unacceptable for future disposal were found to be in excess of 4.6×10^8 kg. Generation rates are estimated at 7.0×10^6 kg per year.

A brief description of the processes which might convert these nitrates to environmentally acceptable waste forms is discussed, and the budget needs are summarized.

INTRODUCTION

Tail end waste treatment operations at nuclear facilities result in the generation of large quantities of low-level radioactive waste nitrates. Increased pressure from the Nuclear Regulatory Commission (NRC) and Environmental Protection Agency (EPA) to remove these materials from nuclear plant effluents, and to protect low-level waste repository ground water from nitrate contamination, suggests waste management practices must be changed. The task at Rocky Flats deals with the technology development necessary to effect that change.

A detailed description of where waste nitrates occur in the commercial fuel cycle and defense nuclear operations is necessary to understand the magnitude of the problem. An intense investigation into plant operations in both sectors was carried out this past year. The quantities and composition of waste nitrates (both in storage and being generated) found in this investigation emphasize the need for continuing research into processes which will render the material environmentally acceptable.

An insight into the regulations (both proposed and in effect) which influence present and future waste management practices for waste nitrate is important. The proposed NRC Rule 10 CFR 61, establishes minimum waste form requirements which current waste nitrates will not meet. This rule is supplemented by EPA rule 40 CFR 141, the National Primary Drinking Water Quality Criteria (DWQC). This rule requires that all plant effluents, and ground water seepage from burial sites, do not exceed 10 mg/l elemental N (45 mg/l NO_3^-).

This task, which supports milestone "B" and the Advance Treatment Milestone of the National Low-Level Waste Management Program (NLLWMP), will address these issues and provide alternative solutions so nuclear facility operators can meet the challenge of stricter regulations.

OBJECTIVE

The objective of this task is the development and demonstration of a process(es) to eliminate or drastically reduce the amount of nitrates in LLW streams without the generation of objectionable oxides of nitrogen. This project will provide the technology to convert these nitrate wastes to carbonates or hydroxides, which are more environmentally acceptable as well as being more amenable to a wider spectrum of immobilization options to meet future transportation and disposal criteria.

FISCAL 1981 ACCOMPLISHMENTS

This task was proposed during the fiscal 1982 budget cycle. Initial funding for fiscal 1981 was requested at $195K, which was reduced by the EG&G lead office to $75K. This has had a serious impact on what was planned originally and what was ultimately achieved. Additionally, the DOE field office in Idaho redirected the effort from technology development to a national problem study. The results of this study will be reported.

There were three level 3 milestones which were imposed by Idaho in a letter from the Idaho field office to the Albuquerque field office in December 8, 1980. They are as follows:

A) Provide characterization and waste generation rate data for nitrate from defense and commercial programs. Progress Letter Report 3/81.

B) Estimate resource recovery rate and generic applicability of a nitrate treatment process to other waste generators. Progress Letter Report 6/81.

C) Provide engineering estimates of cost/benefit for process for inclusion in "Report on Process Parameters," 9/81.

Level 3 milestone A was met on schedule. It was reported that 1.2 x 10^8 kg of waste nitrate is currently in storage in the form of sodium and potassium nitrate, and the annual generation rate was estimated to be 5 x 10^7 kg. A more detailed study later proved this estimate to be conservative.

During the course of the investigations to meet milestone "A", it was determined that milestones "B" and "C" could not be met with the level of funding available. Alternative level 3 milestones were negotiated with the technical lead office in ORNL during the annual NLLWMP site visit April 29, 1981. These milestones are as follows:

B) Characterize composition and quantities of waste nitrate at generators. August 31, 1981.

C) Estimate technical approach to treat characterized groups of waste. September 30, 1981.

The deliverable to satisfy these milestones was later changed from two letter reports to a single informal report which was delivered on schedule. This report will be issued as a formal topical report RFP-3282[18] at a later date.

There are other accomplishments which bear mentioning. Prior to redirection, the technical progress on a process to convert $NaNO_3$ to Na_2CO_3 proceeded on schedule. Crucible tests were successful and scaled up tests in a fluidized bed of sand showed promise. The results of this work received an "excellent progress" rating during the annual NLLWMP site visit review.

DISCUSSION

A brief description of the quantities of waste nitrate found, who the major generators are, and the proposed processes to be investigated for converting the waste to an environmentally acceptable substance is in order.

This can best be accomplished by a summary of the results in the report "Commercial and Defense Nitrate Wastes and Processing Alternatives," which will soon be published as RFP-3282.[18] That report shows the quantities of material to be enormous. The material generated in the commercial fuel cycle is tabulated in Table 1. The bulk of waste nitrate is associated with conversion of U_3O_8 to UF_6. This process accounts for about 9.1 x 10^5 kg annual production with the enrichment of ^{235}U process accounting for an additional 1.2 x 10^4 kg of waste nitrate. None was found at power generators, and since there is no commercial fuel reprocessing currently going on, there is no waste nitrate being generated. However, the potential commercial fuel reprocessing nitrate waste is enormous. Stored nitrate from commercial

Table 1. Nitrate Wastes in the Commercial Fuel Cycle

Activity	Location	Generation Rate per Year	Amount Stored	Remarks
Mining and Milling	All	Virtually None	None	No significant amounts of nitrate waste from current processes.
Conversion	Allied Chemical Metropolis, IL	None	None	Use dry hydrofluor process.[1]
	Kerr-McGee Sequoyh, OK	9.1×10^5 kg	None	Converted to NH_4NO_3 and used as in-plant fertilizer.[2]
Enrichment (All Gaseous Diffusion)	Union Carbide (K-25) Oak Ridge, TN	Included in Oak Ridge rate	None	Transported to Oak Ridge Y-12 for biodenitrification.[3]
	Union Carbide Paducah, KY	8.1×10^3 kg Solution	None	Transported to Oak Ridge Y-12 for further use. (Other small amounts treated and discharged.)[4]
	Goodyear Atomic Piketon, OH	3.8×10^4 kg	None	Treated and released.[5]
Power Generation	All	None	None	*See footnote.

* Light water reactors, both the BWR and PWR types, can be classified as generating no significant amounts of nitrate wastes.

reprocessing is currently being handled as defense waste and is tabulated with the defense waste in Table 3. A survey of the commercial shallow land burial sites did not reveal reportable quantities.

Fuel fabrication plants generate some nitrate, as shown in Table 2. However, the quantities are small compared to the rest of the inventory.

An intense investigation into defense plant waste operations revealed still greater quantities of waste nitrates. The amount of material in Table 3 which is stored as LLW is on the order of 4.3×10^7 kg, and the annual generation rate is now estimated at 9.0×10^5 kg. But, the bulk of material which needs to be addressed is stored as HLW.

Recent actions at DOE Headquarters lends more credibility to construction and operation of the Defense Waste Process Facility (DWPF). One of the major streams from the DWPF flowsheet is LLW nitrate. Therefore, the inventory and generation rates tabulated in Table 4 are potential LLW. The total mass stored is on the order of 4.2×10^8 kg with the nitrate content varying from 54% to 90%. Generation rates through year 2000 are estimated at 6.1×10^6 kg per year. These quantities justify an increased effort to develop technologies to deal with them.

The present DWPF waste management scheme requires mixing the nitrates with cement and internment in shallow land burial as "salt-crete." This material requires a 55% increase in weight from cement which is also costly. SRP is concerned that the cementitious mixtures of nitrate salt will leach nitrates quite rapidly. Consequently, their scientists have expressed interest in a process which will convert the material to an environmentally acceptable form and not jeopardize their DWQC permit for nitrate in ground water.

Seven basic processes were studied which might have application to convert the waste streams to an environmentally acceptable substance. The streams were categorized as dilute nitrate, concentrated nitrate, and dried nitrate salt. Table 5 shows a matrix of the processes and their application. No attempt has been made at applying risk factors to the processes, but the thermal processes are of major interest at this time.

CONCLUSIONS

A number of conclusions were drawn from the previous years work. They are presented here.

- The amount of waste nitrates stored in the commercial nuclear sector is not great, and most sites report little or no nitrate waste inventories.

Table 2. Nitrate Wastes in the Commercial Fuel Cycle

Fuel Fabrication: Operating Facilities

Location	Generation Rate per Year	Amount Stored	Remarks
1. Babcox & Wilcox (B&W)			
(a) Apollo, PA Converts UF_6 to UO_2(ADU)	3.7×10^2 kg	None	Treated and released.
(b) Lynchburgh, VA UO_2 powder from 1(a) into fuel assemblies	None	None	No nitrate on site.
2. Combustion Engineering			
(a) Hematite, MO Converts UF_6 to UO_2(dry)	300 kg	None	Concreted, shipped to U.S. Ecology, Beatty, NV.[6]
(b) Windsor, CT UO_2 powder from 2(a) into fuel assemblies	None	None	No nitrates on site.
3. EXXON Richland, WA Converts UF_6 to UO_2(ADU) and manufactures fuel assemblies	Formal inquiry sent		
4. General Electric (GE) Wilmington, NC Converts UF_6 to UO_2(ADU) and manufactures fuel assemblies	7.3×10^4 kg	None	*Trucked off-site.[7]
5. Westinghouse Columbia, SC Converts UF_6 to UO_2(ADU & dry) and manufactures fuel assemblies	Formal inquiry sent		
6. General Atomic San Diego, CA UO_2 powder into HTGC Reactor fuel assemblies	None	None	No nitrates on site.[8]

TABLE 2 (continued)

Fuel Fabrication: Non-operating Facilities

Location	Generation Rate per Year	Amount Stored	Remarks
1. U.N.C. Resources Wood River Junction, RI	None	12,000 drums con-creted $Ca(NO_3)_2$	Previously stored in solar pond. Plant being decommis-sioned.[9]
2. Westinghouse Cheswick, PA	None	63 drums con-creted nitrates	Plant being decommis-sioned.[10]

* After waste processing step and solar pond storage, the nitrate solution is trucked to a nearby paper mill and mixed with their waste. This can be readily done since radioactivity of waste is at-or-below background.

Table 3. Nitrate Waste Effluents Generated, Stored and Discharged from DOE Facilities

Site	Waste Type	Volume and Mass Stored	Wt % Nitrate	Generation Rates
RFP[11]	Basic solution and sludge in solar ponds	2.0×10^4 m^3 2.1×10^7 kg	6.9*	4.0×10^5 kg/Yr (as spray dried salts)
INEL[11]	Dry nitrate salt	Unknown m^3 1.8×10^7 kg	93.0*	None
NTS[11]	Dry nitrate salt from RFP 1978-1981	1.0×10^4 m^3 3.8×10^6 kg	93.0*	Receives RFP salts
ORNL[12]	Effluents	Unknown	N/A	1.5×10^5 kg/Yr**
Hanford[12]	Effluents to pond	Unknown	N/A	2.48×10^5 kg/Yr**
LANL[12]	Effluents	Unknown	N/A	5.0×10^3 kg/Yr**
NLO[12]†	Effluents	Unknown	N/A	9.1×10^4 kg/Yr**

* Based on NO_3 compounds
** Shown as NO_3-N
† National Lead Company of Ohio

Table 4. Potential LLW Nitrate Generated and Stored as HLW at DOE Facilities

Site	Waste Type	Volume and Mass Stored	Wt % Nitrate	Generation Rates
SRP[13 14 16]	Basic nitrate liquid, sludge and salt cake	1.0×10^5 m^3 1.4×10^8 kg	59.2*	2.5 to 5.0×10^6 kg/Yr
Hanford[15 16]	Basic nitrate liquid, sludge and salt cake	1.9×10^5 m^3 2.7×10^8 kg	53.7*	2.2×10^6 kg/Yr (Average through 1990)
ICPP[16]	Acid nitrate liquid, sludge and salt cake	9.3×10^3 m^3 1.1×10^7 kg	74.0**	1.8×10^5 kg/Yr (Reduction) (Average through 2000)
ICPP[16]	Granular Calcine	2.1×10^3 m^3 2.9×10^6 kg	3.2**	4.2×10^5 kg/Yr**
WNYNSC[17]	Basic nitrate liquid and sludge	2.1×10^3 m^3 2.9×10^6 kg	Liquid-43.0*	None
WNYNSC[17]	Nitric acid liquid	45 m^3 8.1×10^4 kg	90.5*	None

* Based on NO_3 compounds
** Based on NO_3

Table 5. Process Application to Waste Type

Process	Waste Type: Dilute NO_3 Stream	Concentrated NO_3 Stream	NO_3 Salt
Direct Thermal Decomposition			X
Direct Thermal Conversion			X
Thermal Reduction			X
Redox Systems	X	X	
Biological System	X		
Incorporation			X
Recovery	X	X	

- Those commercial sites with waste nitrates have been able to dispose of the waste under present rules and regulations. A lowering of permissible nitrate levels in discharge water (40 CFR 141.11) could definitely hamper some operations.
- By far the greatest amount of nitrate waste at nuclear sites is stored as HLW in tanks at defense facilities.
- New processing facilities such as the DWPF at SRP may convert most of this nitrate waste to LLW.
- There is no process now on stream that will convert nitrate waste into a desirable waste form for final disposition.
- There are several methods for nitrate destruction that appear promising for a waste processing system.
- Work should be started immediately to develop a nitrate LLW form that will be in compliance with 10 CFR 61 for LLW disposal.

FISCAL 1982 PLANS

This project was planned to develop the technology necessary to deal with the nitrate problems. Only a small amount of development work was accomplished in FY 1981 because of minimal funding and a midyear DOE request to shift emphasis toward investigating and tabulating the quantities and characteristics of existing nitrate wastes. Consequently, the technology development is being slipped to FY 82 and FY 83.

In FY 82 the efforts will be directed toward evaluation of potential denitrification processes. Surveys have identified several methods for the reduction of nitrates in waste streams. The use of bacteria, urea, and thermal processes appear to have the best potential for denitrification without the production of objectionable oxides of nitrogen. Bacterial decomposition will not be included in the proposed work because it is already being investigated at ORNL. Consequently, this study will be confined to the use of urea and thermal decomposition, or other denitrification techniques that would be compatible with RFP and other producers' waste treatment processes.

However, since the FY 82 funding has been reduced from $325K to $100K, the amount of actual work will be reduced accordingly. The technical staff is in the process of prioritizing the activities which were planned in the FY 82 current year work plan (CYWP) issued May 1981. A considerable scale down will result.

Within the context of that plan, laboratory scale tests will be conducted on the high priority process(es) as funding permits. The area of emphasis will most likely be one of the thermal processes discussed earlier. Additional funding will be required to accomplish any outside contract work.

SCHEDULE AND MILESTONES

There were three level 3 milestones established for FY 82.

1) Complete process evaluation of urea and thermal decomposition, 7/82.
2) Select candidate processes for bench scale testing, 8/82.
3) Issue Report, 9/82.

Under the present funding condition, it is uncertain how these will be redefined or when they can be completed. However, this task has been included in a level 2 FY 85 headquarters controlled milestone for Advanced Treatment Technology. Enhanced funding is required to meet this milestone.

SUMMARY

The FY 81 goals were all achieved. It was learned that there are tremendous quantities of environmentally unacceptable waste nitrates in storage and being produced, and processes were identified to deal with them. These processes are necessary to convert the nitrates to environmentally acceptable waste forms. Work was planned to investigate these processes, but the funding uncertainties are jeopardizing these efforts.

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DOE LLWMP PARTICIPANTS
INFORMATION MEETING

LIQUID WASTE TREATMENT SYSTEMS
(REVERSE OSMOSIS & ADSORBENTS)
AND
JOULE HEATED GLASS FURNACE

RALPH R. JAEGER
MONSANTO RESEARCH CORPORATION
NOVEMBER 4, 1981

REVERSE OSMOSIS PILOT PLANT DOES A GOOD JOB
OF REJECTING Cs-137, Co-60 AND I-131 (I-125)

FOR EXAMPLE (Cs-137)

Cs CONC.	MEMBRANE - % REJECTION		
C/MIN/ML	0%	50%	97%
170 (LOW)	3.9	39.5	91.1
7,300 (MED)	3.5	43.1	95.7
14,700 (HIGH)	1.1	42.2	97.1

FIGURE 1

IODINE REJECTION BY R.O. MEMBRANES IS
LESS THAN THAT OF SALT

IODINE - 125 CONCENTRATION (C/MIN/ML)	PER CENT REJECTION		
	0%	50%	97%
193	0	70.8	87.3
3400	5.6	34.8	84.4
10000	2.9	49.8	92.8

FIGURE 3

COBALT REJECTION BY R.O. MEMBRANES IS VERY GOOD

COBALT CONCENTRATION	PER CENT REJECTION		
C/MIN/ML	0%	50%	97%
310	0	89.0	97.0
6450	1.8	94.9	97.7
11750	4.9	95.5	97.5

FIGURE 2

THE ADSORBENTS MAIN EFFECTS DESIGN OF EXPERIMENTS WAS COMPLETED FOR

Cs - 137, Co - 60, AND I - 125

Cs - NO EFFECT

Co - YES

I_2 - NO EFFECT

ADSORBENTS: MSC-1, XN2020, AG50WX8, HCR-2W-H

FIGURE 4

MOUND WAS ABLE TO EFFECTIVELY
DECONTAMINATE SAMPLES OF MAXEY
FLATS TRENCH WASTE

BY COMBINATION OF

- ULTRA FILTRATION
- REVERSE OSMOSIS
- COMBINED ELECTROLYSIS CATALYTIC EXCHANGE

FIGURE 5

MEMBRANE TECHNOLOGY

- PLANT DESIGN
- ISOTOPE SEPARATIONS

APPLICATION STUDIES

- CHARACTERIZATION OF WASTE STREAMS
- CHOICE OF PROCESS
- EVALUATION TEST

ADSORBENT TECHNOLOGY

- EVALUATION
- MAIN EFFECTS - INTERACTIONS - PREDICTION EQS
- ADSORBENT PILOT PLANT DESIGN

THE MEMBRANE PLANT DESIGN WILL PROVIDE FEASIBILITY DATA FOR WASTE PROCESS EVALUATION

TOLERATED IMPURITIES

IMPURITY CONCENTRATIONS

FLOW RATES VS. COSTS

FLOW RATES VS. PROCESSING TIME

FIGURE 6

THE ADSORBENT PILOT PLANT DESIGN WILL PROVIDE DESIGN CRITERIA

- COLUMN DIMENSIONS, SPECS.
- PIPING SCHEMATIC
- COSTS
- ADSORBENT SPECS.
- IMPURITY LIMITS

FIGURE 7

SELECTIVE MEMBRANE INVESTIGATIONS ARE HOPED TO RESULT IN A NUMBER OF WASTE STREAM PROCESSING ADVANTAGES.

- DECONTAMINATION OF HIGH-SALT STREAMS
- IMPROVED VOLUME REDUCTION
- RECLAMATION OF BORON FROM REACTOR COOLING WATER

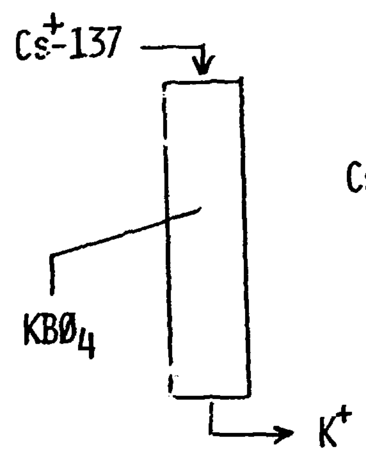
FIGURE 8

SODIUM TETRAPHENYL BORON SUCCESSFULLY
REDUCED THE CESIUM CONCENTRATION

VOLUME	4600 GALLONS
SODIUM (CONC)	11 G/LITER
Cs - 137 (CONC)	
BEFORE	570 CTS/MIN/ML
AFTER	4 CTS/MIN/ML

FIGURE 9

POTASSIUM TETRAPHENYL BORON OFFERS
GREAT PROMOSE FOR COLUMN USE



$$Cs^+ + KB\text{Ø}_4 \rightarrow Cs\,B\text{Ø}_4\downarrow + K^+$$

FIGURE 10

COMMENTS ON FIGURES

Figures 1, 2 and 3

The reverse osmosis pilot plant was tested on cesium-137, cobalt-60, and iodine-125. Three levels of isotopic concentrations were used on each of the three membranes. Distilled water and simulated waste served as the carrier media for the isotopes. The tests showed that the 97% salt rejection membrane rejected greater than 90% of each isotope regardless of other ions and regardless of isotopic concentration. The more porous membranes, 50% and 0% salt rejection, in general, rejected about 40% and 0% of the isotopes.

Figure 4

A series of experiments was performed with cobalt-60, cesium-137, and iodine-125 to determine if potentially competitive ions affected the adsorption of these isotopes on four selected organic resins. The cesium experiment showed a small effect, but no effects were found during the subsequent interaction design experiment which quantitizes the effects. The iodine experiment showed no effects. The cobalt experiment did exhibit effects produced by a combination of pH, NH_4^+, and SO_3^{-2}. An interaction design experiment for cobalt is being performed.

Figure 5

One hundred gallons of trench water from the burial ground at Maxey Flats in Kentucky were processed by ultrafiltration which removed suspended solids and a high percentage of the alpha emitting contamination. The ultrafiltration permeate was treated by reverse osmosis which removed the remainder of the alpha emitters, most of the dissolved solids and significantly reduced the beta emitters except for tritium which was extracted by combined electrolysis catalytic exchange.

Figure 6

The membrane plant design will be a conceptual design for a full-scale waste treatment system consisting of an ultrafiltration unit followed by a reverse osmosis unit. This system will possess the capability of processing a low to intermediate level waste stream contaminated with actinide and/or fission products to the point that the stream may be discharged to the environment. The design is expected to address upper and lower limits of important parameters such as impurity types and concentration levels and other waste stream characteristics and to illustrate the correlation between flow rates, capital investment, operating times, required space, and unit size. Also included will be a cost estimate for a unit sized to accept the permeate from the already-designed ultrafiltration unit.

Figure 7

The conceptual design of an adsorbent pilot plant will be based upon criteria developed during the adsorbent engineering column experiments. The design will include recommended column dimensions and specifications, a piping schematic, operating conditions, capital and operating costs, adsorbent specifications and waste stream chemical and impurity limits.

Figure 8

The expected benefits resulting from ion specific membrane research and development will be the decontamination of heavily salt laden waste streams, improved volume reduction of moderately salty streams through the selective extraction of radioisotopes while salts remain in the original solution. Another possible process resulting from these experiments would be the recovery of boron from contaminated reactor cooling water.

Figure 9

A process for the coprecipitation of cesium-137 with potassium, using sodium tetraphenyl boron, from a salty, low-level, aqueous waste was developed and successfully conducted.

An evaluation of potential treatments for cesium removal from the waste was performed with comparisons made on a number of factors which included cost, safety, equipment availability and decontamination. As a result of this evaluation, physical separation techniques and adsorbents were eliminated because of their capital for a one time need. The chemical treatments, sodium tetraphenyl boron, and copper ferrocyanide were further tested.

Treatment with sodium tetraphenyl boron was chosen and successfully reduced the cesium-137 concentration in the supernatant of the waste from 570 to 4 counts/min/ml.

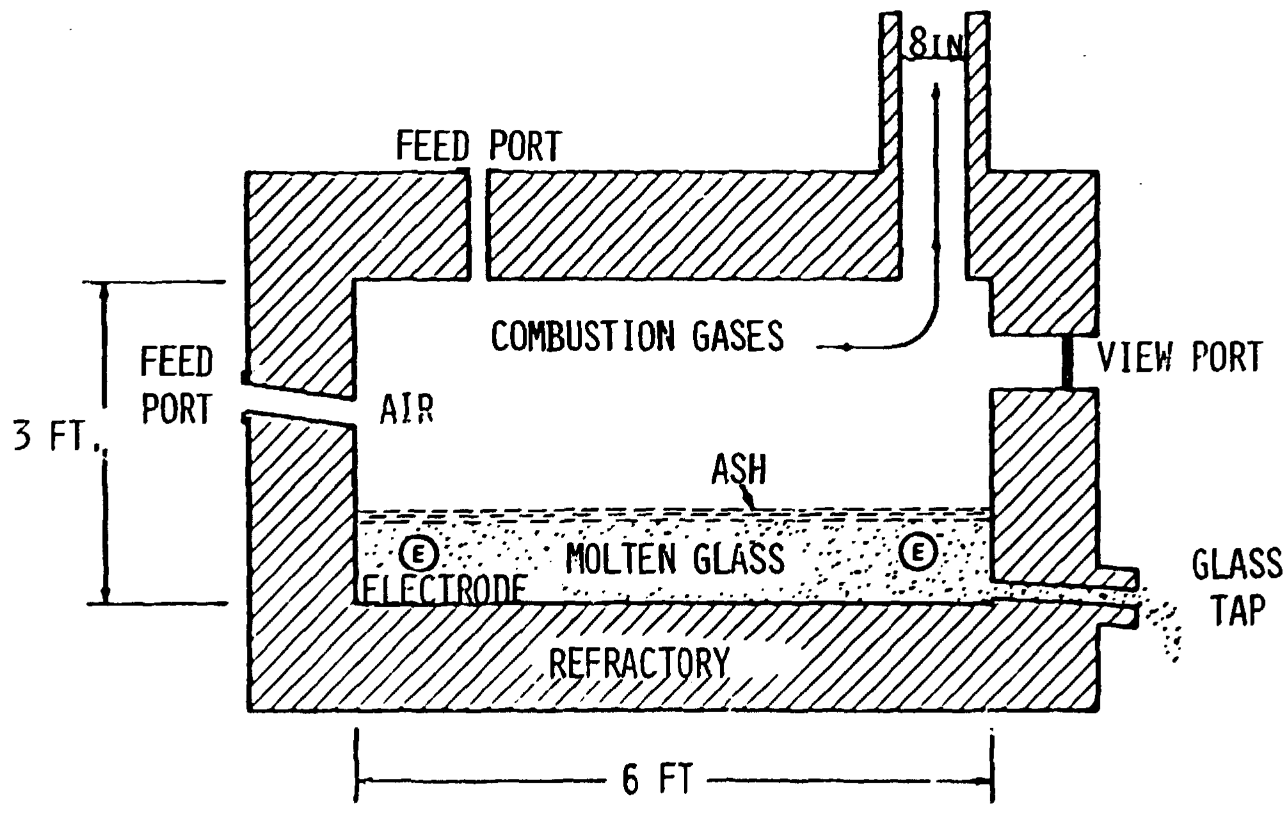
Figure 10

The use of potassium tetraphenyl boron as an exchange medium for the removal of cesium from solutions normally too high in dissolved solids to be processed by ion exchange may be of advantage. The exchange mechanism is shown in the following:

$$C_s^{+} + KB\emptyset_4 \rightarrow C_sB\emptyset_4 \downarrow + K^{+}$$

Potassium tetraphenyl boron exchanges well with cesium, has low solubility in aqueous solutions, and is tolerant of high levels of d ssolved solids.

MOLTEN GLASS FURNACE CONCEPT
OFFERS SEVERAL ADVANTAGES OVER
CONVENTIONAL INCINERATION



FY-1981 ACCOMPLISHMENTS LAID THE GROUNDWORK FOR ESTABLISHING THE PROJECT

APPLICATION STUDIES COMPLETED

EQUIPMENT DESIGNED

PROCURED FURNACE

INSTALLATION

AUXILIARY - COMPLETE

FURNACE - 3 MONTH DELAY

FY-1982 PLANS WILL TEST AND DEMONSTRATE THE GLASS FURNACE CONCEPT

- INSTALLATION
- PROCEDURE DEV.
- COLD BENCH TESTS
- COLD CHECK OUT
- DEMONSTRATION
- DOCUMENTATION

DEMONSTRATION PHASE WILL GENERATE OPERATING DATA

- VOLUME REDUCTION
- RADIONUCLIDE BEHAVIOR
- WASTE FORM CHARACTERIZATION
- THROUGHPUT CAPACITY
- OPERATING COST
- IMMOBILIZATION

VOLUME REDUCTION WILL TREAT LWR-TYPE WASTE

COMPOSITION

- ION EXCHANGE RESIN
- FILTER SLUDGE
- DRY TRASH

NUCLIDE CONTAMINATION

- Cs-137
- Co-60
- I-131

MONITORING DEVELOPMENT WILL MEASURE SYSTEM PERFORMANCE

- PARTICLES
- COMBUSTIBLES
- POLLUTANTS
- RADIOACTIVITY

GLASS FURNACE PROJECT WILL PROVIDE

A DESIGN CRITERIA DOCUMENT

FY-1981

GROUNDWORK

FY-1982

TESTS & DEMONSTRATION

FY-1983

PRODUCT ACCEPTABILITY DEMONSTRATION

DOCUMENTATION

INTERIM REPORT FOR THE MICROWAVE PLASMA INCINERATOR

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ABSTRACT

Microwave Plasma Incineration is being developed to combust "hard to burn" and/or very toxic radioactive contaminated liquid organics. A development schedule is presented specifying significant milestone events. These milestones include the identification and optimization of the independent process variables important to the design and scale-up of the process. Assuming successful scale up of combustion rate, a potential future application of the technology is proposed which joins plasma incineration and low pressure pyrolysis to create an all-purpose incinerator. This incinerator can conceivably be operated to safely process unopened 55 gallon drums of low-level combustible waste, reducing the waste to solid blocks of metal and silicates, and combustion gases which may be released to the environment.

INTRODUCTION

This interim report statuses development of a microwave plasma incineration process for use in disposing of contaminated liquid organic wastes. It is submitted for presentation at The National Low-Level Waste Management Program (NLLWMP) annual information meeting being held in New Orleans, Louisiana on November 4-6, 1981. The present work scope including major milestones for process development is reviewed along with suggestions for further applications of the technology.

The information contained in this report was obtained from current publications on microwave plasma and high vacuum technology and from development performed at Rockwell Hanford Operations in Richland, Washington since 1979.

The fiscal year (FY) 1981 midyear interim report presented an evaluation of the differences between microwave and ordinary flame combustion. Advantages of microwave combustion over other flame combustion processes were discussed and included:

- Efficiency - Due to the uniform microwave field within the plasma flame, activation and combustion proceeds with higher efficiency than with competing flame processes.

- Flexibility - All organic molecules including those with extremely strong bonds such as carbon tetrachloride, burn easily within the plasma flame.

- Safety - Microwave plasma combustion occurs at low pressure. The reactant molecules do not efficiently pass thermal energy from one to another at low vapor density, thereby precluding an explosion. An ordinary spark or flame will not ignite the gaseous mixture. The microwave energy provides the activation energy necessary to sustain combustion.

In addition, microwave plasma incineration is very compatible with the specific requirements of the nuclear industry. These include:

- Containability - All process systems must provide adequate containment to preclude the spread of radioactive contamination. The microwave plasma incinerator is relatively small, light weight, and mobile and can easily be placed in a glovebox.

- Maintainability - The only plasma incinerator equipment component which must be placed inside a glovebox is the combustion chamber. All ancillary equipment can be placed outside the containment such as microwave generators, vacuum pumps, condensers, etc. No moving parts need be placed in the glovebox. This implies that maintenance of electronic components and moving machinery will be simplified.

- Waste Disposal - Process systems designed for the nuclear industry should produce minimum amounts of waste products. These products should be chemically stable and compatible with standard waste management practices.

Scaling up the plasma incineration process was also established as a primary program objective in the last report. The importance of gas throughput to scale up was discussed. As the oxygen and organic feed rates increase, the pumping speed of the vacuum system must simultaneously be increased to maintain optimum operating pressures. Plasma torch designs were proposed with increased volume and pumping speeds to handle increased throughputs. Increasing the combustion rate was shown to result in reduced operating cost.

Other parameters important to process design are gas residence time, and microwave energy field distribution within the plasma flame. These will be accurately measured and optimized during FY82 to provide the design data for scaling-up the process. All of these parameters are discussed in more detail in this report.

The technical program for development of the plasma torch process is presented in this report (Table I). Current progress against this schedule is also shown. Scale up of the plasma torch combustion rate is the primary objective for FY82. Other specific objectives which contribute to this scale-up include:

- Identifying the combustion gas products.
- Monitoring the route of combustion products through the off-gas system.
- Developing the off-gas system design for containing radionuclides within the regulatory limits.

PLASMA TORCH DESIGN PARAMETERS

Development and scale-up of the plasma torch combustion rate requires the identification and optimization of important process variables. Prior researchers have demonstrated "proof of principle" but have not identified the primary process variables important to scale-up. Rockwell has scaled up the process by several orders of magnitude from this earlier research to a 0.1 liter/hr combustion rate. This has been done by expanding the system vacuum capacity to match the gas throughput required at higher combustion rates. Two other design parameters are also important to scale-up. They are the residence time of reactants and uniform plasma temperature within the plasma flame. These three variables are important in determining the size of a given plasma flame.

Residence Time

Residence time is defined as the average time a reactant molecule spends within the plasma volume. This is given by the equation:

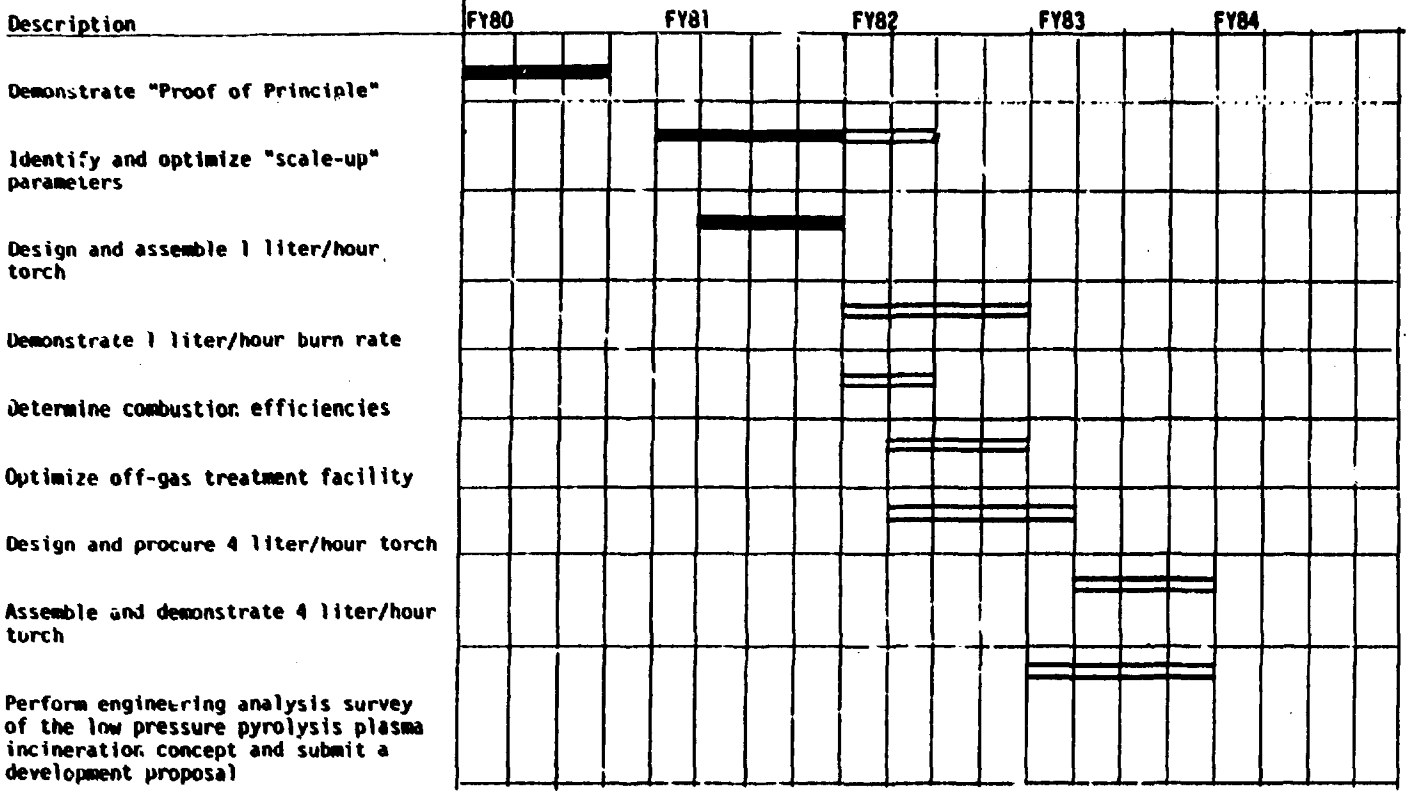
$$T_r = \frac{\text{volume}}{\text{pumping speed}}$$

where T_r = residence time

volume = plasma flame volume

pumping speed = The gas volumetric flow rate.

Table 1 - Plasma Torch Development Schedule



The residence time is a critical parameter. Short residence times will result in inadequate activation of the molecules. This will result in low combustion efficiencies. Long residence times will result in overheating of the gas. If the temperature limitations of the reactor are exceeded, equipment failure will result. An optimum T_r exists where the plasma temperature allows sufficient activation for complete combustion without exceeding temperature limitations. Once an optimum T_r value is chosen (assuming constant pressure and microwave power conditions) it may be combined with the pumping speed (determined from the design combustion rate) to specify the plasma volume.

Gas Throughput

Gas throughput (Q) is defined by:

$$Q = S \cdot P$$

where Q = throughput = (molar gas flow rate at a specified temperature)

P = pressure

S = pumping speed

Gas throughput is an important design parameter. The throughput is a measure of the combustion product gas flow rate. As the combustion rate increases at constant pressure, the vacuum pump must operate at a higher pumping speed. This may require the installation of larger vacuum systems. An increase in pumping speed does not necessarily mean an increase in linear gas velocity. Pumping speed is a volumetric flow rate which can also be increased by increasing the plasma reactor cross sectional area while maintaining a constant linear velocity.

Plasma Temperature

The plasma temperature will vary within the plasma volume as a function of operating pressure and microwave power. The microwave energy attenuates as the waves penetrate radially into the plasma. As the penetration depth increases the temperature decreases for a given power level until at some radial position in the reactor chamber the plasma ceases to exist. A plot of maximum penetration depth versus microwave power must be developed in order to predict the power required for maintaining plasmas with large diameters.

The amount of microwave power needed to sustain a plasma is a function of the pressure. In a high frequency discharge, energy is transferred from the electric field by electrons produced by the ionization of neutral gas molecules or atoms. These electrons gain energy from the field while undergoing elastic collisions with gas molecules. The effect of the collisions is to change the oscillatory motion of the electrons to a random one. In attempting to restore the ordered oscillatory motion, the field does net work on the electrons and thereby increases their energy. As the gas pressure increases the number of electrons out of phase with the oscillatory field increases due to the increased electron-ion collision frequency. Consequently the power demand for a plasma increases as the collision frequency increases above the microwave frequency.

Optimum plasma temperature can be achieved where complete combustion occurs without exceeding the physical limitations of the materials of construction. This optimum temperature falls between 700°K and 1900°K. The plasma temperature must remain below 1900°K to avoid melting the walls of the quartz reactor chamber. A minimum 700°K temperature must be maintained throughout the plasma volume to insure the activation of all combustible molecules.

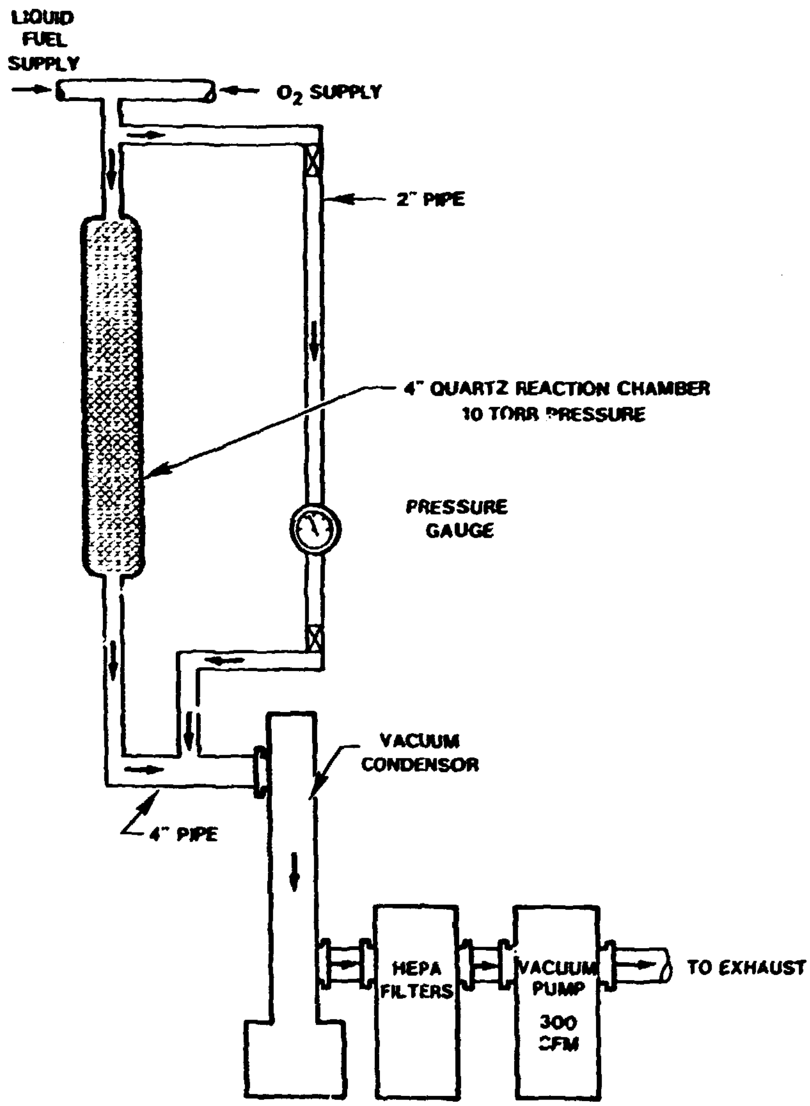
A 4 inch diameter plasma torch has been constructed to study each of the above design parameters. The relations developed from the testing will provide the design basis for further process scale-up.

PLASMA TORCH DEVELOPMENT

Proof of Principle Tests

The first step in developing plasma incineration was a "proof of principle" demonstration. Previously published reports by Lockheed Research in Palo Alto, California allowed Rockwell to build a similar system to establish basic process feasibility. The Lockheed experiments employed a 2-inch diameter 18-inch long plasma flame. Only 10 mls per hour of organic liquid could be oxidized by the system because of low gas density and low gas flow rates. Despite the low combustion rate, very high combustion efficiencies were achieved for all organic molecules tested including stable and difficult to burn molecules such as carbon tetrachloride.

Lockheed's original research was directed at "proof of principle" testing and gave no guidance on scale-up. Based on "proof of principle" test results, Rockwell recognized the importance of providing sufficient pumping speed to draw the necessary flow rate of combustible vapors through the torch to achieve scale-up.



THIRD GENERATION PLASMA TORCH

A second plasma torch was designed based on this principle and tested to demonstrate scale-up of the combustion rate by an order of magnitude to 0.1 liter/hour of organic. A third torch model is presently designed and is being assembled to combust one liter per hour of organic liquid.

The process parameters, gas residence time within the plasma flame and plasma temperature, also affect the ultimate process design. The optimization of these variables are planned by actual testing on the third torch model. The torch design allows a wide range of pumping speeds to be correlated against plasma temperature and combustion efficiency.

Process Optimization

Optimization of the plasma incineration will begin in FY82 and be completed by mid-year. Information obtained in this study will prove the technical basis for developing plasma torches with increased combustion rates. Significant milestones shall be the optimization of pressure and gas residence time for a given gas flow rate, microwave power level, and combustion chamber volume. In addition to optimizing process variables, the maximum combustion rate shall also be determined for the four-inch diameter plasma torch.

The off-gas treatment system shall be studied in FY82 to provide the needed design information for scale-up. The efficiencies of the filter and condenser for removing condensable vapors and entrained particulates will be investigated. This information will be used to design an off-gas system capable of meeting all regulatory limits for radioactive gas discharges to the atmosphere. The off-gas system will be tested and modified as necessary to meet these discharge regulations.

Using all of the design information gathered in the first half of FY82, a plasma torch will be designed which will burn 4 liters per hour of organic liquid. This design will be completed in the last half of FY82. Fabrication or procurement of this torch model will also begin. Testing of this larger torch model is scheduled for FY83.

CONCLUSIONS

Rockwell has made substantial progress in scaling up the combustion rate of the plasma torch. Scale up has been based upon providing adequate gas flow rate capacity. Other important design parameters are plasma temperature and gas residence time. Optimization of these parameters is required in order to effectively scale up the combustion rate further. The testing and optimization of parameters proposed by Rockwell, will allow a decision to be reached by midyear FY82 as to whether continued scale up of the process will be successful. Provided the FY82 scale up activity proceeds successfully, Rockwell envisions the immediate commercial utilization of plasma torch technology for combusting contaminated organic liquids. Development of a safe and economical pyrolyzing reactor for combusting all forms of low level wastes (solids and liquids) without presorting of the waste would also be a potential extension of the technology.

CONTAMINATED METALLIC MELT VOLUME REDUCTION TESTING

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Laboratory scale metallic melts (stainless steel) were accomplished in support of Decontamination and Decommissioning's (D&D) contaminated equipment volume reduction and Low-Level Lead Site Waste programs. Six laboratory scale melts made with contaminated stainless steel provided data that radionuclide distribution can be predicted when proper temperature rates and ranges are employed, and that major decontamination occurs with the use of designed slagging materials. Stainless steel bars were contaminated with plutonium, cobalt, cesium and europium.

Three categories of melt tests were performed with two tests per category:

1. Low temperature controlled temperature melts with the object of concentrating radionuclides within the slag.

2. High temperature melts with the objective of capturing radionuclides within the ingot by the induction furnace induced electromagnetic stirring.

3. Melt tests with glass formulations added to enhance the concentration and capture of radionuclides within the glass/slag.

All proposed mechanisms were demonstrated for the tests performed. Two sets of data, using controlled temperature ranges, provided data showing radionuclide concentration on the upper slag surface of low temperature melts. Even distribution of radionuclides occur in high temperature melts employing electromagnetic stirring.

Qualitative tests provided that an ≈98% decontamination of both beta, gamma and actinide wastes was obtained with the use of a glass formulation, added as components to the metal prior to meltdown. Continued work in this area is required to evaluate the effect of furnace type, metal type and size, and melt size. The heating profile used in the two tests was a "best guess" to obtain screening, yet positive results. The scaled up operation of the vacuum furnace will utilize a cold wall crucible, freezing the early melt material to the crucible wall. In this way, dramatic changes in the results are quite possible. It is not clear that all large scale melts will use such equipment.

Therefore, further work is needed to provide the best possible fluxing formula for decontamination of stainless steel in equivalent type furnaces. The two Borosilicate formulas, used in the flux test, are now being considerd for immobilization of Hanford waste, and would not create a new waste form. This rationale may not be the best answer to a formula which will decontaminate the majority of metals and alloys presently being stored at Hanford.

This study was limited to stainless steel, however, further study is desirable to establish data for other metals and alloys.

This study represents a positive beginning in defining the feasibility of economical volume reduction or conversion from TRU waste forms to LLW forms for a large portion of approximately 50 thousand tons of contaminated metal waste now being stored at Hanford underground or in deactivated facilities.

GAMMA TRACER READINGS OF INGOTS AND FLUX

Low temp melts 1400-1550°C

Ingot #1	Ingot #2
Top = 10 mr/hr	Top = 14 mr/hr
Bottom = 1.5 mr/hr	Bottom = 2 mr/hr

High temperature melts 1500-1600°C

Ingot #1	Ingot #2
Top 2.5 mr/hr	Top 7 mr/hr
Bottom 2.5 mr/hr	Bottom 7 mr/hr

Glass melt metal phase

Ingot #1	Ingot #2
Top = 3 mr/hr	Top = <1 mr/hr
Bottom = <1 mr/hr	Bottom = <1mr/hr

Glass phase

Flux #1	Flux #2
30 mr/hr	25 mr/hr

INSTITUTIONAL INCINERATOR AND SMELTER

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I will address the work being done under the Institutional Incinerator Program and the smelter activity at Idaho. The purpose of this demonstration is to show, by example, that medical research and treatment facilities can successfully incinerate radioactive wastes. There are two incinerators, one at Purdue University and the other at the University of Maryland. The smelter project at Idaho is actually two projects combined under the heading of Waste Experimental Reduction Facility (WERF). The WERF will contain both incinerator and smelting operations.

For the institutional incinerator demonstration, we propose to demonstrate incineration of institutionally-generated waste. Biomedical research waste is the main target of our activity.

In the 1980 assessment, there were about 26,000 m^3 of radioactive waste created by biomedical sources. This number is in our data base at EG&G. There are quite a few carcasses from research facilities to dispose of and sealed sources are a particular problem because you may have a large "burp" of radioactivity releases up a stack. Cooley did a study and found that 85% of radioactive waste (other than contaminated equipment and sealed sources) could be successfully incinerated.

The University of Maryland incinerator is near completion and will be tested later in November. They will demonstrate that the major forms of institutionally-generated waste can be burned in this incinerator without exceeding the MPC's for an uncontrolled area. This incinerator can operate for a couple of days at a time before you have to stop operation, cool off, and remove ash. The small incinerator at Purdue University is a 100 lb/hr, batch operated unit, and can operate for about 8 hours before it is necessary to remove the ash. However, scintillation fluid cannot be incinerated because excessive smoke generation would cause opacity and particulate limits to be exceeded. So, to burn solvent, you would have to modify the incinerator by installing a liquid injector system.

The questions that will be answered by this program are "Can a university or medical school incinerate radioactive wastes?" Also, "can public concerns be addressed adequately?" There have been public talks at the University of Maryland concerning incineration.

The main thing that the University of Maryland will have to do is to continue to segregate sealed sources from other wastes. The economics of a small operation were demonstrated at Purdue University last winter. They compared the cost of disposal of 50 drums by shallow land burial versus incineration. Incinerating the waste, including the fuel, operator cost, etc., showed that these drums were incinerated for about $1000.00. To bury the same waste (including packaging, transportation, and burial cost) costs about $14,000.00. The differences between these two costs would pay for about two of these incinerators.

The WERF at Idaho consists of an incinerator and smelter. At INEL, thirty-seven percent of the waste is metal and 34% is combustible, so greater than 50% of the waste will be able to be treated in this facility. Most of the National laboratories have about this same percentage of incinerable and combustible wastes. The cost of the smelter is about 2 million dollars, and the operating cost for this period is about 1 million. It doesn't really cost much more to treat waste through the WERF than it does to bury the waste directly.

It is hoped that all these can serve as full scale demonstrations for the other DOE laboratories.

Dup

SAVANNAH RIVER PLANT LOW-LEVEL INCINERATOR PROGRAM

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ABSTRACT

Approximately 300,000 ft^3 of combustible solid low-level waste is generated each year at SRP and buried in trenches at the onsite burial ground. Also, 150,000 gallons of separations area waste process solvent is currently stored in temporary tankage at the burial ground, and an additional 5000 gallons is stored each year. A Beta Gamma Incinerator (BGI) has been scoped to incinerate both solid and solvent waste (FY-83 funding is proposed).

A two phase demonstration program is underway at the Savannah River Laboratory (SRL) to support the successful design and operation of the porposed BGI. The first phase is experimentation with a non-radioactive (cold) prototype system, including an incinerator and off-gas treatment equipment. This unit, called the Solid/Solvent Waste Incinerator Facility for Testing (SWIFT), was installed during FY-81. SWIFT-phase one progress to-date is reviewed in this paper.

The second phase involves radioactive (hot) testing of an incinerator system at the SRP burial ground. The backlog of spent process solvent will be burned and suspect low-level combustible waste will be burned. Much of the phase one equipment will be reused in the phase two hot test facility. Beta and gamma radionuclide absorption and migration into the refractory material and throughout the off-gas treatment system will be studied.

INTRODUCTION

A program is in progress at the Savannah River Laboratory (SRL) to support the successful design and operation of an incineration facility for radioactive waste contaminated with low-level beta-gamma emitters. Low-level solid radioactive waste generated in operations at the

Savannah River Plant (SRP) is currently sent to a burial ground for disposal in shallow trenches. Degraded solvent composed of tributyl phosphate (TBP) and an organic carrier is stored in underground tanks at the burial ground. A test facility has been built to burn nonradioactive, simulated waste. The facility is called the Solid/Solvent Waste Incinerator Facility for Testing (SWIFT). This report summarizes progress to-date for the SWIFT program.

The prototype incinerator for β-γ contaminated waste is a full-scale test unit, designed to incinerate 180 kg/hr of solids or 110 kg/hr of liquid. The research program is designed to verify several key design assumptions, including the following:

1) Flexibility to burn a wide variety of materials.

2) Gaseous acid neutralization by spray drying with sodium carbonate.

3) Phosphorous fixation by lime or by titanium based liquid fixatives during spray burning.

4) Efficacy of process vacuum and temperature controls.

5) Process characterization such as decontamination factors and volume reduction data.

A controlled-air, two-stage incinerator was chosen after a survey of current literature and visits to other nuclear facilities. In this method of incineration, waste is pyrolyzed and the nonvolatile residue chars to low carbon ash in an air-starved primary combustion chamber, and the evolved gases are burned in excess air in a secondary combustion chamber. The advantage of this method in radioactive waste application is that minimum solids and radioactivity are entrained in the off-gas. A "dry" off-gas system will be tested. Equipment is provided for cooling, neutralizing, and filtering the off-gas to meet federal and state air emission standards. The SWIFT facility was completed and run-in during FY-81 and testing is currently underway.

Process Description

Processing steps in the test facility are waste feed packaging and loading, incineration, ash residue packaging, and off-gas cleanup. Figure 1 shows the general flowsheet for the radioactive process with the test facility outlined with a dotted line. The elevation arrangement of SWIFT is shown in Figure 2.

The radioactive facility proposed for SRP will include X-ray and assay of the incoming waste and assay of the ash. Waste will not be shredded or sorted at the incinerator facility. Packed cartons of waste conpaining large noncombustibles will be detected with the X-ray scan and

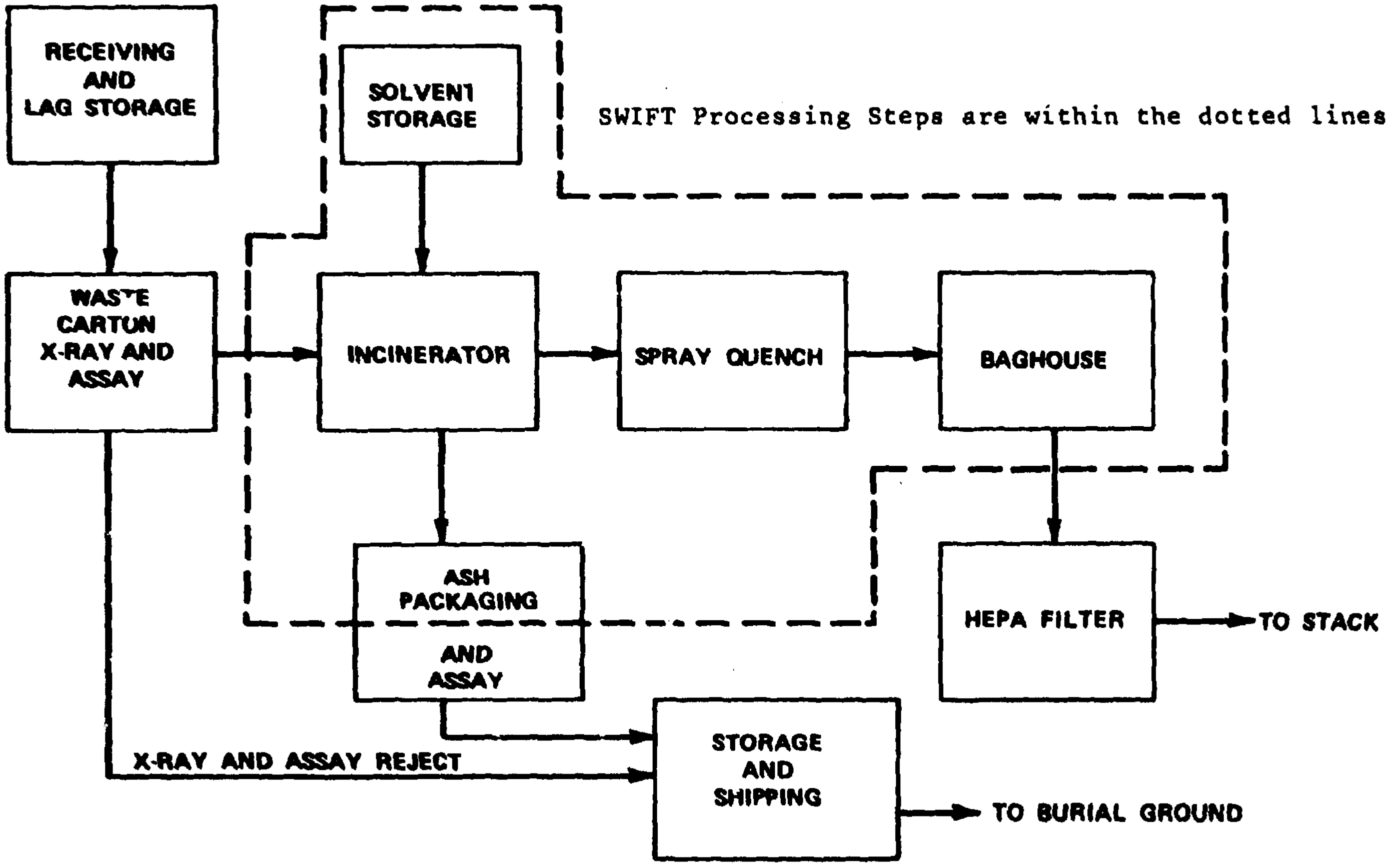


Fig. 1. Low-Level Waste Incineration Facility Flow Diagram

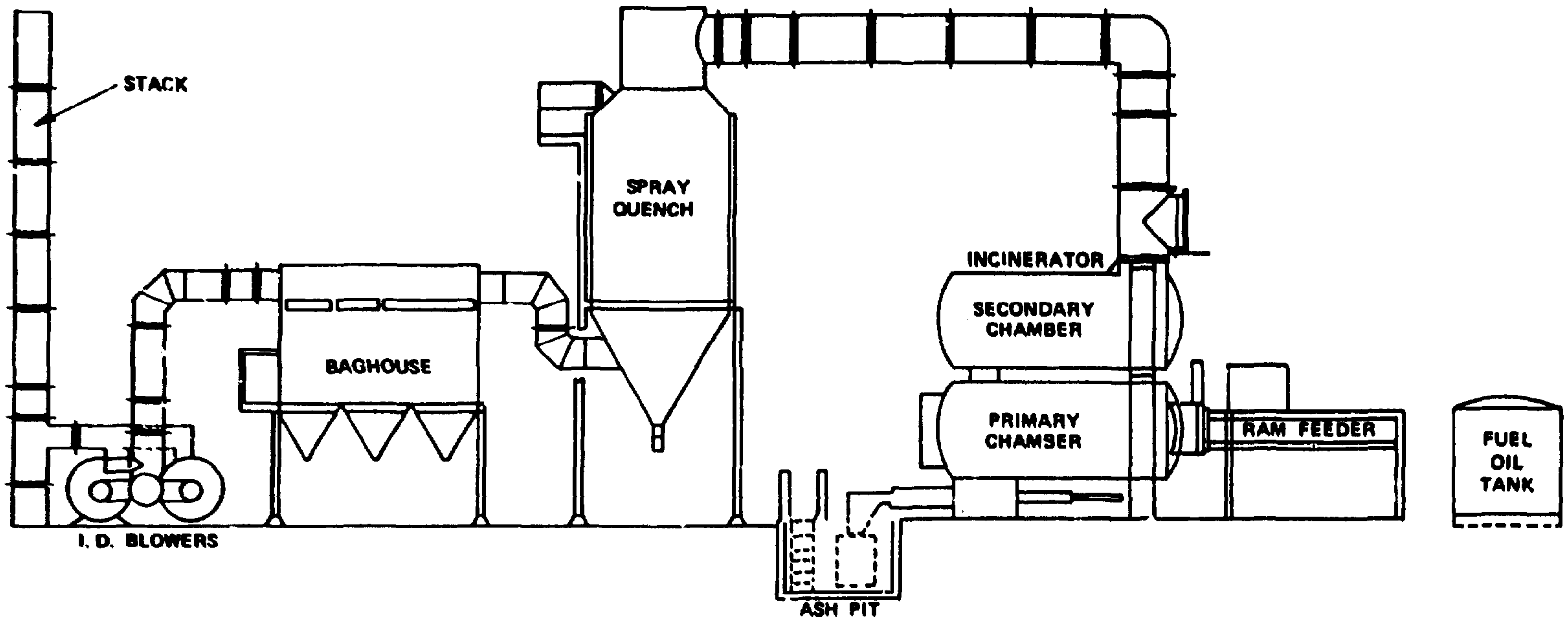


Fig. 2. SWIFT-Elevation Drawing

rejected. Boxes with high β-γ activity levels (above the limits in Table 1) will be rejected by the assay system. The low specific activity of 98% of the waste generated at SRP (Table 2) is within the indicated nuclide limits. Rejected waste will be sent directly to the burial ground.

The following sections deal with components of the cold SWIFT facility.

Incinerator Waste Feed

Cold simulated waste packages are fed directly into the primary combustion chamber by a horizontal ram. The ram assembly is separated from the incinerator by a refractory-lined sliding door. Underfire airflow is reduced automatically in conjunction with the loading cycle to minimize fly ash entrainment during movement of the ash bed. The simulated solid waste feed rate is maintained at 180 kg/hr.

Two different methods are being tested for transferring cold simulated liquid waste into the incinerator. In the reference method, a solid fixative is mixed with the simulated liquid waste. The slurry is then injected into the incinerator primary chamber through a steam-cooled lance at a rate of 0.04 L/sec. An alternative method that will be studied entails mixing the solvent with enough lime to form a thick slurry that is packaged in plastic-lined cardboard cartons. The cartons are fed into the incinerator in the same manner as solid waste.

Incinerator

The SWIFT incinerator is a two-stage, commercially available unit with controlled air. The term "controlled air" denotes the incinerator design feature that permits control of the quantity and location of combustion air. In two-stage combustion, waste is semipyrolyzed in the fuel-rich primary chamber. The pyrogenic gases are oxidized to combustion products in the excess air environment of the secondary chamber. Air enters the primary chamber through several underfire air ports on the side of the hearth as shown schematically in Figure 3. The air flow is sufficient to char the waste by slowly oxidizing the carbon, but is low enough to avoid excessive ash entrainment. Combustion air (100-200% excess) is supplied at the entrance to the secondary chamber in order to oxidize the partial combustion products to H_2O and CO_2. The oxygen concentration in each combustion chamber is continuously measured with online analyzers.

Normal operating temperatures are 650° to 800°C in the primary chamber and 850° to 1000°C in the secondary chamber. The control system maintains these temperatures by modulating two diesel-fired burners and combustion air flow. At full fire, the two low-intensity burners consume 90 L/hr of fuel oil. During campaign burning, the burners modulate down to low fire, which uses ~30 L/hr of fuel oil.

Table 1

β-γ Incinerator Feed Radionuclide Signatures and Limits

Isotope	Energy, keV	Limit, μCi/kg Waste[a]
^{90}Y	202	1.76
^{91}Y	1200	0.53
^{95}Zr	724, 756	0.53
^{95}Nb	766	1.76
^{103}Ru	537	1.41
^{134}Cs	600, 800	0.17
^{137}Ba	661	0.17
^{140}Ba	44, 537	0.70
^{144}Ce	133	0.11
^{144}Pr	622,1490,2189	0.44
^{51}Cr	320	35.3
^{58}Co	810, 1680	0.88
^{60}Co	1170, 1330	0.15

a. Assumes 1) no decontamination factor for incineration and off-gas scrubbing and filtration.
2) no dilution of incineration gases with building ventilation air.
3) based on ERDA Appendix 0524 Controlled Area Inhaled Limits.

Table 2

Activity of β-γ Waste at SRP

Activity Range Curies	Volume, m^3	% Volume	Curies	% Curies
0	13,700	56	0	0
0.01 - 1	10,080	42	144	6
1 - 10	326	1.3	250	10
10 - 100	96	0.4	289	11
100 - 1000	2	0.01	670	26
>1000	74	0.3	1,200	47
Totals for FY-72-76	24,278		2,553	

Table 3

Solid Waste Components

Rubbers	- Latex, Neoprene	
Plastics	- Polyethylene, PVC	
Cellulosics	- Paper, Cardboard, Cotton Fiber	
Special Polymers	- Teflon	
Standard Waste Mix	- Latex	19%
	PVC	8%
	Polyethylene	23%
	Cellulosics	40%
	Moisture	5%
	Non-combustibles	5%

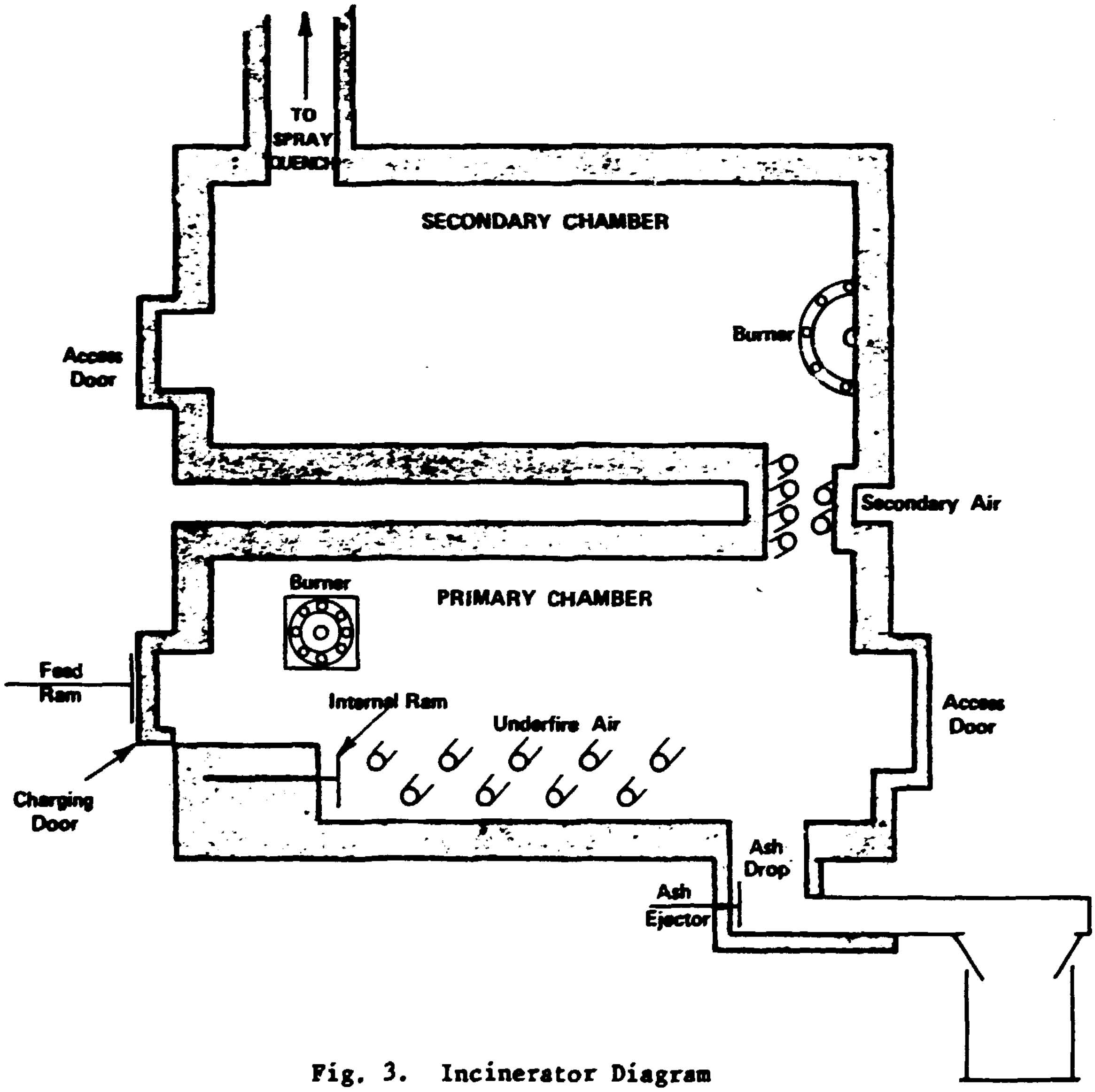


Fig. 3. Incinerator Diagram

The combustion chambers are constructed from 0.63 cm carbon steel. The shell is coated with a protective mastic layer to reduce HCl corrosion of the metal and lined with 5 cm of mineral wool and 12 cm of silica-alumina (52% Al_2O_3, 40% SiO_2) ceramic. The internal dimensions of the chambers are 1.6 m in diameter and 4.3 m long, for a volume of 8.9 m^3 in each chamber. The plug flow residence time in the incinerator is 6 to 8 sec at maximum flow rates.

Ash Packaging

After the simulated waste has charred in the hearth for 8 hours, the remaining ash is pushed along the length of the hearth by an internal ram. At the end of the hearth, the ash falls through an opening in the primary chamber floor, into a retention chamber below the incinerator. The ash cools in this area for 8 hours and is pushed by another ram into a storage drum located below grade level in a 2-m deep pit. This configuration is shown in Figure 4.

The drum fills with ash during one 8-hour shift of operation. The ash is sprayed with water to prevent the top layer of particulates from spreading when the drum is lowered from the incinerator. A gate valve at the exit to the ash hopper is closed, the drum is lowered away from the hopper, and the lid is fastened. The operator manipulates a hoist from the surface to remove the drum from the ash pit.

Off-Gas Treatment

The incinerator off-gas treatment system reduces the temperature of the gas from 1000°C to 150°C, neutralizes acidic components in the gas, and removes entrained solids. The SWIFT off-gas system was designed to be a "dry" system from which no secondary aqueous waste streams are generated.

The combustion exhaust is cooled from 1000°C to 150°C in the quench chamber with an air-atomized water spray. The large volume of the quench chamber (56.6 m^3) provides a 12-sec residence time to accomplish complete water evaporation and neutralization. The flow rate of the water spray is controlled by the temperature of the quench chamber outlet. The exit temperature is maintained at 150°C to ensure that the exhaust gas is unsaturated (above the dew point) and below the maximum operating temperature of the baghouse (200°C). During the SWIFT test program, when hydrogen chloride and sulfur dioxide are present in the gas, an aqueous neutralizing solution of Na_2CO_3 is sprayed into the chamber. This reduces corrosion problems from the HCl generated during incineration of chlorinated polymers and SO_2 formed from the sulfur in latex and fuel oil. The heavier particulates and salts formed during neutralization settle at the bottom of the quench chamber and are removed by gravity discharge.

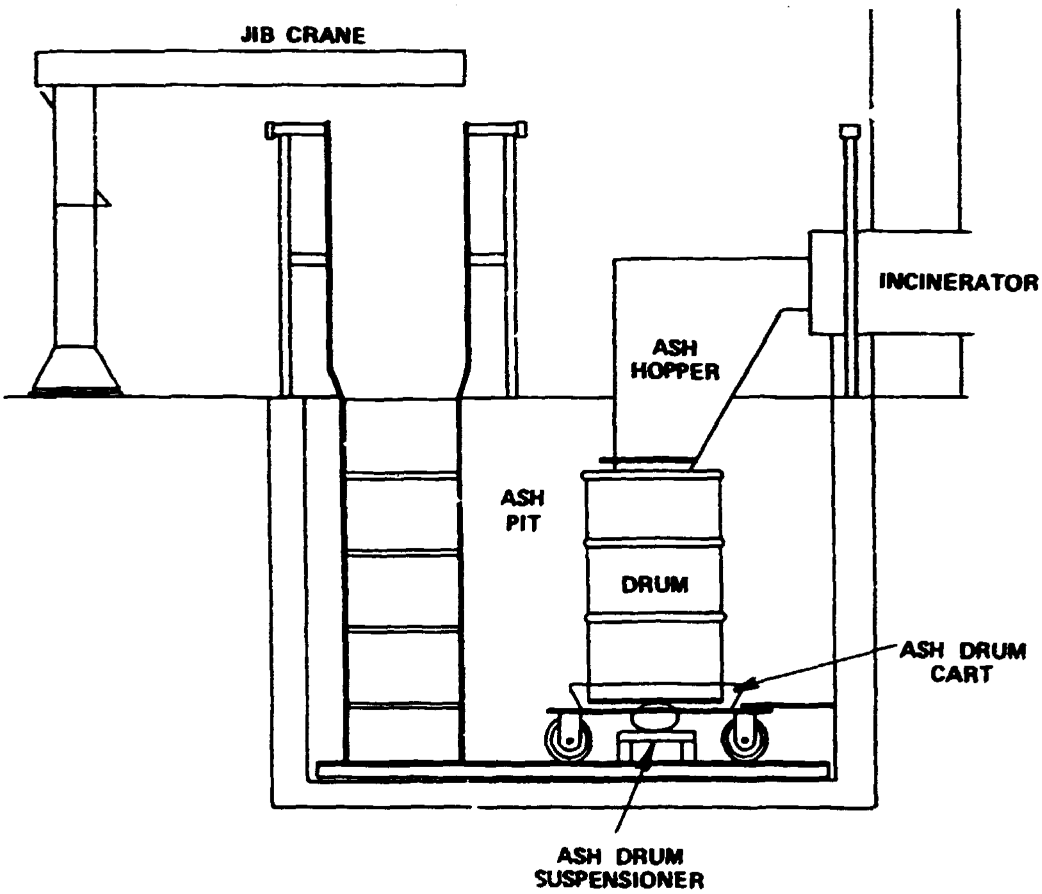


Fig. 4. Ash Drum Removal System

The cooled off-gas from the spray quench is drawn through a fabric filter baghouse, which removes particulates and dried salts. The structure contains 96 envelope-shaped Nomex filter bags that have a total surface area of 190 m^2. Envelope-type bag filters are being tested because of their suitability in "bagging out" techniques used in radiation zones. The inlet flow rate is 116 m^3/min (actual), which maintains the facial velocity at 0.61 m/min. The removal efficiency of the filters is 98% for particulates with a diameter of 1 µm. Particulate cake on the filter surface is removed with intermittent reverse air pulsing. The caked particulates fall into a hopper for later gravity discharge into a steel collection drum.

In the radioactive plant facility, the baghouse will serve as a prefilter to a bank of high efficiency particulate air (HEPA) filters. HEPA filters were deleted from the test facility design since their performance is already well defined.

Two induced draft (I.D.) blowers pull the off-gas through the system and maintain a constant negative pressure. Each blower has a capacity of 2360 L/sec at 10 kPa. A 0.61-m butterfly valve throttles the draft pressure pulled on the system. A 0.30-m valve located behind the larger valve between the blowers and the atmosphere regulates the amount of dilution air added to the stack gas to reduce the exit temperature from 150 to 90°C.

The stack vents the gas to the atmosphere 10.1 m above the process area. The sampling probe for a stack monitor is located in the stack 8 m above the ground. Samples from the stack are monitored for CO_2, CO, SO_2, HCl, and particulates.

Construction

The incinerator, spray quench, and baghouse were purchased from commercial vendors. The items were either "off-the-shelf" units or standard modifications that the manufacturer could supply. Concrete foundations, steel supports, and interconnecting piping were designed and fabricated at SRP. Figure 5 and 6 show the installation of the completed facility.

Instrumentation and Safety Interlocks

Thermocouples, pressure sensors, and online oxygen analyzers were installed in the incinerator and off-gas train. Measurements of temperature, pressure, and O_2 concentration will be used for operation control and performance monitoring. The incinerator is protected from overpressurization with a 0.84-m relief valve in the exhaust stack immediately above the secondary chamber. When the pressure in the secondary increases to +0.25 kPa, the valve opens and the I.D. blowers

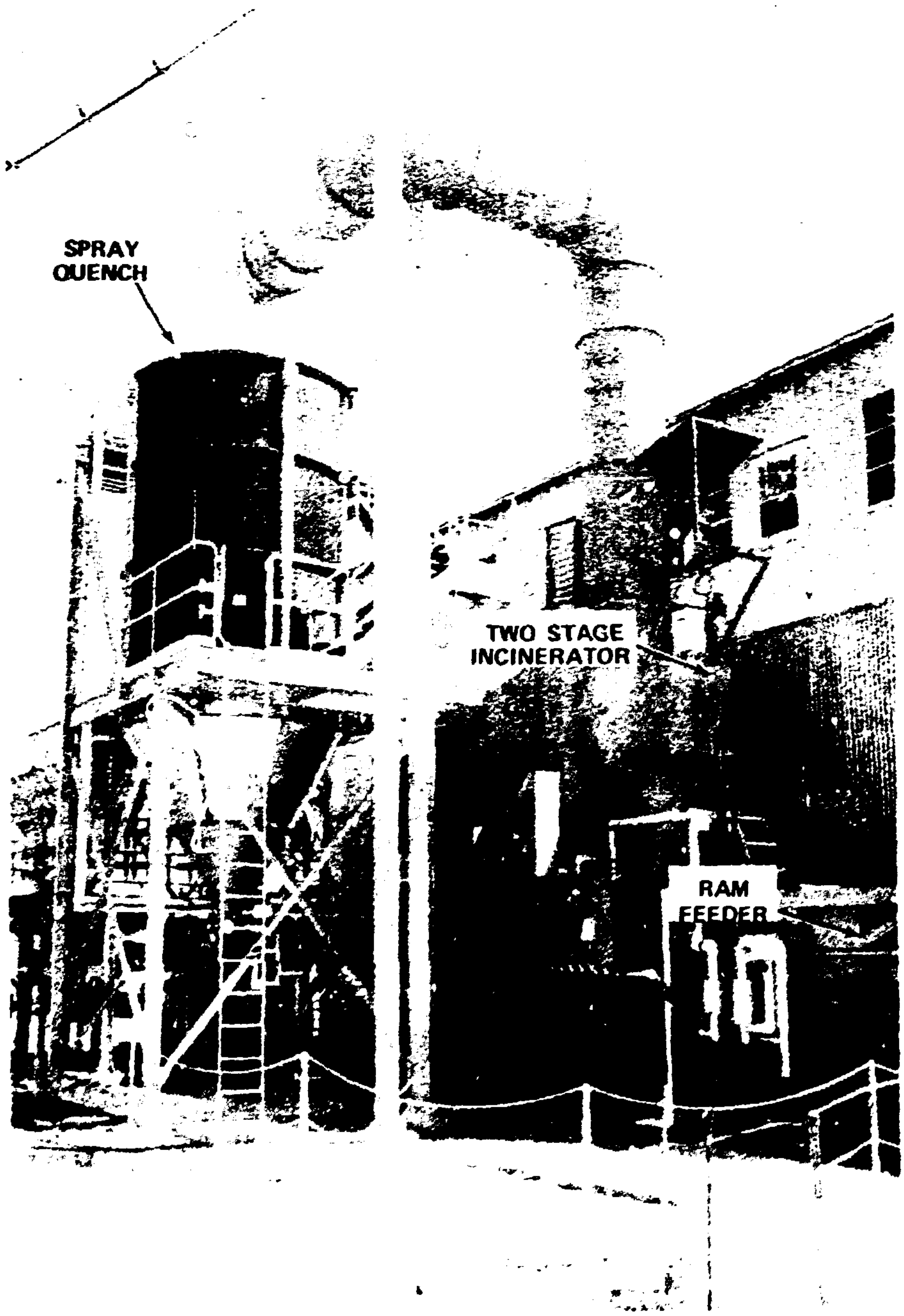


Fig. 5. Front View of SWIFT Facility

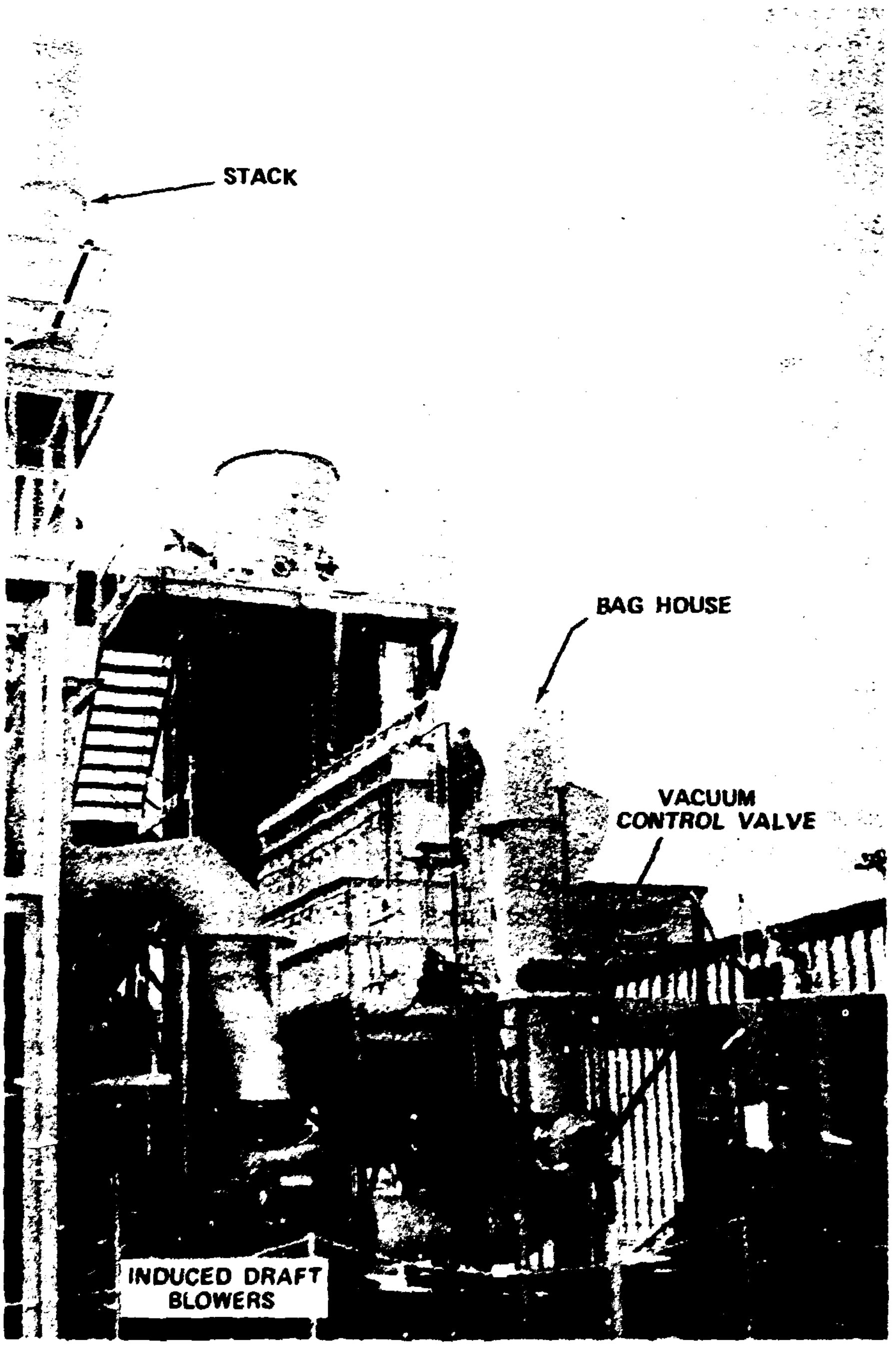


Fig. 6. Rear View of SWIFT Facility

are deactivated. Most of the safety features are interlocked with the waste feed system. For example, the ram is locked out when the exit temperature from the secondary chamber increases above 1200°C or when the O_2 content decreases below 5%. In the case of a power loss, the incinerator is automatically purged with nitrogen, the pressure relief valve is opened, and an emergency water line to the spray dryer is opened.

Startup

A field engineer from the incinerator manufacturer has perform the checkout and initial startup of the incinerator. The castable ceramic in the combustion chambers and stack was slowly heated initially to cure the material. The water was evaporated from the ceramic at 120°C for 8 hours. Then the temperature were increased at a rate of 50°C/hr to 900°C.

The spray quench, baghouse, and I.D. blower were checked out individually and run for a trial period to ensure correct operation.

Research Program

The Phase I experimental schedule for the SWIFT Facility is shown in Figure 7. Solid and solvent burning tests will be performed and, concurrently, off-gas equipment performance will be monitored. The purpose of the test is to confirm the fluid dynamics of the system, soot and ash entrainment, thermal cycling behavior, corrosion rates, and off-gas cleanup performance. The research program is designed to verify several key design assumptions, including the following:

1) Flexibility to burn a wide variety of materials.

2) Gaseous acid neutralization by spray drying with sodium carbonate.

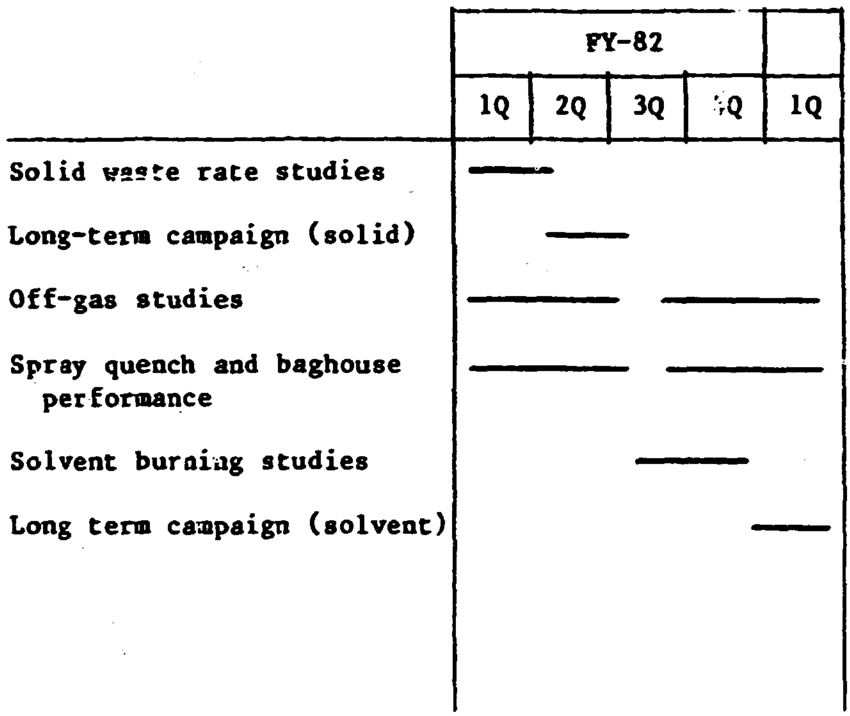
3) Phosphorous fixation by lime or by titanium based liquid fixatives during spray burning.

4) Efficacy of process vacuum and temperature controls.

5) Process characterization such a decontamination factors and volume reduction data.

Solid Waste Studies

The combustible solid waste generated at SRP is composed of plastics, rubber, and cellulosics. The main components of the waste are paper, cardboard, polyethylene, PVC, and latex, but small amounts of neoprene,



FY - Fiscal Year goes from October 1 to September 30

Fig. 7. Experimentation Schedule

Teflon® (Du Pont Trademark), and cotton fiber are present. Table 3 shows the composition of the β-γ contaminated waste currently generated at SRP. Uncontaminated samples of the materials will be burned in the test facility.

The solid waste incineration program begins with the parametric testing of waste composition, box size, and packing density. Most of the radioactive waste at SRP is packed in 0.38-m or 0.61-m cubic cartons before being sent to the burial ground. The average packing density is 90 kg/m^3, but varies from 30 to 130 kg/m^3. Several box sizes and packing densities will be tested with each waste component and a standard mixture. The weight of waste cartons will range from 5.5 to 38.6 kg during the parametric testing.

The SWIFT system must be capable of burning a wide variety of materials at the design rate of 180 kg/hr. This flexibility is necessary since waste packages will not be opened to determine their contents. The test program is constructed to verify design assumptions concerning maximum heat release (pure polyethylene) and maximum instantaneous air feedrate requirements (pure latex). In addition, PVC releases HCl during incineration. The test program will determine the efficiency of neutralization of gaseous HCl by spray dried Na_2CO_3 produced in the spray quench operation.

Ash and particulate samples from the parametric testing will be weighed and analyzed for carbon content. This will indicate the efficiency of the incinerator. The amount of particulates entrained in the gas stream will be measured before and after filtration. The decontamination factors for the system will be determined from these data. An EPA-approved stack sampler will be used to isokinetically sample the stack gas. In addition to particulate quantity and size distribution, the O_2, CO_2, CO, HCl, and SO_2 concentrations will be measured. Table 4 shows the expected concentration of pollutants in the off-gas.

The solid waste studies will be concluded with a 3 to 5-day burn campaign designed to simulate production operation. The incinerator will be operated 24 hours a day at a constant feed rate of 180 kg/hr. The extended burn will test demonstrate the controllability of the system during constant operation. Temperature and pressure fluctuations and off-gas equipment performance will be studied.

Solvent Burning Studies

Exhausted solvent from plutonium and uranium extraction is currently stored in underground tanks at SRP. The inventory of solvent in these tanks is 570,000 L and is increasing at a rate of 19,000 L yearly. The exhausted solvent contains fragmented alkanes and di- and mono-butyl phosphate, which are formed by radioactive and thermal degradation of TBP and n-paraffin. The scope of the β-γ incinerator program at SRP

Table 4

Effluent Gas Composition (at 1 km from process stack)

Pollutant	Calculated Air Quality, $\mu g/m^3$	State Standard, $\mu g/m^3$
SO_2	14	1,300
NO_x	2	100
CO	0.001	25,000
Non-methane hydrocarbons	None	130
HCl	7.5	Not Specified
Particulates	0.40	60

Note:

The data are obtained by using a thermodynamic equilibrium computer code to calculate the production rate of each component in the off-gas on a per hour basis. The production rate is then adjusted for the spray quench neutralization effect (~75%) and the baghouse filtration efficiency (~98%). The adjusted generation rate of each component is time-averaged according to the standard measuring interval specified by South Carolina guidelines. Using a decontamination factor derived from meteorological data recorded at SRP, the air quality is calculated for a distance of 1 km from the stack.

includes burning the solvent to combustion gases that are to be cooled, filtered, and released to the atmosphere.

Experimental support for solvent burning includes developing a reference and alternative backup method of transferring the solvent into the incinerator and determining the effectiveness of lime fixation of the phosphorous in TBP. In the reference method tested, the solvent will be mixed with lime and pumped through an atomizing spray lance into the primary chamber. Phosphorous fixation is desired since P_4O_{10} or H_3PO_4 released in the system attacks the ceramics and metals, and condenses in the spray quench and plug filters. Initial solvent tests will use only n-paraffin solvent and will not require phosphorous fixation. The concentration of TBP will be increased to 50% by weight during subsequent tests.

Burning the solvent in a lime and ash matrix will be tested as an alternative to spray burning. The solvent will be mixed with enough lime and recycled ash to form a slurry that is packaged in plastic-lined cardboard boxes. The cartons will then be fed to the incinerator through the solid waste feed system.

After the more effective method of solvent incineration has been determined. a 24 to 48-hr continuous burn will be attempted. Campaign burning is comparable to the method proposed for solvent incineration in a radioactive β-γ facility. The ability of the solvent to maintain a flame and burn completely (not just vaporized) will be demonstrated during the burn campaign. Transfer and handling of solvent mixed with slurry will be practiced by the operators so that procedures for a radioactive facility can be developed.

Acknowledgment

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Dup

COMMERCIAL INCINERATION DEMONSTRATION

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ABSTRACT

Low-level radioactive wastes (LLW) generated by nuclear utilities presently are shipped to commercial burial grounds for disposal. Substantially increasing shipping and disposal charges have sparked renewed industry interest in incineration and other advanced volume reduction techniques as potential cost-saving measures. Repeated inquiries from industry sources regarding LLW applicability of the Los Alamos controlled-air incineration (CAI) design led DOE to initiate this commercial demonstration program in FY-1980. The selected program approach to achieving CAI demonstration at a utility site is a DOE sponsored joint effort involving Los Alamos, a nuclear utility, and a liaison subcontractor. Required development tasks and responsibilities of the participants are described. Target date for project completion is the end of FY-1985.

INTRODUCTION

Since 1975, low-level waste transportation costs have increased by 50 per cent and disposal fees have risen five-fold.(1) This adverse expenditure trend has caused many within the commercial nuclear industry to view advanced volume reduction techniques with renewed interest. Among the alternative technologies being considered, incineration of combustibles is recognized as one of the most effective methods for reducing both the mass and volume of waste shipments.

At present, several universities and hospitals are operating, installing, or have committed to install combustion processes to treat institutional wastes.(2) Nuclear utility commitment in this area, however, has been substantially less. Factors in this hiatus include cost, technical, and licensing uncertainties associated with reactor waste combustion systems. To fill this technical need and in response to continued, substantial utility interest in the Los Alamos controlled air incineration (CAI) system (developed for transuranic (TRU) waste treatment), DOE initiated this program i. FY-1980 to support demonstration at a nuclear utility site.

A key and early objective is to determine design/operating changes which must be made to effect the transition from a Defense waste incinerator (CAI/TRU system) to one capable of accepting utility wastes (CAI/LLW system). As opposed to Defense program wastes, which primarily contain non-volatile heavy metal radionuclides, power reactor wastes are contaminated with a broad spectrum of fission and activation products of varying volatility. In addition, utilities generate significant quantities of spent ion exchange (IX) resins which have been identified as a challenging combustion disposal problem by earlier tests in other systems.Data obtained from Los Alamos development studies of the preceding technical concerns will be transferred to industry as a base for design and licensing of the CAI/LLW demonstration. Target date for completion of the demonstration at a nuclear utility site is FY-1985.

COMMERCIAL INCINERATION DEMONSTRATION PROGRAM

The goal of this program is demonstration of CAI/LLW technology at a nuclear utility site. Program objectives contributing to this goal include resolution of technical uncertainties through development studies at Los Alamos, preparation of a design specifically adapted to nuclear utility LLW handling and treatment requirements, NRC licensing of the process, and installation/operation at a utility site. The selected project approach is a DOE-sponsored joint effort involving participation of Los Alamos, the nuclear utility which will serve as demonstration site, and a subcontractor to serve as interface in design, licensing, fabrication, and installation activities. Elements of the program including technical background and participant reponsibilities are described in the following paragraphs.

Technical Background - CAI/TRU System

The technical starting point for the CAI/LLW demonstration program is the transuranic waste treatment process shown in Figure 1. The CAI/TRU system which has been described in detail in several earlier reports (3,4) incorporates many industrially available components which have been modified and enclosed to varying degrees to meet health and safety standards for plutonium operations. As demonstrated with Pu-239 contaminated wastes (completed April 1980), the CAI/TRU process consists of four major subsystems: feed preparation. incineration, offgas cleanup, and scrub solution recycle. The heart of the system is a dual-chamber controlled-air incinerator which exhausts to a high-energy aqueous offgas cleanup train. Prominent features of the design include secondary

Figure 1. CONTROLLED-AIR TRANSURANIC WASTE INCINERATION PROCESS

containment throughout the process to prevent alpha contamination release, an instrumentation control package substantially upgraded from commercial nonradioactive systems, and a high degree of redundancy among critical process components. Each system modification and/or addition was a response to the extensive and formal safety analysis which proceeded in parallel with project planning and design activities.

Los Alamos Program

Objectives of the Los Alamos program in support of the CAI/LLW demonstration goal are to: 1) develop and transfer design and operating data to the liaison subcontractor, 2) select subcontractor and provide management review of his activities (beginning in FY-1982), and 3) provide technical assistance to both subcontractor and utility through licensing and demonstration completion. As such, Los Alamos assumes the technical lead role in determining the design and operating parameters for the CAI/LLW demonstration process.

FY-1981 accomplishments

During FY- 1980 and 1981, design information derived from CAI/TRU demonstration program was transferred to Koch Process Systems, Inc. (formerly Helix Process Systems, Inc.), the designated liaison contractor under provisions of a DOE/ALO contract. This information served as a starting point for preliminary design and engineering of the CAI/LLW system and also was incorporated in a Technical Support Document (TSD) which will be submitted to NRC as technical basis for licensing proceedings. Koch completed a preliminary design in FY-1981; a draft TSD is expected early in FY-1982.

In addition, development studies to determine the behavior of fission and activation products within the CAI system were initiated. A five-day test burn was conducted with solid waste spiked with selected fission products (Fe-59, Co-60, Ru-106, I-131, and Cs-137). The charged solid waste mix is shown in Table 1; included radionuclides were those with chemical and physical characteristics of potential concern to process operations. Before conducting this experiment, a carbon bed adsorber was incorporated in the offgas system to trap volatile species and five hybrid germanium detectors were installed to determine decontamination factors for individual isotopes (see Figure 2). Experimental data indicated excellent process performance with a volume reduction ratio well in excess of 100:1 and extremely effective overall containment of the radionuclides. Detector data is being analyzed to provide insight into individual isotope behavior within the process.

Figure 2.

OFFGAS CLEANING SYSTEM

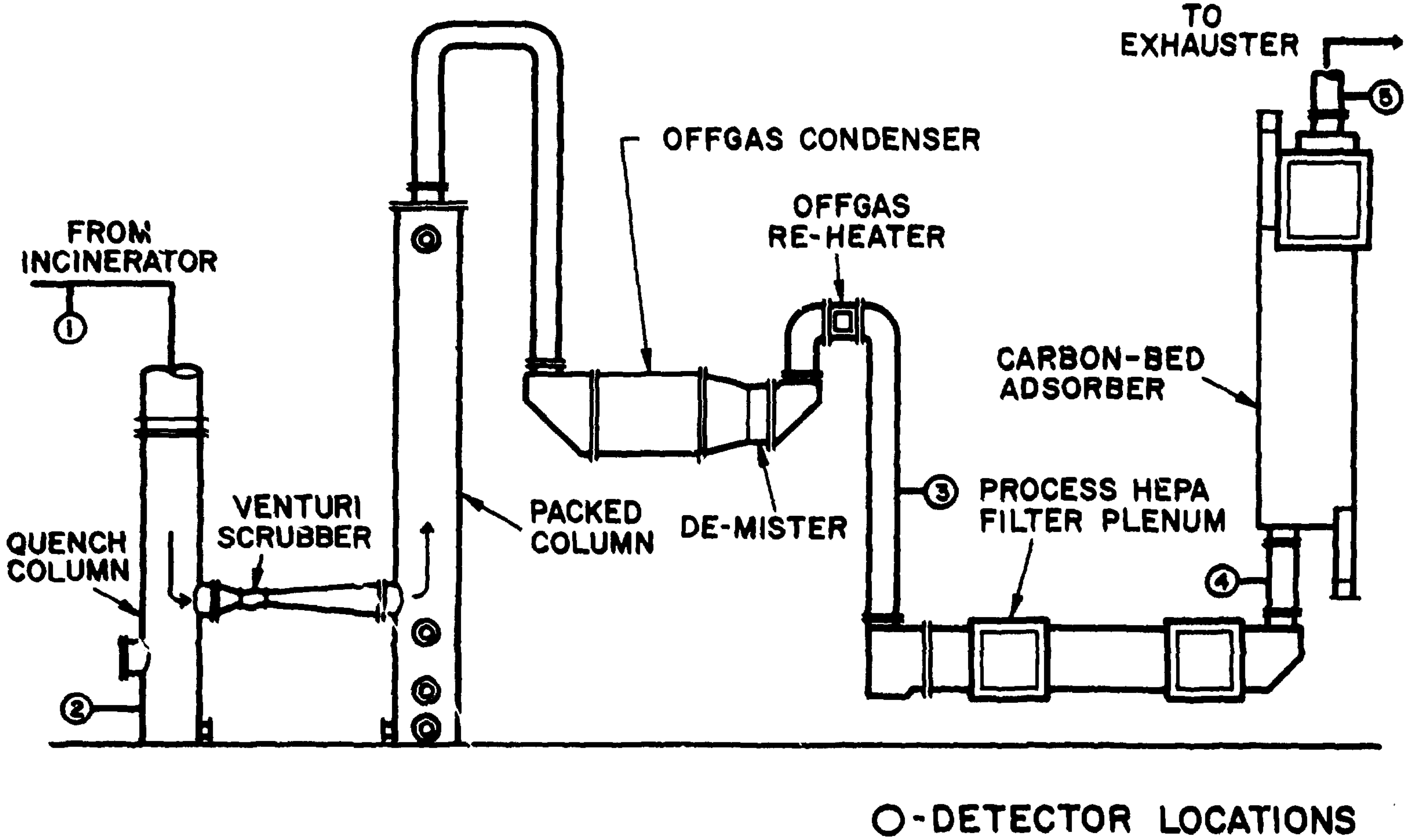

Table 1. Incinerator Feed Mix
Fission Product Distribution Test

Waste	Composition
Cellulosics	35%
PVC	12%
Polyethylene	23%
Rubber	30%

Efforts related to incineration of spent IX resins likewise were initiated in FY-1981. At the end of the LLW test burn, several IX resin types were charged to the CAI in 0.06 m^3 batches. Although the resins used were clean and nonradioactive, observation of burning characteristics showed the absence of problems reported with other incineration systems (e.g., violent spalling reactions and melting). In addition, a liquid burner design, which will provide a continuous resin slurry burning capability, has been cold tested successfully and installed in the lower CAI chamber (see Figure 3).

FY-1982 plans

At the end of FY-1981, DOE transferred management responsibility for this program from the Transuranic Waste Systems Office to the Low Level Waste Management Program Office (LLWMPO). Subsequent LLWMPO program review resulted in some redefinition of the Los Alamos role, specifically, the Laboratory will be responsible for management review and approval of subcontractor activities. A milestone schedule (Figure 4) provides an overview of planned FY-1982 Laboratory and subcontractor efforts.

Likely the single most important Los Alamos task during FY-1982 is the selection of a subcontractor for the commercialization effort. A request for proposal will be issued in December with contract award planned prior to April 1st. As a minimum, the industrial firm selected for this role must be familiar with: 1) nuclear utility waste management requirements and construction practices, 2) NRC licensing procedures, and 3) process design practices.

Technology development studies will include both spent IX resin and fission product distribution test burns. Final installation and mechanical checkout of the new liquid burner which will accept IX resin/mineral oil

Figure 3.

LIQUID BURNER SYSTEM SCHEMATIC

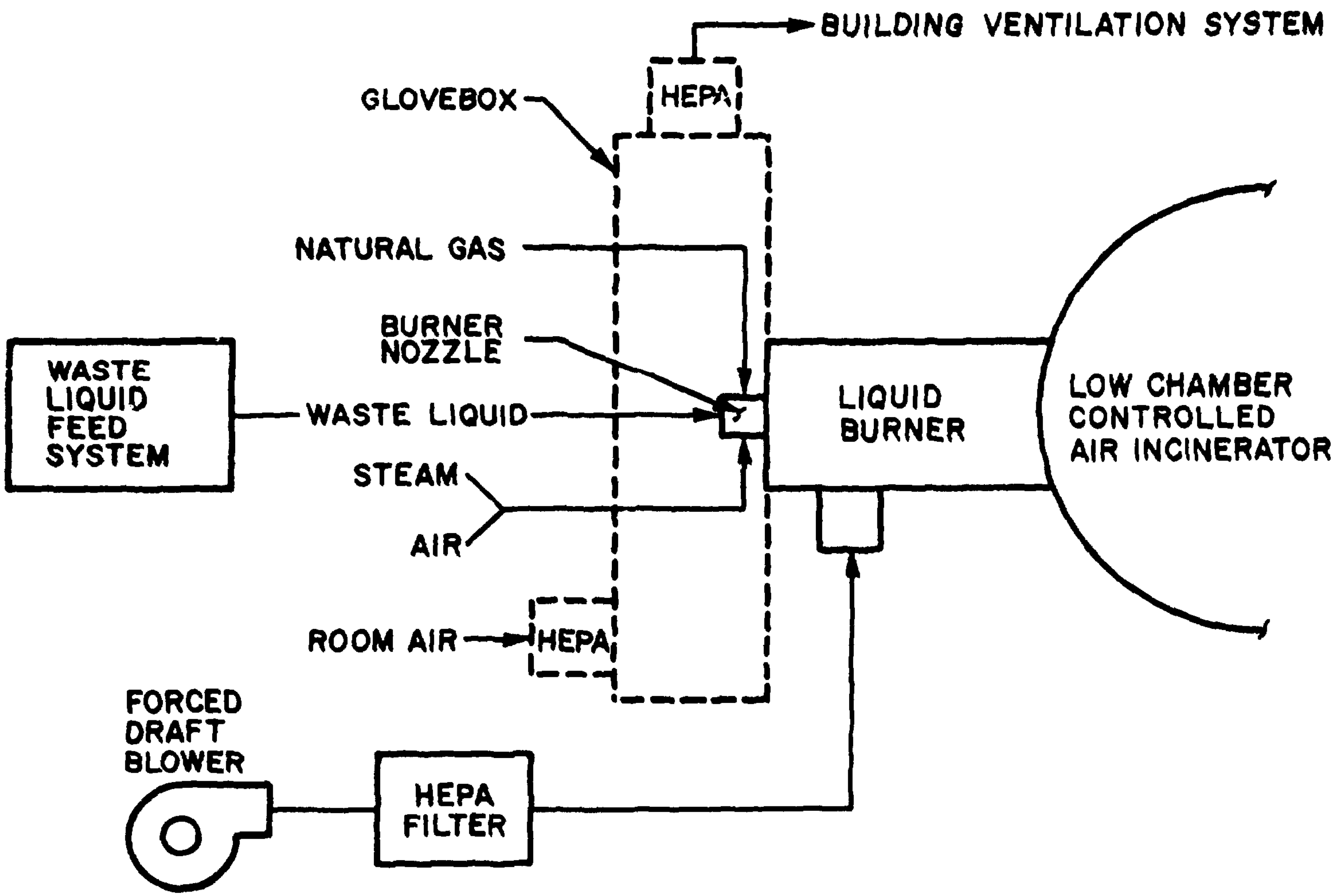

Figure 4. Commercial Incineration Demonstration
Milestone Schedule for FY-1982

WORK ELEMENT: INCINERATION DEMONSTRATION	O	N	D	J	F	M	A	M	J	J	A	S
Incineration Demonstration												
1. Program Management			A ▽			B ▽						
2. Technology Development												
2.1 Resin Incineration			A ▽						B ▽			C ▽
2.2 Tracer Testing								A ▽	B ▽	C ▽		D ▽
3. Commercialization Support						A ▽				B ▽		
4. Subcontractor Services (Proposed)									A ▽		B ▽	C,D ▽

EXPLANATION OF MILESTONES

1.0 PROGRAM MANAGEMENT

A. Request for proposal (A/E service) issued	Dec.	15
B. Subcontract placed	March	30

2.0 TECHNOLOGY DEVELOPMENT

2.1 RESIN INCINERATION

A. New burner checkout completed	Dec.	31
B. Resin incineration testing completed	June	30
C. Resin combustion letter report issued	Sept	30

2.2 TRACER TESTING

A. Tracer experiments designed	May	30
B. Calibration run	June	30
C. Tracer test	July	30
D. Letter report issued	Sept.	30

3.0 COMMERCIALIZATION SUPPORT

A. Technical support document issued	March	31
B. New preliminary design reviewed	July	30

4.0 SUBCONTRACTOR SERVICES

A. Project schedule issued	June	30
B. Preliminary design completed	Aug.	31
C. Commercialization site identified	Sept.	30
D. Economic evaluation completed	Sept.	30

slurry feed is in progress and nonradioactive experiments are planned for early CY-1982.

A second fission/activation product distribution test is scheduled for the final quarter of FY-1982. The purpose is to supplement data obtained during the initial run to provide information required for NRC licensing, offgas design data, and to establish a basis for shielding calculations.

Direct commercialization support will include transfer of base design information to the liaison subcontractor. In addition, the TSD prepared by Koch Process Systems, Inc. will be reviewed, revised as necessary by Laboratory staff, and forwarded to NRC. This initial TSD draft will be used for generic review by NRC staff.

Subcontractor Role

The subcontractor will be responsible for both liaison and facilitating functions within the demonstration program. Although specific elements of the contractor package will be refined after subcontractor selection, currently identified tasks include: 1) preparation of the CAI/LLW design incorporating Los Alamos input and utility requirements, 2) demonstration site selection, 3) active participation in NRC licensing proceedings, and 4) continued involvement through demonstration completion.

In FY-1982, the subcontractor will be required to establish an overall project schedule, complete a preliminary CAI/LLW process design, identify the commercial demonstration site, and prepare an economic evaluation of the project reflecting specific waste management circumstances at the demonstration site.

Program plans beyond FY-1982

Utility involvement, scheduled to begin in FY-1983, will require, as a minimum, the definition of site-specific waste management needs, participation in the licensing proceedings, and CAI/LLW operation. At the outset, tasks, objectives, and responsibilities will be redefined to reflect the capabilities and circumstances of all participants.

In addition to continued management overview of subcontractor activities, anticipated Los Alamos activities will include the conduct of incineration tests using site-specific wastes. These experiments will serve to verify design and operating parameters for the CAI demonstration unit. Further, assistance will be provided to the subcontractor and host utility during start-up, nonradioactive tests, and demonstration operation of the CAI/LLW system.

Utility and subcontractor activities in FY-1983 will focus on licensing of the demonstration process and preparation of final design documents. Following NRC approval, fabrication, site preparation, and installation are expected to require 14 to 18 months for completion. Demonstration tests are targeted for the end of FY-1985.

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WASTE FORM DEVELOPMENT

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ABSTRACT

In this program, contemporary solidification agents are being investigated relative to their applications to major fuel cycle and non-fuel cycle low-level waste (LLW) streams. Work is being conducted to determine the range of conditions under which these solidification agents can be applied to specific LLW streams. These studies are directed primarily towards defining operating parameters for both improved solidification of "problem" wastes and solidification of "new" LLW streams generated from advanced volume reduction technologies. Work is being conducted to measure relevant waste form properties. These data will be compiled and evaluated to demonstrate compliance with waste form performance and shallow land burial acceptance criteria and transportation requirements (both as they exist and as they are modified with time).

The work conducted under this program in FY 1981 and planned FY 1982 efforts are discussed.

PROGRAM SCOPE AND OBJECTIVES

The objective of the Department of Energy's National Low-Level Waste Management Program (NLLWMP) is to "provide an acceptable Low-Level Waste Management System by 1988" which will enable disposal "of materials that have been declared as low-level waste (LLW) in a manner which will protect public health and safety in the short and long terms." The Waste Form Development program is an integral part of the NLLWMP's plan to develop technology applicable to the aggregate of LLW streams from generation to disposal as expressed in Milestone B, "Develop Technology for Waste Treatment, Handling and Packaging for Shallow Land Burial Site Disposal." Data from this program also provide input into other NLLWMP Milestones.

Low-level wastes at nuclear facilities have traditionally been solidified using portland cement. Urea-formaldehyde has also been used for LLW solidification while bitumen (asphalt) and thermosetting polymers will be applied to domestic wastes in the near future. However, operational difficulties have been observed with each of these solidification agents. Such difficulties include incompatibility with waste constituents inhibiting solidification, free standing water, premature setting and fires. Some specific wastes, so-called "problem" wastes, have proven difficult to solidify with one or more of the contemporary agents or are solidified at low efficiencies. Existing technologies may not be directly applicable to the solidification of "new" wastes which are beginning to be generated using advanced volume reduction technologies in an effort to reduce waste disposal costs. In addition, consideration must be given to the application of any additional agents which may be introduced in the near future for the solidification of low-level wastes. The scope of this work includes both major fuel cycle and non-fuel cycle LLW streams.

This program will identify and evalute potential agents and processes for the improved solidification of low-level wastes and the solidification of "new" LLW streams generated from advanced volume reduction technologies. The data developed will provide input into DOE efforts to develop a handbook for LLW treatment and disposal by shallow land burial. It will also provide the basis to demonstrate compliance with waste form performance and shallow land burial acceptance criteria and transportation requirements (both current and as they change with time).

SURVEY OF POTENTIAL SOLIDIFICATION AGENTS

A survey was conducted in FY 1981 to identify and review those agents and processes that could be employed for the solidification of LLW. This survey included not only those agents and processes currently used for LLW solidification, but also those either under development or proposed. In addition, agents and processes utilized for the solidification of other types of wastes, such as chemical toxic wastes and high-level radioactive wastes, were also considered. Available information concerning the characteristics of solidification agents, solidification agent chemistry and applicability to specific waste streams, processing techniques and waste form properties was collected. A report entitled A Survey of Agents and Techniques Applicable to the Solidification of Low-Level Radioactive Wastes was issued at the end of FY 1981. Agents and processes described in this report must be capable of meeting existing waste form performance requirements and also not be so complex and/or expensive as to preclude reasonable applicability to LLW. Potential LLW solidification agents reviewed fall into several generic classes including hydraulic cements, thermoplastics, thermosetting polymers, glasses, ceramics, mineralization processes and composite processes. A partial listing of these agents is found in Table 1. The information compiled in this effort will be used to select agents and processes for further study. Such agents should potentially be capable of solidifying (either with or without modification) a wide variety of LLW streams, with particular emphasis on "problem" wastes and "new" wastes as previously described. Also, it is desirable if a particular agent chosen is compatible with existing installed waste solidification equipment so as to minimize the need for major capital expenditures.

WASTE COMPOSITION CHARACTERIZATION

In support of waste form development studies, efforts are directed at identifying specific LLW streams and determining their compositions. Table 2 lists generic types and sources of LLW. The specific wastes produced within a given class vary considerably in regards to composition, activity content and concentration. While wet wastes obviously require solidification, some dry wastes, particularly incinerator ash and dry salts, must also be solidified because they are easily dispersible. In addition, some wet wastes, ion exchange resins in particular, have typically been disposed in a dewatered form. However, regulations and burial site operating licenses are moving to require solidification of these wastes.

The emphasis of initial waste form development studies is the solidification of "problem" wastes and "new" wastes. The "problem" wastes currently under study include ion exchange resins, oils and organic liquids, specific aqueous concentrates and decontamination solutions. Studies of "new" wastes include incinerator ash, dry solids, such as those generated by thin film evaporators and calciners, and high solids content evaporator concentrates.

FORMULATION DEVELOPMENT STUDIES

Work is being conducted to determine appropriate operating parameters for the solidification of specific LLW streams with various solidification agents. This includes verification of the compatibility of solidification agents with various waste types, identification of waste stream constituents which impede or impair solidification and determination of appropriate compositional limits. FY 1981 formulational development work included the waste-solidification agent combinations listed in Table 3. Work has been initiated to investigate the solidification of ion exchange resins, incinerator ash, oil wastes, scintillation liquids and nitrate salt and concentrate wastes. Solidification agents applied include hydraulic cements (portland type I

Table 1. POTENTIAL LLW SOLIDIFICATION AGENTS

HYDRAULIC CEMENTS	GLASSES
Portland Cement	Soda-Lime Glass
High Alumina Cement	Phosphate Glass
Masonry Cement	Borosilicate Glass
Gypsum Cements	Nepheline-Syenite
Cement Grouts	Thermite
Pozzolanic Cements	Slag
Cement - Sodium Silicate	
Polymer Impregnated Cement	
Hot Pressed Cement	
THERMOPLASTICS	**OTHERS**
Bitumen	Ceramics
Polyethylene	Pelletized-Coated
Sulfur	Pelletized-Impregnated
THERMOSETTING POLYMERS	
Vinyl Ester-Styrene	
Water Extendable Polyester	
Epoxy	
Polyester-Styrene	

Table 2. TYPES AND SOURCES OF LLW

DRY WASTES	FUEL CYCLE	NON-FUEL CYCLE
Combustible (paper, clothing, plastics)		
Compactible	X	X
Non-Compactible	X	
Non-Combustible (metals, glass, incinerator ash, dry salts)		
Compactible	X	X
Non-Compactible	X	
WET WASTES		
Spent Resins	X	X
Slurries	X	
Sludges	X	
Aqueous Concentrates	X	
Special Aqueous Solutions	X	
Filter Cartridges	X	
Oil	X	
Other Organic Liquids	X	X
Membranes	X	
Biological	X	X

Table 3. FORMULATION DEVELOPMENT STUDIES INITIATED IN FY 1981

Waste Type	Hydraulic Cements (w, w/o additives)	Polymer Modified Gypsum Cement	Thermosetting Polymers
Ion exchange resins	X	X	X
Incinerator ash	X	X	X
Oils	X	X	
Scintillation liquids	X	X	
Nitrates	X		X

and III cements and high alumina cement), polymer modified gypsum cement (Envirostone) and thermosetting polymers (primarily vinyl ester-styrene). Both the polymer modified gypsum cement and vinyl ester-styrene are recently developed agents that appear applicable to the initial wastes studied. Work with hydraulic cements includes a variety of cement types and additives with a view towards applying existing facilities to improved solidification of current wastes and investigating their potential for the solidification of "new" wastes. Formulational development information is typically expressed in the form of a ternary phase diagram such as those shown in Figures 1-4 for the solidification of ion exchange resin wastes in portland type III cement. Acceptable formulations must be capable of meeting existing waste form criteria (free standing monolithic solid with "no" free standing water) and also pass a water immersion test which is indicative of long-term waste form integrity. The development of acceptable formulations requires study of a variety of parameters. For example, formulations for the solidification of ion exchange resin wastes were found to be dependent upon cement type, resin type, resin loading and water content, and water/cement ratio. Information related to mechanical operating parameters, such as mixing method and order of addition of constituents is also being developed.

Work has been conducted to identify well characterized, readily available commercial additives that could be used to reduce leachability (particularly cesium leachability from cement waste forms). Such an additive(s) could be readily applied to a wide range of fuel cycle and non-fuel cycle operations. A number of potential additives have been identified and subjected to screening sorption tests using solutions indicative of actual conditions. Leaching tests of concrete waste forms containing additives have been initiated to investigate improvements in activity retention.

WASTE FORM PROPERTY EVALUATION STUDIES

The waste form formulations developed in this program for the solidification of various wastes are being tested to determine their characteristics relative to desired waste form properties. Property studies include leachability, mechanical properties (compressive strength, impact strength), radiation stability, thermal properties (flammability, thermal conductivity), chemical stability, corrosivity towards the waste form container and biodegradability. Property evaluation studies were begun in FY 1981 for ion exchange resin and organic liquid waste forms. This effort has progressed furthest with ion exchange resin waste forms for which leachability, mechanical properties, radiation stability and biodegradability testing have begun. For example, leach studies of portland type III cement-mixed bed

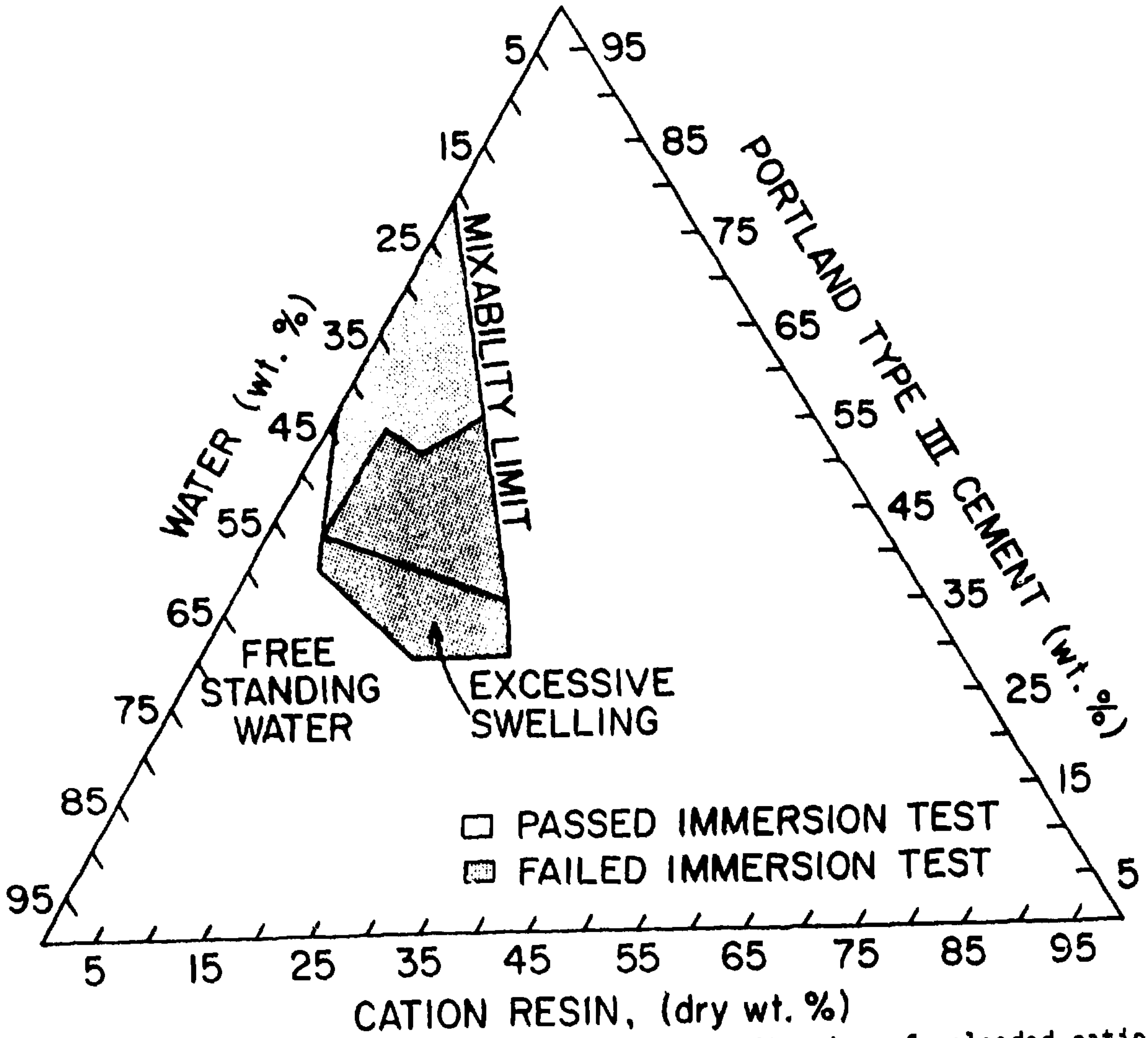

Figure 1. Ternary composition diagram for the solidification of unloaded cation resin in portland type III cement.

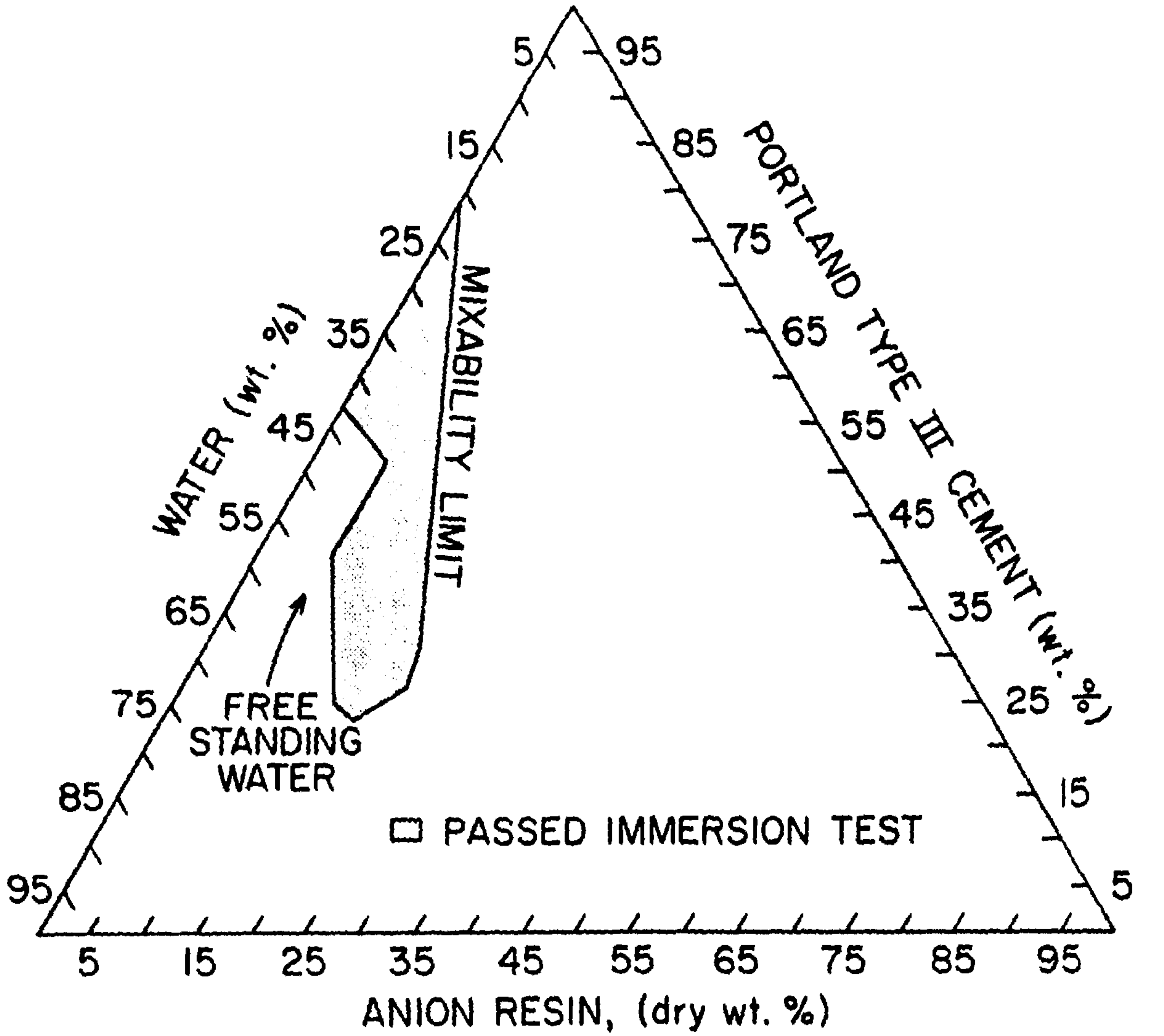

Figure 2. Ternary composition diagram for the solidification of unloaded anion resin in portland type III cement.

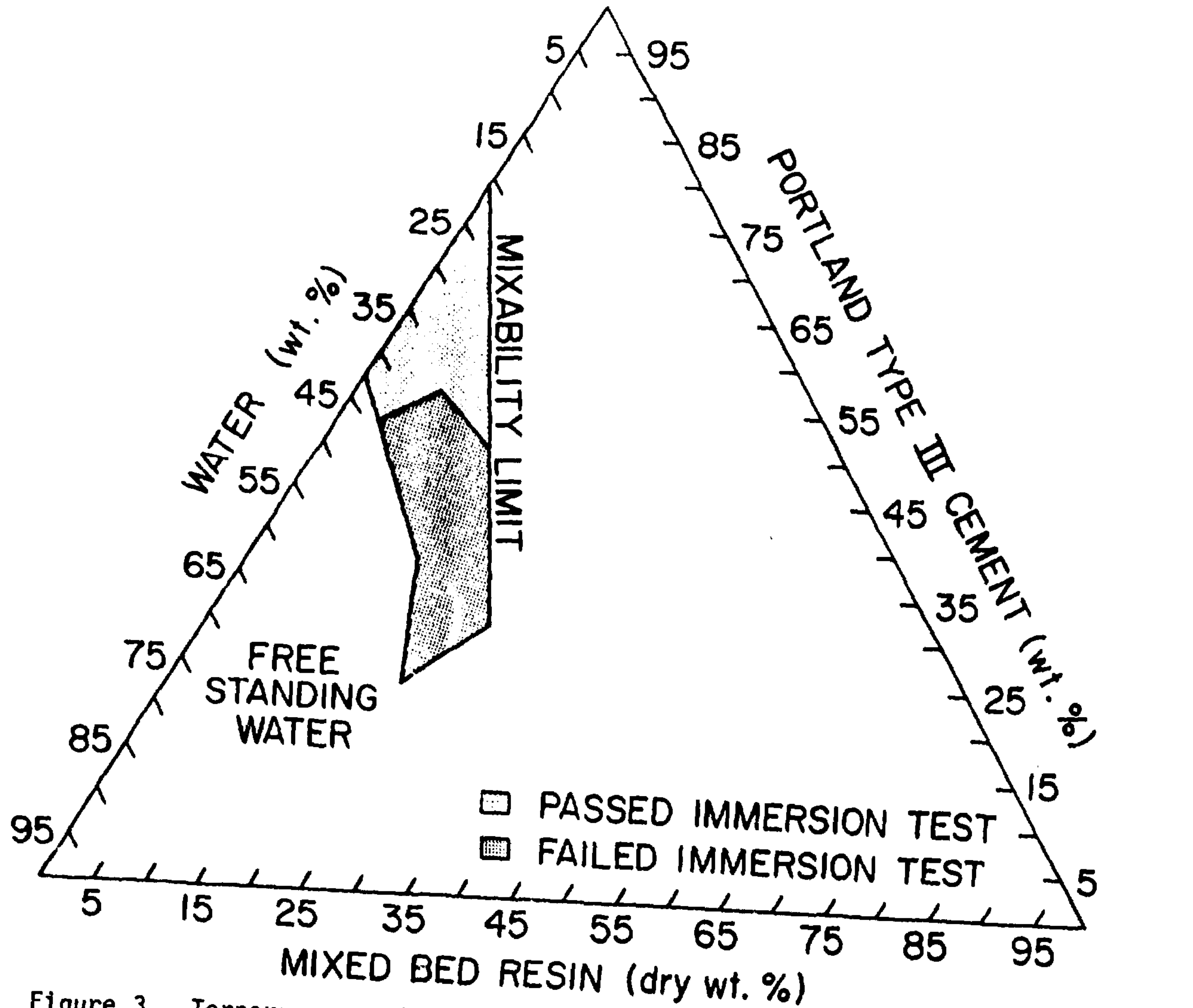

Figure 3. Ternary composition diagram for the solidification of unloaded mixed bed resin in portland type III cement.

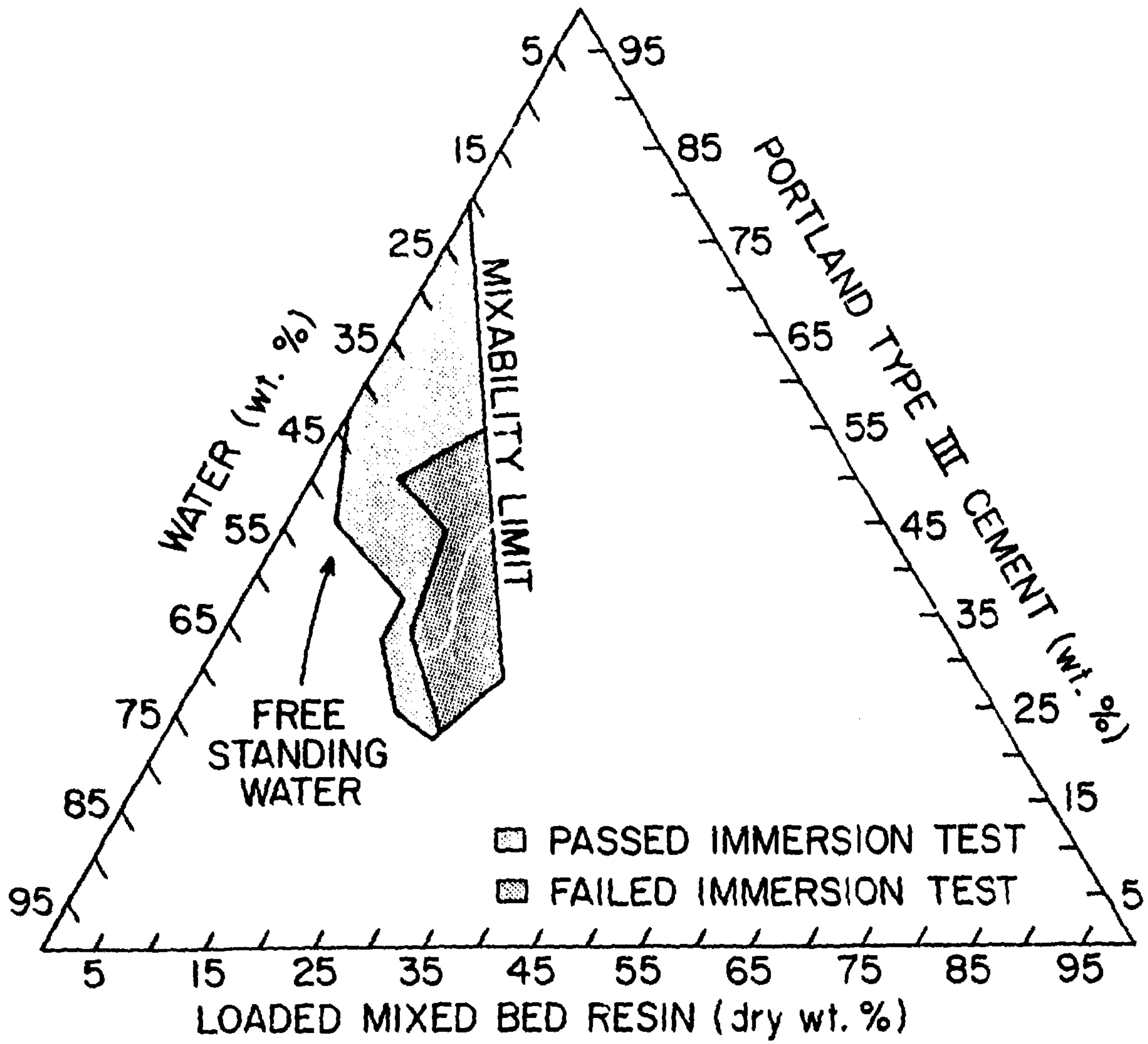

Figure 4. Ternary composition diagram for the solidification of loaded mixed bed resin in portland type III cement.

resin waste forms showed that activity retention is relatively independent of leachant composition (demineralized water-seawater) and leachability is not affected by Co-60 gamma irradiation doses of up to 10^8 rads. Irradiation and leaching experiments using unsolidified mixed bed resin were also conducted to provide a baseline for solidification studies. Property evaluation studies will continue for these waste forms and progress to include other relevant waste form properties. Similar efforts with additional waste-solidification agent combinations will begin as their respective formulation development studies are completed. The results of the property evaluation studies can be used to optimize waste form formulations. The data developed will also be needed to demonstrate compliance with waste form performance criteria, disposal site criteria and transportation requirements. In addition, these data are useful in assessing and developing alternative disposal options and establishing shallow land burial site performance criteria which can be used to judge the acceptability of site locations, trench designs and operating practices for new and existing sites.

TECHNICAL ASSISTANCE

The Waste Form Development program has established a nucleus of competent individuals with a range of expertise that can be called upon by the NLLWMP to provide technical assistance as necessary. In FY 1981, technical assistance requests consisted of expert participation in ad hoc task groups on waste classification and on LLW treatment, packaging and handling system performance standards. In addition, system evaluation and leaching experiments were conducted in support of a demonstration at the Maxey Flats, KY shallow land burial site of a new polymer solidification system (ALAP waste form, Imperial Professional Coatings, Inc.).

FY 1982 EFFORTS

In FY 1982, formulational development work will be completed for ion exchange resins, oil and organic liquid wastes, incinerator ash and nitrate salt wastes. Waste form property testing will continue and progress to include measurements not initiated with these systems in FY 1981. Topical reports will be issued on ion exchange resin waste solidification and for the solidification of oil and organic liquid wastes. Studies to investigate the solidification of additional wastes will begin. Technical assistance will be performed as requested by the NLLWMP. FY 1982 efforts are summarized in Table 4.

Table 4. FY 1982 EFFORTS

(1) Formulation development work will be completed for:

- ion exchange resins
- oils
- organic liquids
- incinerator ash
- nitrate wastes

(2) Waste form property measurements will continue and be expanded to include additional waste form types.

(3) Topical reports will be issued for the solidification of:

- ion exchange resin wastes
- oils and organic liquids

(4) Formulational studies for the solidification of additional waste streams will begin.

(5) Technical assistance will be performed as requested by NLLWMP.

DECONTAMINATION EFFECTIVENESS FOR METALLIC LOW LEVEL WASTE

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ABSTRACT

The effectiveness of decontamination methods for low-level metal waste is being evaluated. The major effort is gathering and evaluating information on existing and developing methods. A secondary task is assisting with the evaluation and analysis of a demonstration campaign of melt slagging for decontamination.

INTRODUCTION

The objective of this program is to review and evaluate the effectiveness of techniques for decontaminating metallic low-level waste. We are reviewing the various metal volume reduction and decontamination methods in use or under study at both DOE and commercial facilities. The techniques are being evaluated for effectiveness, radionuclide distribution and concentration in the products, relative cost, state of development, and applicability to the various types of metal waste. The primary measure of effectiveness is the impact on diposal requirements. The potential impacts on disposal requirements are being considered both with and without the existance of *de minimus* regulations which would allow recycle of certain cleaned scrap.

For the purpose of evaluating decontamination methods, low-level metallic waste may be divided into two categories. The first is metal which is contaminated only on its surface. This contamination may produce α, β, and/or γ radiation. The bulk of this metal scrap consists of glove boxes, tools, and equipment used in fabricating or processing reactor fuels. The second type is metal that is contaminated throughout. This scrap may contain transmutation products and/or fission fragments and consists generally of metal that has been exposed to a high neutron fluence such as spent fuel cladding and reactor structurals. In general, it will not be possible to decontaminate these metals with transmutation products spread throughout. The following discussion is limited primarily to the surface contaminated metals.

DECONTAMINATION METHODS

The decontamination methods being investigated may be grouped into three categories for convenience of discussion: (1) methods which do not alter the surface, (2) methods which remove a surface layer, and (3) methods that alter the shape or form of the metal.

Methods That Do Not Alter The Surface

Decontamination methods that do not alter the surface of the metal include strippable coatings and fixatives, spray cleaning with a variety of solutions, and vapor degreasing. The strippable coatings serve a dual purpose. In addition to providing decontamination as loose contamination adheres to the film, the coating can help minimize contamination spread during size reduction of scrap. Spray cleaning is used widely with a variety of cleaning solutions. The solutions should be chosen carefully to remove the contamination, be capable of being cleaned for recycle, and to be compatible with liquid waste treatment facilities at the site.

The spray systems in use includes both low and high pressure, manually controlled and automatic, and are sometimes combined with a brushing or scrubbing action. Spray cleaning is effective for much contaminated scrap, is relatively inexpensive, and is recommended for most scrap. Even if the scrap is not to be completely decontaminated, the loose contamination removed by spray cleaning can be concentrated and either reclaimed or put into a more stable form for disposal.

Vapor degreasing is effective for decontaminating some types of scrap. A low pressure liquid spray of the degreasing solvent is often used in addition to the vapor condensing action. The degreasing solvent needs continuous removal of contaminants to avoid back contamination of the scrap.

Decontamination Methods That Remove a Surface Layer

Decontamination methods that remove a surface layer of the metal include electropolishing, vibrapolishing, chemical milling, and abrasive blasting. Electropolishing has been demonstrated to be a highly effective technique for decontamination.[1] Its disadvantages include high cost, limited applicability, and relatively high volumes of secondary waste. A distinct advantage of electropolishing is that tools and fixtures can often be completely decontaminated by electropolishing and still be functional for their original use. Vibrapolishing is a highly effective method that has lower cost, applicability to more materials and shapes, and a lower volume of secondary waste.[2] Chemical milling is similar to electropolishing in that a surface layer is dissolved. It is more flexible in regard to shapes but less flexible in regard to materials which may be processed in a given bath. Abrasive blasting is used extensively for surface cleaning other than decontamination. Its disadvantages for decontamination are mainly difficulty in containment of contaminants, difficulty in removing contaminants from abrasive media, and resulting large secondary waste volumes. It is relatively inexpensive and should be applicable to many shapes and materials. It has not been demonstrated extensively for radioactive decontamination.

Decontamination Methods That Alter The Shape

The only practical method of decontamination which involves changing the shape or form of the metal scrap is melting, which results in both decontamination and volume reduction. However, since size reduction of the metal scrap is required for many of the decontamination techniques, we may logically include mechanical volume reduction techniques in this section on shape change. Those methods include shredding, compaction, and baling.

Melting under a slag has been demonstrated for a variety of contaminated metals, slags, and furnace types on the laboratory and engineering scale.[3,4] Furnace types used or currently under investigation include induction, inductoslag, arc, plasma arc, and reverberatory. The contaminants investigated have primarily been uranium or transuranics. This program is now participating in a demonstration melting campaign with a 6-ton capacity induction furnace at the Paducah Gaseous Diffusion Plant. The size reduction and melting are funded by other programs. This program's participation will allow broader analysis, evaluation, and reporting of the results. Doping of the scrap with cesium and strontium is planned near the end of the campaign.

Melting has unique advantages in addition to the good decontamination achieved for some contaminants and metals. The product of melting can be shaped and sized as desired from powder to large ingots. The product is of minimum volume and in general is uniform and homogeneous. This uniformity will allow more reliable verification of the cleanliness achieved. Disadvantages of melting include high cost and limited applicability. Reactive metals such as aluminum and zirconium do not decontaminate readily. In general, transmutation products will not be removed by slag melting.

If the metal waste still requires burial after decontamination, volume reduction by shredding, baling, or compacting may be economically desirable. Those mechanical operations do not result in any decontamination but will reduce burial and transportation costs and conserve burial ground space.

DISCUSSION AND SUMMARY

The wide variety of metal scrap classified as low-level waste and the large number of decontamination methods available leads to a large number of potential flowsheets. In a review of decontamination methods for transuranic wastes,[5] several techniques appear to have desirable combinations of good effectiveness, low cost, low secondary waste generation, and high applicability. These methods are spray cleaning, vibrapolishing, and melt slagging. Spray cleaning appears to be desirable for most metal scrap even if another method is required later for more complete decontamination. Recommendations will be developed for cleaning solutions and spraying techniques for several types of scrap. Vibrapolishing appears to be a very effective and practicable process for many types of scrap. Melt slagging may be preferable for certain types of scrap due to the homogeneity of the product, especially if recycle is feasible. Development programs are currently underway for both vibrapolishing and melting.

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OVERVIEW OF LOW-LEVEL WASTE MANAGEMENT PROGRAM SHALLOW LAND BURIAL MILESTONES AND ACTIVITIES FOR MILESTONE C*

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INTRODUCTION

There are two shallow land burial (SLB) technology milestones in the DOE Low-Level Waste Management Program (LLWMP). These are Milestone C, Develop Technology and Documentation Required to Open a Shallow Land Burial Site (3/84) and Milestone D, Develop and Document Remedial Action Technology for SLB Sites (12/84). Milestone C is focused on the development, demonstration, and documentation of the technology needed to site, design, construct, operate, and close a safe, reliable shallow land burial facility for the disposal of low-level radioactive waste. Milestone D, on the other hand, is focused on techniques for correcting unsatisfactory performance of SLB sites as required.

This review will provide an overview of two aspects of Milestone C. First, the steps in the evolution of the program for SLB technology development activities will be reviewed and then the current R,D&D activities will be summarized.

HISTORY

The current technology development program in shallow land burial has evolved from four components.

1. Shallow Land Burial Steering Committee Recommendations - 1979

2. State-of-the-Art Review of Shallow Land Burial - 1980

*Operated by Union Carbide Corporation under contract W-7405-eng 26 with the U.S. Department of Energy.

3. LLWMP Management Meeting at Des Moines, Iowa - 1980

4. LLWMP Participants Annual Meeting in San Diego - 1981

The first two of these components relate to definition of technology development needs and the second two components relate to the way the program is structured.

The Shallow Land Burial Steering Committee was established in 1975 and continued from that year through 1977 to advise AEC, ERDA or DOE Headquarters management staff on the research requirements for shallow land burial. In 1979, the committee was convened for a last time to provide a listing of gaps and issues in shallow land burial in support of the present DOE Low-Level Waste Management Program. The committee approach was a modified delphi one where the issues were identified and discussed in the course of two meetings and associated correspondence. During the set of meetings in 1979 the committee identified 13 major unresolved technical issues in shallow land burial. Three of these pertained to the site, five pertained to issues involving the waste and its migration through geologic media, three of them concerned operational practices, and two addressed performance evaluation. The issues identified by the committee are summarized on Table 1. They formed the principal basis for the LLWMP plan and funding of activities for FY 1980.

During FY 1980 a state-of-the-art review of shallow land burial (1) was prepared by the Evaluation Research Corporation in response to a request from the ORNL Program Office. This review took as its starting point the statement of technical issues from the steering committee and proceeded to evaluate the current practice of shallow land burial and provide the detailed technical information which was needed to support the technical issues identified by the committee. The state-of-the-art review did support the committee's recommendations and identified no further major technical issues in shallow land burial.

The LLWMP management meeting in Des Moines was convened for the purpose of establishing a concise set of major top level program milestones. This meeting, held late in 1980, produced a list of major milestones which were designated by the letters A through I and thus became known in the program as the "Alpha" milestones. The technology development Alpha milestones are listed on Table 2. The shallow land burial related milestones are C and D. Milestone C, the development of technology for shallow land burial, is the principal milestone of the technology program.

Finally in the time frame of the 1981 Participants Information Meeting held in San Diego, California, a "handbook" structuring was developed to support the production of the information required to meet the Alpha milestones. This structure, as developed in support of Milestone C, led to the identification of six chapters for the handbook. These are:

Table 1. Listing of Identified Issues by Technical Area

Title	Type of Problem Resolved: Remedial Action	Type of Problem Resolved: Future Improvement
3.1 Site Issues		
3.1.1 Development of Techniques to Characterize and Improve Sites for Optimizing Burial Ground Performance	X	X
3.1.2 Development and Evaluation of Erosion and Intrusion Control Barriers	X	X
3.1.3 Evaluation of the Technical Feasibility of Intermediate Depth Burial		X
3.2 Waste Issues		
3.2.1 Determination of Mechanisms Controlling Water/Radionuclide Transport in Unsaturated Zones	X	X
3.2.2 Determination of the Effects of Organic and Inorganic Complexation on Transport of Radionuclides	X	X
3.2.3 Determination of Sorptive Capacities for Radionuclides in Soil/Solution Systems		X
3.2.4 Determination of the Effects of Soil Microorganisms on Transport and Transformation of Radionuclides		X
3.2.5 Determination of the Potential Hazards from Long-Lived Radionuclides		X

(over)

Table 1. (Continued)

Title	Type of Problem Resolved: Remedial Action	Type of Problem Resolved: Future Improvement
3.3 Operational Issues		
3.3.1 Development of Methods to Prevent or Minimize Structural Failure of Trenches	X	X
3.3.2 Development of Instrumentation to Verify Waste Receipts		X
3.3.3 Development of Operational Practices to Minimize Reliance on Post-Operational Control and Surveillance		X
3.4 Performance Evaluation Issues		
3.4.1 Development of Methodology and Equipment for Monitoring Burial Sites	X	X
3.4.2 Integration and Verification of Models for Evaluation of Waste Burial	X	X

Table 2. Major LLWMP Technology Development Milestones

A. Develop and document technology for waste generation reduction (4/82).

B. Develop and document technology for waste treatment, handling, and packaging for shallow land burial (12/83).

C. Develop and document technology required to open a shallow land burial site (3/84).

D. Develop and document remedial action technology for SLB sites (12/84).

E. Develop and document technology needed to open a site providing greater confinement than shallow land burial (3/86).

G. Develop and document technology for waste treatment, handling and packaging for greater confinement than SLB (12/85).

I. General Requirements

Criteria and Standards
Waste Classification

II. Site Selection

III. Site Design

IV. Site Operation

V. Site Closure

VI. Post Closure Methods

The general requirements section of the handbook is essential to its preparation but is not part of the technology development program. Input from this type of activity will be provided to the technology development work as it becomes available. The last five components or chapters of the handbook are the principal components of technology development. As is illustrated in Figure 1, all of the Steering Committee issues are addressed as part of the program in one or more of these components.

Milestone C Technology Development Activities

The technology development work supporting the components of Milestone C is carried out in nine major areas. These nine areas are listed and their relationship to the four components of Milestone C is displayed on Figure 2. Each of the technology development areas is addressed in more detail in the following paragraphs. Some of the principal items of concern or interest are discussed for each area along with an identification of the major program participants in that area.

The area of site selection technology covers those activities required to identify, characterize, and qualify sites for shallow land burial facilities. The two areas of principal concern involve (1) the production of an integrated site selection methodology and (2) the development of site performance prediction techniques for application to site selection. In support of the development of an integrated selection methodology, EG&G is preparing criteria and methods for the identification of potential sites and Oak Ridge National Laboratory (ORNL) is planning to test the application of the available integrated methodology to a recently selected site at the Oak Ridge Reservation. Part of this ORNL effort will involve the attempt to validate the model used in connection with this task.

Fig. 1. Correlation Between Shallow Land Burial Steering Committee Issues and LLWMP Technology Development Effort.

	COMPONENTS OF EFFORT FOR M/S *C*			
STEERING COMMITTEE ISSUES	SITE SELECTION	FACILITY DESIGN	FACILITY OPERATION	CLOSURE AND POST-CLOSURE
SITE CHARACTERISTICS MODIFICATION		X		
EROSION AND INTRUSION BARRIERS		X		X
UNSATURATED ZONE TRANSPORT MECHANISMS			X	
COMPLEXATION TRANSPORT OF MECHANISMS			X	
SORPTION IN SOIL/SOLUTION SYSTEMS			X	
SOIL MICROORGANISM EFFECTS			X	
HAZARDS FROM LONG-LIVED NUCLIDES		X	X	X
TRENCH STRUCTURAL FAILURE		X	X	X
WASTE RECEIPT INSTRUMENTATION		X	X	
SITE STABILIZATION AND CLOSURE		X	X	X
MONITORING METHODS & EQUIPMENT		X	X	X
MODEL INTEGRATION & VERIFICATION	X		X	X

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Fig. 2. Correlation Between the Major Technology Development Areas and the Program Components of Milestone C.

TECHNOLOGY DEVELOPMENT AREAS	COMPONENTS OF EFFORT FOR M/S C: SITE SELECTION	FACILITY DESIGN	FACILITY OPERATION	CLOSURE AND POST-CLOSURE
SITE SELECTION PROCEDURES	X			
BURIAL TECHNOLOGY		X	X	X
STABILIZATION AND POST-CLOSURE			X	X
GEOHYDROLOGIC SITE CHARACTERIZATION	X	X	X	X
ENVIRONMENTAL MONITORING	X	X	X	X
MIGRATION MECHANISMS	X	X	X	X
RADIONUCLIDE TRANSPORT DATA BASE	X	X	X	X
MODELING	X	X	X	X
PACKAGE ASSAY INSTRUMENTATION		X	X	

Improved burial technology covers the development, testing, and demonstration of improved burial techniques for application to new shallow land burial sites. The principal considerations in this effort are (1) water management, (2) intrusion control, and (3) engineering scale proof testing. The water management development activities include those aimed at both surface and groundwater. Surface configurations, drains, caps, liners, and grouts are being evaluated in the program. Intrusion barriers are being tested against both plant and animal intrusion. Engineering scale proof testing is also underway. Most of these activities are being carried out at Los Alamos National Laboratory (LANL) and ORNL.

Stabilization and post closure work involves those activities focused on providing long-term stability to a burial site. The principal considerations in this area are in many ways similar to those involved in improved technology development. They are (1) water management, (2) subsidence, erosion, and intrusion, and (3) management procedures. The principal long-term stability concern in connection with water management is control of the water table level. The subsidence, erosion, and intrusion studies involve such items as backfill density, revegetation, and caps and covers for the trenches. The management procedures for post closure require a clearer statement of the needs and goals in connection with the post closure period of site operation. LANL, ORNL and Savannah River Laboratory (SRL) are involved in water management studies and subsidence, erosion and intrusion technology development. Rockwell Handford Operation (RHO) and EG&G have also worked in this latter area. EG&G is doing the work on criteria development in connection with the post closure phase of site operation.

Geohydrologic site characterization involves the development of methods and equipment required to collect information in this field which is basic to all phases of shallow land burial site selection, design, operation and closure. The principal current issues of interest involve the collection of the data and the development of the necessary equipment. Data collection is being carried out by ORNL, SRL, Pacific Northwest Laboratory (PNL), and the U. S. Geologic Survey (USGS). Equipment development and testing is underway by the USGS and PNL.

The field of environmental monitoring includes the development of methods and techniques necessary to demonstrate compliance of a burial site with regulatory requirements, to provide early warning information regarding potential problems with the site, or to support experimental research activities. The principal items of concern in this area involve (1) development of methodology for sampling, (2) development and testing of instrumentation, and (3) definition of a basis for the monitoring effort. Sample collection for environmental monitoring involves the methodology to select the correct radionuclide(s) to monitor and the location and frequency of sampling required. Both the sampling approach and the instrumentation employed must provide the sensitivity required to support the necessary level of confidence in the predictions obtained by applying the modeling system to the data. Argonne National Laboratory (ANL) is supporting the development of methodology and sampling system requirements in connection with their work on the generic monitoring handbook. PNL and RHO have participated in the development of instrumentation for this area while SRL, PNL, ORNL and LANL are working on components of the required modeling system.

The area of migration mechanisms includes the work focused on developing information regarding the mechanisms by which radionuclides migrate through geologic medium of the burial site. The principal considerations in this work involve (1) integrated systems studies, (2) unsaturated zone transport, (3) complexation mechanisms, and (4) the effects of microbial action on the transport of radionuclides. currently, integrated system studies are being carried out by SRL, LANL and PNL in lysimeter experiments and by ORNL in the engineering scale test facilities. Saturated zone transport and complexation effects are being evaluated by PNL and LANL while microbial effects are being evaluated by Brookhaven National Laboratory (BNL) and LANL.

A radionuclide transport data base is required to provide field data needed in connection with the validation of technology developed in this program. The principal current components of this effort involve (1) definition of data needs, (2) data collection, and (3) data handling systems. The data needs requirements in connection with performance modeling, model validation, and research and development activities require clear exposition. The data collection activity is underway at a number of sites and needs to be integrated. Data handling systems are required to facilitate retrieval, manipulation, and interpretation of the data collected. ANL and PNL are currently involved in defining data needs. BNL, LANL, ORNL, PNL and SRL are currently engaged in data collection activities and, along with EG&G, have various data handling systems in operation.

Modeling involves the development and testing of mathmatical simulations of burial ground facilities. The principal current concerns in the modeling area are (1) provision of fully integrated model systems, and (2) verification of the validity of these model components and systems. Practical verified model systems are essential to the verification of satisfactory radionuclide containment performance of shallow land burial system during all phases from site selection through the post-closure phase. A large number of model components are currently available and these must be integrated and applied to shallow land burial problems. Currently SRL, ORNL, PNL and LANL are active in this field.

Package assay instrumentation is intended to verify the radionuclide content of packages upon receipt at shallow land burial facilities. This information is required for proper waste handling and emplacement, and for accurate waste inventory. Two principal considerations in this area are (1) the feasibility of both making the required measurements and of using available instrumentation and (2) the design of overall systems for doing the package assay work. PNL is currently investigating this area.

In summary, as shown in Table 3, there is broad participation by DOE contractors in the technology development activities of the program. Further integration of these efforts and an overall evaluation of the program are timely at this point in the program. It is of course the intent that integration and evaluation activities of this type will result during and as a part of this current meeting.

Finally, the timing of the technology development efforts is intended to support the issuance of the shallow land burial handbook at the end of March 1984. In order to achieve this goal, the research and development activities must reach a fruitful end by the close of FY 1983. Some typical examples of important deliverables in the program are:

1. Issue Monitoring Manual - ANL - 9/82
2. Issue SLB Test Reports - ORNL, SRL, PNL, LANL - 9/82
3. Report Assay and Borehole Monitoring Equipment Projects - PNL - 12/82
4. Report SLB Performance Models - ORNL, SRL, PNL - 9/83
5. Issue Shallow Land Burial Handbook -ORNL - 3/84

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TABLE 3. **BROAD PARTICIPATION IN TECHNOLOGY DEVELOPMENT FOR MILESTONE *C***

TECHNOLOGY DEVELOPMENT AREAS	PARTICIPATING CONTRACTORS								
	ANL	BNL	EG&G	LANL	ORNL	PNL	RHO	SRL	USGS
SITE SELECTION PROCEDURES			X		X				
BURIAL TECHNOLOGY				X	X				
STABILIZATION AND POSTCLOSURE				X	X				
GEOHYDROLOGIC SITE CHARACTERIZATION				X	X			X	X
ENVIRONMENTAL MONITORING	X					X	X		
MIGRATION MECHANISMS		X		X	X	X		X	
RADIONUCLIDE TRANSPORT DATA BASE	X	X		X	X	X		X	
MODELING				X	X	X		X	
PACKAGE ASSAY INSTRUMENTATION						X			

RADIONUCLIDE MONITORING AT SAVANNAH RIVER PLANT

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ABSTRACT

The humid, eastern shallow land burial site operated at Savannah River Plant for disposal of solid, low level waste is given technical support by monitoring activities at Savannah River Laboratory. These activities include drilling wells on the burial site, operating lysimeters containing well characterized waste samples, and basic laboratory study. New concepts and conclusions developed over the past year will be described.

INTRODUCTION

Savannah River Plant has practiced shallow land burial in a humid, eastern location since the early 1950's for the purpose of disposing of low level solid defense wastes. The site is located on the Atlantic Coastal Plain, a region of mostly sedimentary deposits, about 20 miles down the Savannah River from Augusta, GA. There are actually two physically adjacent burial areas on the plant site: the original ("old") burial ground covers about 76 acres and was filled in the mid 1970's, the present, operating, site covers about 120 acres and is expected to be filled in the mid 1990's. The burial sites are located in an interstream region between two fuel reprocessing facilities. The water table is typically about 45 feet below the surface, and moves generally to the southwest where it outcrops into Four Mile Creek. There is a groundwater divide across the north corner of the burial ground; groundwater from this area moves toward Upper Three Runs Creek. Both creeks flow into the Savannah River.

MONITORING WELLS

Savannah River Plant burial trenchs are dug 20' deep, 20' wide, and as long as can be accommodated within the burial ground area. Waste is emplaced to within four feet of the surface, and is covered with soil. Three types of wells are used to monitor these trenches: dry boreholes that pass through and below the trenches, trench wells screened to detect water "perching" in the trenches, and groundwater wells. Detectors lowered annually into the boreholes have shown no downward movement of radioactivity, and gradual decay of the sources. Water can "perch" in the trenches if the permeability of material in the filled trench is greater than that of the undisturbed soil below it. Eight of twenty four trenches have shown perched water. During the past year only three have contained enough water to sample.

Eight of the 75 groundwater wells in the old burial ground show radioactivity, other than tritium, at above background levels. These appear to be correlated with areas in which solvents have been spilled, or detergents used to wash equipment.

A plume containing tritium at above-background levels follows groundwater flow southwest of the burial ground and was outcropping into an eroded ditch. Ditch repair work reported last January has cut off this outcrop of tritium (approximately 800 Ci/year) and should extend the path to the normal outcrop by about two tritium half-lives. A method to reduce the release of tritium to burial ground water by packing tritiated wastes into spent melt crucibles and plugging their ends with epoxy has been proposed by Savannah River Laboratory and accepted by Savannah River Plant.

LYSIMETER PROGRAM

Our lysimeter program is a major effort to measure radionuclide migration from thoroughly characterized sources that are subjected to the same conditions as waste in trenches. A field of 42 lysimeters containing typical, unencapsulated Savannah River Plant wastes has been operating for about 4 years. We have just finished building twelve similar lysimeters for testing typical wastes produced by power reactors. This waste is solidified in matrices such as concrete and plastic resins. Our objective is to compare radionuclide release from these advanced forms with the unencapsulated Savannah River Plant wastes. Results will guide decisions for improving Savannah River Plant waste management practice and will be incorporated into the design of a greater confinement site at Savannah River Plant, to be discussed in another talk at this meeting.

Migration through the lysimeters has been modeled with a one-dimensional transport equation in order to estimate the useful lifetime of the tests. ^{90}Sr is an important example because our dose-to-man model shows that it will give the greatest hazard to future users of the burial ground area. With a K_d of 50, detectable amounts of ^{90}Sr should move through about two feet of soil in 2 years. Easily observable amounts should appear in water pumped from the lysimeter sump with 6 years. We have recently begun seeing small amounts of radioactivity in water samples from the defense-waste lysimters but we haven't been able to positively identify the radionuclide.

LABORATORY K_d TESTS

During the past year we have also made extensive laboratory tests to determine the actual K_d of ^{90}Sr on soil in the flowpath of water out of the burial ground. Batch, closed loop, and column tests were used. As expected, in layers composed primarily of sand found at about 60' below the surface, the ^{90}Sr K_d is much lower than in areas of higher clay content. We plan to perform similar measurements for ^{99}Tc and ^{129}I during FY82.

CONCLUSIONS

1. There is little movement of radionuclides other than tritium beneath the burial ground. The movement of small amounts of activity appears related to specific events such as a solvent spill.

2. Repair of an early outcrop of tritium appears successful.

3. Defense waste lysimeters are functioning properly. Results from the special wasteform lysimeters emplaced this year will come in about four years later than for the defense lysimeters.

4. ^{90}Sr will move more rapidly through sandy layers about 60' below surface than through clay. The sandy layers are not continuous, and it is unlikely that measurable amounts of ^{90}Sr will reach the outcrop.

MONITORING AND PHYSICAL CHARACTERIZATION OF UNSATURATED ZONE TRANSPORT: RADIONUCLIDE MIGRATION STUDIES

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INTRODUCTION

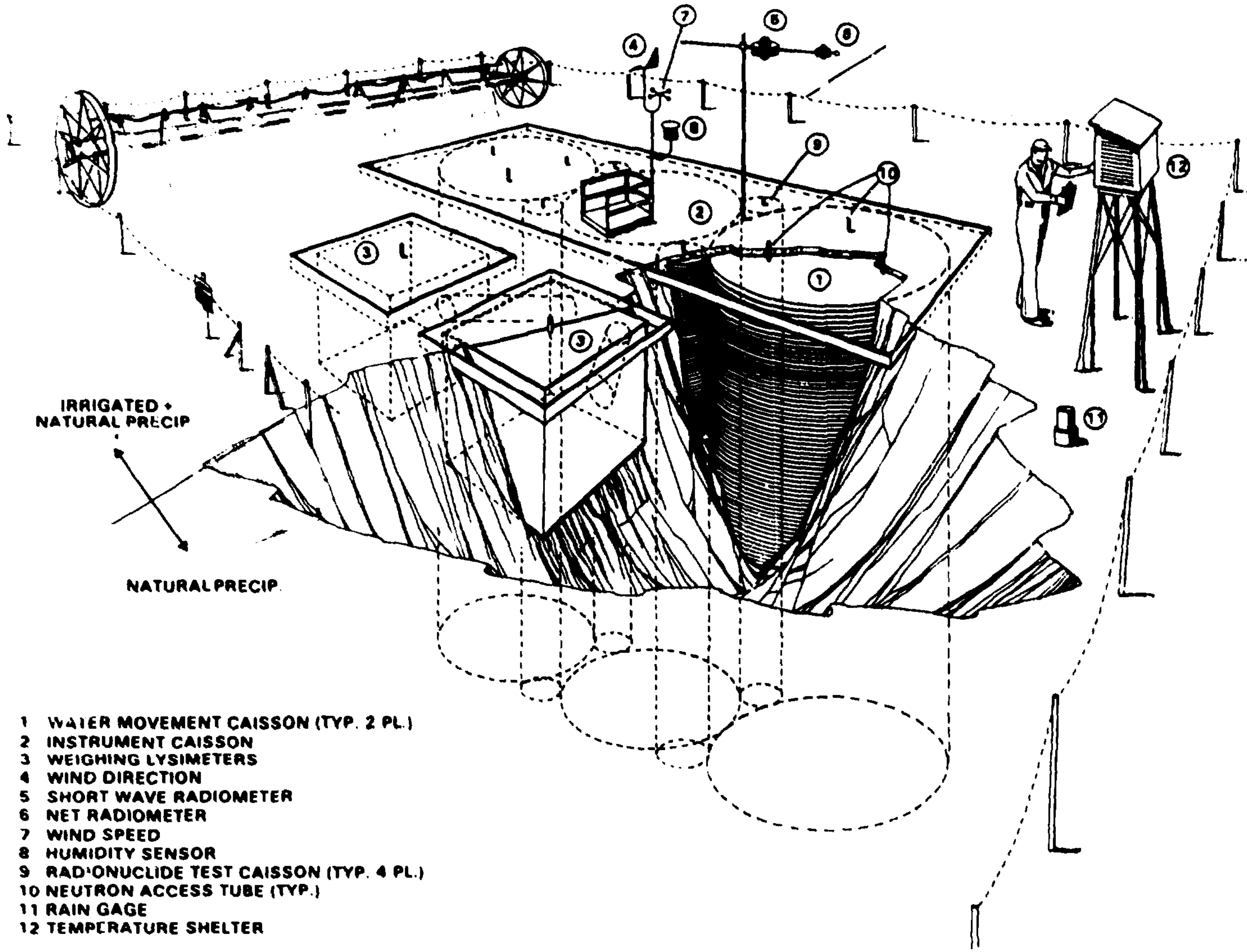
The Low-Level Waste Management Program (LLWMP) is providing the technology necessary to properly dispose of low-level radioactive waste by shallow land burial. As part of the LLWMP, Milestone C, Pacific Northwest Laboratory (PNL) is studying soil water movement in arid regions, as it applies to shallow land burial technology.

At the DOE Hanford Site in Richland, Washington, a field installation called the Buried Waste Test Facility (BWTF) has been constructed to study unsaturated soil water and contaminant transport. [The facility is shown schematically in Figure 1.] PNL is collecting data at the BWTF to help explain soil water movement at shallow depths, and specifically evaporation from bare soils. The soil energy balance and thermal regime is monitored by using thermocouples throughout the facility to monitor the response of soil temperature to incoming solar radiation, measured by both net radiometers and short-wave radiometers. The water balance is monitored with surface rain gauges to record precipitation and with neutron moisture gauges to follow changes in soil water content at depth. There are also two load-cell-type weighing lysimeters to provide direct measurements of average evaporation rates. Data recorded at the BWTF are to be used to evaluate various methods for predicting water and energy balance changes that could take place in a shallow land burial ground. Calculation procedures proven acceptable may then be used to aid the design and evaluation of burial ground cover designs.

WATER BALANCE STUDIES

Preliminary calculations of lysimeter water balance have been performed for the two weighing lysimeters at the BWTF lysimeters. Precipitation, irrigation, and drainage data for 1979 and 1980 are represented in Figure 2. One lysimeter was irrigated so the total water added (irrigation and precipitation) was approximately three times ambient levels on an annual basis. The other lysimeter received only ambient levels of precipitation. In Figure 2, the precipitation data are from rain gauges located on the BWTF plot and represent ambient levels of rainfall. The

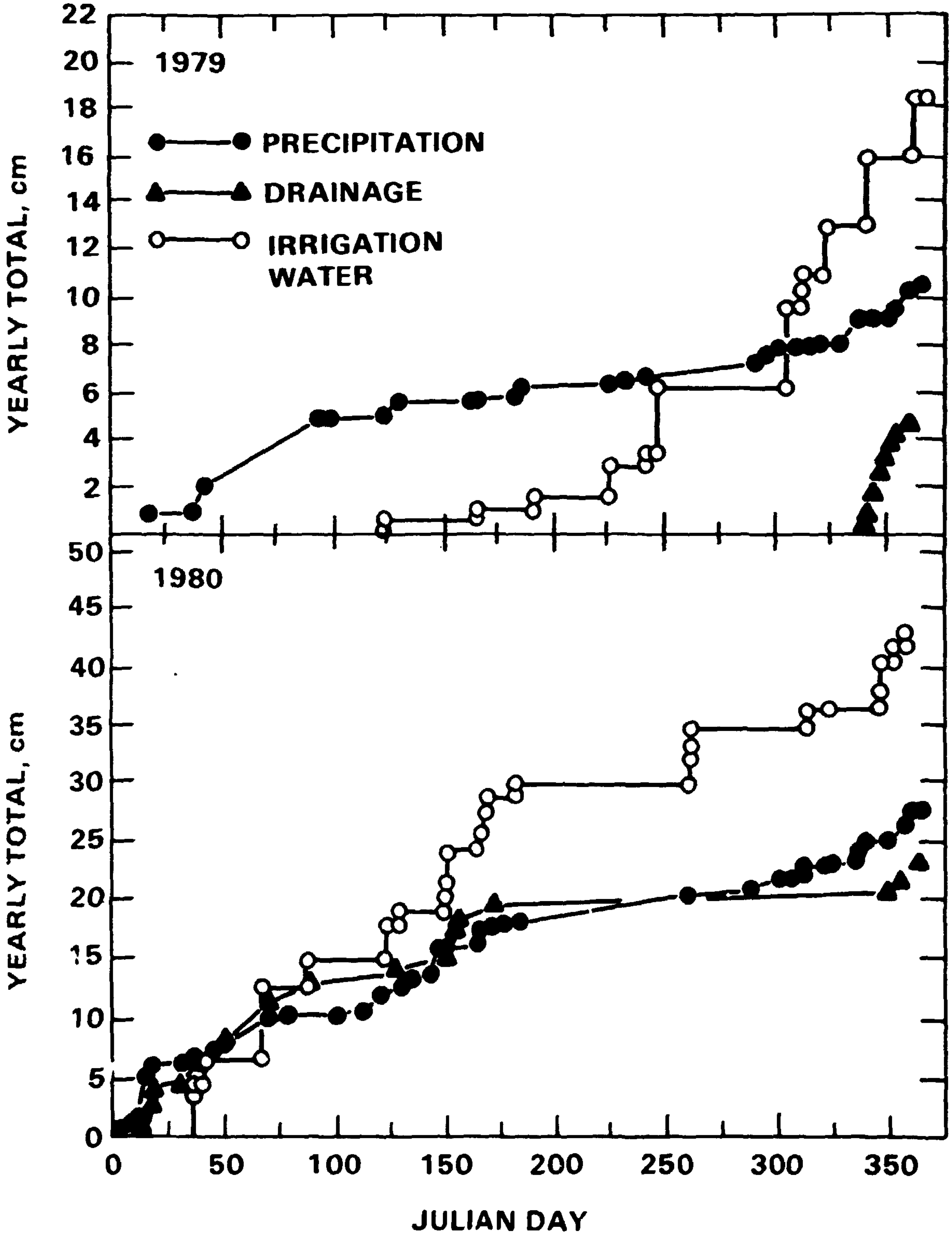
BURIED WASTE TEST FACILITY



1 WATER MOVEMENT CAISSON (TYP. 2 PL.)
2 INSTRUMENT CAISSON
3 WEIGHING LYSIMETERS
4 WIND DIRECTION
5 SHORT WAVE RADIOMETER
6 NET RADIOMETER
7 WIND SPEED
8 HUMIDITY SENSOR
9 RADIONUCLIDE TEST CAISSON (TYP. 4 PL.)
10 NEUTRON ACCESS TUBE (TYP.)
11 RAIN GAGE
12 TEMPERATURE SHELTER

Figure 1.

Fig. 2. Precipitation, Irrigation and Drainage Records for the Burial Waste Test Facility



precipitation curve applies to both the ambient and irrigated lysimeters. The irrigation data are a record of water added to the irrigated lysimeter in addition to the ambient precipitation.

The drainage curves represent the water removed through ceramic suction candles located in the bottom of the irrigated lysimeter. No water was removed from the ambient lysimeter until 1981. Neutron probe data show no significant change in the total water storage in either lysimeter, so Figure 2 gives a rough approximation of the lysimeter water balance. The fact that no water was removed from the ambient lysimeter and there was no measurable increase in total stored water implies that the total evaporation was approximately equal to the total precipitation. Water was removed in 1981, indicating that there probably was some storage of water during 1979 and 1980, but the neutron probe measurement technique as too insensitive to account for small increases or decreases in water content. The results are quite different for the irrigated lysimeter, where 17% of the total water added (irrigation and precipitation) was drained from the lysimeter in 1979 and 33% in 1980.

These results indicate that in a year of less than average precipitation, a small net loss of water may be realized while in years of normal to high precipitation a net gain of water would result. How this averages out over long time periods is still unknown. Also, these data are for bare soils. If vegetation were present, much lower drainage rates would be expected even under irrigated conditions.

FIELD MOVEMENT OF TRITIUM

In order to monitor the movement of radionuclides in situ, tritium was placed in two of the tracer caissons at the BWTF. One tritium caisson is on the irrigated half of the facility and one is on the ambient half. The tracer was placed into the caissons at a depth of 60 cm in the form of a 1 cm thick layer of soil which contained tritium at a concentration of 6.34 μCi/g.

The tracer study was initiated in April of 1979 and Figure 3 shows the tritium profiles measured four times between October 1979 and September 1980. The tritium measurements were made on soil samples obtained by destructive sampling through the caisson walls. A two to four gram sample was removed each time.

Figure 2 shows that during the period of April 1979 to September 1980 approximately 25 cm of precipitation was added to the ambient caisson while over 78 cm of rain plus irrigation was added to the irrigated caisson. This caused enough drainage in both caisson to move the tritium to below the 7 meter level. The tritium buried in the irrigated caisson naturally shows the greatest amount of movement.

Two interesting concepts can be illustrated by Figure 3. First is the upward movement of tritium from the 60 cm level during tracer placement

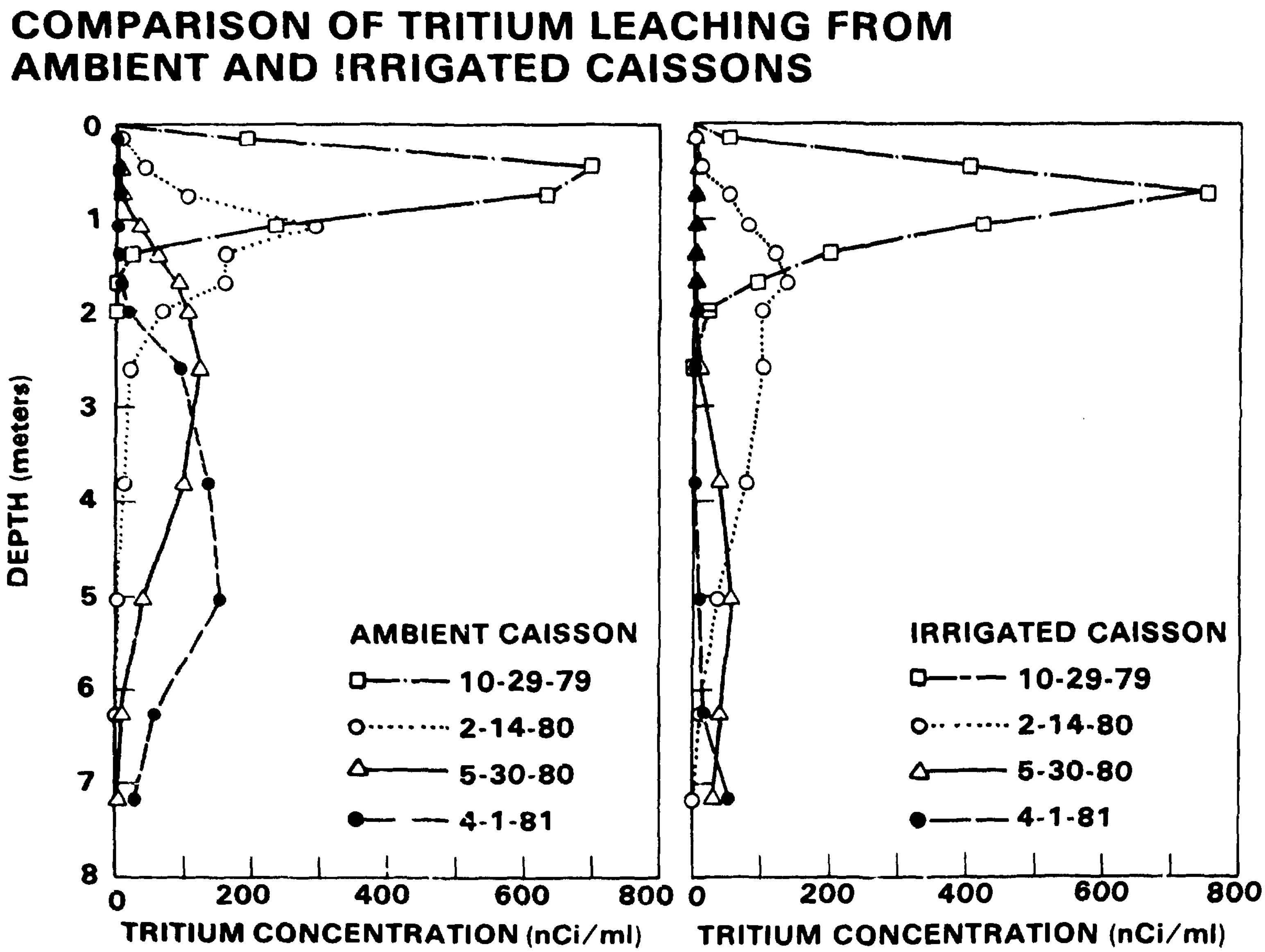


Fig. 3. Field Tritium Concentrations in Caissons

in April 1979 and the first sampling in October 1979. During this time there was approximately 2 cm of precipitation added to the ambient caisson and 8 cm of rain and irrigation added to the irrigated caisson. This water was added at small increments over the summer months when evaporation was highest. Whether the upward movement was caused by the evaporation of water at the soil surface or by self-diffusionof tritium in the water is not known at this time. During the summer of 1980 no upward movement is seen because by that time the tracer had been moved to a deep enough depth that the water flow was consistently downward.

The second concept illustrated is the apparent reversibility of the tritium movement. The figure shows upward movement of tritium during times of upward flow of water, but during times of drainage the tritium is carried deeper into the caisson. This implies the movement of tritium follows the net movement of water and therefore may be modeled with steady-state approximations of the transient water flow. The low Kd value of tritium makes this an expected result but more work needs to be done to examine the validity of this concept for highly sorbed radionuclides.

Dup

EFFECT OF ORGANIC COMPLEXANTS ON THE MOBILITY OF LOW-LEVEL WASTE RADIONUCLIDES IN SOILS

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During the last year, we have been attempting to quantitatively determine the effect of (selected) organic complexants on the equilibrium sorption properties of typical low-level waste radionuclides on soils. Development of standard procedures for such quantitative determinations was also an objective of this work.

The systems we have examined are listed in Table 1. The five elements studied have radionuclides that are present in low-level wastes. Cesium, strontium, cobalt, and nickel radionuclides are the predominant ones present in nuclear power plant wastes, which comprise a large fraction of the low-level wastes generated in this country. EDTA and DTPA are complexants that are commonly used in the nuclear industry, and thus may be present in low-level wastes. Humic acid is a complexant that occurs in some soils. Hanford soil is typical of that encountered at the Hanford site, but results obtained with it may not be at all the same as results obtained with soils from other low-level waste disposal sites. All our work so far has been in the presence of air; different results might result in some systems under reducing conditions that exist in some groundwaters. We are preparing to make some measurements under anoxic/reducing conditions.

Table 1. Systems Examined in FY 1981

Element:	Eu, Cs, Sr, Ni, Co
Complexant:	EDTA, DTPA, Humic Acid
Soil:	Hanford
Atmosphere:	Air
Temperature:	Ambient (~21°C)
Type of Experiment:	Batch

The goal of this work has been to obtain data that are at equilibrium so that the results would be meaningful in a thermodynamic sense. This goal was met with europium, cesium, and strontium but, unfortunately, this has not been possible with cobalt and nickel where slow kinetics have prevented equilibrium data from being obtained. Slow, but measurable, rates of complex formation and of complex dissociation (when diluted) have been observed. Some of these reactions are so slow that the utility of thermodynamic-type data in predicting the migration of cobalt or nickel from a complexed source is highly questionable. However, some of the complex dissociation reactions are fast enough that migration predictions based on continuation of complete complexing would also be of questionable accuracy (but defensible on the basis of conservatism).

Figure 1 presents typical data illustrating the slow changes with time in the cobalt or nickel/EDTA or DTPA/Hanford soil systems (in the presence of air). Essentially identical results were obtained at a soil-to-solution ratio of 0.010 g/ml as at 0.033 g/ml; this suggests that the slow changes are being caused by the slow complex dissociation rather than by slow soil-sorption reactions.

There is another feature to these data, aside from the slow changes with time, that illustrates the overriding importance of kinetic factors in these systems. Thermodynamically, the DTPA complexes of nickel and cobalt are reported to be stronger than the EDTA complexes. Thus, at equilibrium at a given pH and a given free complexant concentration, a greater fraction of nickel or cobalt should remain in solution in the DTPA cases than in the EDTA cases. Since the reverse behavior has been observed (so far) in these experiments at the same pH and total complexant concentrations (thus presumably at comparable free complexant concentrations), it is concluded that the attainment of equilibrium in some of these systems is extremely slow.

The data of Figure 1 were obtained with dilutions (to 1.0×10^{8} M DTPA or EDTA and 5.0×10^{-9} M Co or Ni) of 2-day old stock solutions that contained 2×10^{-5} M complexant and 1×10^{-5} M metal ion. When similar experiments were done with 35-day old stock solutions, the additional aging was found to have little or no effet in the Co/EDTA system but a large effect in the Co/DTPA system. With dilutions of the 35-day old stock solutions, the fraction of cobalt remaining in solution was slightly higher in the DTPA case than in the EDTA case, instead of being markedly lower as was the case with the 2-day old stock solutions. This result demonstrates the existence of another kinetic problem in the Co/DTPA system; that is, slow attainment of an equilibrium complex position in the absence of soil even at the 10^{-5} M concentration level. It is thought that slow attainment of this equilibrium position may involve oxidation of Co(II) to Co(III).

In other series of experiments we are attempting to define how high the complexant concentration must be to prevent dissociation of the cobalt complexes. Figure 2 presents the initial results obtained at soil-to-solution ratios of 0.033 g/ml, with dilutions of 35-day old stock solutions. It is apparent that the free complexant concentration is not

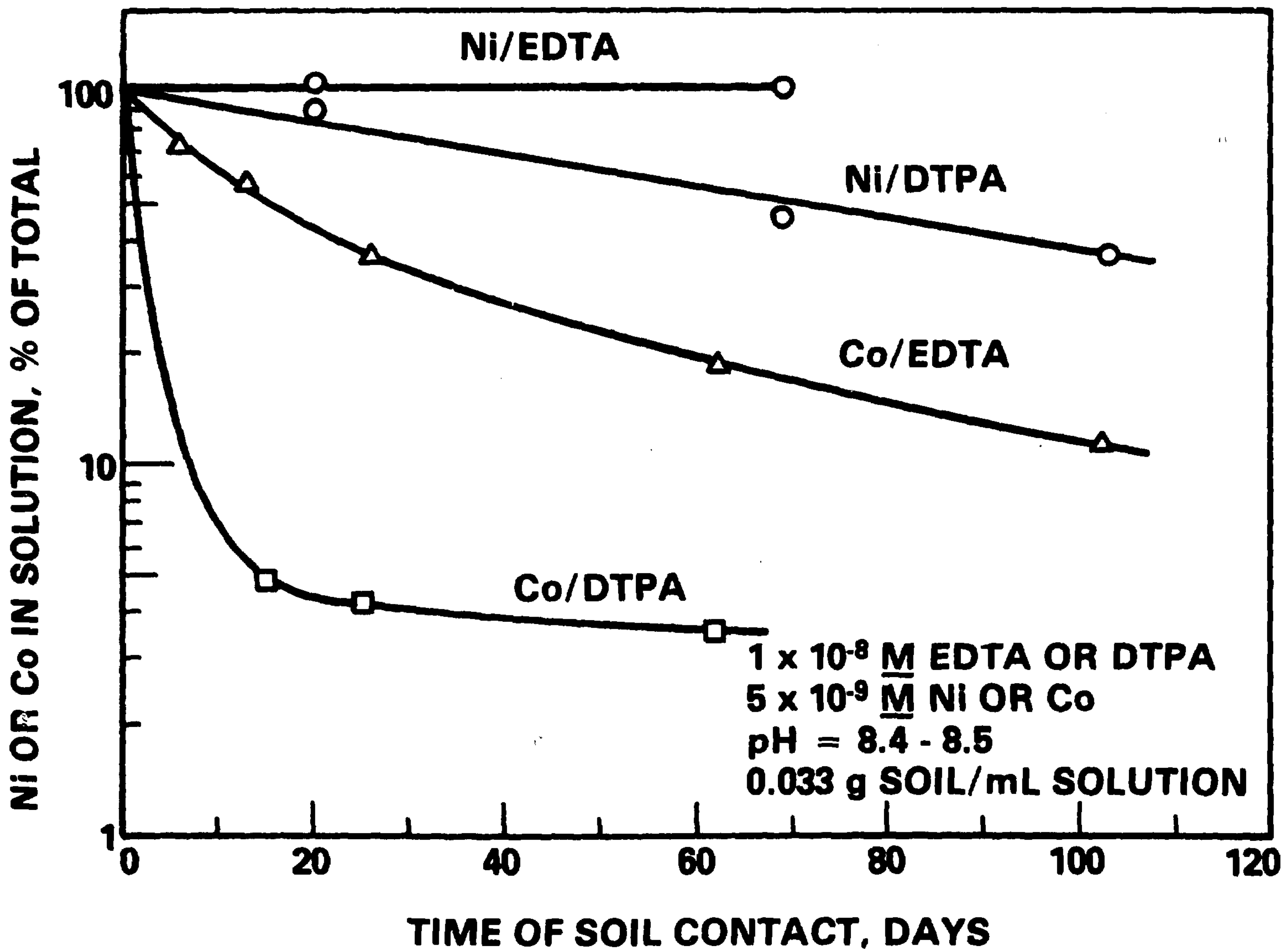

Fig. 1. Examples of Slow Dissociation and Sorption in Nickel and Cobalt Systems

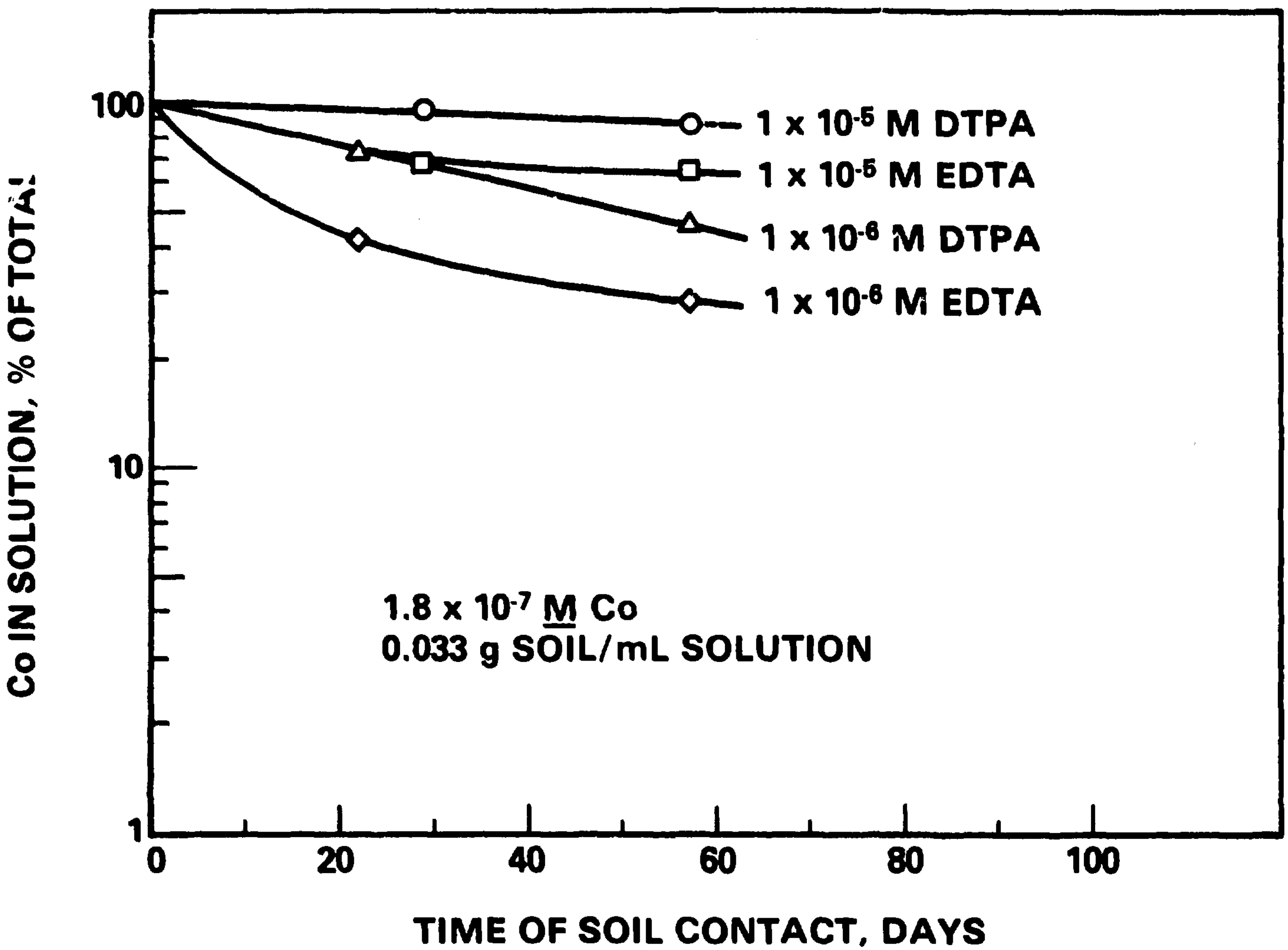

Fig. 2. Effect of Complexant Concentration on Cobalt Behavior

sufficiently high to prevent complex dissociation at a 10^{-5} *M* total complexant concentration.

Similar experiments with these complexants and Hanford soil have shown concentrations of calcium in solution that are higher than the complexant concentrations. Because of the stability of the Co/EDTA and Co/DTPA complexes, the concentration of free complexant must be much lower than the concentration of total complexant.

Some experiments have also been done in which nickel and cobalt were first sorbed onto soil in the absence of complexants and then complexants were added to desorb the metal ions. Results of such experiments with EDTA are given in Figure 3. Desorption is seen to also be a slow process, especially for nickel. From the results of the sorption experiments presented earlier, all of the nickel or cobalt should be in solution at equilibrium under the conditions of these experiments.

Shifting now to the europium/EDTA system, there are results that are much more pleasing than those obtained with nickel and cobalt. With europium, apparent equilibrium values were obtained within a week or two from either the sorption direction or the desorption direction. Furthermore, the distribution coefficients were independent of the direction of approach to equilibrium; this is a good indication that the values are indeed equilibrium values and thus useful in a thermodynamic sense.

The Eu/EDTA data are shown in Figure 4. The Eu distribution coefficient (apparent Kd) decreases regularly with increasing total EDTA concentration at a given soil-to-solution ratio. There is a slight effect of the soil-to-solution ratio; higher distribution coefficients are obtained at higher ratios. This is thought to be due to lower free EDTA concentrations at the higher ratios, caused by increased complexing by calcium leached from the soil.

Only a few experiments were done with cesium and strontium. The results verified the expected lack of effect of complexants on the sorption behavior of these elements (Table 2).

As mentioned earlier, one of the initial goals of this work was to develop meaningful equilibrium data and another was to develop standard procedures for obtaining such data. Since there is often no correlation between an equilibrium position and a position that does not change measurably in a convenient time period, a prime concern has been proof of equlibrium. One procedure that has been valuable in this area is to approach equilibrium from both the sorption (in which previously complexed metal ions are contacted with soil) and the desorption (in which metal ions are sorbed by soil in the absence of complexants and complexants are then added) directions. If the same result is obtained

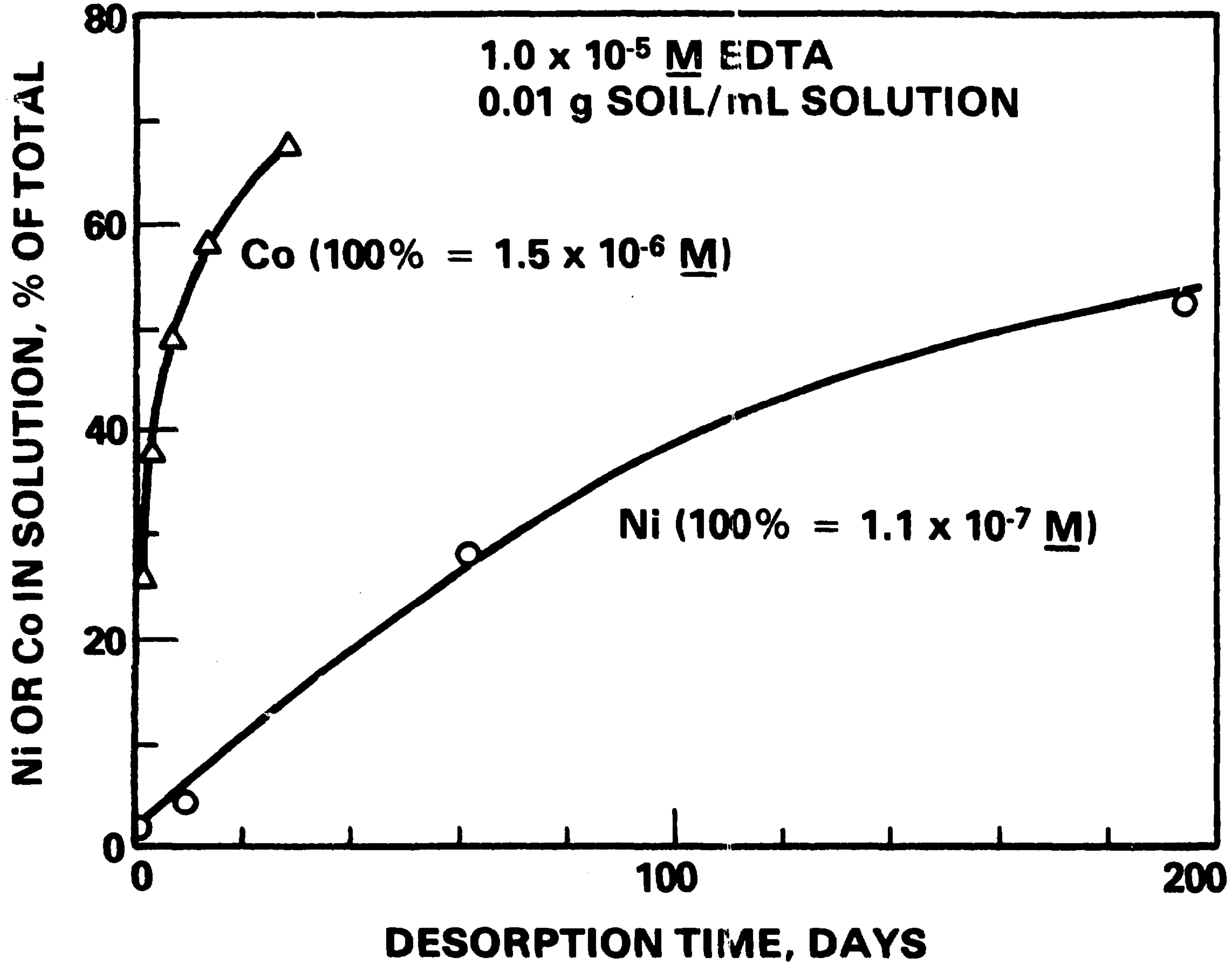

Fig.3. Examples of Slow Desorption with Nickel and Cobalt

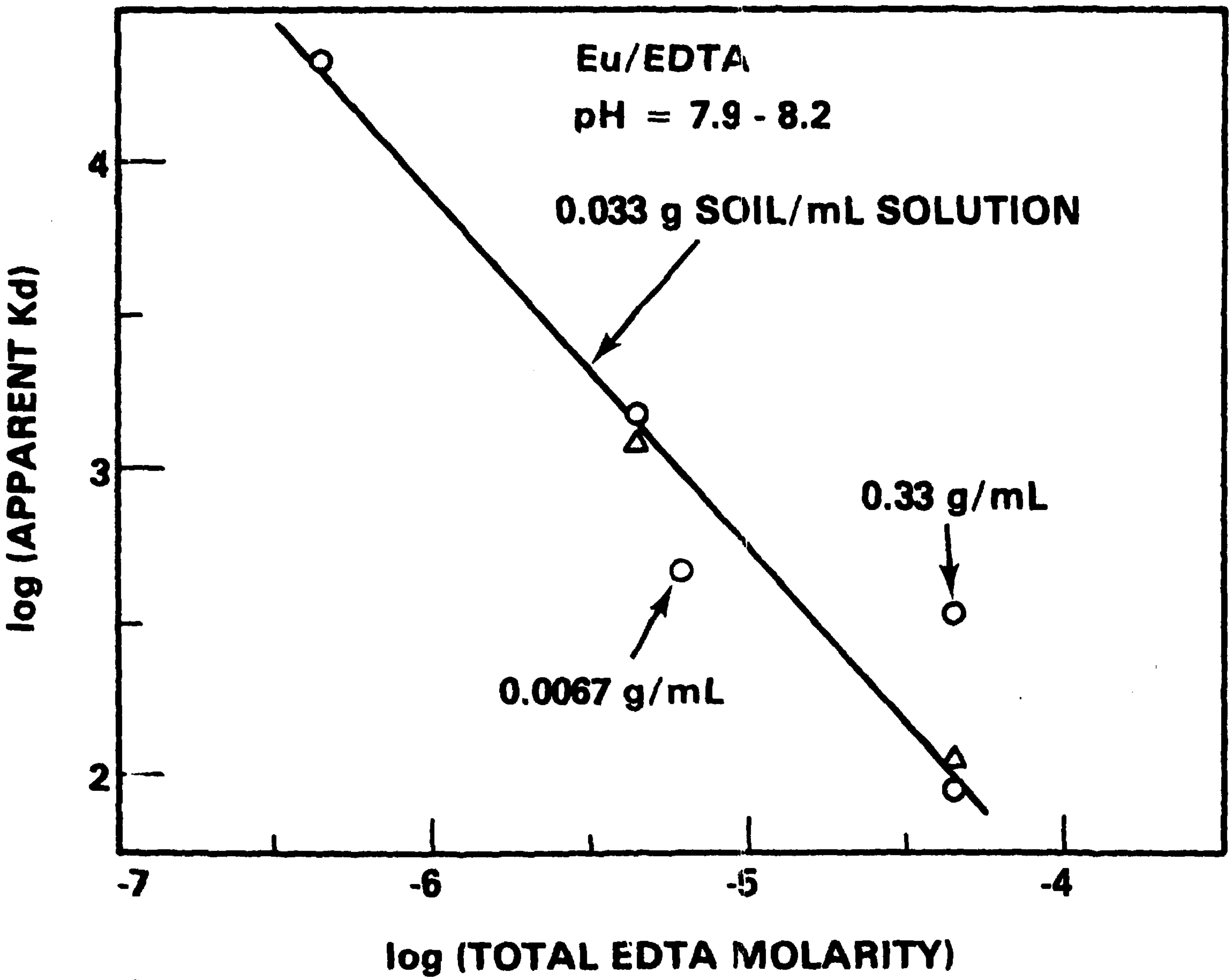

Fig. 4. Results with Europium/EDTA System

Table 2. Results with Cesium and Strontium

Element	Complexant	Apparent Kd
Cs	--	7400
	9×10^{-5} M EDTA	5500
	4×10^{-4} M DTPA	8700
Sr	--	180
	9×10^{-5} M EDTA	180
	1×10^{-4} M DTPA	180

from both directions, the result is indeed an equilibrium result. Another very valuable procedure has been to contact a solution that appears to be at equilibrium with one portion of soil with a second portion of soil. Unless the same distribution coefficient is obtained in the second contact as in the first, the result is not an equilibrium result.

The Eu/EDTA data shown earlier (Figure 4) showed comparable distribution coefficients for the two different directions of approach to equilibrium. The second contact procedure also gave comparable results (indeed, even a third contact gave comparable results) in this system (Table 3), further demonstrating that this is a well-behaved system. Such was not the case with nickel systems, however. With this metal ion, some early results were shown to be invalid by this second contact procedure (Table 3). While the early results looked good within themselves, the second contact procedure showed that they were not valid. Further investigation then showed that they were artifacts of the experimental procedure employed (insufficient time was allowed for complex formation to occur before contact with soil was begun).

We are continuing our study. Currently planned areas of investigation include: 1) the kinetic aspects of the nickel and cobalt systems, 2) work under anoxic/reducing conditions, and 3) work in other element/complexant/soil systems.

Table 3. Results of Multiple-Contact Experiments

System	Contact Number	Contact Time, Days	Apparent Kd, ml/g
Eu/EDTA	1	7	24
	2	7	37
	3	7	44
Ni/EDTA	1	6	180
		17	185
	2	7	0
Ni/DTPA	1	7	16
		14	20
	2	7	C

MICROBIAL EFFECTS ON RADIOACTIVE WASTES AT SLB SITES

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ABSTRACT

A significant fraction of DOE and commercially generated low-level radioactive waste consists of organic materials. These materials are subject to degradation by microorganisms present in the shallow land burial environment and may contribute to enhanced migration of radionuclides through the formation of gases, mobile complexes and bioaccumulation. This scanning study will determine the effects of microbial degradation at present disposal sites and their impact on shallow land burial performance criteria, trench construction and segregation of organic wastes.

The main objective of this program is to determine the significant effects of microbial activities on shallow land burial (SLB). The program is in support of DOE/LLW Management Program alpha milestones 3, C, and D.

INTRODUCTION

A significant fraction of DOE and commercially generated low-level radioactive waste consists of organic materials such as those shown in Table 1. These materials are subject to degradation by microorganisms present in the shallow land burial disposal environment and the wastes themselves. This degradation, in turn, may contribute to enhanced migration of radionuclides (and chemically toxic compounds) into the biosphere by a number of mechanisms. Such microbial effects include direct attack on the waste form/container, alteration of the trench environment (e.g., pH, redox potential), formation of mobile complexes,

Table 1. Typical Organic Materials Buried At Shallow Land Disposal Sites

Clothing	Oils
Plastics	Ion Exchange Resins
Paper	Liquid Scintillation Cocktails
Cellulosics	Animal Carcasses
Rubber	Solidification Agents
Solvents	

bioaccumulation and gas generation. Problems relevant to subsidence and trench deterioration have also been attributed to microbial degradation of solid organic wastes.

While several mechanisms for enhanced radionuclide migration as a result of microbial degradation have been proposed (and some observed), there is no consensus concerning which mechanisms predominate or whether they are even significant. The significance of microbial degradation, however, may vary widely between humid and arid sites.

The biodegradation of organic wastes, if indeed significant to radionuclide migration, may impact several areas of waste disposal technology. In particular, it may suggest the segregation or even exclusion of some organic wastes from burial at a given site. This could also affect acceptable waste forms (solid fication agents) and the need for additional waste treatment operations, such as incineration, which are aimed at decreasing the amount of organic wastes in disposal. Microbial degradation may influence shallow land burial siting criteria and trench construction. It may also impact interim storage and transportation of organic wastes.

This scanning study will determine the significance of the biodegradation of organic low-level radioactive wastes in shallow land burial and, if significant, ascertain which mechanisms predominate and under what conditions. Recommendations will be developed with the object of minimizing the impact of microbial degradation or radionuclide migration.

PROGRAM OBJECTIVES

The objectives of this program are: (1) determine the significance of microbial degradation of organic wastes on radionuclide migration in shallow land burial for both humid and arid sites, (2) establish which mechanisms predominate, (3) ascertain the conditions under which these mechanisms operate, (4) provide recommendations directed towards minimizing the effect of degradation on the mobility of radionuclides in shallow land burial (such as segregation/exclusion of some wastes/waste forms) and (5) assess the impact of these recommendations on waste treatment, interim storage, transportation and disposal.

This work was identified as a major data need in "Unresolved Technical Issues in Land Burial of Low-Level Radioactive Wastes," ORNL/NFW-79/62 (October 1979). The program is in direct support of DOE/LLW Management Program Alpha Milestone B, "Develop technology for waste treatment, handling, and packaging for shallow land burial site disposal", Milestone C, "Develop technology and documentation to support a shallow land burial site", and Milestone D, "Develop remedial action technology for shallow land burial sites".

PROGRAM AREAS

The program will consist of literature and experimental work, where required, to identify the significant mechanisms that may contribute to the migration of radioactivity at shallow land burial sites resulting from microbial degradation of organic materials. Work tasks for FY 82 include: (1) Identification of significant microbial degradation mechanisms, (2) Assessment of microflora in humid and arid SLB sites, (3) Bioaccumulation and transformation of radionuclides, (4) Microbial generation of volatile compounds, (5) Microbial degradation of organic compounds and organo-radionuclide complexes, and (6) Other mechanisms that may enhance radionuclide migration.

Identification of Significant Microbial Degradation Mechanisms

A literature search will be made to determine the present state of knowledge dealing with radionuclide movement attributed to microbial activities at shallow land burial sites. Technology gaps will be identified and experimental work will be conducted to generate new data or to supplement existing data where required.

Assessment Of Microflora In Humid And Arid SLB Sites

Microorganisms indigenous to humid and arid SLB sites, such as aerobic, anaerobic, sulfate reducing, denitrifying and methanogenic bacteria will be identified and classified with respect to the role they play in the decomposition of organic materials. This will permit quantification of both the potential for microbial interactions with low-level radioactive waste materials and the effects of these interactions on enhanced migration of radionuclides.

Bioaccumulation And Transformation Of Radionuclides

Microorganisms are capable of uptake and retention of various radionuclides which can be transported by ground water movements and released to the environment upon cell lysis. Several isolates of bacteria from the trench environment will be evaluated for their ability to bioaccumulate one or more of the radionuclides (e.g., ^{60}Co, ^{90}Sr, $^{134,137}Cs$, $^{238,239,240}Pu$) normally found in SLB trenches.

Microbial Generation Of Volatile Compounds

Organic compounds, in soils, can be degraded by bacterial action to yield H_2, CH_4, CO_2, H_2S, NO_x, low molecular weight volatile organic acids, alcohols, aldehydes, ketones and esters under aerobic and anaerobic conditions. Trenches at SLB sites are known to contain ^{14}C-carbon compounds and tritium in abundance. Volatile gases resulting from microbial activity, such as CO_2, CH_4, H_2, H_2S, will not only contain radioactivity but could result in possible container pressurization and explosion. Radioactive gases emanating from selected trenches at a humid and arid SLB site will be identified and quantified. This work will be done on a limited basis for the purpose of assessing the amounts of ^{14}C-tagged and tritiated methane released into the atmosphere as well as its impact on personnel safety and other life forms at the burial site.

Microbial Degradation Of Organic Compounds And Organo-Radionuclide Complexes

Organic wastes can be degraded by microbial processes to innocuous compounds or transformed into compounds having an affinity to form complexes with radionuclides. Microorganisms can also act upon existing organo-radionuclide complexes to release radionuclides as water insoluble compounds or as compounds which can easily be transported by ground water movement. The rate of degradation of the various organic materials found in SLB trenches and organo-radionuclide complexes will be determined.

Other Mechanisms

Microbial interaction with radionuclides could also enhance volatilization through alkylation reactions. Methylation of heavy metals occurs under both aerobic and anaerobic conditions to form volatile toxic compounds. Attempts will be made to identify and characterize radioactive methylated compounds resulting from microbial activities although the production of such species has not been previously reported in the literature. Microbial production of chelated radionuclides will also be examined.

SIGNIFICANT RESULTS

Since this is a new program that commenced in FY 1982, significant results are not available.

MONITORING AND PHYSICAL CHARACTERIZATION OF UNSATURATED ZONE TRANSPORT: MODEL DOCUMENTATION AND APPLICATION

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INTRODUCTION

A major part of the zone transport project has been to evaluate the applicability of existing water and solute transport models. The water transport work has evaluated the common parameter estimation techniques, particularly hydraulic conductivity, and is currently concentrating on evaluating evaporation models. The solute transport work has been evaluating the applicability of two solute models to a variety of radionuclides and transport coniditions. The models examined are the two parameter convective-dispersive equation and the four parameter mobile-immobile water equation of van Genuchten and Wierenga. The movement of tritium and strontium-85 was evaluated using standard column methods and the movement of strontium-85 was also investigated under changing levels of soil salinity.

UNSATURATED CONDUCTIVITY MEASUREMENTS

The method of Campbell (1974) and the method of Bresler, Russo, and Miller (BRM), (1978) were compared against measured steady state values (Figure 1). The Campbell method is highly dependent upon the range over which the experimental coefficient b, (equation 3) is determined. In these tests, the slope (b) of the log-transformed pressure head versus water content curve was determined over the 10 to 100 cm matric potential range at the flexpoint of the water retention curve, as recommended by van Genuchten (1980a). For soil bulk densites of 1.65 g/cm^3 and 1.80 g/cm^3, the b values were 1.84 and 2.29, respectively. The two curves for the Campbell equation stay consistently within an order of magnitude and are in reasonable agreement with the experimentally measured values using steady state methods (Klute 1972). The BRM method under predicts hydraulic conducitivity at very low water contents.

Figure 2 in addition to showing experimental steady state conductivities and calculated BRM conductivities compares the calculated hydraulic conductivities of Millington Quirk (1961) and Davidson et. al (1969) with the hydraulic conductivities measured under transient evaporation conditions of Rose (1968). The conductivities measured by the method of Rose

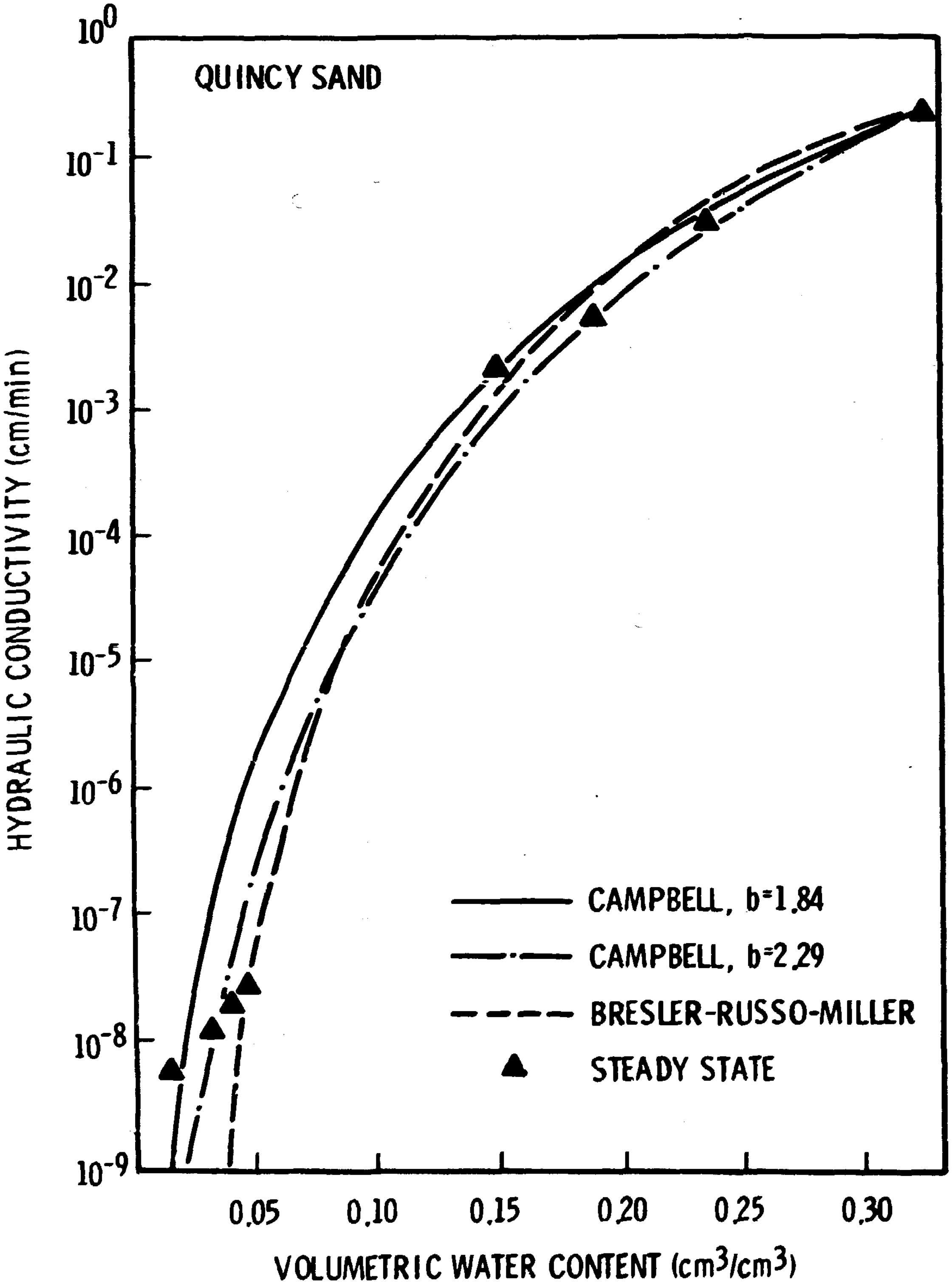

Fig. 1. Calculated and Measured Hydraulic Conductivites, Campbell and BRM Method

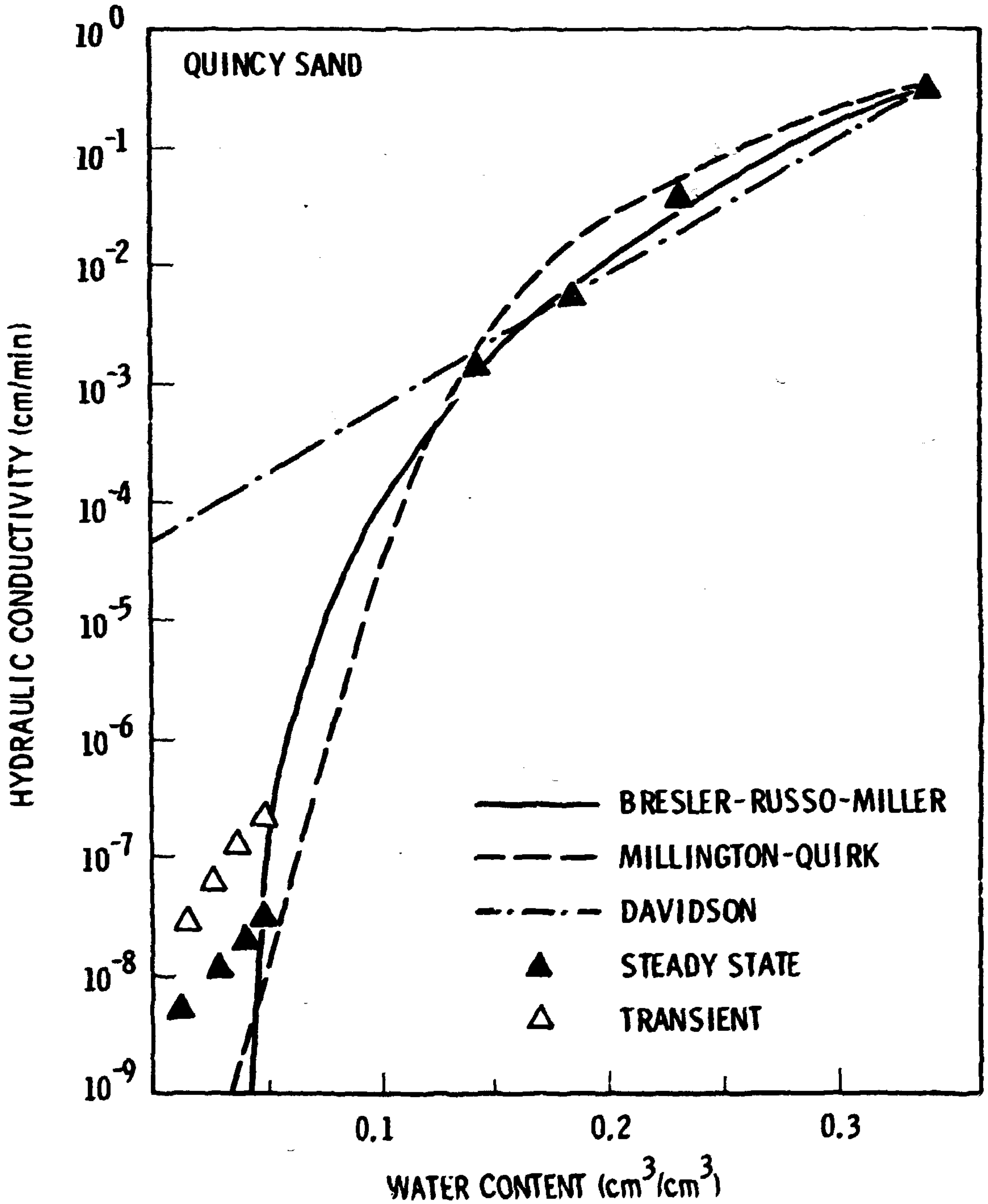

Fig. 2. Calculated and Measured Hydraulic Conductivities, BRM, MQ and Davidson et al. Methods

(1968) are somewhat higher than the steady state values. The Millington and Quirk method under predicts the low water content conductivities for this soil. The exponential relationship of Davidson et al. (1969) does a reasonable job in the wet range but over predicts the low range water conductivities by as much as three orders of magnitude.

The method of van Genuchten (1980a) was also used to evaluate the hydraulic conductivity. Analytical expressions were developed for both the wetting and drying soil water characteristics and these equations were used to generate the equation for hydraulic conductivity. When these expressions were used to calculate the hydraulic conductivity, good agreement between calculated and experimental values was obtained in the wet range of soil water contents (Figure 3) with the experimental data falling on or within the calculated curves. The model failed to match the measured dry range soil water conductivities of the steady state or transient methods.

The extensive work of Jackson (1964a,b,c, 1965) and Jackson et al. (1974) on water diffusion in dry soils indicates that the hydraulic conductivity curve can be extended to include the transport in the dry range only by accounting for water vapor diffusion. An effective conductivity which accounts for water vapor diffusion can be constructed using procedures of Fink and Jackson (1973), and Jackson (1964c) which more accurately predict the dry range hydraulic conductivity. The only input data required for this calculation is the water vapor isotherm for the soil in question. It therefore seems necessary to incorporate vapor diffusion characteristics into models where low water content data is of interest. For Hanford site burial grounds where sandy soil materials are dominant, the low water content range is of major interest. Field data show that virtually all burial ground soil profiles are drained to water contents of <0.1 cm^3/cm^3. For well drained sandy sediments like Rupert Sand, typical drained water content values range from 0.05-0.07 cm^3/cm^3. Transport by iosthermal vapor diffusion becomes increasingly more important in this range and the addition of a vapor flow term should improve the match between measured and calculated conductivities.

It is apparent from Figures 3, 4, and 5 that unsaturated hydraulic conductivities can be reasonably predicted in the wet range but care must be taken in extrapolating the equations to the low water content range. A complete analysis of vapor flow and coupled liquid and vapor flow would be required to assess the hydraulic conductivity in the dry region. Since well drained sediments at burial grounds of the Hanford site are normally drier than 0.1 cm^3/cm^3, additional effort is needed to evaluate the hydraulic conductivity relationship in this low water content range.

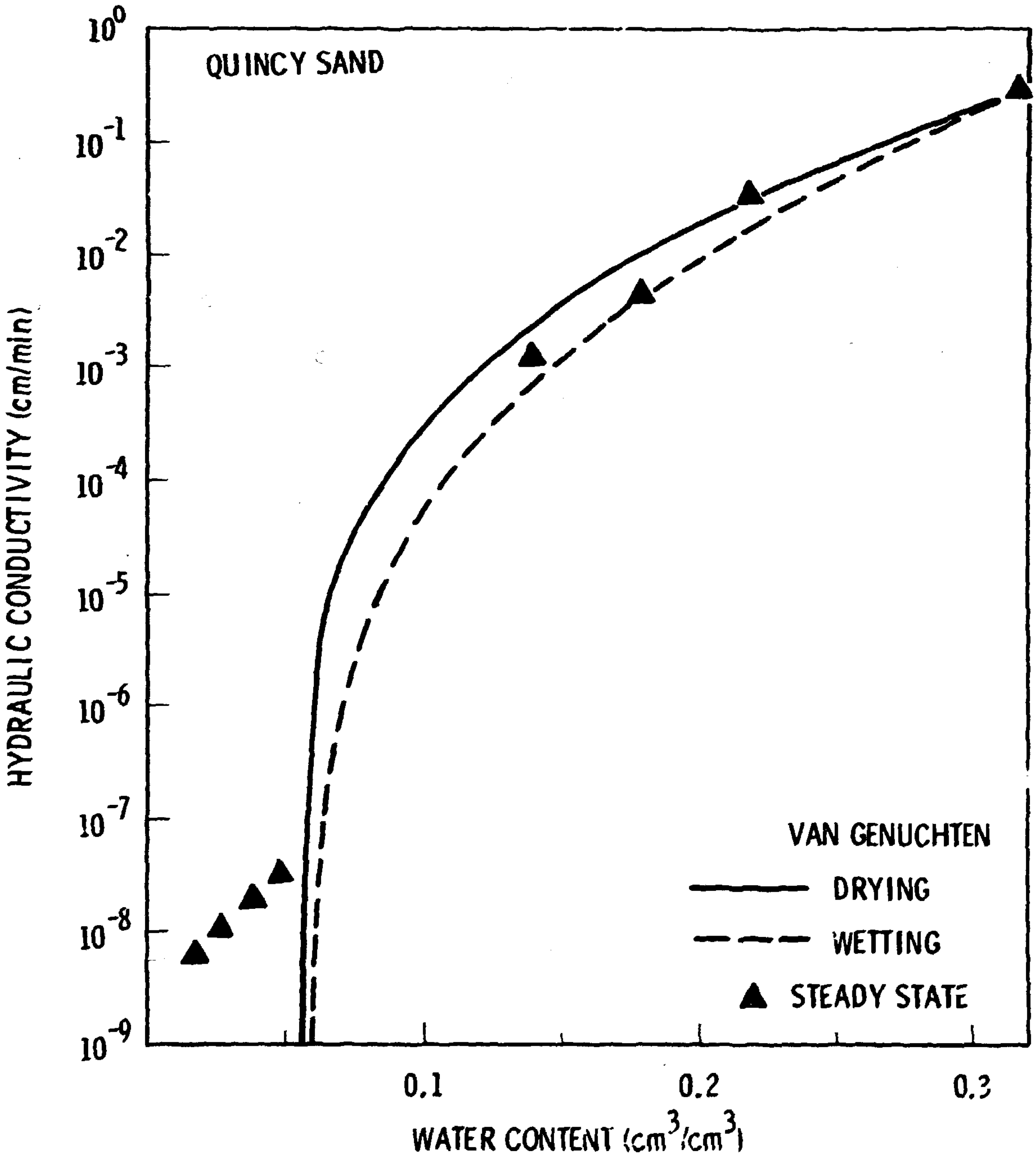

Fig. 3. Hydraulic Conductivity Determined by the Method of van Genuchten from Wetting and Drying Water Characteristics of Rupert Sand Compared with Steady State Experimental Data

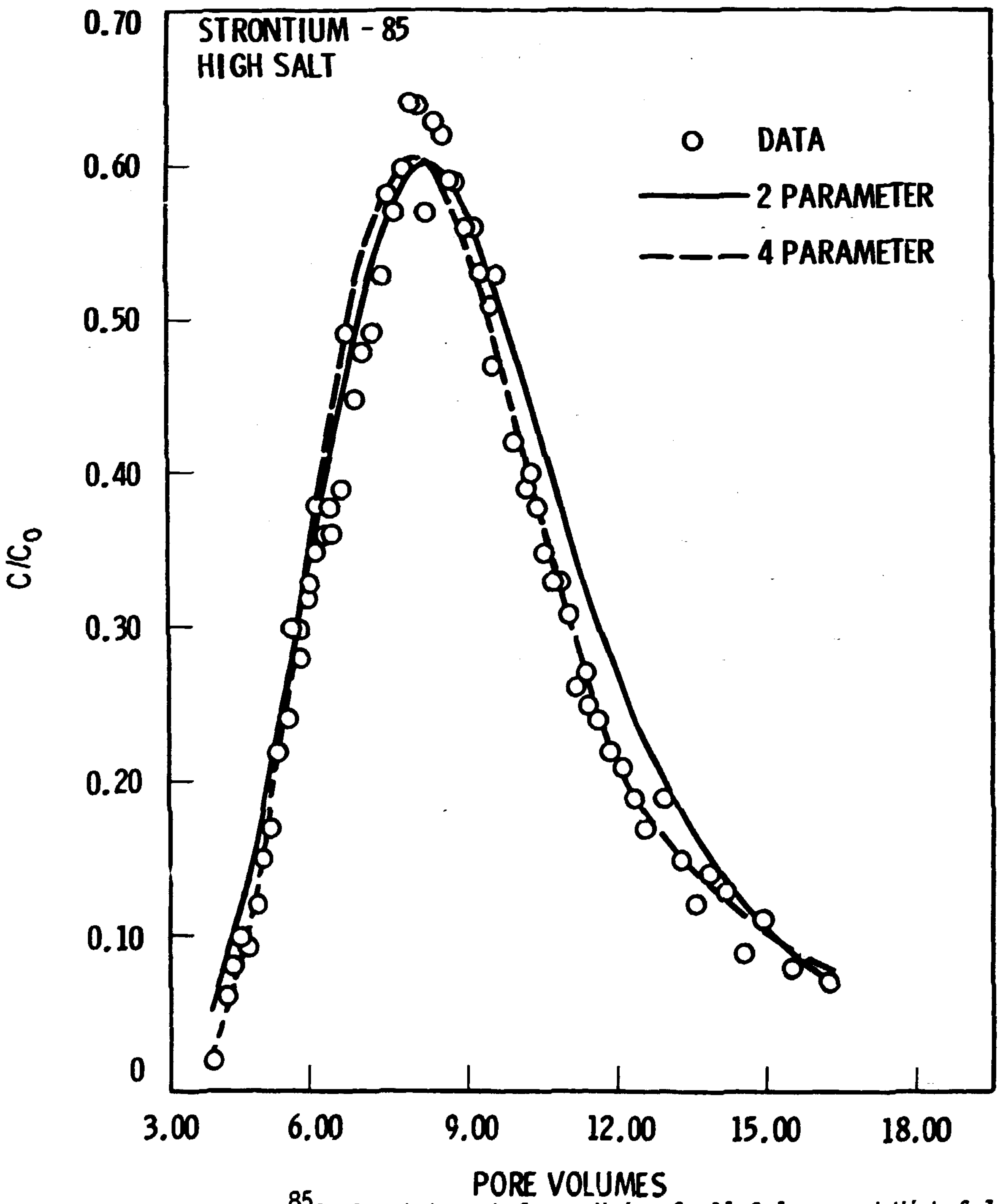

Fig. 4. ^{85}Sr Breakthrough Curve Using Small Column and High Salt Solution

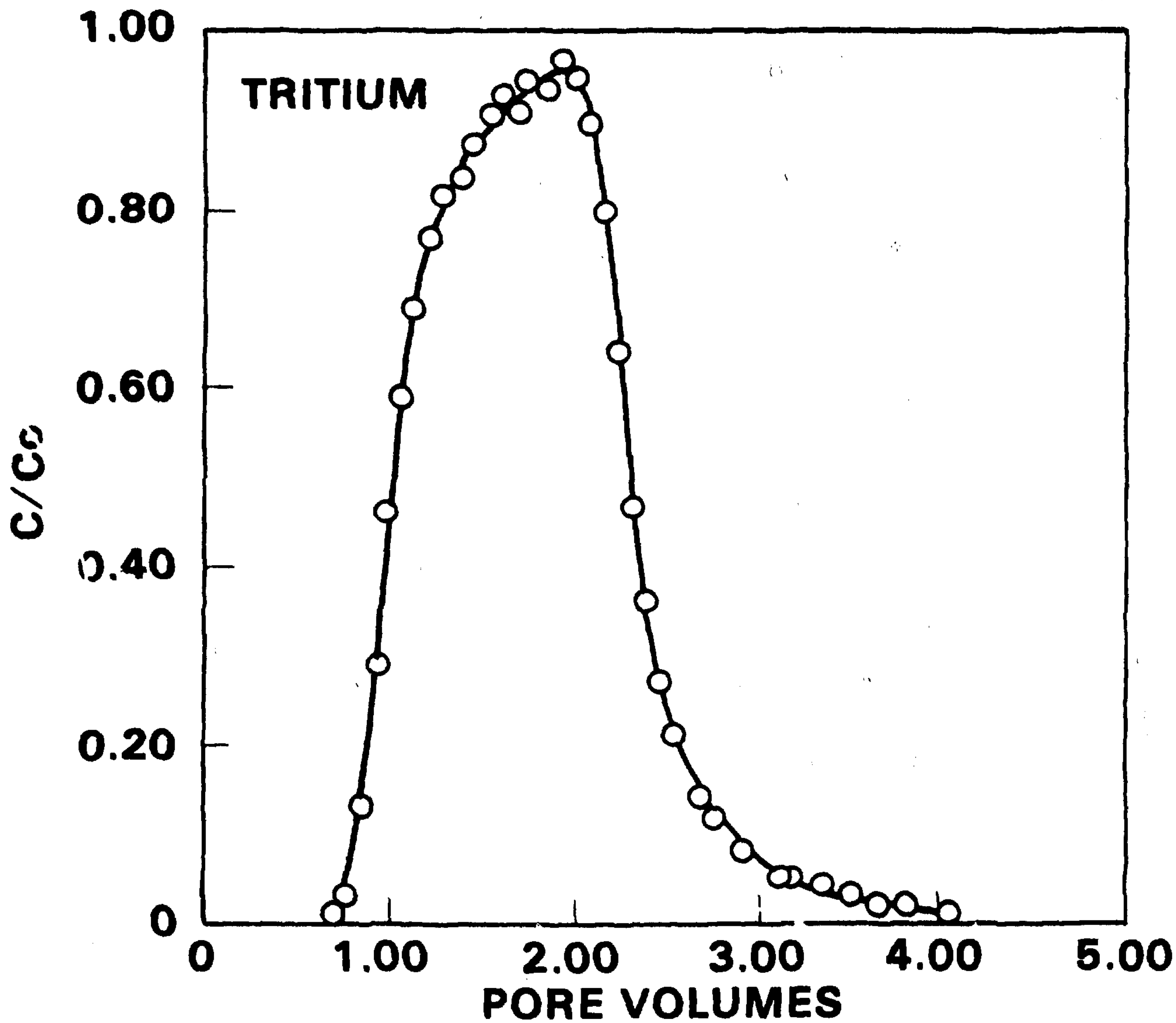

Fig. 5. Tritium Breakthrough Curve Using Small Column and High Salt Solution

EVAPORATION MODELING

The evaluation of evaporation models is being done cooperatively between PNL and Washington State University. The effort will use currently available evaporation algorithms to simulate evaporation at the BWTF. The effectiveness of each approach will be judged on total accuracy as well as soil characterization data and meteorological input needed.

One of the methods of characterizing evaporation from bare soils, being evaluated in the current study with Washington State University (WSU), involves calculating, what is called, the coupled flow of mass and energy. In most flow calculations, this "coupling" is ignored; however, evaporation is one process where such a simplification may not be justified. The WSU effort is, therefore, designed to consider coupling when evaluating evaporation from bare soils. During FY 81 the initial phase of this project has been completed which was to use samples of soil from the BWTF to measure transport coefficients and soil properties that are fundamental to the analysis of evaporation (Cass et al. 1981). Water balance and meteorological information collected at the BWTF are being summarized to allow simulation to be performed during FY 82.

RADIONUCLIDE TRANSPORT MODELING

Column and batch adsorption tests were conducted as described in Gee et al. (1980,1981). The parameter values used in the models were estimated by curve fitting solute breakthrough curves. The procedure used is a nonlinear least squares routine described by van Genuchten (1980b). The routine requires a first estimate of the parameters being fit. The curve fitting procedure was used twice on the data from the small column tritium and strontium experiments, in order to measure the reproducibility of the output. These runs are referred to in Table 7 of Gee and Campbell (1980). They are the strontium run of 10/27/78 and the tritium run of 11/27/78.

SMALL COLUMN EXPERIMENTS

Table 1 shows the parameter values obtained for both the two parameter convective-dispersive equation, and the four parameter mobile-immobile water equations. The parameter P, the Peclet number, theoretically depends only on the column length, soil moisture content, and the flow velocity. It should not depend on the solute. Table 1 shows that the four parameter fit produces an average P value for tritium of 106 while the average value for the strontium run is 29. The same column, soil, water content, and flow velocity, were used for each experiment. The Peclet numbers should be the same but they vary by more than a factor of 3. The two parameter model gives P values that vary by a factor of 6. This same observation was made by van Genuchten and Wierenga (1977b), when comparing tritium movement with movement of the pesticide 2,4,5-T.

TABLE 1. Parameter Values Estimated by Curve Fitting Routine for Small and Large Column Experiments

Isotope	Column	Fit No.	R	P	β	α
^{3}H	Small	1	1.11	111	0.86	0.50
		2	1.11	102	0.86	0.42
		avg	1.11	106	0.86	0.46
		1	1.10	113	—	—
^{3}H	Large	1	1.17	22	0.76	0.36
		1	1.01	12	—	—
^{85}Sr	Small	1	8.4	28	0.72	0.47
		2	8.4	30	0.71	0.49
		avg	8.4	29	0.71	0.48
		1	7.2	19	—	—

The second observation from analyzing these two data sets is that in some cases the two parameter equation seems to describe the data as well as the four parameter model. Figures 4 and 5 show the comparison of the two models together with the experimental data. For the strontium data, two distinct curves are produced, however in practical applications the two parameter model may prove as useful. The two curves produced from the tritium data were indistinguishable and are shown as one curve in Figure 5. The two parameter model can sometimes reproduce the curves generated by the four parameter model by adjusting the values P and R. Table 1 shows the two parameter model generally gives a much smaller P value and a slightly smaller R value. The tritium data shows something else, however. The R and P values are nearly identical between the two parameter and the four parameter models. It appears that setting α and β equal to 0.50 and 0.86, respectively, does not alter the shape of the curve to any measurable degree. Apparently the large Peclet number (106) and small R value (1.11) of our experiment reduces the affect of α and β on the shape of the curve.

LARGE COLUMN EXPERIMENT

The breakthrough curve generated for tritium from the large column experiment is shown in Figure 6. Figure 6 shows a comparison of a two parameter and a four parameter fit for the large column data. A two parameter fit corresponds to using the conventional convective dispersive equation (van Genuchten 1980b) while the four parameter fit comes from using the mobile-immobile water concepts (van Genuchten and Wierenga 1976a). The two approaches do produce different predicted curves; however, it would be hard to say that one was better than the other. Table 1 shows the values of the parameter estimates found through the curve fitting routine. As mentioned above, it can be seen that using a two parameter equation

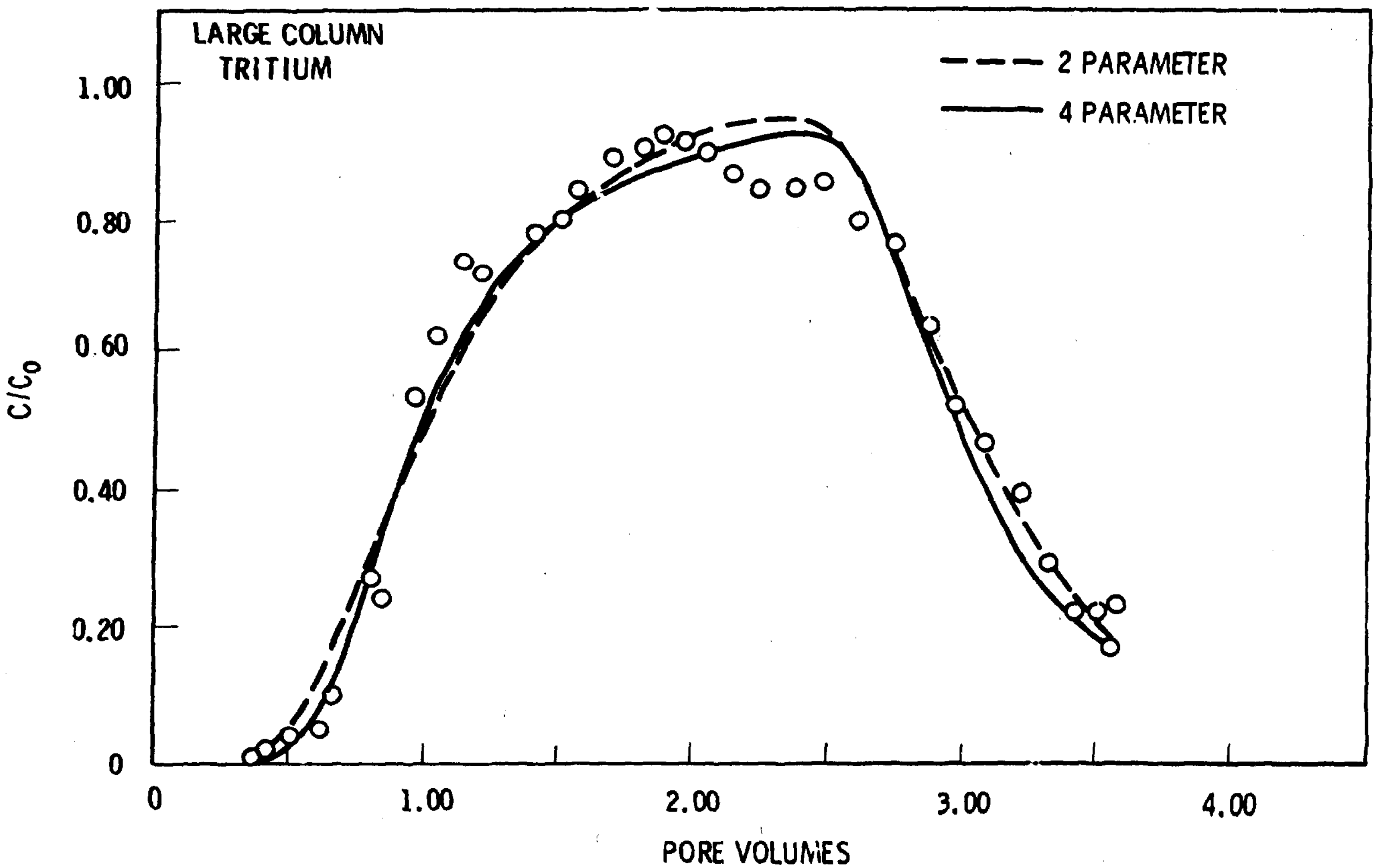

Fig. 6. Comparison of Two and Four Parameter Models for Large Column Tritium Breakthrough Curve

requires a much smaller Peclet number and a higher D. The Peclet number is defined as the water velocity times the column length divided by the dispersion coefficient. Generally a longer column produces a larger dispersion coefficient and therefore smaller Peclet number. Also, it is usually true that the four parameter model predicts a larger Peclet number and a smaller D than the two parameter model. This is because some of the asymmetry seen in the breakthrough curve can be accounted for in the α and β terms, therefore requiring a smaller dispersion coefficient. The exception was seen to be the small column tritium experiment where the Peclet numbers were above 100. In the large column tritium experiment and the strontium experiments, where the Peclet numbers are approximately 10 to 30, the four parameter model predicts lower dispersion coefficients.

One of the major problems in using laboratory data for field simulations is the variation of the dispersion coefficient (D) with both velocity and scale. The ratio D_L/D_S, the dispersion coefficient (D_L) of the large column experiment divided by the small column experiment (D_S), is equal to 31 for the two parameter model and 18 for the four parameter model.

The coefficients α and β were consistent throughout all experiments. This may mean that for any soil these may be treated as constants regardless of column length or radionuclide. It has already been pointed out, from the small column tritium example, that these parameters appear to have little effect on the shape of the curve when the Peclet number exceeds 100. More work needs to be done with different tracers to characterize the variations of the parameters α and β.

SNOW PLOW EFFECT

The breakthrough curve for this test is shown in Figure 7. The pore volumes start at 17. The tracer was stopped at approximately 4 pore volumes with the low salt solution being stopped and high salt solution started at 18.25 pore volumes. The strontium was quickly released after the addition of the high salt solution. This is the result expected following the analysis of Starr and Parlange (1979). Also shown in Figure 7 are the results of the two and four parameter model simulations. The parameters used for the simulations were taken entirely from previous laboratory tests.

The dispersion coefficient (D) was determined using $P = 29$ for the four parameter model and $P = 19$ for the two parameter model. These values were taken from the high salt solution run shown in Table 1. The mobile water fraction (ϕ) was estimated using the reasoning of van Genuchten and Wierenga (1977a, 1977b).

Three values for the Kd were used. The value of the low salt Kd was taken to be 6 from batch equilibrium studies (Gee and Campbell 1980), and high

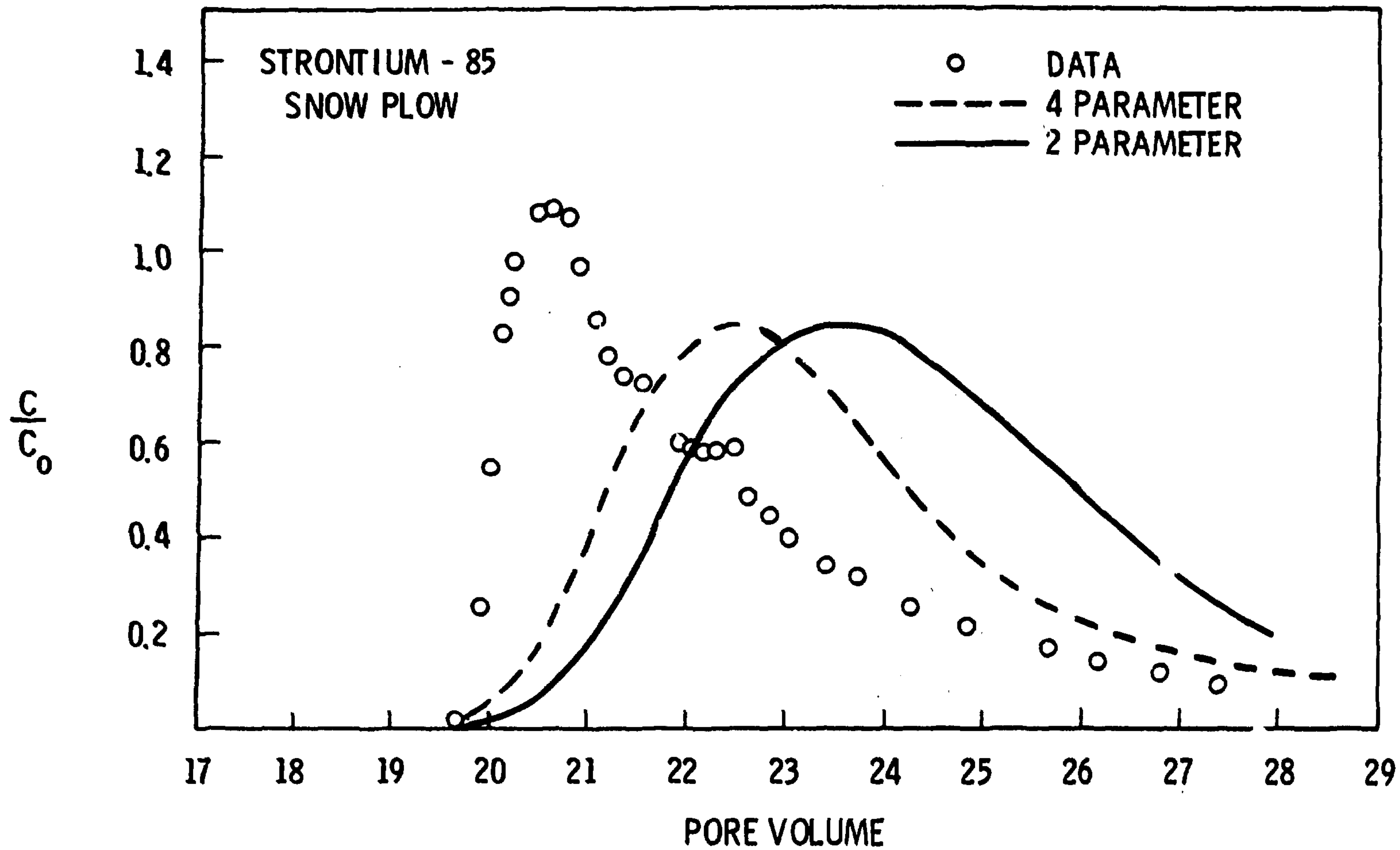

Fig. 7. Comparison of Two and Four Parameter Models for Snow Plow Effect

salt Kd was set at 0.745 for the four parameter model and 0.6 for the two parameter model. These values were obtained by using the R values from Table 1. As the salt concentration in the column varied from low to high the Kd was varied linearly from 6 to 0.745 or 0.6. The results of these two simulation models are shown in Figure 7. Figure 7 shows the comparison between the two and four parameter approach. It was shown by Gee and Campbell (1980) that column Kd values are generally less than batch values. Using a lower Kd value than 6 for the low salt would seem justifiable and would move both curves to the left and possibly improve the fit.

WORK IN FY 82

The goal for FY 82 is to incorporate the field tracer test into the solute transport analysis. A comparison of transport parameter estimates between laboratory or field studies will be possible.

A new task has been added in FY 82 which will examine guidelines for numerical model evaluation and documentation. This task will describe procedures and techniques useful in describing the usefulness of unsaturated zone transport models for shallow land burial applications.

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Dup

ARID SITE TECHNOLOGY DEVELOPMENT AT THE LOS ALAMOS NATIONAL LABORATORY MODEL VERIFICATION

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INTRODUCTION

Later papers by G. L. DePoorter and T. E. Hakonson will discuss the majority of the subtasks being worked on for SLB Technology Development at the Los Alamos National Laboratory. This paper will describe model verification. The purpose of this subtask is to provide the experimental facilities and experimental procedures to obtain the data necessary to validate and verify, on a field scale, models for unsaturated transport of water and radionuclides. In addition to providing this data base for model verification, a two-dimensional, two-phase unsaturated transport model developed at the Los Alamos National Laboratory will be field validated. The major accomplishments during FY-1981 were the design and emplacement of the experiment clusters, the planning for the experiments to be emplaced in these units, and the start of the cooperative effort with Group ESS-5 of the Los Alamos National Laboratory to field validate their unsaturated transport code.

FY-1981 ACCOMPLISHMENTS

The experiment clusters in the Los Alamos Experimental Engineered Test Facility are described by the author in a subsequent paper in these proceedings. Figure 1 is a scale drawing of the experiments to be emplaced in two of these units which will provide the data for model verification. Neutron moisture probe access tubes will be placed in the profile as shown in the figure. In addition, one vertical tube for the neutron probe will be emplaced. Copper-constantan thermocouples will be emplaced to obtain temperatures as a function of depth as well as across the profile of the experiment. Tensiometers and porous cups will be emplaced as shown to measure matric potential and to take aqueous samples. One unit will have tracers and one will not.

The material to be used in these first two units will be crushed tuff. This material was chosen because a large amount of background information exists at Los Alamos on the properties of crushed tuff, such as soil moisture characteristic curves and laboratory measurements of both saturated and unsaturated hydraulic conductivity. Since the unsaturated transport model developed by Group ESS-5 requires physical properties of the material such as porosity, bulk density, and the soil moisture characteristic curve as input, the model validation work will be generic. That is, if these properties are available for any backfill materials, this unsaturated transport model can be used.

FY-1982 WORK PLANS

During fiscal year 1982 the experimental units will be filled, the instrument emplaced, and data collection started. The first two units, as mentioned above, will be filled with crushed tuff at a moisture content to maintain the matric potential greater than −100 KPa. This is the moisture content regime for which tensiometers, porous cups, and the instantaneous profile method can be used.

After the units are filled and the instruments emplaced, additional water will be added to the units. Both moisture content and matric potential will be measured as functions of both time and depth in the caisson units. Data will be collected during both wetting and drying of the backfill materials. This experimental data will be compared with the predicted water movement from the unsaturated transport model, will be used to determine the hydraulic conductivity *in situ* using the instantaneous profile method and any other field methods that are appropriate, and will be made available for other researchers to use in validating their models. In the unit with the emplaced tracers, aqueous samples will also be drawn and analyzed to provide the data on the contaminant movement.

Not all of the experiment clusters will be filled at the start of FY-1982. Replication of these experiments with soil from other sites (brought in or mocked up) would establish, beyond doubt, their generic nature.

OTHER MODELING WORK

The work described above has been directed only at the subsurface component of the modeling problem. Another important component is that dealing with the surface. In a later paper by L. J. Lane, the CREAMS Model, which handles the surface component of the modeling, will be described.

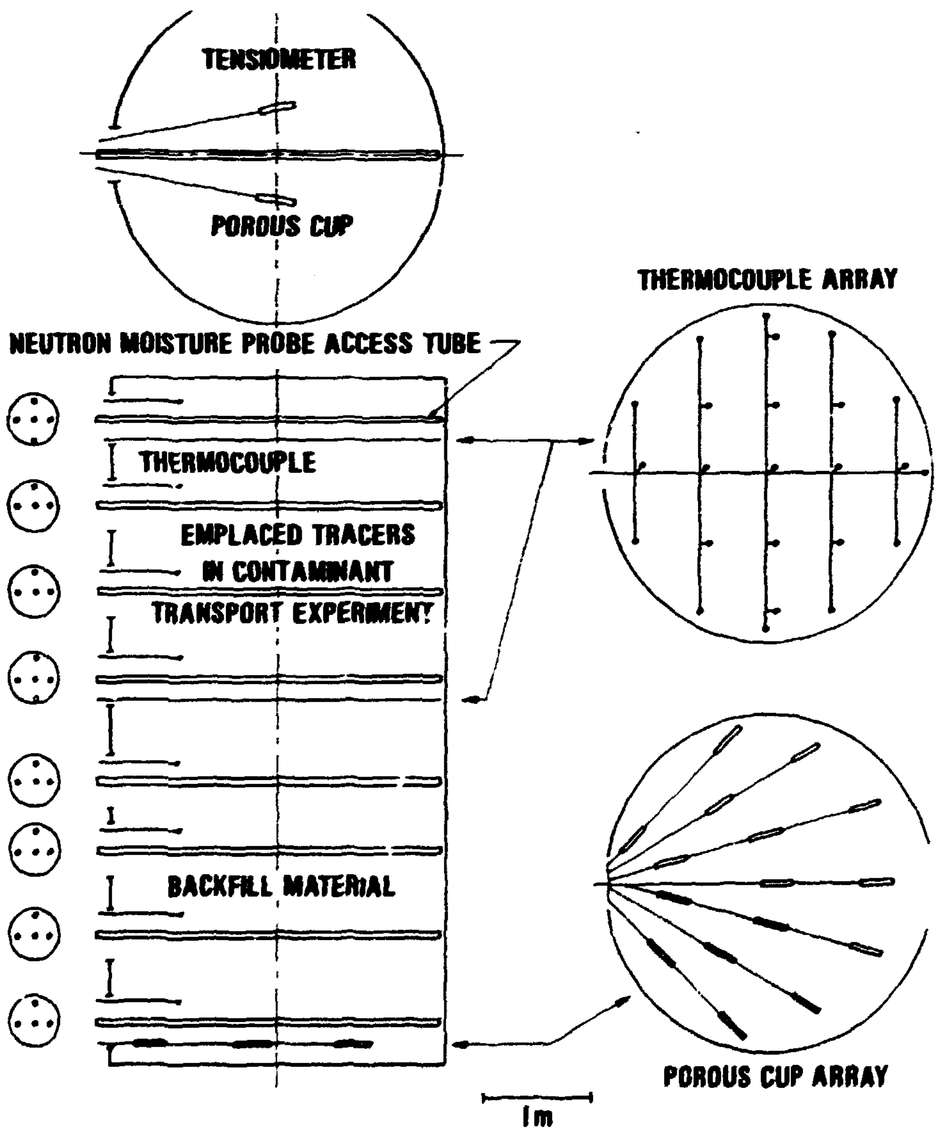

Figure 1. Experimental Configuration to Measure Water and Contaminant Transport

SITE SELECTION PROCEDURES EVALUATION*

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INTRODUCTION

The application of the Low Level Waste Management Program (LLWMP) site selection criteria to a test case would allow timely feedback on their usefulness. A Site Selection Procedures Evaluation Task is proposed as part of the Shallow Land Burial Technology Field Task Proposal to support the continued development and testing of the LLWMP site selection criteria. The task will: 1) evaluate the proposed LLWMP criteria, 2) provide a methodology for applying the criteria, 3) apply the criteria to a site at Oak Ridge, TN, and 4) evaluate the use of computer models for assisting in site selection.

BACKGROUND

The proposed task supports Milestone C of the LLWMP: "Develop the Technology and Documentation Required to Open a Shallow Land Burial Site". While directly funded under work breakdown structure (WBS) 3.5: "Low Level Waste Technology", it is related to several other WBS. "System Studies" and "Hazard and Risk Studies" are important considerations in site selection for predicting exposure levels and preventing unacceptable exposure to the public. The site selection criteria were developed under "DOE Criteria - Standards and Regulations" (WBS 3.3). The potential application of the criteria to commercial sites is related to "Technolgy Transfer in Support of New Disposal Sites" (WBS 3.4.4.1).

Specific LLWMP tasks related to the Site Selection Procedures Evaluation Task are proposed or ongoing. Savannah River Laboratory (SRL is currently working on a dose-to-man model application and Los Alamos National Laboratory (LASL) has a barriers, water management, and model verification task which have site selection implications. A principal function of the shallow land burial handbook being developed at Oak Ridge National Laboratory (ORNL) is an evaluation of waste and site selection guidelines. Site selection activities for greater confinement facilities are also related. The Nevada Operations Office is working on an alternative disposal facility for greater confinement disposal and Savannah River Laboratory proposes developing methods for screening greater confinement facility sites.

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Other related work at ORNL is ongoing. An "EPA Low Level Waste Assessment Model" has been developed by ORNL personnel. ORNL is co-sponsoring with NRC a symposium on Low Level Waste Disposal. The first topic to be addressed is site suitability.

SUBTASKS

The subtasks proposed are 1) evaluate the site selection criteria and develop a methodology for application, 2) apply the criteria to a specific site in Oak Ridge, and 3) evaluate the use of computer models for assisting in site selection.

To accomplish the first subtask, the site selection criteria and information relative to existing EPA, NRC, or DOE guidelines will be obtained. The criteria will be evaluated for completeness and for their level of applicability. Generally, there may be several levels of application. The target area for a shallow land burial site must be defined. Criteria which identify absolute exclusion areas within the target area provide an initial screening process. In selecting the best sites within the target area, significant financial investments are required to obtain the necessary site specific data. In developing the methodology for applying the criteria at each level, consideration may be given to establishing quantitative limits or weighting factors to some of the parameters.

The three Oak Ridge plants operated for DOE by Union Carbide have been studying siting factors for locating a solid waste disposal facility to accommodate sanitary, hazardous, and low level radioactive solid wastes. It is proposed to apply the LLWMP site selection criteria to this specific case. The target area for application will be the Oak Ridge Reservation. Screening level parameters considered in the siting study included flood zones, exclusion areas, topography, incompatible land use, and geologic regimes. The site selection level considerations included geologic characterization, pathways analysis, site access and preparation, and future land commitments. The application of the criteria to the Oak Ridge case minimizes the limitations related to data availability, allows testing of the criteria and methodology, and provides an opportunity for comparison of results.

As the last phase of the proposed task, the use of computer codes or models will be evaluated. Available site selection codes such as the System Analysis of Shallow Land Burial (NUREG-CR-1963) will be identified. The concerns of data acquisition, confidence limits, and general ease of application will be evaluated to determine their potential use.

The activities as proposed will provide an evaluation and early feedback on the application and further development of the proposed LLWMP criteria.

SAVANNAH RIVER LABORATORY DOSE TO MAN MODEL

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ABSTRACT

A radionuclide transport model designed to provide guidance for present SRP burial ground operation and decommissioning, and for design of an improved future site will be described. Results of modeling ^{137}Cs, ^{90}Sr, and Pu transport will be presented. Vegetative uptake studies to improve critical-path data will also be described.

INTRODUCTION

A radionuclide transport model has been in use at Savannah River Laboratory for the past two years for predicting exposure of possible inhabitants of the Savannah River Plant shallow land burial site after loss of institutional control. The objective of this work is to determine effective ways to improve present site operations and to guide in selecting ways to decommission the site. While the model is being used for site-specific calculations, the model itself is general and can be used for any site given the proper transfer coefficients. The model considers mobilization by groundwater, uptake by vegetation, and intrusion by animals. Erosion and resuspension are included in the model.

MODEL DESCRIPTION

The model divides the radionuclide pathways into 69 comparments that are linked by transfer coefficients. Inventory in the various compartments at any step in time is then given by the solution of a set of linear differential equations. The model has been validated by simple test cases that were verified by hand calculations, and by keeping account of mass balance in the more complex cases.

This year calculations were completed for ^{137}Cs, ^{90}Sr, and Pu doses in the "Home Farm Scenario". This scenario assumes a family of four moves into the burial ground area 100 years after operations cease, and grow all their food on the 200 acre site. We consider this a worst case in that it gives maximum individual doses. This case is plausible, however, and consistent with pre-SRP use of this land.

MODEL RESULTS

For Pu isotopes there are periods of maximum uptake at about 500 and 50,000 years that correspond to ^{238}Pu and ^{239}Pu, respectively. Both maxima give doses well below 0.5 rem/year. ^{238}Pu dose is mainly due to uptake by vegetation, and the ^{239}Pu dose is due to eventual migration into the groundwater.

VEGETATIVE UPTAKE TESTS

Nearly all of the ^{90}Sr dose results from vegetative uptake. Decommissioning the present site should thus include building up an additional approximately 10 feet of earth over the trenches so that waste would be below the root zone. Future disposal should be in the deeper facility that will be discussed in a later talk. We are also conducting field tests of root uptake to improve transfer coefficients used in the model. Corn and soybeans were grown on 100' x 130' plots over a beta-gamma waste trench last summer. Winter wheat will be planted later this month. We plan to publish results from these tests as soon as they are available. In addition to these food crops, trees are being grown over an alpha-waste trench and in selected lysimeters.

CONCLUSIONS

1. The SRL dose-to-man model is a general transport code that is providing burial site design, operation, and decommissioning guidance at Savannah River Plant.
2. Even in a worst-case scenario Pu and ^{137}Cs doses are small.
3. Vegetative uptake provides a path for migration of a significant amount of ^{90}Sr.
4. Cropping studies over actual burial trenches are being used to improve input data on the vegetative uptake pathway.

DEVELOPMENT TESTING OF GROUTING AND LINER TECHNOLOGY FOR HUMID SITES

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ABSTRACT

Shallow land burial, although practiced for many years, has not always secured radionuclides from the biosphere in humid environments. To develop and demonstrate improved burial technology the Engineered Test Facility was implemented. An integral part of this experiment was site characterization, with geologic and hydrologic factors as major the components. Improved techniques for burial of low-level waste were developed and tested in the laboratory before being applied in the field. The two techniques studied were membrane trench liner and grouting void spaces.

INTRODUCTION

Shallow land burial as a disposal method for low-level radioactive wastes has been simple, cost-effective and practical for many years. In most cases the method involves digging a trench, emplacing the untreated waste, and covering with native soil. In humid environments, however, radionuclides have not always remained secure from the biosphere, as a result of water seeping into the trenches, soaking the waste, and mobilizing the radionuclides. Examples of radionuclide migration from trenches are at Oak Ridge National Laboratory, Maxey Flats, and West Valley (Dana et al., 1980; Jacobs, et al., 1980).

Although disposal in an arid climate is technically preferable, transportation costs and socio-political considerations prevent disposal of all low level radioactive waste at arid sites. Hence, improved methods of disposal are required at humid sites if radionuclide migration is to be minimized and costly remedial actions such as exhumation, repackaging, and reburial are to be avoided (Cutshall, 1980). To develop the necessary technology for disposal in humid areas the Engineered Test Facility (ETF) was implemented at Oak Ridge National Laboratory in solid waste storage area (SWSA) 6. Its major goal is to provide pilot-scale field data for evaluating the effectiveness of trench treatments in retarding radionuclide movement in humid areas. ETF will also aid in identifying the types and amounts of data necessary for adequate site characterization.

EXPERIMENTAL DESIGN

The design of the experiment requires nine trenches, three of which are used as controls, three are lined with a membrane, and three are grouted (Fig. 1). The trenches are on three meter centers and are nominally 3 m x 3 m x 3 m. Although they are small compared to standard operational trenches, they are never the less, in scale with the 0.3 ha site. Each treatment is assigned to a set of trenches based on a Latin Square design which eliminates any bias that might be introduced by trenches of differing depths. Thus each treatment occupies a row and a column that are unique, for example on the diagonal. A different chemical tracer is designated for each trench so when leakage begins the trench can be identified. Once all the trenches are filled and closed, four wells will be placed around each trench for monitoring the tracer movement.

For baseline studies prior to excavation ten 10-meter deep wells in a horseshoe configuration were drilled along with two 15 meter wells to the east and west of the horseshoe (ETF 11 and 12 in Fig. 1). The wells were used primarily for collecting groundwater data, but five of the wells were cored for geologic information. Two flumes and a rain gauge were also installed to measure surface hydrologic conditions.

SITE CHARACTERIZATION

An integral part of the experiment includes an hydrologic and geologic description of the ETF site. First to be the discussed will be geologic factors: stratigraphy, petrology, structure, geophysical aspects, and soils. The hydrologic factors include: precipitation, surface water occurrence and quality, ground water occurrence and quality, infiltration rates, and soil moisture.

Geologic Investigations

The Oak Ridge Reservation lies in the Ridge and Valley Province, which is characterized by alternating, elongate, northeast trending parallel ridges and valleys (McMaster, 1963). Differential erosion of the northeast striking Paleozoic strata has influenced, the parallel ridge-valley trend (Stockdale, 1951). These features are aligned with the major thrust faults in the Province. The area of interest is located in Melton Valley which is underlain by strata of the Middle to Late Cambrian Conasauga Group. Although the Conasauga Group generally underlies valleys throughout the region, it locally forms hillocks such as the one depicted in Figures 1 and 2.

ORNL-DWG 81-14049 ESD

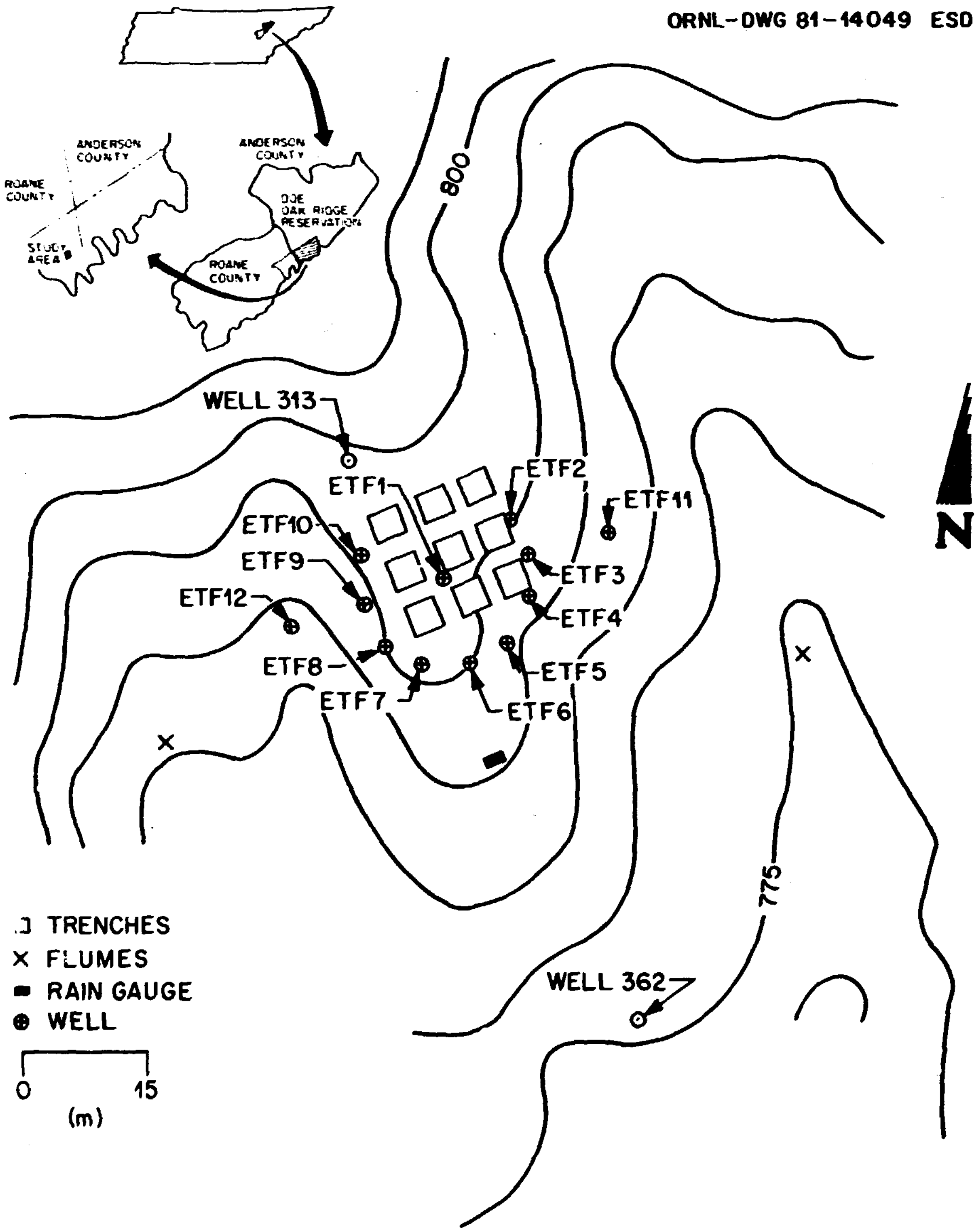

Fig. 1. Location of Engineered Test Facility. The trenches are numbered consecutively beginning in the upper left hand corner. Each succeeding row is numbered left to right.

ORNL-PHOTO 1994-81

Fig. 2. View of the ETF during trench excavation. The trenches being dug are the middle three. [Notice the rounded hillock the backhoes are sitting on.] The barrels are to protect the wells and provide a stable platform for the water level recorders. Nearest barrel covers well 12.

The Conasauga Group is a very heterogeneous unit, consisting basically of alternating shaley limestones and limey shales. The six constituent formations, in ascending order are: Pumpkin Valley Shale, Rutledge Limestone, Rogersville Shale, Maryville Limestone, Nolichucky Shale, and Maynardville Limestone. It is the limestone members that are responsible for the hillocks as they are resistant to erosion. The ETF site is specifically underlain by the Maryville Limestone, a massive silty interclastic limestone interbedded with a dark gray mudstone (Haase and Vaughan, 1981).

The elevation to the top of the Maryvilie Limestone was determined from well drilling varies from 235 to 241 meters. The lowest elevations are at the southernmost end and rise to the 238 meter level which runs approximately along the line delineated by wells ETF 12 to ETF 11. A knoll of Maryville Limestone is situated by well ETF 2 and rises to an elevation of 241 meters. Toward the northwest the elevation falls to 236 meters. The top of the Maryville Limestone shows a distinct east-west alignment, which is not reflected in the north-south orientation of the surface topography.

Upon excavation the knoll of bedrock near well ETF 2 was revealed to be a tight anticlinal fold (Fig. 3). The axis of this fold was traced across the middle three trenches (trenches 4, 5, and 6 in Fig. 1). The northern limb of the anticline dips away from the center to the northwest at between 44° and 52° while the other limb dips to the southeast at between 47° and 70°. In Figure 4 the fracture patterns in the rocks on the limbs are shown. Between the rectangular slabs of rocks and the more massive units are fractures, resulting from tensional stresses. Immense deformation in the core of the anticline further fracturing the rock is evident. Finally, openings created by alternating bands of rock and soil are noted. It is these fractures and openings that are responsible for carrying the water.

Another anticlinal fold was traced from the lower left hand corner of Trench 1 to the upper right hand corner of Trench 3. The northern limb dips northwest at between 32° and 57° while the southern limb dips southeast at between 28° and 56°.

These two anticlines are drag folds resulting from the deformation caused by the thrust faults which were mobilized during the Appalachian Orogeny. The folds are widespread features and can be observed in most trenches in SWSA 6. Shallow seismic surveys identified the first anticline, and shallow resistivity surveys found the top to the bedrock which was verified later by drilling.

Soil samples were obtained from trench walls to construct a soil profile for the site. As expected the soils derived from as heterogeneous formation as the Maryville are themselves varied. Soils ranged from weathered siltstone and sandstone to a silty or sandy loam. The siltstone-sandstone component is a result of the carbonate being leached from the parent rock. This mechanism gives the soil a

ORNL-PHOTO 1997-81

Fig. 3. Anticlinal fold uncovered by excavation of the westernmost trench in the middle row. Observer is facing east.

ORNL-PHOTO 4164-81a

Fig. 4. Close-up of a anticlinal fold in Figure 3. Deformation in the core indicates that this fold is most likely a double anticline.

shaley appearance and has led over the years to the misnomer "Conasauga Shale". Soil pH ranges from 4.2 to 5.2 and is always acidic, in contrast to typical caclareous soils which exhibit pH's in the range of 7.2 to 8.2. Some of the horizons have particles coated with manganese and iron oxides, and when distribution coefficient (Kd) ^{85}Sr was determined it was these layers that had the highest values (sample VIIc in Table 1).

Hydrologic Investigations

The water level for the area was monitored in the wells. While the water table fluctuates, it always has an east-west trend which coincides with that of the structure of the Maryville. As might be expected the water table is highest at the northern end of the hillock and lowest at the southern end. Since the period has been dry, the water table level between 238 and 237 meters is considered low. The rain gauge (Fig. 1) measured only 897 mm of precipitation over the past year instead of the normal 1430 mm (NOAA, 1980). When it does rain, some of the wells have a delayed response of a few hours.

A pump test using well ETF 12 showed a drawdown lineation that ran from well ETF 12 through wells ETF 9 and ETF 1 to include ETF 2, with a saddle point at ETF 9 (Fig. 1). This lineation coincides with the anticlinal fold found in the middle row of trenches, and lends support to the concept that the fractures and overall structure are controlling water flow in the area. Other pump tests showed the range of transmissivities to be between 0.8 and 25.0 m^2/d and storage coefficients to be between 3.9×10^{-7} and 2.8×10^{-2}. Again these support the concept of fractured flow from a field standpoint and agree well with the results of a fracture model by Sledz and Huff (1981).

Tracer tests were performed by investigators from University of Arizona and Indiana University under subcontract to ORNL. New tracers were used by the groups along with established ones to further the art of ground water tracing. Fluorocarbon tracers were used by the investigators from Indiana University. These tracers are highly desirable because they have minimal sorption properties, are essentially non-toxic, and have no natural background component so that small amounts may be used (Cooper, 1981).

The fluorocarbons were injected in the well ETF 1 (Fig. 1) and arrived before they were anticipated based on calculation and previous studies of the area. The calculated rate of movement for the fluorocarbons was 1 to 2 m/d. An even more startling result was initial location of the tracer arrival; in wells ETF 2, ETF 3, ETF 7, and ETF 8. The expected result was a first arrival at ETF 6. The conceptual model derived from the results is the tracer moved along a line between wells ETF 2 and ETF 3, and wells ETF 7 and ETF 8. Another line was also described from the results and includes wells ETF 4,

Table 1. Profile Description

Profile Sketch	Horizon and Depth (in cm)	Description of Horizon
A	0-5.1	Brown (7.5 YR 4/6) silt loam; medium to coarse granular structure; moderate friable; pH = 4.8; many fine roots; smooth boundary.
B	5.1-12.7	Finely laminated dull yellow orange (10 YR 7/2) and dark brown (10 YR 3/2) weathered siltstone; very coarse platy rock structure; pH = 5.0; few roots; smooth boundary.
IIC	12.7-22.9	Dull orange (10 YR 7/4); weathered sandstone; very coarse platy rock structure; pH = 4.7; clay and iron oxide coating; few roots.
IIIC	22.9-27.9	Finely laminated dull yellow orange (10 YR 7/2) and dark brown (10 YR 3/3); weathered siltstone; very coarse platy rock structure; pH 4.7; brown and brownish black iron and manganese coating; few roots.
IVC	25.4-38.1	Brown (7.5 YR 4/4); silt loam; moderate, medium coarse granular structure; weathered platy siltstone fragments; firm; pH = 4.9; Fe & Mn coatings.
VC	38.1-66.0	About same as IIIC; pH = 4.7.
VIC	66.0-86.4	Dark, reddish brown (5 YR 3/4); other features are the same as IVC; pH = 4.9.
VIIC	86.4-96.5	Finely laminated dull yellow-orange (10 YR 6/3) and brownish black (10 YR 2/2) slightly weathered siltstone; very coarse platy rock structure; pH = 5.2; heavy manganese coatings.
R1	96.5-130.0	Slightly weathered, undull.
R2	130.0^{+}	

ETF 5, ETF 9, and ETF 10. A plausible reason for this unexpected result was found by examining at fracture patterns in the Conasauga Group. These patterns are related to major structural elements in the area such as the Copper Creek Fault, a thrust fault, and a major fold (Sledz and Huff, 1981). The tracer results fall along the fracture pattern with its major control described as the Copper Creek Fault (Cooper, 1981). This finding provides more evidence that the ground water flow at the site is structurally controlled.

Water quality data have been gathered on a quarterly basis and Table 2 lists selected results. The major cation is calcium and the major anions are silicate and sulfate. Water quality was also performed on the water collected at the flumes. The only surprising result was a ^3H level at 10^3 Bq/l at the flume abutting the rest of SWSA 6. This is the level normally found in burial ground wells. This suggests that the waste trenches are releasing ^3H to the draw which drains the area. Neither the other flume nor the ETF wells had ^3H levels above detectable levels. As a result of low precipitation, soil moisture measurements were not readily availabile. During the first seven hours of an infiltration test the water flowed at 41.6 m^3/d attesting to the ability of the fractures to move water.

TREATMENTS

The treatments for this experiment are intended to retard water movement and reduce trench subsidence both of which are problems with aging trenches. A membrane or liner was chosen to retard the water movement into the trench, and a grout was developed to halt trench subsidence.

These treatments were developed by laboratory experiments involving aquaria filled with a synthetic waste mixture in proportions of buried low level waste (Fowler, et al., 1973). The waste was placed in the aquaria trenches approximating the burial mode used at ORNL (Fig. 5). For the first laboratory experiment only native soil was used to backfill the aquarium; a standard practice in burial grounds. Water was poured on the top and collected at the base of the trench. The trench was then flooded with a 7% bentonite suspension from below (Fig. 5). The suspension filled the voids between the waste and some of interstices between the soil particles. Water was again introduced, and only milliliters of water were recovered instead of liters of water noted before flooding; a decrease in water flow of approximately two-orders of magnitude was achieved.

The second experiment also involved an aquarium filled with waste, but backfilled with a bentonite (15% by weight) and shale mixture (Fig. 6), which is the same proportions as the bentonite seals used at ORNL. Water was poured on top of the trench, and the first liter ponded on top (Fig. 6). Although this mixture retards water movement, the

Table 2. Water Quality of ETF Wells

Well (ETF)	1	2	3	4	5	6	7	8	9	10	11	12
ions (μg/ml)												
Ca	49.0	37.0	28.3	30.0	39.0	43.0	36.0	39.0	41.0	27.8	49.0	31.0
Na	2.84	2.49	1.98	2.10	2.60	3.23	2.50	2.40	5.18	2.09	3.53	2.60
Fe	0.14	0.16	0.043	0.180	0.023	0.15	0.88	0.33	0.097	0.068	0.029	0.037
Al	0.021	0.018	0.019	0.028	0.022	0.019	0.039	0.017	0.015	0.26	0.014	0.019
Sr	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	10.1	<0.1
Mg	3.86	3.90	2.42	2.56	2.60	3.82	2.90	3.20	6.30	3.38	7.40	3.40
K	0.67	0.91	0.51	0.55	0.54	0.92	0.66	0.76	1.08	0.51	0.93	1.11
Mn (ng/ml)	6.9	201	8.2	7.2	9.0	56.0	17.0	11.0	41.0	2.20	66.0	2.20
SiO_2 (μg/ml)	14.4	14.2	10.5	15.6	14.0	13.3	13.7	13.3	9.3	14.0	15.7	15.1
SO_4	5.12	4.42	9.78	9.8	6.36	6.50	6.18	8.18	13.6	3.92	11.2	6.44
Cl	0.56	0.48	2.18	2.56	1.39	1.92	1.48	1.28	1.76	0.64	2.60	1.26
F	0.05	0.05	0.17	0.08	0.05	0.17	0.07	0.05	0.17	0.07	0.19	0.10

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Fig. 5. First experimental trench after having been flooded with a 7% suspension of bentonite. Note the penetration of the bentonite between the soil particles and into the voids between the waste.

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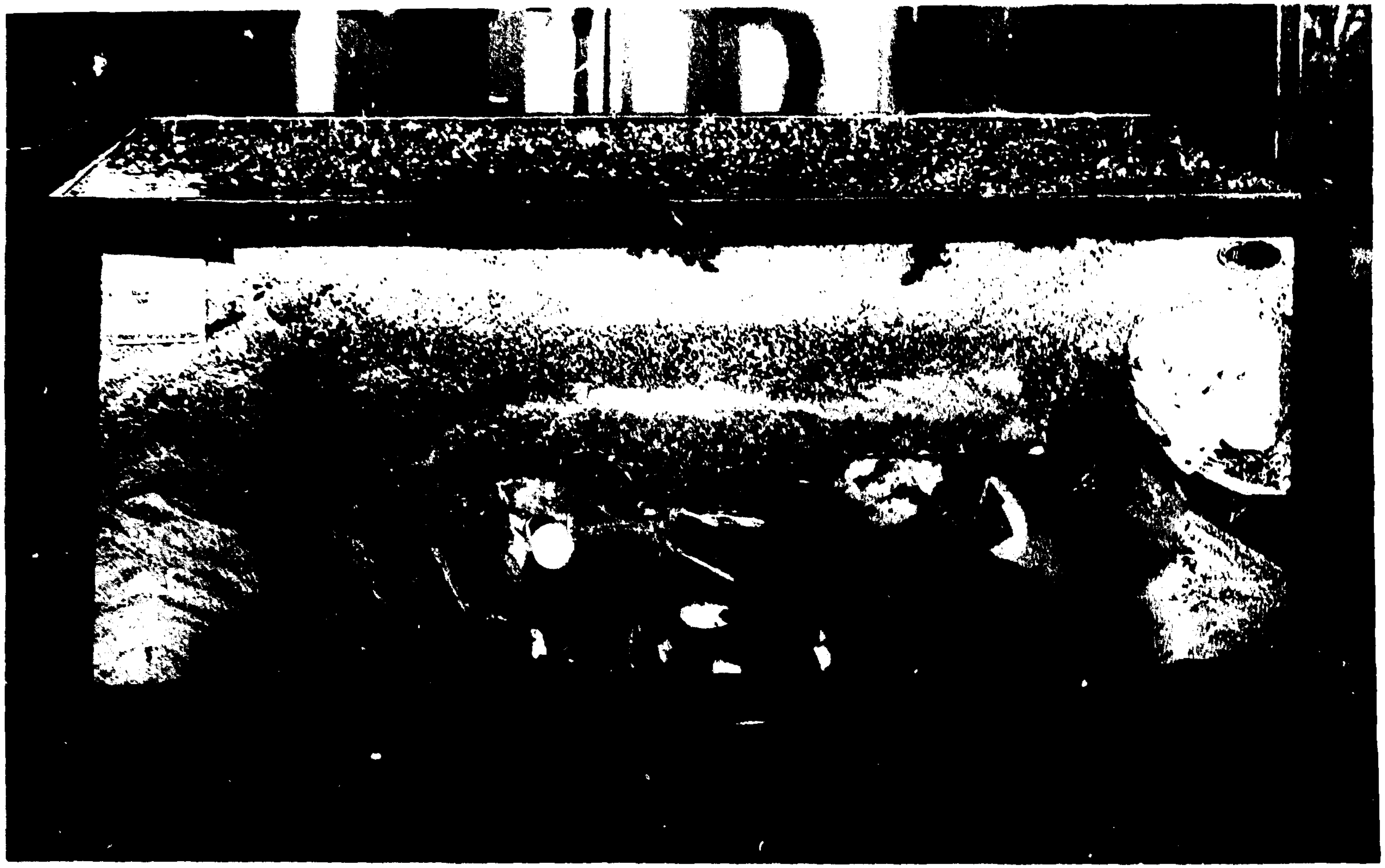

Fig. 6. Second experimental trench with a dry mixture of bentonite (15% by weight) and soil as cover. The void space between waste containers is 50%. The water standing on top is the first liter added.

dryfill did not pack into the voids between the waste. Only when this trench was flooded from below with a 7% bentonite suspension was water retardation of the same order of magnitude achieved as noted above.

From these two experiments it was decided that the fill would have to be a wet grout in order to achieve the void occlusion required. Also a membrane of bentonite could be used. The membrane was applied on the top of the second trench and exhibited good strength and flexibility. With several wettings it did not dislodge nor did it lose its elasticity.

Three grout mixtures were studied in detailed before selecting one composed of cement, fly ash and bentonite. A 7% bentonite suspension was considered first. However, during pumping into the aquaria, it lifted the top covering. Due to possible problems of floating waste in the trench this suspension was rejected. Another mixture was 0.1 M MgCl and 10% $NaSiO_2$ solution. Because the precipitate formed only filled part of the void and the remaining liquid filled the rest, this mixture was not chosen. Furthermore, neither of these mixtures possess the desired rigidity to prevent trench collapse. Finally, a cement, fly ash and bentonite mixture produced a pumpable slurry that filled the voids with solid material when set, and provided the rigidity desired (Sealand, per. comm.). This was a variation of a grout already used by ORNL (Tamura, per. com.). The grout will be flooded into the trench from the top while the membrane, 1.27 cm thick, will be sprayed on the walls of the trenches.

ACKNOWLEDGMENTS

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10up

ARID SITE SLB TECHNOLOGY DEVELOPMENT AT THE LOS ALAMOS NATIONAL LABORATORY

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INTRODUCTION

The program goal for shallow land burial (SLB) Technology Development at the Los Alamos National Laboratory is to field test new disposal concepts and strategies for all aspects of arid SLB on an accelerated basis and on a reasonable scale. The major accomplishments during FY-1981 were the development of the Los Alamos Experimental Engineered Test Facility, the emplacement of the biointrusion barrier testing experiments, the design and emplacement of the moisture cycling experiments, the design and construction of the experiment clusters, and the planning for the experiments to be emplaced in these units.

This paper will describe the site development work, the design and construction of the experiment clusters, and the experiments planned for these units. The biointrusion barrier testing experiments and results will be described later in these proceedings in a paper by T. E. Hakonson, and the moisture cycling experiments will be described in a subsequent paper by G. L. DePoorter. The last section of this paper will describe the work planned for FY-1982.

THE LOS ALAMOS EXPERIMENTAL ENGINEERED TEST FACILITY

At the start of FY-1981 the land had been obtained, the site had been surveyed and the archaeological ruins located, a fencing plan had been completed and the fencing contract had been awarded. In FY-1981 the site and ruin fencing was completed, and 1000 m of 4.6-m-wide base course roads was constructed. Also, a 30 m by 30 m equipment compound was cleared, covered with base course, and fenced with 2.5 m security fencing. A Model 975 diesel Bobcat Skid-Steer Loader with back hoe, buckets, and auger was acquired for use by project personnel for experiment emplacement. In FY-1981 alone the Bobcat has paid for itself in saved additional experimental construction costs. Figure 1 is a site map which shows the layout of the site and the experimental units in place as of October 1, 1981.

EXPERIMENT CLUSTERS

The experiment clusters provide environments with known and controllable hydrology, with the provision for extensive monitoring, to be used for the isolated variable experiments. Plan and section views of these units are shown in Figure 2. This design is a modification of the one developed by S. J. Phillips and co-workers (1). Engineering drawings of these units are available but are not included here.*

The experiment clusters consist of 6 corrugated metal pipes, 3 m in diameter and 6 m deep, placed around a central instrument and access caisson of the same size. In five of the six interstitial positions there are pipes 46 cm in diameter and 6 m long. Access ports are situated at regular intervals between the central caisson and each of the eleven surrounding caissons. The access ports are shown in detail in Figure 3 and a completed unit is shown in Figure 4.

The engineering design work on these experiment clusters was done by M. B. Ragsdale of Los Alamos Group ENG-2, and the low bidder on the construction contract was Saunders Construction Company of Santa Fe, New Mexico. Two of these units, about 30 m apart from center to center, were constructed in the Los Alamos Experimental Engineered Test Facility during FY-1981, although the units were not accepted until October 14, 1981. The location of the two experiment clusters is shown in Figure 1.

A collection of conceptual experiments to be performed in the experiment clusters is shown in Figures 5, 6, and 7. These figures were put together early in FY-1981 and subsequently some of them have been modified extensively. The experiments from this collection that will be emplaced in FY-1982 will be discussed later in this paper and in the subsequent paper in these proceedings by this author.

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*Copies of the drawings are available from G. L. DePoorter.
Telephone: 505) 667-1033
FTS 843-1033

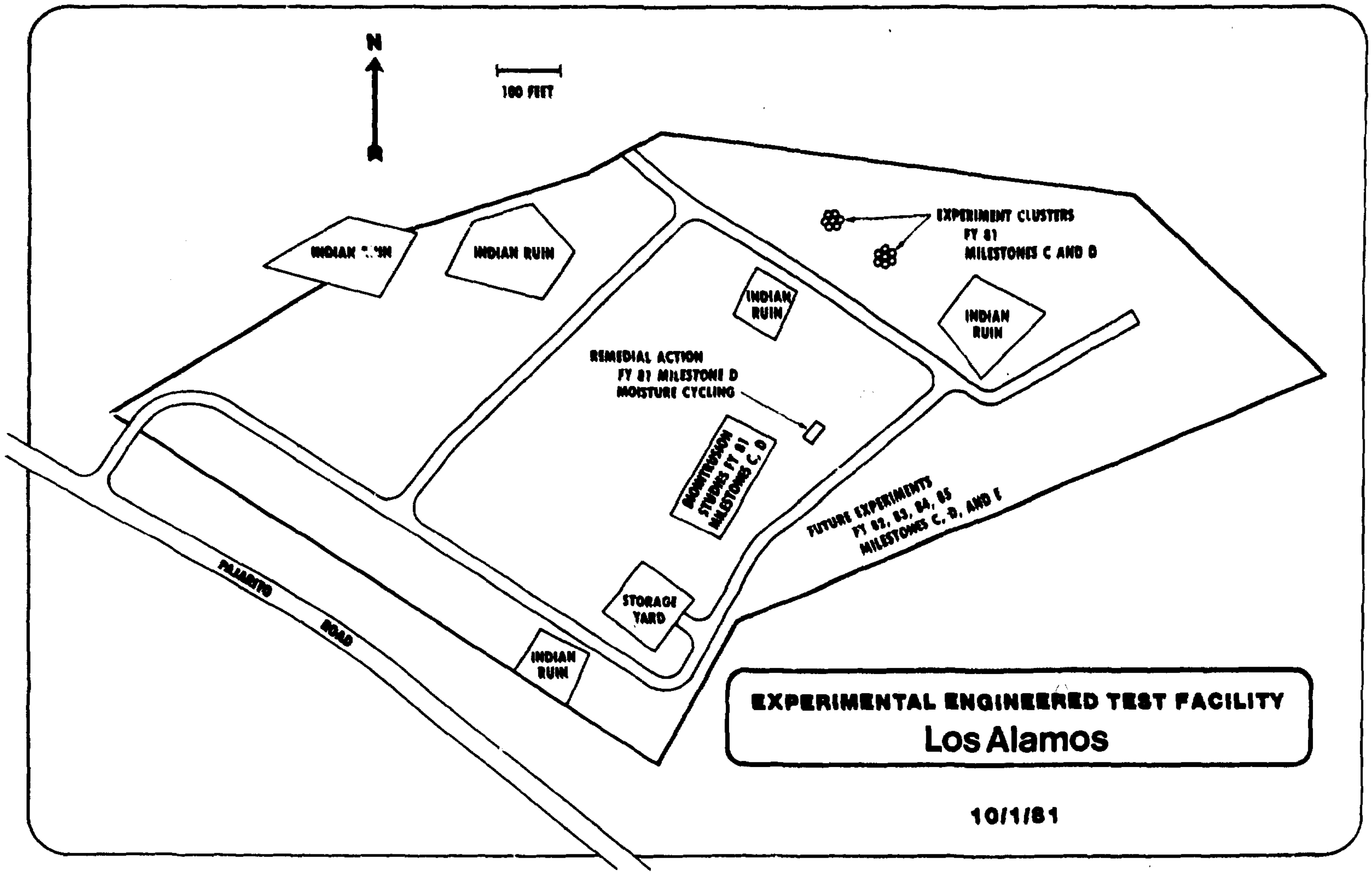


Figure 1. Site Map for the Los Alamos Experimental Engineered Test Facility

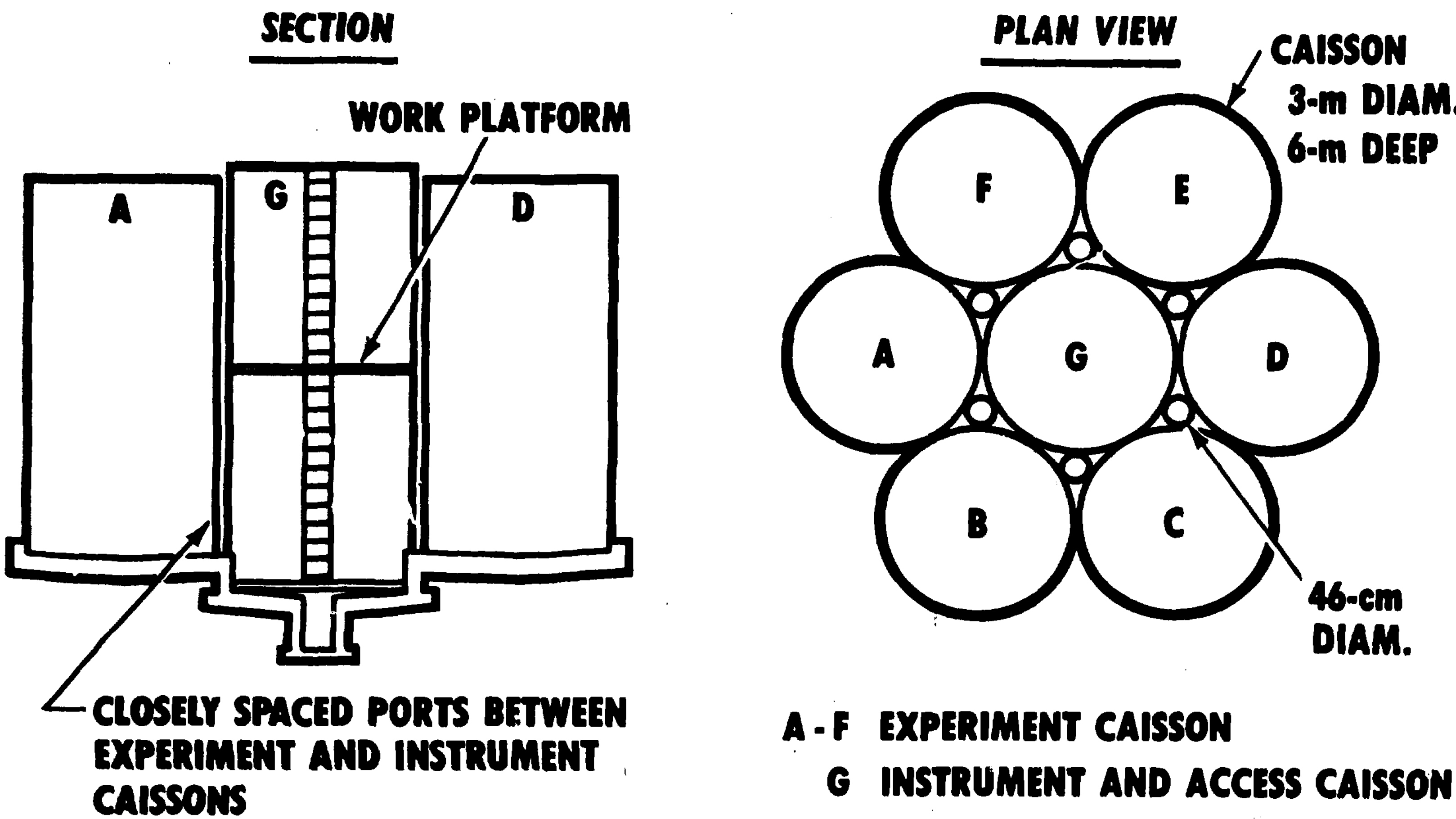


Figure 2. Construction Details of the Experiment Clusters

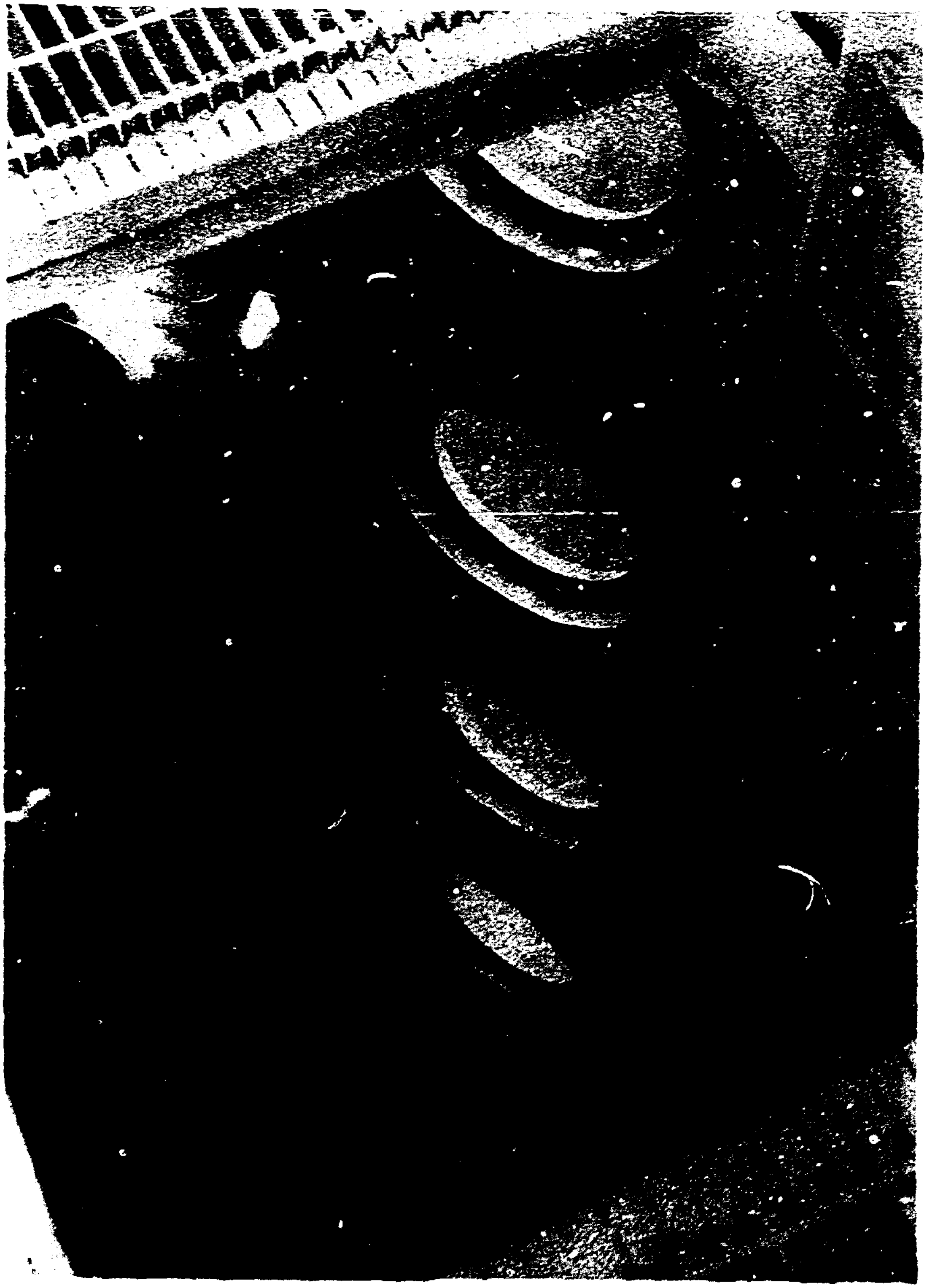


Figure 3. Access Port Details in the Experiment Clusters

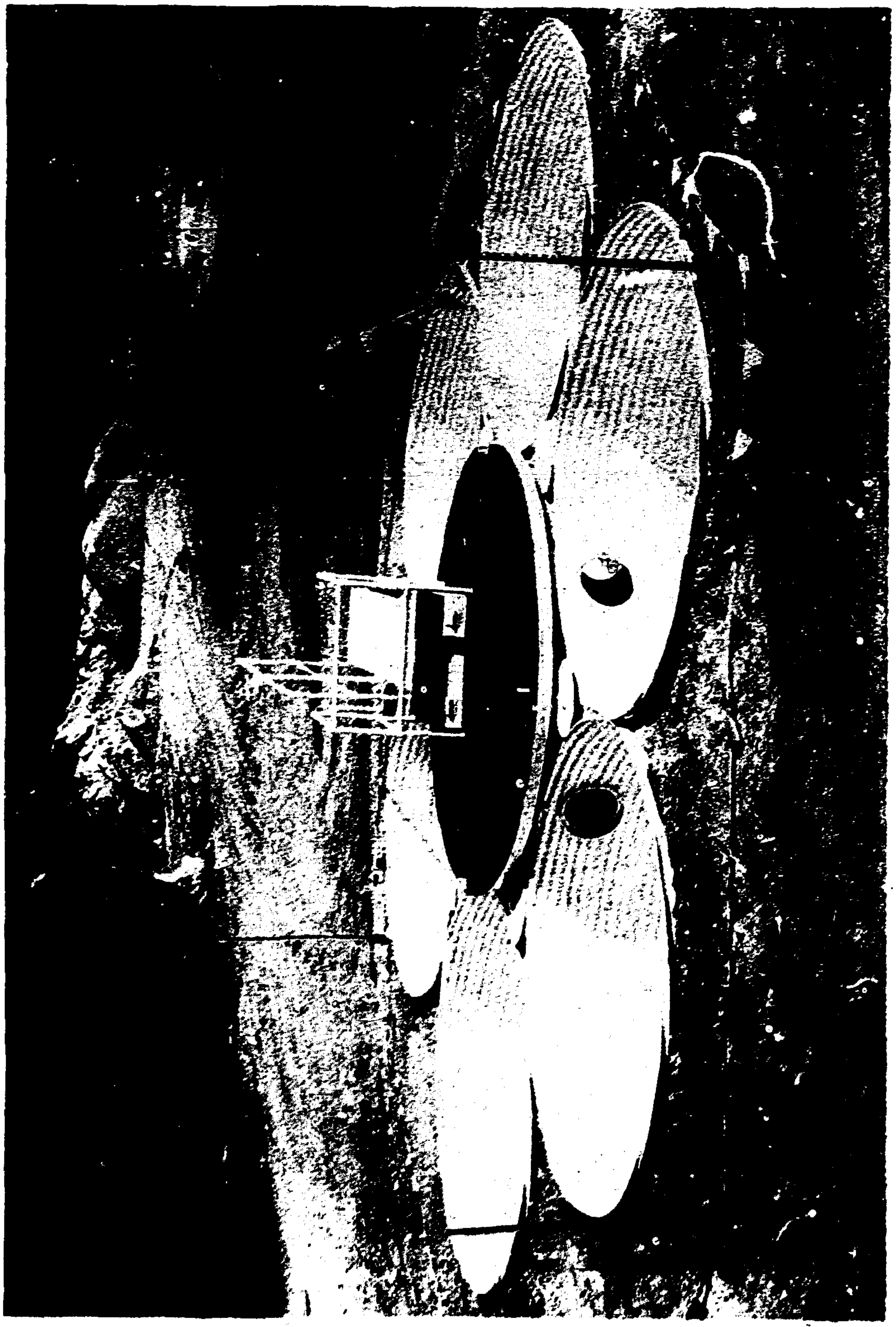
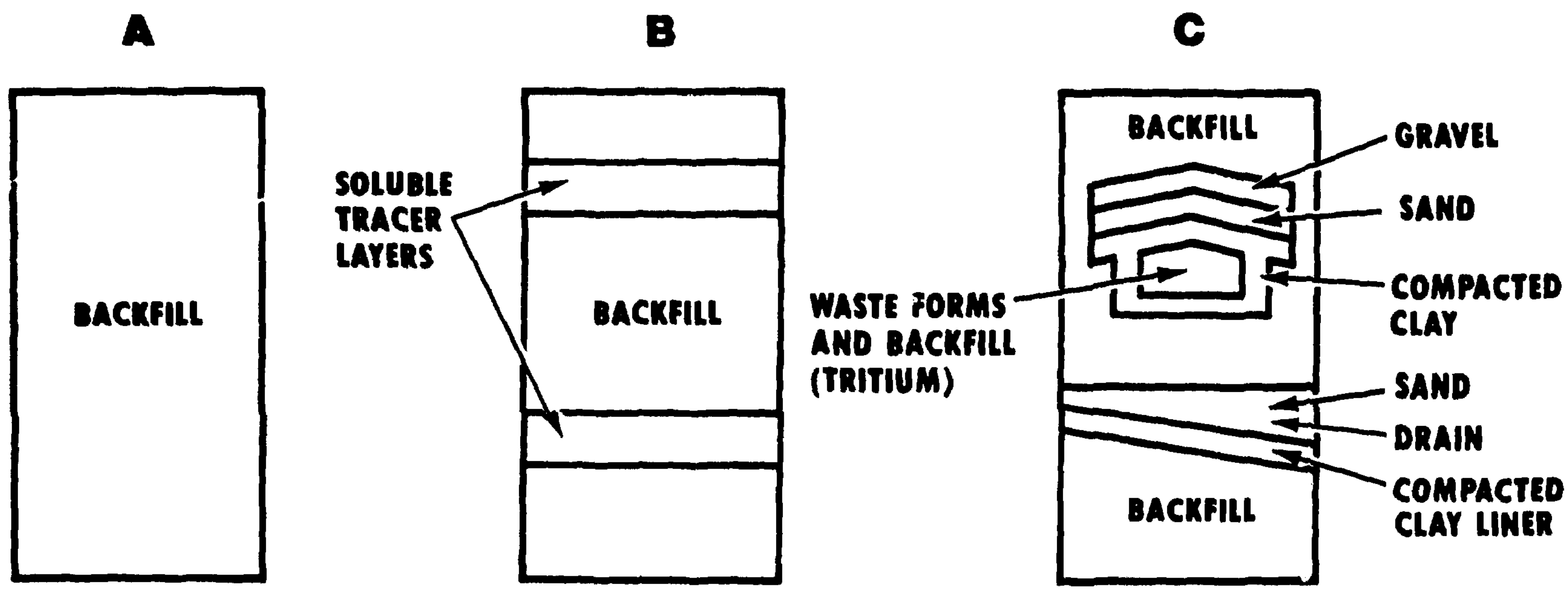


Figure 4. Top View of a Completed Experiment Cluster



DETERMINES MIGRATION POTENTIAL FOR WATER AND RADIONUCLIDES

PROVIDES DATA TO VALIDATE TRANSPORT CODE FOR UNSATURATED FLOW

EVALUATES

- **MULTILAYERED CAP-CLAY LINER SYSTEM**
- **NATURAL LINER SYSTEMS**
- **TRITIUM CONTAINMENT SYSTEM**

Figure 5. Possible Experiments for the Large Caissons

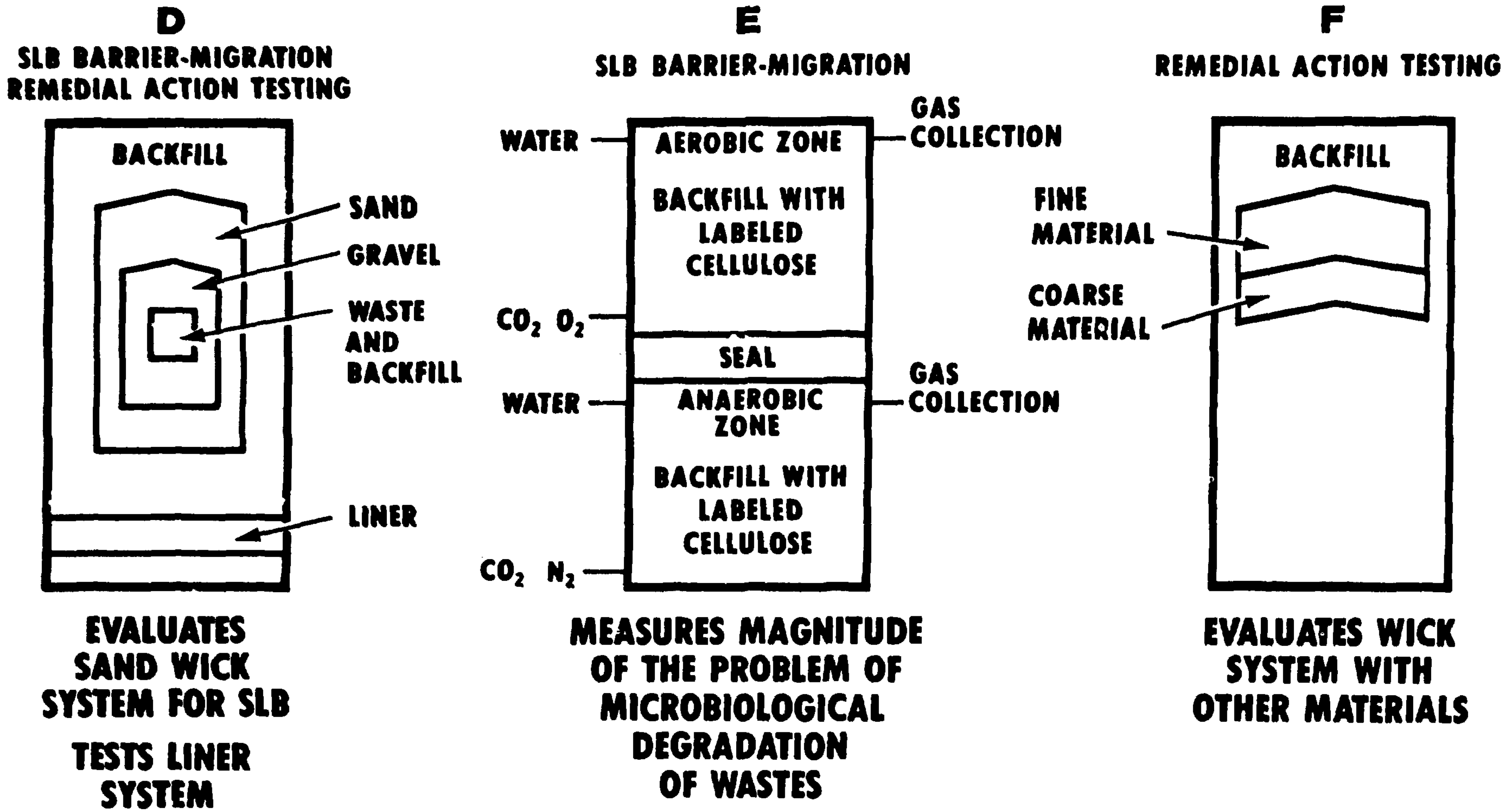


Figure 6. Possible Experiments for the Large Caissons

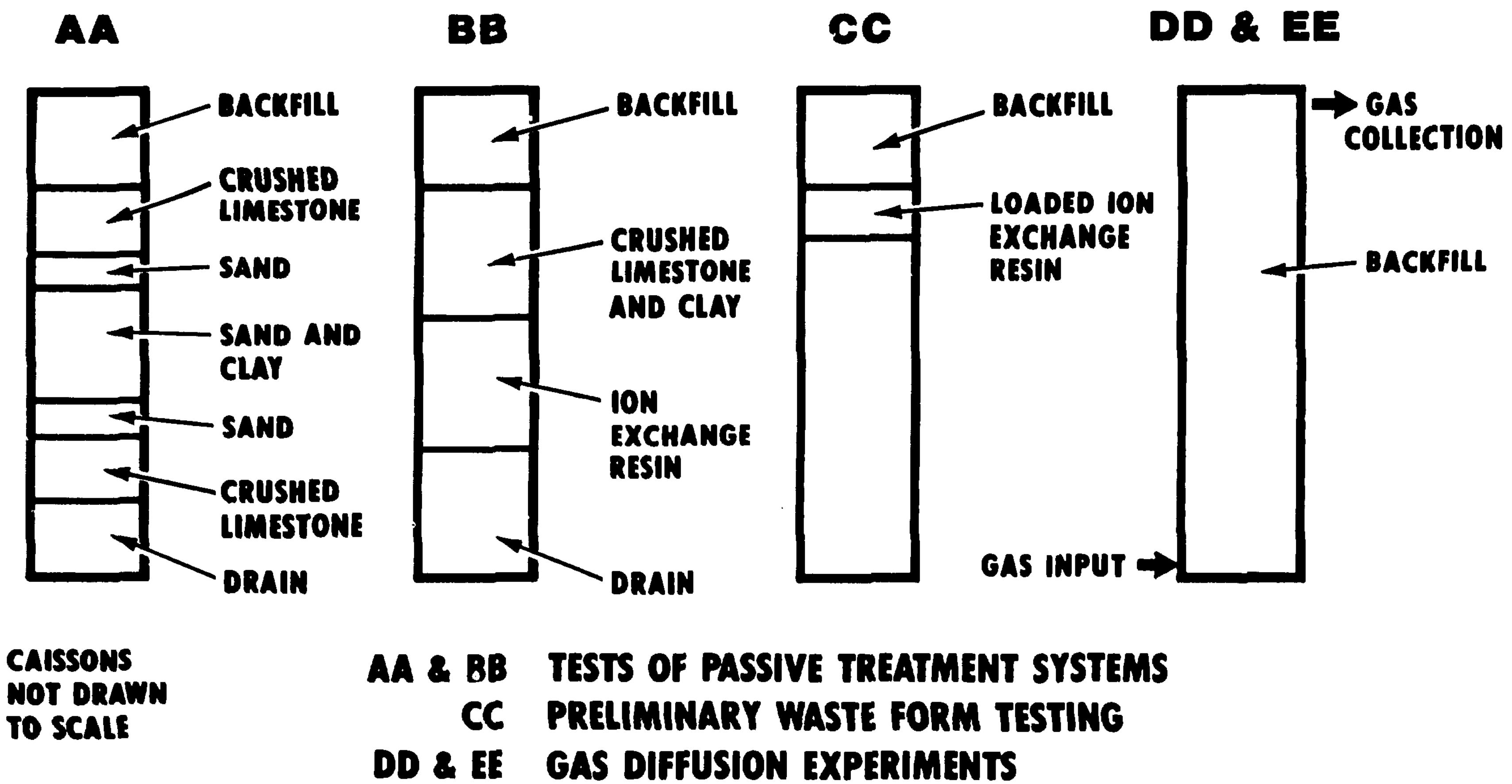


Figure 7. Possible Experiments for the Small Caissons

Figure 8 shows the experimental configuration to be used for experiments A and B as depicted in Figure 5. The access port spacing is shown in the figure to scale. Aluminum neutron moisture probe access tubes will be used and the thermocouples will be copper-constantan. These experiments will provide data on the movement of water and contaminants and to determine what is required for migration barriers under typical arid conditions. Although these units will be filled with crushed tuff, the results will be generic. If necessary, to confirm the general nature of the results, the capability exists to perform similar experiments on materials from other parts of the country.

In an arid environment, a promising technique for the control of surface and or ground water movement is the wick system. A possible experimental configuration to examine in detail the performance of a wick system is shown in Figure 9. This experiment will be placed in one of the large caisson units.

WORK PLANNED FOR FY-1982

The Arid Site SLB Technology Development experiments planned for FY-1982 are divided into four subtasks:

1. Biointrusion barrier testing.
2. Migration barrier testing.
3. Ground and surface water management system testing.
4. Model verification.

Subtasks 1 and 4 are described in other papers in these proceedings.

Migration barrier testing and experiments related to it, subtask 2, will be performed as indicated in experiments A and B on Figure 5 with the experimental configuration as shown in Figure 8. The hydraulic conductivity will be measured *in situ* using the instantaneous profile method in both units, and the movement of tracers will also be measured in the other unit.

Based on the measurements of water and tracer movement in these large caisson experiments, migration barrier needs for arid SLB will be determined. Based on these needs, configuration of promising natural materials will be evaluated late in FY-1982 to identify possible liner

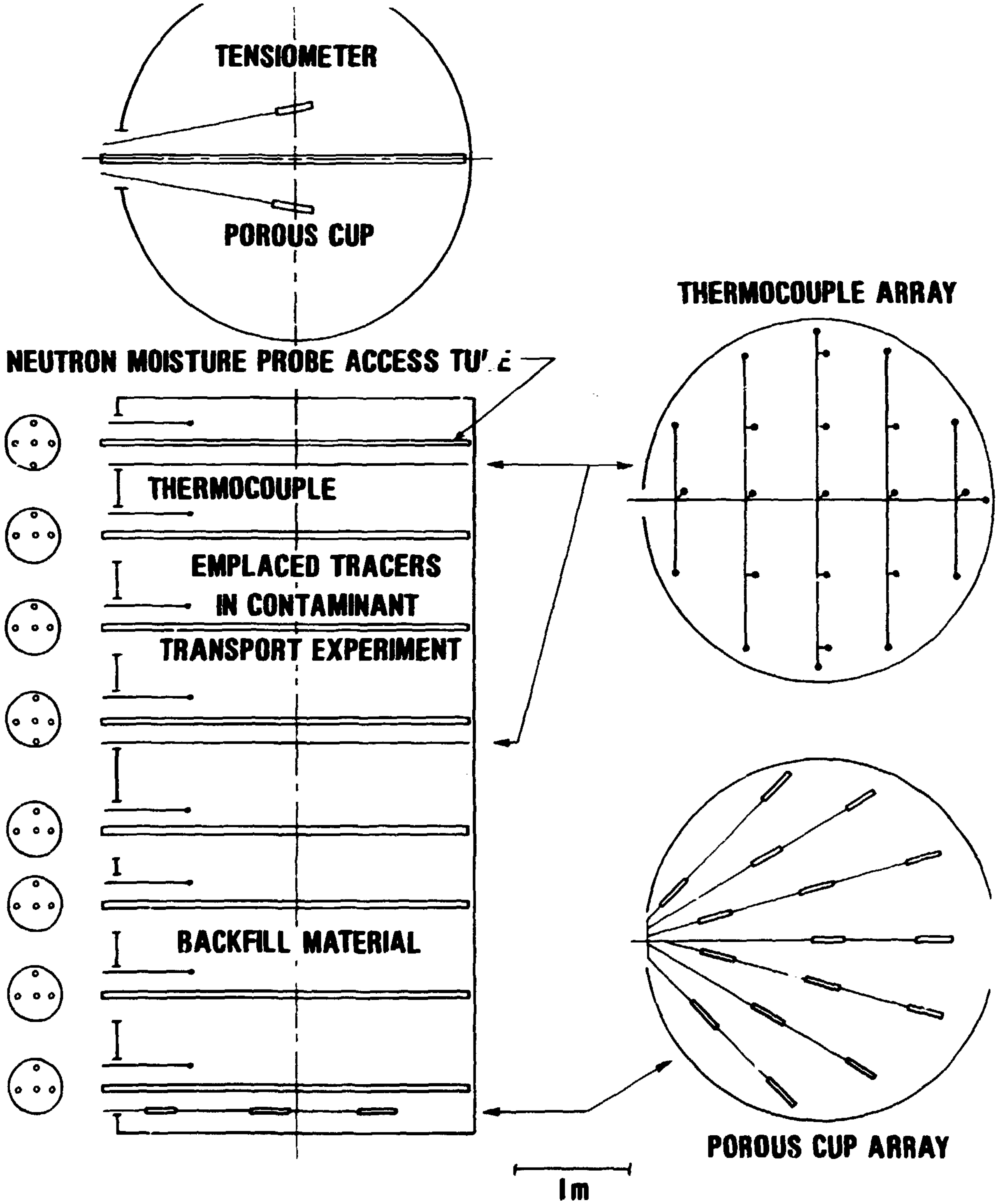


Figure 8. Experimental Configuration to Measure Water and Contaminant Transport

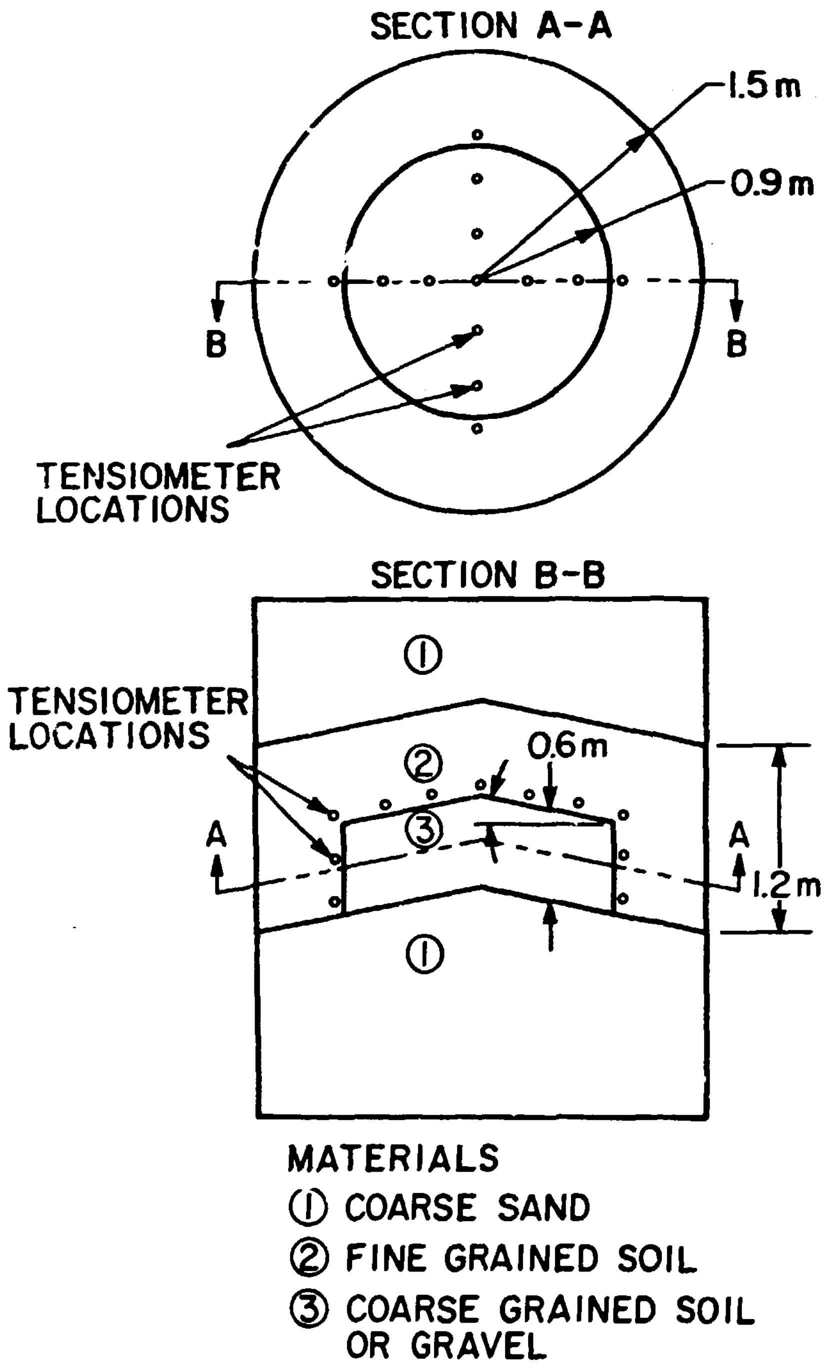


Figure 9. Possible Configuration for Wick System Experiment

materials. The second experiment cluster will be available for emplacement of experiments of this type.

In fiscal year 1982, work on subtask 3 will be a continuation and completion of the experiment illustrated in Figure 9. The final design for this experiment will be completed and the experiment emplaced. If possible, more than one configuration of materials and angle between layers will be evaluated. Based on the experimental results, applications to arid SLB will be outlined and field tested on a larger scale.

SUMMARY

Fiscal year 1981 was a year of great progress at the Los Alamos National Laboratory. The Experimental Engineered Test Facility was brought from idea to reality and two experiments were emplaced (biointrusion barrier and moisture cycling). The experiment clusters were designed and constructed, and are now available for experimentation. These units are reusable. After an experiment is complete it can be removed and another experiment put in its place. Several of the experiments were planned and designed while some of the other experiments are still in the planning stage. Based on the work done in FY-1981, significant progress toward Milestones C, D, and E should be made in FY-1982.

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Aup

PRELIMINARY ASSESSMENT OF GEOLOGIC MATERIALS TO MINIMIZE BIOLOGICAL INTRUSION OF LOW-LEVEL WASTE TRENCH COVERS AND PLANS FOR THE FUTURE

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ABSTRACT

The long-term integrity of low-level waste shallow land burial sites is dependent on the interaction of physical, chemical, and biological factors that modify the waste containment system. Past research on low-level waste shallow land burial methods has emphasized physical (i.e., water infiltration, soil erosion) and chemical (radionuclide leaching) processes that can cause radionuclide transport from a waste site.

Preliminary results demonstrate that a sandy backfill material offers little resistance to root and animal intrusion through the cover profile. However, bentonite clay, cobble, and cobble-gravel combinations do reduce plant root and animal intrusion through cover profiles compared with sandy backfill soil. However, bentonite clay barrier systems appear to be degraded by plant roots through time. Desiccation of the clay barrier by invading plant roots may limit the usefulness of bentonite clay as a moisture and/or biological barrier unless due consideration is given to this interaction.

Future experiments are described that further examine the effect of plant roots on clay barrier systems and that determine the effectiveness of proposed biological barriers on larger scales and under various stress conditions.

INTRODUCTION

Low activity wastes and wastes suspected of being contaminated are generally buried in shallow trenches (1.5 to 45 m wide, 2 to 11 m deep, 6 to 300 m long) that are covered with less than 1.0 to 2.5 m of material when the trenches are full (1). Most waste burial facilities attempt to revegetate the trench covers to minimize soil loss and to increase aesthetic appearance of the site. Although it has been recognized (2,3) that biological intrusion of low-level waste trenches can lead to transport of radionuclides from a burial site, little has been done to quantify the magnitude of the problem and to develop measures, when needed, to prevent the intrusion.

The stability of low-level waste trench covers is a function of physical, chemical, biological, and climatological factors that interact in both obvious and subtle ways. The importance of biological factors in altering the integrity of trench covers is often overlooked despite evidence that plants and animals can influence trench cover stability and, as well, can mobilize radionuclides buried in the trench (2,3). Biological interactions with trench covers can be direct, as in the case of radionuclide uptake by plant roots, or they can be indirect, such as when tunnel systems created by burrowing animals increase the rates and depths of rain water penetration into the trench cover profile.

The purpose of this paper is to describe short-term, small-scale field experiments at the Los Alamos Experimental Engineered Test Facility that evaluate the effectiveness of several geologic materials in minimizing biological intrusion through low-level waste trench covers. In addition, preliminary results are presented on the effectiveness of various barrier materials, along with plans for future experiments.

METHODS AND MATERIALS

A series of experiments was initiated at Los Alamos in the Experimental Engineered Test Facility to determine the effectiveness of several natural geologic materials as barriers that inhibit plant and animal intrusion into low-level waste cover profiles. Initial experiments employ 288 lysimeters consisting of 25-cm-diameter PVC pipe ranging from 105 to 210 cm in length. Cover profiles were constructed in the lysimeters to evaluate the effect of four different variables on plant root penetration with depth (Table 1). The profiles, as shown by the example in Fig. 1 consist of a simulated waste (CsCl) at the bottom of the profile. The waste layer is covered by a barrier layer consisting of four different types of natural geologic materials (cobble, cobble-gravel, bentonite clay, and crushed tuff) at three different depths. Top soil is applied at two different depths as an overburden to complete the profile. Three species of fast-growing, deep-rooted plants (alfalfa, barley, yellow sweet clover) were seeded into the lysimeters to produce the biological stress for evaluating the barrier systems.

A companion study was also initiated to evaluate the effectiveness of the barrier systems in inhibiting animal burrowing with depth. Four galvanized metal culverts (1.9 m diameter by 2.2 m height) were filled with an experimental waste cover profile consisting of each of the bio-barrier materials covered by top soil. A pocket gopher (*Thomomys bottae*), a highly active burrowing animal, was introduced into each culvert system and was allowed to construct a burrow system within the cover profile. The success or failure of the barriers was evaluated by analyzing plant tissue for stable cesium, using a neutron activation analysis, throughout the growing season in the case of the lysimeter study, and by physically mapping the plant root and

TABLE 1

EXPERIMENAL DESIGN OF
PLANT ROOT INTRUSION STUDY

VARIABLE	NUMBER	REMARKS
Plant Species	3	Barley, Clover, Alfalfa
Top Soil Depth	2	30 cm, 60 cm
Barrier Type	4	Crushed Tuff Bentonite Clay Cobble Cobble–Gravel
Barrier Depth	3	Clay. 15 cm, 30 cm, 45 cm Others. 30 cm, 60 cm, 90 cm
Replications	4	
Total Number	288	

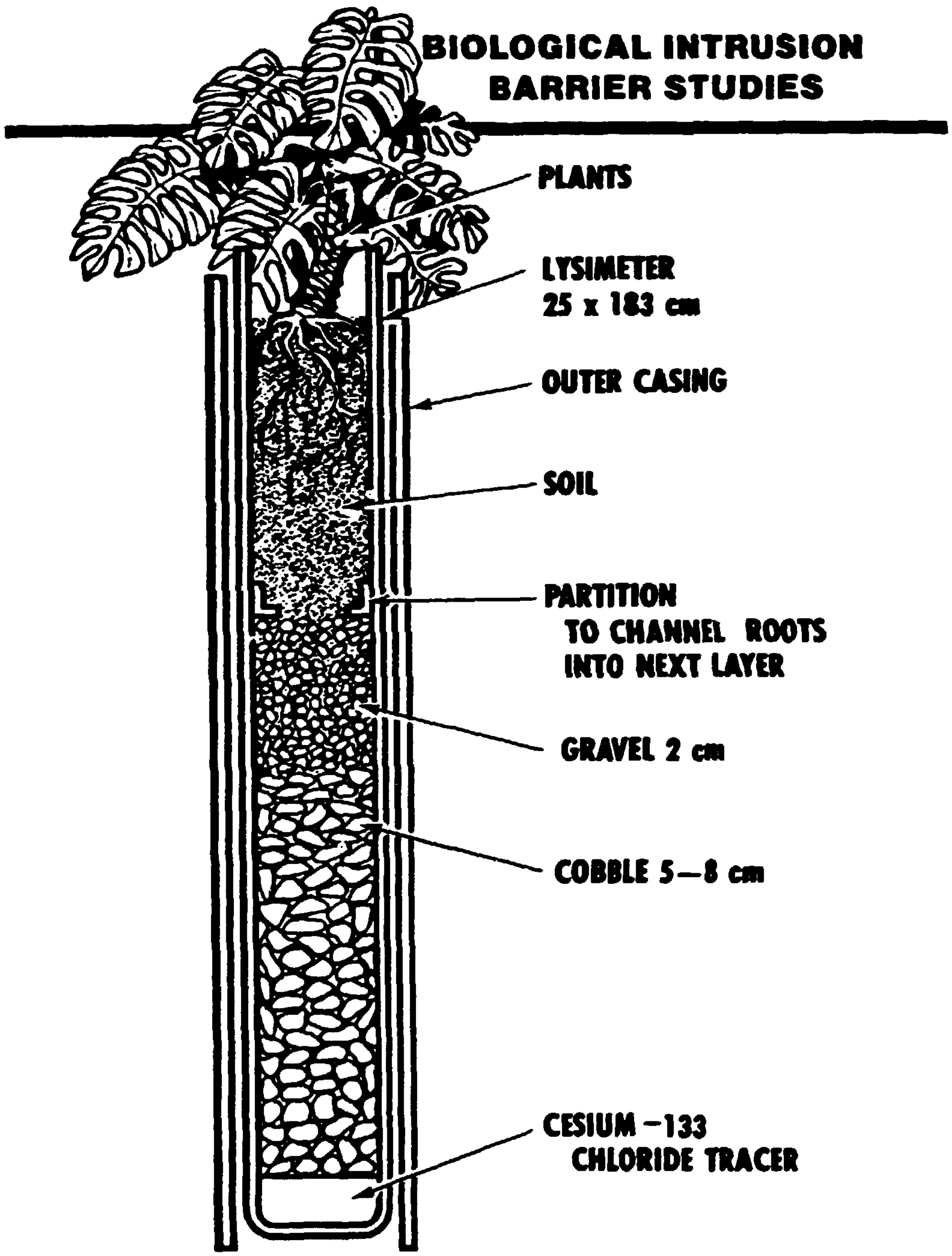

Figure 1. Experimental Soil Profile Configuration used to Evaluate Geologic Materials as Root Intrusion Barriers

animal burrow systems in the cover profile at the conclusion of the experiment. The biological intrusion barrier studies are one of several studies being conducted in the Los Alamos Experimental Engineered Test Facility. The purpose of these studies is to design and evaluate integrated barrier systems that are effective in limiting erosion, moisture infiltration, and biological intrusion of low-level waste cover profiles (Table 2).

PRELIMINARY RESULTS

Plant Root Barriers

Initial results from sampling vegetation for cesium tracers indicate that 126 of the 288 cover profiles had been completely penetrated by plant roots in a 102-day period. Analyses of these data by experimental variables show that about 50% of the penetration through the barrier

TABLE 2

EXPERIMENTAL APPROACH TO DESIGNING AND EVALUATING CRITERIA FOR CONSTRUCTING LOW-LEVEL WASTE BURIAL SYSTEMS

SURFACE AND NEAR SURFACE	SUBSURFACE
Integrity of the Cover	*Containment of Waste*
–Erosion	–Moisture Flux
–Soil Moisture	–Contaminant Mobilization and Transport
–Evapotranspiration	–Biological Transport and Translocation
–Percolation	–Structural Stability
–Biological Intrusion	

Problem	*Model*	*Experiments*
Integrity of Cover	CREAMS	–Erosion –Moisture Cycle –Biointrusion
Waste Mobility	Unsaturated Flow	–Moisture Cycle –Biointrusion –Moisture Barriers –Subsidence –Microbial Effects –Wick Systems

materials were caused by barley, whereas clover and alfalfa were each associated with about 25% of the penetrations. These initial differences in the rate of root penetration between plant species indicate the need to carefully consider rooting characteristics of species used to stabilize low-level waste covers. Consideration should also be given to the rooting characteristics of successional species that eventually replace the species initially used to reclaim low-level waste sites.

The relationships between barrier penetrations with barrier type, barrier depth, and soil overburden depth are presented in Tables 3-6. All of the profiles containing a sandy backfill material (crushed tuff) had been penetrated by plant roots after 102 days regardless of barrier or soil depth. About 30% (22/72) of the cobble barriers systems and about 22% of the clay and cobble-gravel systems had been penetrated after 102 days. Increasing soil and barrier depth substantially reduced barrier penetrations. Minimum barrier and soil depth combinations were associated with the highest rate of root penetrations through the clay, cobble, and gravel. The most effective depth combination at this stage of the study appears to be 60 cm of soil and 90 cm of barrier.

TABLE 3

NUMBER OF ROOT PENETRATIONS THROUGH COBBLE BARRIER MATERIALS AS A FUNCTION OF BARRIER AND SOIL DEPTH AFTER 102 DAYS

Barrier Depth (cm)	30	60	90	Total
Soil Depth (cm)				
30	7*	3	3	13
60	4	3	2	9
Total	11	6	5	22

*The maximum sample size for each cell is 12.

TABLE 4

NUMBER OF ROOT PENETRATIONS THROUGH BENTONITE CLAY BARRIER MATERIALS AS A FUNCTION OF BARRIER AND SOIL DEPTH AFTER 102 DAYS

Barrier Depth (cm)	15	30	45	Total
Soil Depth (cm)				
30	6*	4	2	12
60	2	2	0	4
Total	8	6	2	16

*The maximum sample size for each cell is 12.

TABLE 5

NUMBER OF ROOT PENETRATIONS THROUGH CRUSHED TUFF BARRIER MATERIAL AS A FUNCTION OF BARRIER AND SOIL DEPTH AFTER 102 DAYS

Barrier Depth (cm)	30	60	90	Total
Soil Depth (cm)				
30	12*	12	12	36
60	12	12	12	36
Total	24	24	24	72

*The maximum sample size for each cell is 12.

TABLE 6

NUMBER OF ROOT PENETRATIONS THROUGH COBBLE-GRAVEL BARRIER MATERIALS AS A FUNCTION OF BARRIER AND SOIL DEPTH AFTER 102 DAYS

Barrier Depth (cm)	30	60	90	Total
Soil Depth (cm)				
30	4[a]	4	2	10
60	2	3	1	6
Total	6	7	3	16

[a]The maximum sample size for each cell is 12.

While bentonite clay and cobble-gravel performed equally well in preventing plant root intrusion, plant roots greatly altered the integrity of the clay barrier system. During the course of the study it was noted,by visual observation in clear lucite lysimeters, that the integrity of the clay layer changed through time. A gradual, but continual, shrinkage of the clay layer occurred as a result of depletion of moisture from the clay by invading plant roots. This observation, if confirmed by further data, has significant implications on the use of bentonite clay as a moisture, gas, and/or biological barrier.

Animal Intrusion Study

Tunnel systems created by pocket gophers in the four metal culverts were mapped by injecting each system with an expanding polyurethane foam. Excavation of the tunnel casts revealed that the sandy backfill (crushed tuff) offered little resistance to the burrowing activities of pocket gophers whereas bentonite clay, cobble, and cobble-gravel barrier systems all prevented gopher burrowing with depth. Gophers were physically unable to move cobble 5-7.5 cm in diameter. While gophers could transport gravel 1.9 cm in diameter to the ground surface, tunnels created in the gravel were unstable and collapsed thereby preventing unrestricted movement of gophers in this zone. Bentonite clay, because of its cohesive consistence, discouraged gopher tunneling. However, the action of plant roots in drying the clay may change the ability of gophers to tunnel in this material.

FUTURE STUDIES

The small-scale plant root intrusion study will be concluded by sampling each lysimeter to determine root biomass versus depth within the profile. Although none of the root barrier systems may prove 100% effective, certain of these systems may greatly reduce root biomass with depth and thereby reduce the potential for contaminant uptake.

Further studies in the small-scale lysimeters will focus on the effect of plant root systems on the integrity of clay barrier systems. A variety of clay types suggested for use in large volume waste reclamation methodologies will be evaluated under various experimental conditions. These conditions include clay barrier depth and position within the profile under various moisture regimes. The results of this experiment will provide data useful in selecting clay materials that are effective as moisture, gas, and biological barriers.

Biological intrusion studies will be initiated at intermediate scales in the caissons at the Experimental Engineered Test Facility. In addition to providing performance data for biological barrier materials at larger scales, these studies will relate the influence of barrier materials on moisture regimes within the cover profile.

Best estimates of effective biological barriers will be evaluated on a low-level waste trench at Area G, the Laboratory's current low-level waste disposal site. The emphasis of the experiment will be on evaluating barrier effectiveness under actual site operating conditions using native grass species for ground cover and with natural precipitation.

SUMMARY

Small-scale, short-term biological intrusion studies at the Los Alamos Experimental Engineered Test Facility show that typical sandy backfill material is readily penetrated by invading plant roots and animals. Bentonite clay, cobble, and cobble-gravel combinations reduce the rate of root and animal intrusion through experimental waste cover profiles compared to the sandy backfill. Intermediate scale studies with proposed barrier materials will provide further technical support for selecting effective biological intrusion barriers. Current data suggest that cobble-gravel combinations appear to offer the most resistance to biological intrusion when all factors are considered.

Important future goals of this study are to evaluate plant root effects on clay barrier integrity and to test cobble-gravel barrier systems at expanded scales. Experimental designs for the biological barrier studies will incorporate other factors affecting cover integrity as demonstrated by moisture and chemical cycling experiments and computer modeling.

ACKNOWLEDGEMENTS

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TRENCH SUBSIDENCE

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ABSTRACT

Settlement gages have been installed over four SRP trenches to quantify the amount & duration of settling which occurs as soil and waste compact and/or decay with time. The data will be used to quantify an observed effect and estimate the long-term maintenance requirements for burial trenches.

PROGRAM DESCRIPTION

The purpose of our trench subsidence work is to quantify the amount and duration of the settling which occurs after trenches are filled and covered. Most of the wastes which are buried in trenches at SRP are wrapped in plastic and packaged in cardboard cartons. This type of packaging is permissible because the waste never leaves the Plant site. Some compaction of the waste occurs after burial as a result of soil pressure and due to eventual decomposition of the organic components of the wastes and packaging materials. This effect is minimized by the fact that spoil dirt from a newly excavated trench is generally heaped on a just-filled trench in order to effect initial compaction of the soil and wastes in that trench. Volume changes of the wastes after burial causes subsidence which permits ponding of surface water. Also, fissures can occur at the interface between undisturbed and disturbed (backfilled) soil as settling of the disturbed soil occurs. These effects can cause admittance of surface waters to the trench space, and this may result in perched water and increased leaching of radionuclides from wastes.

We have a program at SRP which is designed to evaluate the extent of subsidence which occurs at "old" and "new" (i.e. recently backfilled) trenches and also at trenches which were filled with cardboard box wastes vs trenches filled with primarily scrap metal wastes. Figure 1 is a sketch of settlement gages which have been installed. The elevation of these gages, referenced to a benchmark, is determined periodically with surveying instruments (Fig. 2).

Figure 3 shows the location and type of trenches chosen for the study. Two are in the old burial ground two are in the new burial ground. The gages have been installed and some data has been taken, but no pattern has been established at this point in time.

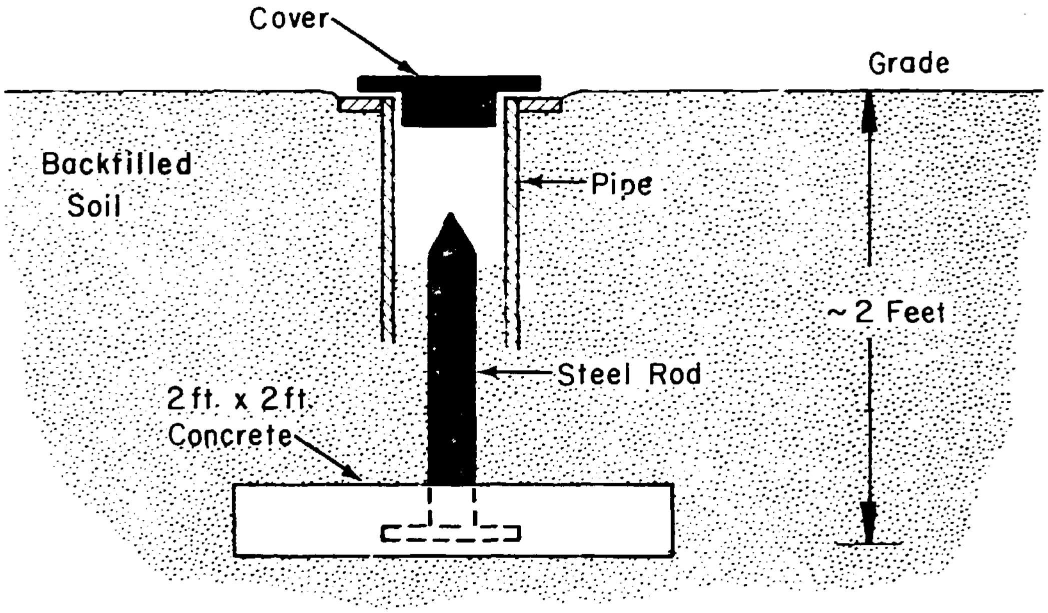


Figure 1. Settlement Gages

Figure 2. Measuring Elevation of Settlement Gages

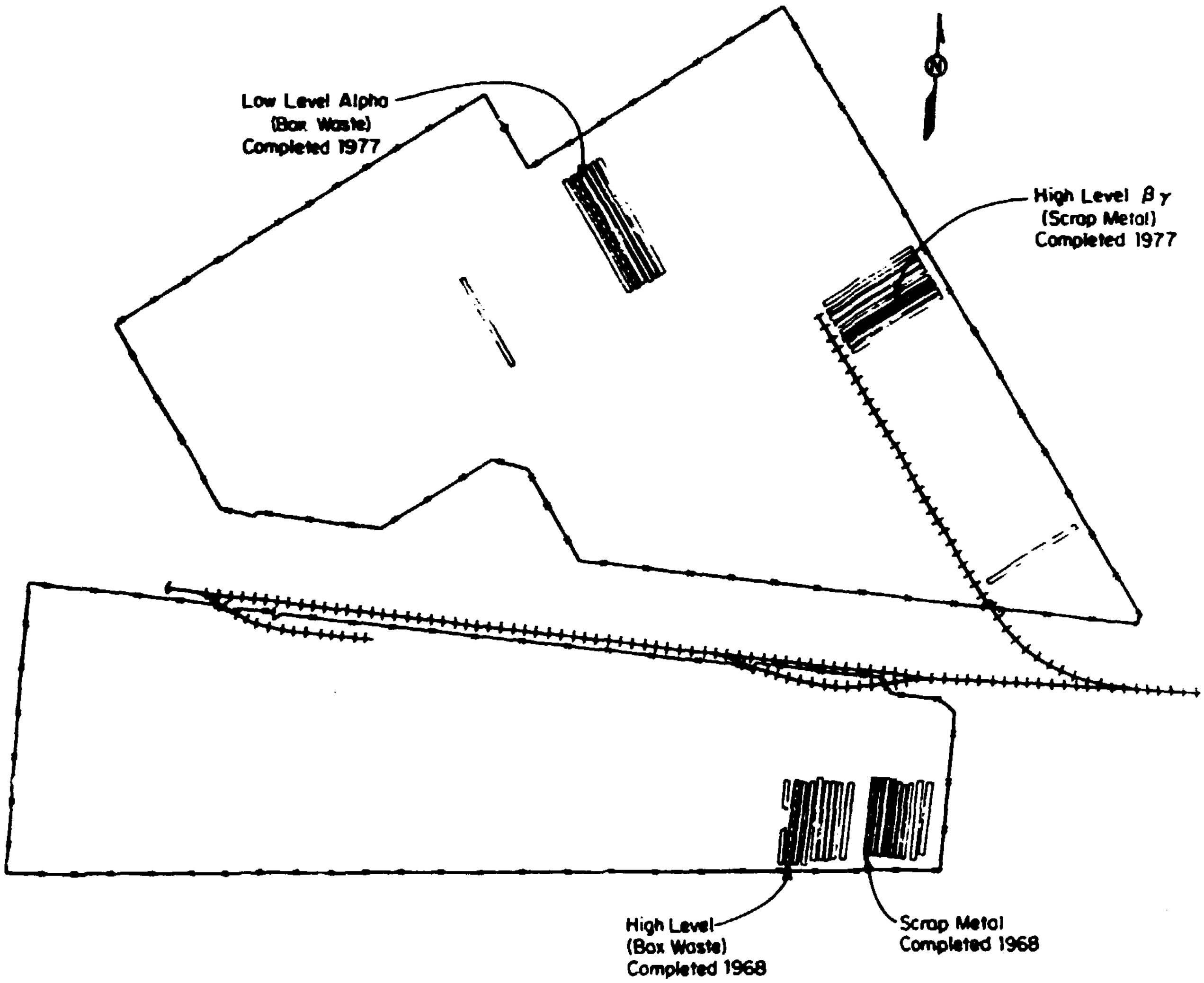


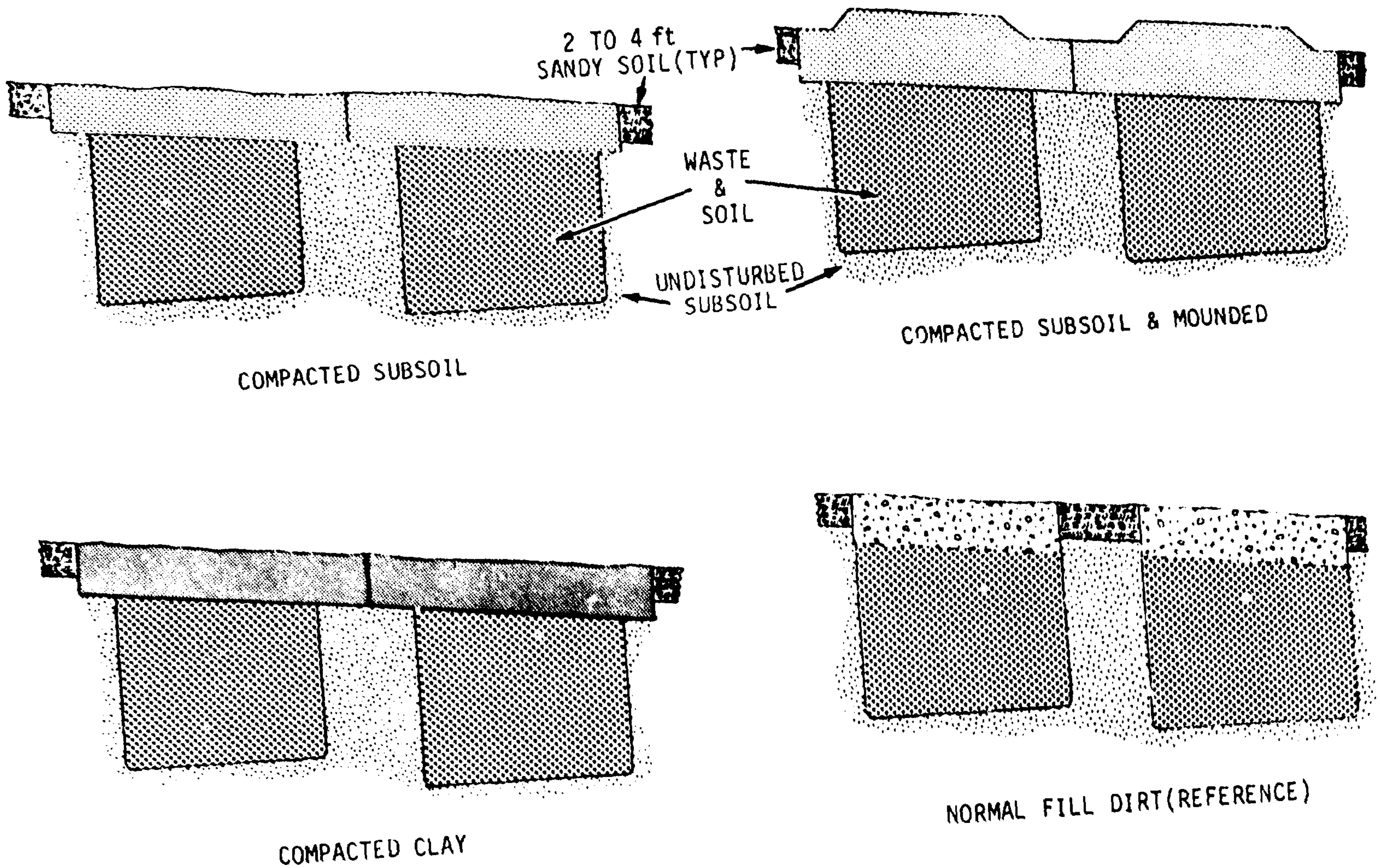
Figure 3. SRP Burial Ground Trench Settlement Study

Some consideration has been given to the use of clay and compacted soil caps for inhibiting incursion of rainwater (Fig. 4). The plan of

filling in sunken areas and compacting the fill soil over old and new trenches has been adopted. More extensive action (e.g. mounding or use of clay caps) was considered unnecessary because investigations have shown little or no movement of radionuclides (other than tritium) from the trenches.

Trench settlement data will provide a basis for predicting how long maintenance of burial trenches will be required. This will be of use from an interim operational standpoint, as well as for long-term planning for decommissioning.

Figure 4. **TRENCH COVERS**



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HUMID SITE STABILIZATION AND CLOSURE

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It is functionally and economically imperative that planning for final stabilization and closure of shallow land burial sites begin early in the course of site utilization, preferably as a component of site selection. Site characteristics will greatly influence the cost and degree of effort required for site closure. The purpose of the work I shall describe here will be to identify and evaluate the importance of factors that are expected to dictate the nature of site stabilization and closure requirements. Subsequent efforts will plan for implementation of such requirements. This project will be new in FY1982 and the present report simply outlines current planning for the two major areas of effort that will be pursued at the outset. Those areas are: (1) geological management, and (2) vegetation management.

The two most important geological processes related to site stabilization and closure are expected to be chemical weathering and surficial erosion. Chemical weathering typically occurs throughout the soil zone and, at humid sites, is most intense where downward-percolating waters encounter less weathered bedrock and the saturated ground water zone. There, neutralization of the relatively acidic waters derived from precipitation and soil reactions result in conversion of the most abundant metallic elements into soluble ionic forms such as Na^+, Mg^{++} and Ca^{++}. Removal of these soluble ions in dilute ground water solutions leaves a rather less-aggregated set of oxides of Si, Al and Fe. Engineered structures such as burial vaults, ground water diversion barriers, etc. will be subjected to stresses during gradual weathering process. It is necessary that chemical weathering and surficial erosion processes be considered to ensure attainment of long term site management goals.

At the surface, the component of incoming precipitation which does not infiltrate but runs off provides a transport medium that strips away the surface residual material. In some situations, wind erosion will supplement erosion by runoff. Susceptibility to erosion will be influenced by site operations including land clearing, excavation and installation of infiltration control systems. The relative significance of wind and water erosion will be partly determined by such environmental factors as climate, amounts of rainfall, intensity

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of rainfall, surface slope, rock type, vegetation coverage and anthropogenic factors such as compaction and solidification of wastes. In the long run, unchecked surficial erosion will expose most buried waste and eventually transport it away. (I have assumed that siting is likely to avoid upland depositional areas where ground water problems will probably be greatest.)

Erosion will be closely related to vegetation management. Invasion of a burial site by plants will occur whether or not revegetation is practiced. This invasion and the subsequent development of plant communities has been termed "succession" and surprisingly consistent successional sequences have been delineated for humid Eastern U.S. environments. In the most direct approach to vegetation management, the natural successional trends are countered by planting and nurturing desired species coupled with cutting or mowing of undesired species. This approach is both labor and cost intensive and is consequently unsuitable for site closure. Ideally, we would like to ensure that the natural course of succession would would be compatible with site management goals. In actual practice it may be necessary to provide infrequent, periodic control actions such as are practiced along highway or power line rights-of-way.

In addition to providing erosion control, plants can act as a shunt for buried materials into the surface environment. Root growth in zones containing water, nutrients or merely the interstices between waste packages can invade trenches and, perhaps, waste packages themselves. Radioisotopes of elements mobilized by the plants can be delivered to the surface much more rapidly than if invasion had not occurred. Furthermore, the roots are powerful invaders that can destroy the integrity of waste containers or engineered barriers and leave major pathways for entry of percolating waters into waste. Thus it will be necessary to ensure that the rate and course of plant succession at a site will be compatible with site management goals.

In summary, two principal areas of site stabilization and closure effort will be pursued initially--geological management and vegetation management. The geological effort will focus on chemical weathering and surficial erosion. Such catastrophic geologic events as landslides, flooding, earthquakes, volcanos, etc. are already considered in site selection and operation and these factors will not be emphasized initially. Vegetation management will be designed to control erosion, to minimize nuclide mobilization by roots and to be compatible with natural successional pressures. It is anticipated that the results of this work will be important both to site selection and operation as well as the actual stabilization and closure procedure.

INSTRUMENTATION DEVELOPMENT, MONITORING AND MODELING AT IDAHO NATIONAL ENGINEERING LABORATORY

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This paper was not cleared for publication when the Proceedings were compiled. Those interested in the paper may contact the author:

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PACKAGE RECEIPT ASSAY SYSTEMS

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ABSTRACT

Relevant waste package parameters are identified. Waste package measurement requirements and capabilities are evaluated and prioritized. A passive TRU package assayer is described.

INTRODUCTION

The objective of this research program is to organize, apply, and develop as required, instrumentation for assaying the radionuclide content of waste packages received by land burial operators, both to verify the data provided by the generator/shipper and to provide the most accurate records possible of buried materials. This program is directed toward the National Low-Level Waste Management Program Milestones C and B, but the technology is also applicable for the Greater Confinement scenarios in Milestones E and G.

Based on site visits and discussions with operators at seven low level waste disposal sites, both commercial and defense, some rather practical insight was used to temper the panacea instrumentation which would be ideal. Realistic expectations of waste package parameters which can be assayed are described below, along with existing or under-development instrumentation capable of making the measurements. Also included are recommendations for standardization of waste packages which would facilitate assay, provide additional barriers to mobilization and migration of the wastes, and aid in stabilization of the disposal site.

WASTE PACKAGE PARAMETERS

Unquestionably, the most important aspect of radioactive waste disposal by land burial is the ability to confine the wastes until they have decayed to innocuous levels. Just as unquestionably, the greatest mobilizing factor for buried wastes is water intrusion.

Proper operation of a land disposal site with respect to long-term management can be generally defined as the efficient interment of radioactive wastes in a manner such that hazardous quantities of radionuclides never enter the biosphere under normal climatic conditions or from predictable catastrophic events. This means that the combination of engineered barriers and geological containment should be adequate to confine the wastes for periods of time far beyond the anticipated operation and maintenance period of a disposal site. Through proper choice of waste form, matrix material, waste package, trench construction, and terrestrial geology, such confinement can probably be assured in arid western environments, but will be exceedingly more difficult to accomplish in a humid eastern environment. Consequently, disposal at an eastern site can be considered a worst possible case, and acceptable methodology at a humid site will be more than adequate for use at arid western sites.

Ideally, all waste package parameters which could have any bearing on confinement or mobilization of the radioactivity should be measured at the disposal site just prior to interment, and these measurements should be made on each package in a very short period of time and should provide extremely accurate results. A realistic approach, however, can at best hope to measure the radionuclide content of a representative number of waste packages from each shipment. The choice of acceptable waste forms, matrix materials, and packages will have to be made legislatively, and after that has been done, a decision can be made regarding implementation of a nondestructive assay technique to test for compliance. Obviously, visual inspection can be used to determine if the package itself is acceptable.

In order to make reasonable predictions of management potentials, it will be necessary to know the concentrations and total activities of the radionuclides present in the waste package. Again, however, it is expedient to consider only those radionuclides which present a long-term potential hazard. Relatively short-lived nuclides or those which represent minimal biological hazard can realistically be presumed to be containable for periods of time sufficient to render them innocuous. The radionuclides ^{3}H, ^{14}C, ^{90}Sr, ^{99}Tc, ^{129}I, ^{237}Np, and the transuranics have been determined to be the most important activities in terms of radiological health, due to their high mobility potential, high hazard-to-man index, and/or long half-life. The concentration and total activity of these radioisotopes are the important waste package parameters to be determined. The volume and weight of the waste packages are also of interest and are easily measurable by conventional techniques. The concentrations of other radioactivities present, such as gamma-ray emitting fission products, are also of interest but of less importance from a long-term management standpoint. These types of isotopes can probably be determined to sufficient accuracy levels with state-of-the-art high resolution gamma-ray spectrometric techniques.

Of the important radionuclides listed above, only ^{237}Np and the transuranics are likely to be measurable with nondestructive assay techniques. Such measurements are extremely important, however, since waste packages containing transuranic concentrations above prescribed levels are not allowed to be disposed of in low-level land burial sites. Therefore, the capability to segregate waste packages containing enough transuranic activities to be considered TRU waste is extremely important. The exact definition of which isotopes at what concentrations constitute TRU wastes differs depending on the government agency and is likely to be changed or modified in the future.

Tritium and ^{14}C concentrations will probably have to be estimated or measured prior to encapsulation in a waste package. The ability to measure ^{90}Sr, ^{99}Tc, and ^{129}I nondestructively in a sealed package will depend largely on the success of measurement technology currently under development.

MEASUREMENT REQUIREMENTS AND CAPABILITIES

Prioritization of waste package measurement requirements is treated in descending order of importance in the following paragraphs.

1) Probably the most important measurement requirement for low level waste receipts is the transuranic activity concentration. Certainly, if the TRU concentration exceeds the prescribed limit for low level wastes, then the offending package does not qualify as low level waste and cannot legally be disposed of in a low level land burial site regardless of its other attributes or shortcomings. The current generally accepted definition of TRU wastes are those that contain greater than 10 nCi of alpha activity per gram of matrix material and variously include or exclude ^{235}U, ^{238}U, ^{237}Np, and ^{238}Pu. No single measurement technique currently in existence or under development is capable of measuring all TRU activities at the prescribed level of sensitivity in all packages. In fact, it will require a combination of techniques to make TRU measurements at 10 nCi/g and even then, not all determinations will be possible.

The most informative TRU assay technique available is the measurement of the distinctive gamma-ray lines emitted by specific isotopes utilizing high resolution germanium diode gamma-ray spectroscopy. With this technique, ^{235}U, ^{238}U, ^{237}Np, ^{239}Pu, ^{241}Pu, and ^{241}Am can all be measured simultaneously at 10 nCi/g but only in the absence of large quantities of other gamma-ray emitting radionuclides. This latter condition is not likely to be found in most low-level waste packages. Another shortcoming of the gamma-ray measurement technique is the inability to measure ^{238}Pu, ^{240}Pu, or the curium isotopes.

Active neutron interrogation techniques are less sensitive to gamma-ray interferences but only measure the fissile species present. A technique which measures the increase in a steady state neutron flux caused by multiplication due to fission is not likely to be sensitive enough and is very dependent on matrix material. This technique, e.g. a steady state neutron flux produced by $^{241}AmBe$ sources and measured with ^{3}He proportional counters, again cannot measure ^{238}U, ^{237}Np, ^{238}Pu, ^{240}Pu, or the curium isotopes and cannot tell the difference between ^{235}U, ^{239}Pu, and ^{241}Pu, the fissile species. A shuffler system, ^{252}Cf cyclic induced fission with delayed neutron detection, is more sensitive than the steady state increase technique, but is subject to all the other limitations.

A passive neutron detection technique, such as in use at the Kernforschungszentrum, Karlsruhe, or that being developed in this program, measures the neutrons emitted by spontaneous fission of transuranic elements of alpha induced neutron emissions from light isotopes in the matrix. These techniques can be made sufficiently insensitive to gamma radiation, are adequately sensitive for measuring TRU levels, and can measure the total quantities of both spontaneous fission activity and alpha particle activity. These measurements are also very matrix dependent, however, and reinforce the necessity for standardized packages and matrix materials.

Other more exotic TRU measurement techniques under consideration, such as accelerator induced interrogation, are not sufficiently practical for application to real disposal operations.

2) The next most important measurement requirements are for the radionuclides ^{3}H, ^{14}C, ^{90}Sr, ^{99}Tc, and ^{129}I. Unfortunately, as if to confirm Murphy's law, these are also the most difficult to measure nondestructively in a sealed package. In fact, no existing techniques appear at all suitable for ^{3}H and ^{14}C. It may be possible to measure the bremsstrahlung radiation emitted by $^{90}Sr(^{90}Y)$ in the waste package, but the interferences caused by gamma-ray emitting radioactivities which are likely to be present in many instances and the variations introduced by the waste form and matrix material, create substantial accuracy problems for this technique. The potential of this method will be better defined as soon as current research developments in this field are completed. The ability to measure ^{99}Tc and ^{129}I nondestructively does not now exist, but research is ongoing or proposed for investigating such technologies.

3) As has been implied in the two preceding requirements, a knowledge of the waste form and/or matrix material is extremely important in order to obtain meaningful information from other package assay methods. However, even more important than being able to measure the waste form or matrix material, is the necessity to bureaucratically specify acceptable forms/materials. Since both the waste form and the matrix material are important, and since the distinction between them is not necessarily apparent, no attempt to separate them will be made here. Once the acceptable forms/materials have been specified, ordinary measurement techniques, such as densitometry, magnetometry, radiography, etc. will be available for testing compliance.

4) The easiest requirement to measure is the package itself. Again, a bureaucratic edict should specify a number of acceptable waste packages. This requirement is necessary to make all other measurement requirements practical. Obviously, a single piece of survey equipment cannot make quantitative measurements on an infinite variety of package shapes and sizes. Visual inspection should suffice for determination of compliance with this requirement.

5) Measurement of radionuclide concentrations other than those specifically referenced in the preceding paragraphs, is necessary from an inventory and control standpoint even if of little importance from a long-term

management position. Most radionuclides in this category emit distinctive and copious gamma radiations which can be quantitatively measured with a segmented gamma scanner or other similar high resolution gamma-ray spectrometric equipment.

6) Of least importance are the total volume and weight of the waste. The volume is only important from a record keeping and cost distribution standpoint and is most easily determined by utilizing standard packages of known volume. The weight is only important for normalizing the radioactivity concentration, such as for TRU activities, or for determining compliance with waste form/matrix material requirements. Standard scales or load cells will perform adequately for these measurements.

PASSIVE TRU PACKAGE ASSAYER

A passive neutron TRU package assay system has been optimized for application to low level waste package measurements. An array of $^{10}BF_3$ proportional neutron counters, each fit with its own mini amplifier/discriminator, have been wired into "octets" (four inner annular quadrants and four outer annular quadrants). The counter system was found to be totally unaffected by gamma-ray doses up to 35 R/hr. With the addition of an optional lead shield, the counter could measure 10 nCi/g of transuranics from a waste package emitting 1.5 million R/hr of gamma activity. This is, of course, not the typical low level waste package.

It is expected that the passive neutron counter system will be able to analyze a 200 ℓ steel drum of low level waste, emitting the maximum allowable gamma activity of 1 R/hr at one meter, for transuranics at a sensitivity level of 10 nCi/g in less than one minute.

Tests will begin soon on the sensitivity of this system for quantitatively determining the concentration and distribution of TRU materials in a waste package as well as the general nature of the matrix material. If the concentration of TRU activities in a waste package can be rapidly assayed at the 10 nCi/g level, the package can be properly directed to low level waste disposal or to TRU waste storage; thus making the most cost effective operation possible. If a single "hot spot" of TRU activity can be located within the waste package, retrieval may permit the rest of the package to be disposed of as low level waste rather than transuranic waste. Finally, the relative degree of thermalization of neutrons generated and moderated within the waste package will provide information concerning the hydrogenous composition of the matrix material, particularly when coupled with information on the bulk density of the package. A method is being examined which will allow a simple, rapid conversion of the TRU assayer data acquisition system from this octant counter for spatial and distribution measurements to a coincidence counter for isotopic and concentration measurements.

STANDARD WASTE PACKAGES

Fabrication of standard waste packages will begin in FY 1982. These standard packages will be of accepted dimensions and materials, will contain selected matrix materials, and will be spiked with known concentrations of appropriate radionuclides. These standards will then be available for calibration and testing of package assay equipment. A procedure for calibration of the radionuclide spikes to be used was perfected and documented during FY 1981. Absolute uncertainties of less than 2% are attainable which will provide ample accuracy for preparation of the standards.

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WELL LOGGING INSTRUMENTATION

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ABSTRACT

Research investigations on techniques for in situ determination of ^{90}Sr, tritium, and transuranic isotopes are described. Results of neutron activation analysis experiments on ^{90}Sr and passive neutron detection experiments on transuranics are given.

INTRODUCTION

The objective of this research program is to develop appropriate well-logging equipment capable of determining ^{90}Sr, ^{3}H, and transuranics at sensitivity levels that will provide useful information for the proper operation of a shallow-land burial site. This program is primarily directed toward the National Low-Level Waste Management Program Milestone C, but the technology is also applicable for Remedial Action and Greater Confinement scenarios included in Milestones D and E. The development of instrumentation capable of measuring ^{99}Tc and ^{129}I has recently been identified as important technology for proper long term monitoring and management of a low level waste disposal site, and these tasks are planned as outyear efforts. Many significant research accomplishments were achieved in FY 1981, and these, along with FY 1982 goals, will be discussed in greater detail below.

INSTRUMENTATION FOR ^{90}Sr

Investigation of the neutron activation analysis of ^{90}Sr was completed in FY 1981, and an open literature publication entitled "In Situ Neutron Activation Analysis of and the Neutron Capture Cross Section for ^{90}Sr," by L. A. McVey, R. L. Brodzinski, and T. M. Tanner, has been submitted to the Journal of Inorganic and Nuclear Chemistry. The suitability of this technique was found to be substantially less than originally anticipated when the thermal neutron capture cross section was measured to be more than a factor of 50 below that reported in the literature. This discovery firmly reinstated the bremsstrahlung technique developed earlier in this program as having the most potential for in situ analysis of ^{90}Sr. Consequently, a major effort has been expended on obtaining calibration data and developing a computer code for reliable spectral stripping and data reduction.

Neutron Activation Analysis of ^{90}Sr

The reaction $^{90}Sr(n,\gamma)^{91}Sr$ was investigated as a potential method for in situ analysis of ^{90}Sr based on suitable decay characteristics of the product, ^{91}Sr, and the favorable thermal-neutron capture cross section of 800 mb reported in the literature.(1)

Although the neutron activation product, ^{91}Sr, emits several relatively intense gamma-rays at energies of 556, 750, and 1024 keV, the target material, ^{90}Sr, is itself radioactive, and generates large quantities of bremsstrahlung radiation which interfere with the spectroscopic analysis.

Initial experiments were performed in the laboratory utilizing a solution containing ^{90}Sr. Interferences from the bremsstrahlung radiation produced by deceleration of ^{90}Sr beta particles was minimized by using lucite and lead absorbers around the sample and the high resolution germanium diode gamma-ray spectrometer in the configuration shown in Figure 1. The 6.4 mm thick lucite attenuates the beta particles emitted by ^{90}Sr and ^{90}Y, while the low Z matrix minimizes the generation of bremsstrahlung radiation. The 2.54 cm thick lead disc prevents a large fraction of the bremsstrahlung photons generated in the lucite from reaching the germanium diode, allowing only those in a direct line from the sample to be incident on the detector. The 3.2 mm lead plug in the bottom of the conical hole in the lead disc attenuates low energy bremsstrahlung photons preferentially to the higher energy activation product photons which maximizes the signal-to-noise ratio. This counting configuration was chosen after several experiments were performed to determine the optimum geometry for counting the photon peaks while maintaining satisfactory detector dead-time levels. Nevertheless, because of the bremsstrahlung radiation, the maximum amount of ^{90}Sr which could be counted was limited to about 4 mCi.

Standards were prepared from NH_4Br and NBS Orchard Leaves. Bromine was selected as a primary standard because of its well-known cross section and because the neutron activation product, ^{82}Br, emits relatively intense gamma-rays at energies of 554 keV, 776 keV, and 1044 keV -- very nearly the same as ^{91}Sr. The Orchard Leaves provided a matrix which would contain some of the anticipated interferences (^{76}As, ^{140}La, and ^{42}K), yet still be a calibrated source of several isotopes for calculating the neutron flux. In addition, empty irradiation containers and double-distilled water samples were prepared to be irradiated as blanks.

Care was taken during the preparation and handling of the samples, standards and blanks to eliminate potential interferences from activation of impurities. Each sample, standard, or blank was heat sealed in a small primary polyethylene vial which had been cleaned in boiling nitric acid. These small vials were then heat sealed in larger, cleaned, secondary polyethylene vials. Finally, the secondary vials were sealed in plastic bags. The samples were rotated during irradiation in a one megawatt TRIGA reactor at a measured thermal neutron flux of $9.36 \pm .35 \times 10^{11}$ n/cm^2sec for five hours. Following the irradiation the small primary polyethylene vials were transferred into

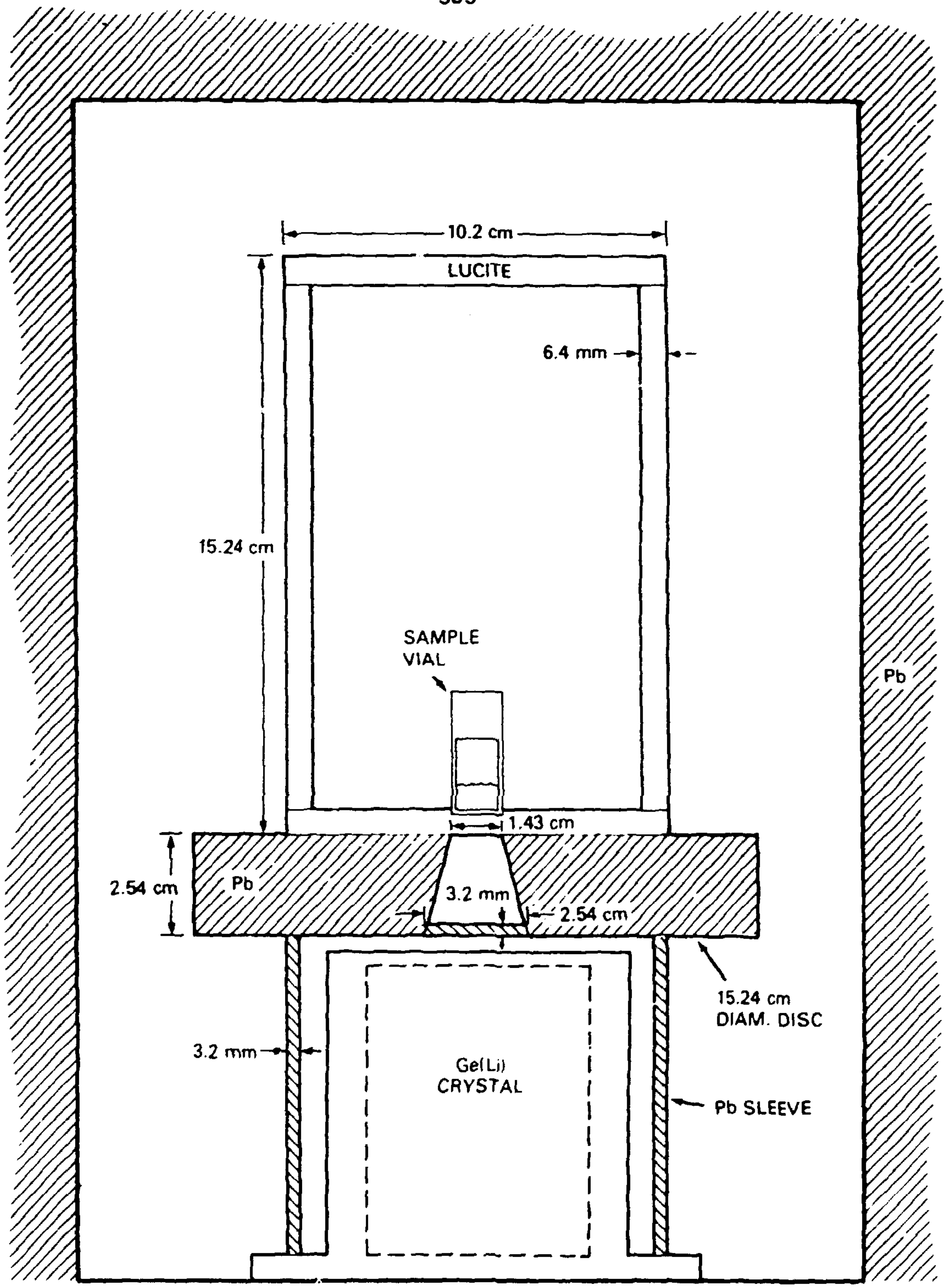


FIGURE 1. Counting System Configuration and Shielding.

larger unirradiated sample containers. This step eliminated the radioactive impurities associated with the large secondary polyethylene vials, leaving only those from the primary containers.

All samples were counted on a Ge(Li) diode gamma-ray spectrometer having a relative efficiency of 16.2% and a FWHM resolution of 1.84 keV at the 1332 keV line of ^{60}Co. Data were stored in a 2048 channel analyzer and transferred to both a floppy disc for computer data reduction and a hard-copy channel-by-channel printout for manual data evaluation.

The absolute efficiency of the detector and counting geometry was determined as a function of gamma-ray energy by counting an NBS traceable $^{152,154}Eu$ standard prepared in the same geometry as the samples. The weighted efficiency curve is shown in Figure 2.

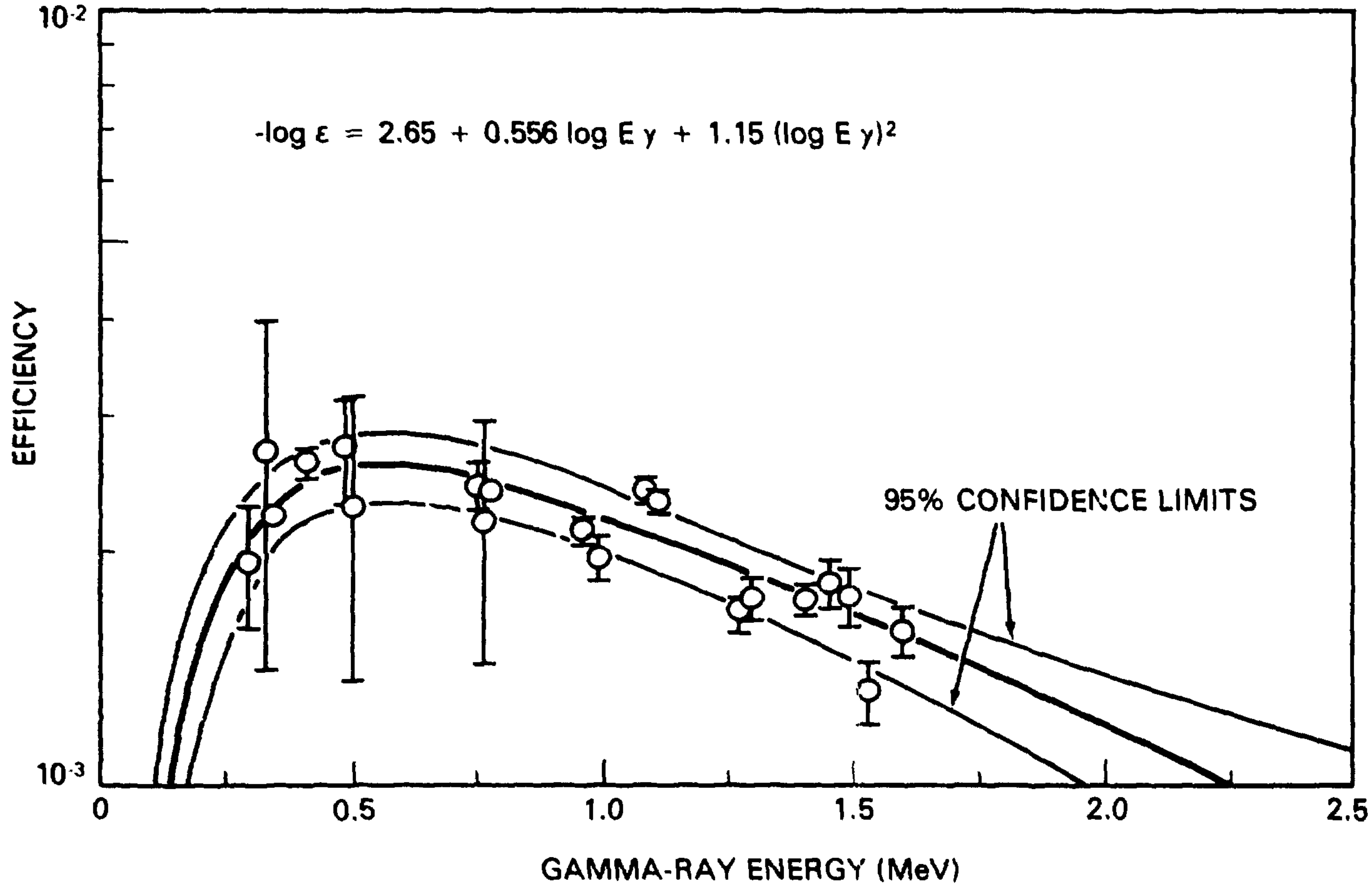
A plot of the gamma-ray energy spectrum from the irradiated ^{90}Sr sample is shown in Figure 3. The magnitude of the ^{91}Sr and impurity photopeaks relative to the ^{90}Sr bremsstrahlung continuum clearly demonstrates the difficulty of the measurement.

The half-lives, major gamma-ray energies, and branching fractions for the activation products of interest in this study are given in Table 1. Standard equations of radioactive growth and decay were used to determine the reactor neutron flux from the known cross sections and the measured activities induced in the NH_4Br and Orchard Leaves standards. These data are presented in Table 2. The average flux and the measured ^{91}Sr activity level were then used to calculate the $^{90}Sr(n,\gamma)^{91}Sr$ cross section.

All sources of error have been propagated by standard mathematical methods throughout the computations to determine reasonable and conservative uncertainties. Where several peaks were measured for a given isotope the production rate was taken to be the average of the values calculated from each photopeak, and the uncertainty was taken to be the standard deviation of these values. For individual photopeaks the error was propagated based on the uncertainties in the basic nuclear data, i.e. half-life, branching fraction, cross section, etc., taken from the literature.(2,3) All reported uncertainties represent one standard deviation.

The thermal neutron capture cross section for the reaction $^{90}Sr(n,\gamma)^{91}Sr$ is determined to be 14.0 ± 2.4 mb.

The thermal neutron capture cross section for ^{90}Sr may be slightly in error due to a contribution from resonance capture. However, no corrections were made for the resonance integral capture reactions in any of the standards. Therefore, unless the epithermal capture reactions in ^{90}Sr contribute substantially differently than the average of the monitor reactions, no significant error is expected.



<u>FIGURE 2</u>. Weighted Counting Efficiency Curve.

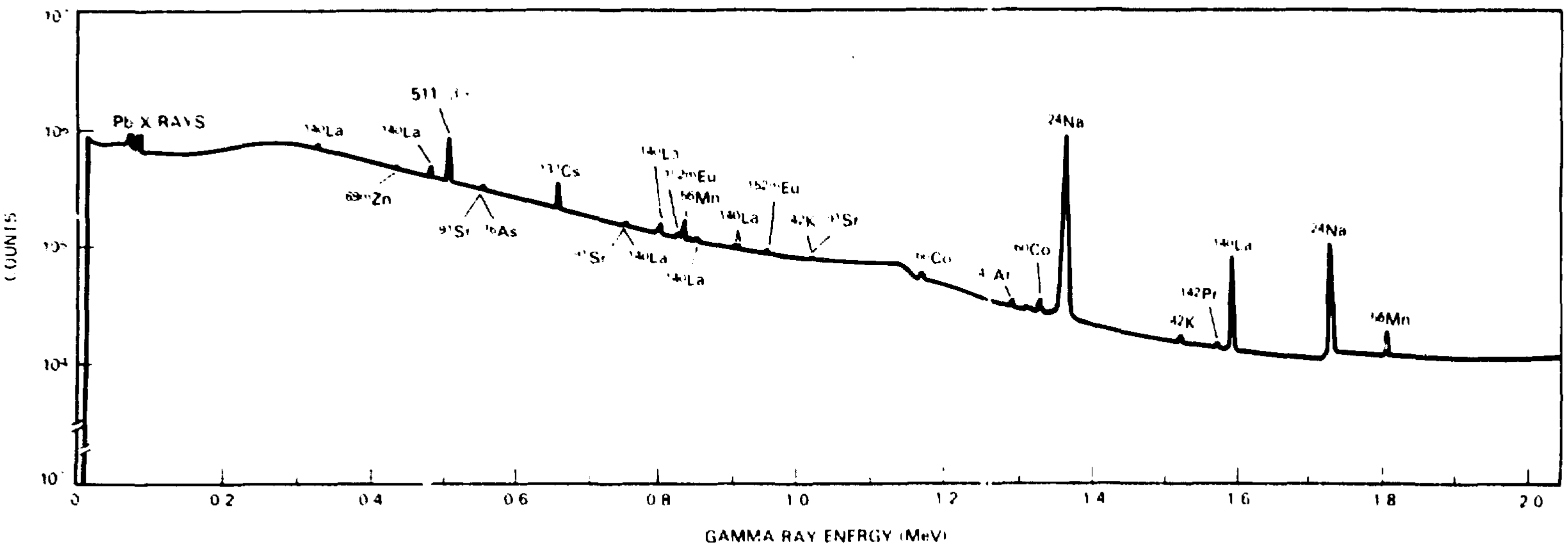


FIGURE 3. Gamma-Ray Spectrum of a Thermal Neutron Activated ^{90}Sr Source.

TABLE 1
NUCLEAR DATA FOR ACTIVATION PRODUCTS OF INTEREST

Isotope	$t_{1/2}$	E_γ	Branching Fraction
^{91}Sr	9.48 ± .01 h	556 keV	.607 ± .049
^{91}Sr	9.48 ± .01 h	750 keV	.228 ± .017
^{91}Sr	9.48 ± .01 h	1024 keV	.33 ± .02
^{24}Na	14.964 ± .015 h	1369 keV	1.00
^{24}Na	14.964 ± .015 h	2754 keV	.9985
^{42}K	12.361 ± .003 h	1023 keV	$(2.09 \pm .16)\cdot 10^{-4}$
^{42}K	12.361 ± .003 h	1525 keV	.188 ± .006
^{82}Br	35.344 ± .013 h	554 keV	.707 ± .008
^{82}Br	35.344 ± .013 h	698 keV	.286 ± .008
^{82}Br	35.344 ± .013 h	776 keV	.834 ± .009
^{82}Br	35.344 ± .013 h	828 keV	.239 ± .008
^{82}Br	35.344 ± .013 h	1044 keV	.274 ± .005
^{82}Br	35.344 ± .013 h	1317 keV	.269 ± .006
^{82}Br	35.344 ± .013 h	1475 keV	.166 ± .002
^{140}La	40.27 ± .05 h	1596 keV	.955 ± .003

TABLE 2
REACTOR NEUTRON FLUXES FROM MEASURED ACTIVITIES

Standard	Reaction	Cross Section	Flux
NH_4Br	$^{81}Br(n,\gamma)^{82}Br$	5.7 ± .2 mb	$(8.98 \pm .44) \times 10^{11}$
Orchard Leaves #1	$^{23}Na(n,\gamma)^{24}Na$	.528 ± .005 mb	$(9.06 \pm .37) \times 10^{11}$
Orchard Leaves #2	$^{23}Na(n,\gamma)^{24}Na$	.528 ± .005 mb	$(9.67 \pm .40) \times 10^{11}$
Orchard Leaves #1	$^{41}K(n,\gamma)^{42}K$	1.46 ± .03 mb	$(9.84 \pm .28) \times 10^{11}$
Orchard Leaves #2	$^{41}K(n,\gamma)^{42}K$	1.46 ± .03 mb	$(9.60 \pm .24) \times 10^{11}$
Orchard Leaves #1	$^{139}La(n,\gamma)^{140}La$	8.63 ± .34 mb	$(9.39 \pm .78) \times 10^{11}$
Orchard Leaves #2	$^{139}La(n,\gamma)^{140}La$	8.63 ± .34 mb	$(8.99 \pm .75) \times 10^{11}$
Average			$(9.36 \pm .35) \times 10^{11}$

When more than one isotope contributed to a photopeak of interest due to similar gamma-ray energies, the interfering activity was determined from other independent and resolveable peaks, corrected for branching fractions and efficiencies, and subtracted from the peak of interest. Generally, the identifiable interferences were from ^{76}As, ^{140}La, and ^{42}K.

Interferences from the 559 keV photopeak of ^{76}As and the 752 keV photopeak of ^{140}La could not be adequately resolved from the 556 and 750 keV peaks of ^{91}Sr in the Sr sample. In addition, a correction to the 556 keV peak would need to have been made due to the contribution from thermal neutron capture reactions on ^{90}Y, the equilibrium daughter-product of ^{90}Sr, leading to the same gamma-ray cascade via the ^{90}Y$(n,\gamma)^{91m}$Y reaction. Hence, the ^{91}Sr activity was obtained based on only the 1024 keV peak which, although lower in intensity than the 556 or 750 keV peaks, had virtually no interference. Other peak interferences were less of a problem. Corrections for the activities in the blanks were less than 1% in all cases, except for ^{24}Na.

Based on this measured cross section for the ^{90}Sr$(n,\gamma)^{91}$Sr reaction, an average thermal neutron flux of 5×10^{4} n/cm^{2}sec throughout the matrix, and empirical sensitivities for a subterranean high resolution germanium diode gamma-ray spectrometer, the detection limit for in situ measurement of ^{90}Sr in sediments by neutron activation analysis is calculated to be 366 mCi/cm^3 for a 10,000 second irradiation and count period. This lack of sensitivity is largely due to the intense bremsstrahlung radiation from the ^{90}Sr(^{90}Y) beta activity and leaves the technique unsuitable for practical applications.

A review of the reactions ^{90}Sr$(n,p)^{90}$Rb and ^{90}Sr$(n,\alpha)^{87}$Kr was made with consideration given to experimentally measuring the cross sections. However, there is no reason to believe that these fast neutron reaction cross sections should differ markedly from comparable reactions on other elements of similar mass and Q value. Hence, cross sections on the order of 5 mb are expected for these reactions with 14 MeV neutrons. If such a value is assumed, the detection of the ^{90}Rb and ^{87}Kr products would not be possible with a fast neutron flux of less than about 10^{12} n/cm^{2}sec. At the present time such a flux is unobtainable, consequently no attempt was made to measure these cross sections. Similarly, the low anticipated reaction cross sections and the even lower fast neutron fluxes obtainable in a subterranean environment make these transmutation reactions even more impractical than the thermal capture reaction as a method for determining the ^{90}Sr concentration in soil.

Analysis of ^{90}Sr by Measurement of Bremsstrahlung Radiation

Development of a mathematical model which can describe the shape of a gamma-ray spectrum has begun. At the present time it looks as though the best way to proceed is to construct the spectrum in pieces using strict boundary conditions. In this manner, it is hoped that the limitation confining a library of standard spectra to one set of parameters can be overcome, and that individual components of a gamma-ray spectrum can be accurately stripped to leave only the bremsstrahlung radiation spectrum from ^{90}Sr. The general shape of the broad Compton plateau and the region between the Compton edge and the beginning of the full energy peak are currently receiving the most attention since mathematical models of these areas have not been well defined. Monte Carlo simulations of these regions are also being investigated. Computer code development will be continued in FY 1982.

A Natural Activities Calibration Facility has been established in a pristine area on the Hanford Site. This area has been extensively sampled both surficially and as a function of depth, and the primordial radionuclide concentrations have been accurately determined. This facility is used to provide both empirical data for computer code development and calibration parameters for field survey instrumentation.

INSTRUMENTATION FOR TRITIUM

Development of the Nafion sampler/gas proportional counter tritium logging system was continued in FY 1981. The system has progressed to six subassemblies which are currently undergoing bench tests.

A change in the design of the system which would eliminate the need for a high-temperature furnace in the probe has been tested. The magnesium reduction furnace was replaced by a calcium carbide converter and hydrogen/palladium reducer to generate tritium tagged ethane counting gas. Problems were encountered with the efficiency of the calcium carbide conversion step, and the original magnesium reduction furnace was reinstalled. Problems involving proper operation of the cold trap also resulted in several modifications to that portion of the system. The magnesium reduction furnace controller has been tested and calibrated. Sufficient heat is provided by the system to maintain the furnace at 600°C even while the casing is submerged in water. Procedures for transferring the sample from the cold trap into the furnace are being investigated. The design manual for the tritium logging system has been completed and will be issued as PNL-4069.

A preliminary study which demonstrates the potential for real time in situ tritium analysis by mass spectrometry has been completed. This study indicates mass spectrometric techniques could be as much as a factor of two more sensitive than predicted gas proportional counting techniques. As soon as the actual sensitivity limits of the sophisticated gas proportional counting system currently under development are determined, the results from the preliminary mass spectrometric analysis study will be reexamined with a view toward the potential cost/benefits obtainable.

A basic investigation into the potential application of laser excitation analysis to well logging tritium measurements has been completed, and the results and findings are being evaluated. Preliminary indications are that a pure laser excitation technique will not provide satisfactory sensitivity by itself, but that when laser excitation is used as the ion source for a mass spectrometer, extremely sensitive measurements may be possible. Comparisons between the sensitivities and cost effectiveness of the proportional counting technique, static mass spectrometric analysis, and laser/mass spectrometer hybrid techniques will continue to be examined.

A tritium enrichment procedure involving cryogenic/magnetic techniques is also being considered as an input stage to any of the potential analytical systems.

INSTRUMENTATION FOR TRANSURANICS

A computer code has been developed to generate calibration factors for the passive neutron transuranic measurement technique developed earlier in this program. A five dimensional empirical data field has been programmed such that inputting the relative transuranic isotopic composition, the fluorine to oxygen ratio, the moisture content, the monitoring well size, and the matrix material, generates a calibration coefficient for converting the experimentally measured thermal neutron flux to the absolute concentration of all actinides in the matrix. The effect of the fluorine to oxygen ratio on the neutron yield from (α, n) reactions on light isotopes in the matrix material has been accurately measured. A linear increase in this portion of the neutron flux with increasing F/O ratio corresponding to the factor $4.509 \cdot 10^{-3}$(F/O) $n\ cm^{-2}\ sec^{-1}/nCi\ \alpha\ cm^{-3}$ has been observed.

Laboratory experiments were conducted on the x-ray fluorescence analysis of actinides utilizing ^{57}Co and ^{139}Ce isotopic excitation sources. These experiments concentrated on optimizing source-sample-detector geometries for maximum sensitivity and selectivity. This technique has the potential to quantitatively measure all transuranics through curium if satisfactory sensitivity levels can be attained. These experiments will be continued in FY 1982.

An investigation of the sensitivity limits for the neutron activation analysis of transuranics will also be conducted during FY 1982.

Tungsten collimators for improved spatial resolution with the actinide photon well-logging spectrometer were obtained. Field tests are currently underway at the Natural Activities Calibration Facility to provide calibration factors for each new configuration and to compare the effectiveness of the new system to that with the old lead collimators. This work will also be completed in FY 1982. An open literature publication entitled "In Situ Subterranean Determination of Actinides by High Resolution Gamma-Ray Spectrometry," by R. L. Brodzinski, will appear in the Proceedings of the International Symposium on Methods of Low Level Counting and Spectrometry, Berlin, April 6-10, 1981.

TECHNOLOGY TRANSFER

In order to be patently useful to the National Low-Level Waste Management Program, technology developed on this program must be made available to other operations and research personnel. During FY 1981, technology developed on this program was transferred by written and/or oral communication to personnel from 10 different companies, contractors, and national and international laboratories.

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BOREHOLE-GEOPHYSICS APPLICATIONS TO LOW-LEVEL, RADIOACTIVE-WASTE DISPOSAL TECHNOLOGY

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ABSTRACT

Borehole geophysics represents one of the most important methods for the measurement of hydrogeologic properties in situ. The U.S. Geological Survey's research project on borehole geophysics is developing a broad spectrum of borehole techniques and data-analysis procedures for the integration of various geophysical measurements into a set of coupled equation that may be solved for hydrologic unknowns, such as porosity and hydraulic conductivity. Several areas of investigation offering opportunities for significant progress have been identified: borehole-wall imaging, acoustic determination of rock properties, gamma-spectral analysis, and flowmeter analysis. Recent progress in these areas is reviewed, and efforts planned for the immediate future are discussed. A planned assessment of the relationship between well-log resolution and ground-water model performance also is described.

INTRODUCTION

The role of the U.S. Geological Survey in the low level, radioactive-waste disposal program is that of a scientific agency providing technical advice and developing analytical and onsite techniques for use in evaluating potential waste-disposal sites and investigating waste migration. During a recent interagency workshop on modeling and low-level waste management (Little and Stratton, 1981) the need for model-parameter input and definition of the geohydrological environment were identified as important limitations to the use of ground-water models in the prediction of the performance of disposal sites. Borehole geophysics represents one of the primary techniques for investigating the in situ properties of the hydrologic environment at proposed disposal sites. The Geological Survey's research project on borehole geophysics currently is addressing a broad range of geophysical research topics that have direct applications to the characterization of possible low-level, radioactive-waste disposal sites, or that can be used to provide parameter definition for ground-water-flow and solute-transport models used to predict site performance.

One of the most important aspects of well-log acquisition and analysis is the independent measurement of electrical, acoustical, nuclear, geochemical and other bulk geologic properties that permit simultaneous solutions of coupled equations for important hydrological properties. Recent advances in digital-recording equipment and computer processing now permit the rapid recording of many separate measurements, commonly providing more data than could be processed by established graphical techniques. The numerical processing of digitized well logs is a rapidly advancing research topic in petroleum exploration, and offers a similar opportunity in the application of otherwise routine well logs to waste-disposal studies. The computerized manipulation of digitized well logs, although not a research topic specifically related to a given type of logging measurement, is an important part of the Geological Survey's program to improve log analysis. Some of the important progress in the digital analysis of recorded logs is reviewed by Keys, (1979), and Keys, Eggers, and Taylor, (1979).

The Survey also is concentrating research efforts in several specific areas of study that offer especially good prospects for improved hydrogeologic resolution. These areas include acoustic borehole wall-imaging, quantitative radioisotope determination on the basis of gamma spectra in boreholes, acoustic characterization of porous and fractured rocks, and the construction of permeability profiles on the basis of flowmeter and acoustic televiewer logs. Recent progress and efforts planned for the immediate future under each of these specific topics will be discussed below. Three additional areas of interest have been identified for future work. These areas are the downhole neutron-activation analysis, the relationship between geochemical alteration and ground-water flow, and nuclear magnetic resonance logging.

BOREHOLE-WALL IMAGING

The primary effort in borehole-wall imaging has been directed towards improvement of fracture identification and characterization using the acoustic televiewer (ATV). The ATV logging system transforms recorded amplitudes of ultrasonic reflection off the borehole wall into a photographic image that is especially effective in the location and orientation of fractures and other fine lithologic detail. Typical ATV results compared to fracture information obtained from core, and from visual inspection of the borehole wall by a remote television camera are shown in figure 1. The figure shows a cylindrical section of the borehole wall opened along the north side of the borehole. Ongoing research thrusts include: development of a new analog recorder, enhancement of the ATV image through signal processing techniques applied to onsite data recorded on tape, identification and enhancement of those parts of the ATV signal associated with penetration at finite depths into the borehole wall, and the development of quantitative fracture-permeability profiles on the basis of ATV data. Several examples of ATV applications are given by Keys (1979), Keys, Eggers and Taylor (1979), and Keys and Sullivan (1979). Preliminary results indicate that the ATV log can be especially effective in defining narrow fracture conduits that account for a major part of ground-water flow in otherwise impermeable rocks. These narrow conduits typically constitute a very small percentage of the recovered core samples, or may be entirely missing from the core record. Borehole-wall imagery appears to offer a much more consistent and economical representation of fracture and shear-zone permeability that can be achieved with core inspection or impression packers.

ACOUSTIC DETERMINATION OF ROCK PROPERTIES

Even when fractures are recognized in recovered core, the contribution of fractures to total permeability can be difficult to define. The difficulties encountered when trying to make such interpretations include the lack of fully representative fracture samples, fracture alteration due to drilling effects, and the sensitivity of fracture permeability to changes in effective confining stress and other in situ conditions. The image displayed by the ATV log represents the borehole wall/fracture intersection, where apparent fracture width may have been greatly affected by drilling. Acoustic-waveform logging based on frequencies substantially less than those used by the ATV allows sampling of properties in relatively large volumes of rocks (typically) about 1 meter in diameter) and at distances away from possible drilling effects. Recent theoretical studies (Paillet and White, unpublished data, 1981) have shown that most of the modes of acoustic propagation in the fluid-filled borehole actually represent a complicated interaction between the laterally confined fluid and the elastic wall rock, and are not simple seismic vibrations within the rock alone (Paillet, 1981a). These physical insights have been used as a basis for relating acoustic waveform data to the effective permeability of fractured rock bodies (Paillet, 1980; Paillet and White, unpublished data, 1981).

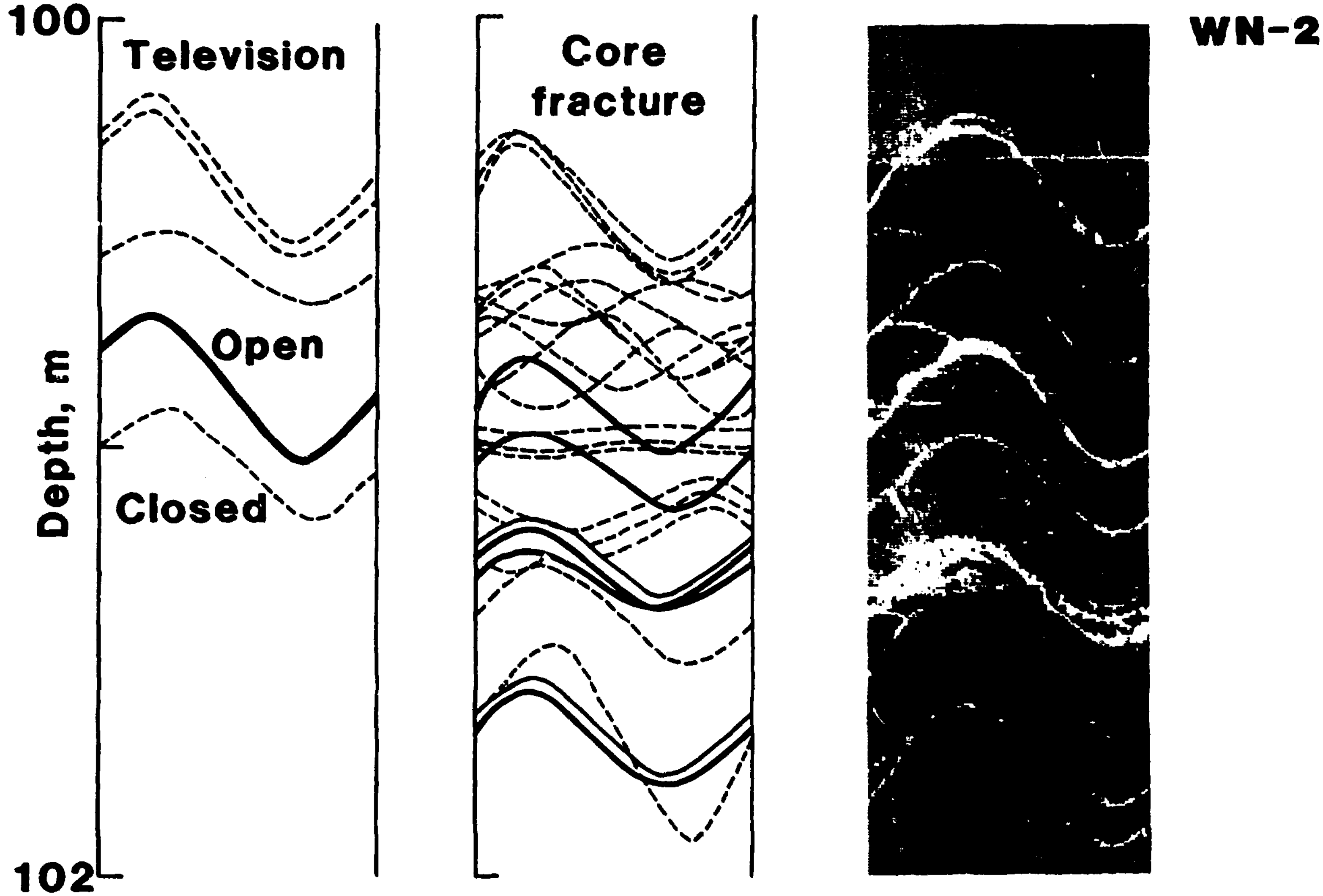

Fig. 1. Comparison of ATV log with fracture data obtained from core inspection and remote television for typical fractured crystalline rock.

Although the waveform methods are applicable to a wide range of lithologies, initial applications were restricted to fractured granite where fracture density and lithologic variations were both minimal, and amplitude anomalies could be associated with individual fractures. Several alternative methods for the construction of amplitude logs from waveform data were correlated with fracture permeability for these simple fractured rocks (Paillet, 1980). The approach was subsequently applied to nearly vertical fractures in a limestone with somewhat more variable lithology. The results again showed an apparent correlation between fracture permeability and acoustic-amplitude decreases, although the number of open fractures was rather limited (Paillet, 1981b). A typical example of the acoustic-amplitude response to an apparently open fracture in limestone is illustrated in figure 2.

On the basis of these initially encouraging results, the method was extended to a series of test wells with a closely spaced fracture density, and with a significant degree of lithologic variation. Fracture-permeability logs were constructed by integrating the amplitude decreases in the fundamental fluid mode (usually known as the "tube wave") throughout 2-meter intervals. A typical example of the correlation between amplitude deficit logs and permeability as measured by packer isolation and injection tests is given in figure 3 (Paillet, 1981c).

Some of the limitations in the existing theory include the limited amplitude response for rocks at depths less than 20-50 meters, and the lack of the test results for softer rocks such as shales. An important research goal for the future is the identification of the mechanism or mechanisms responsible for the erratic tube-wave excitation when there are minimal effective confining pressures. Efforts also will be made to understand the generally more complicated acoustic waveforms obtained from shales and unconsolidated sandstones. Because the theory of waveform generation has indicated that acoustic propagation in boreholes is more complicated than was originally supposed, an intensive effort also will be made to investigate the effect of various acoustic energy frequencies on waveform character. The Geological Survey has begun a cooperative research program with several organizations in order to pool data obtained in the same boreholes using different acoustic-energy sources. These results should provide a definite indication of logging-tool characteristics best suited for the acoustic characterization of porous and fractured rocks.

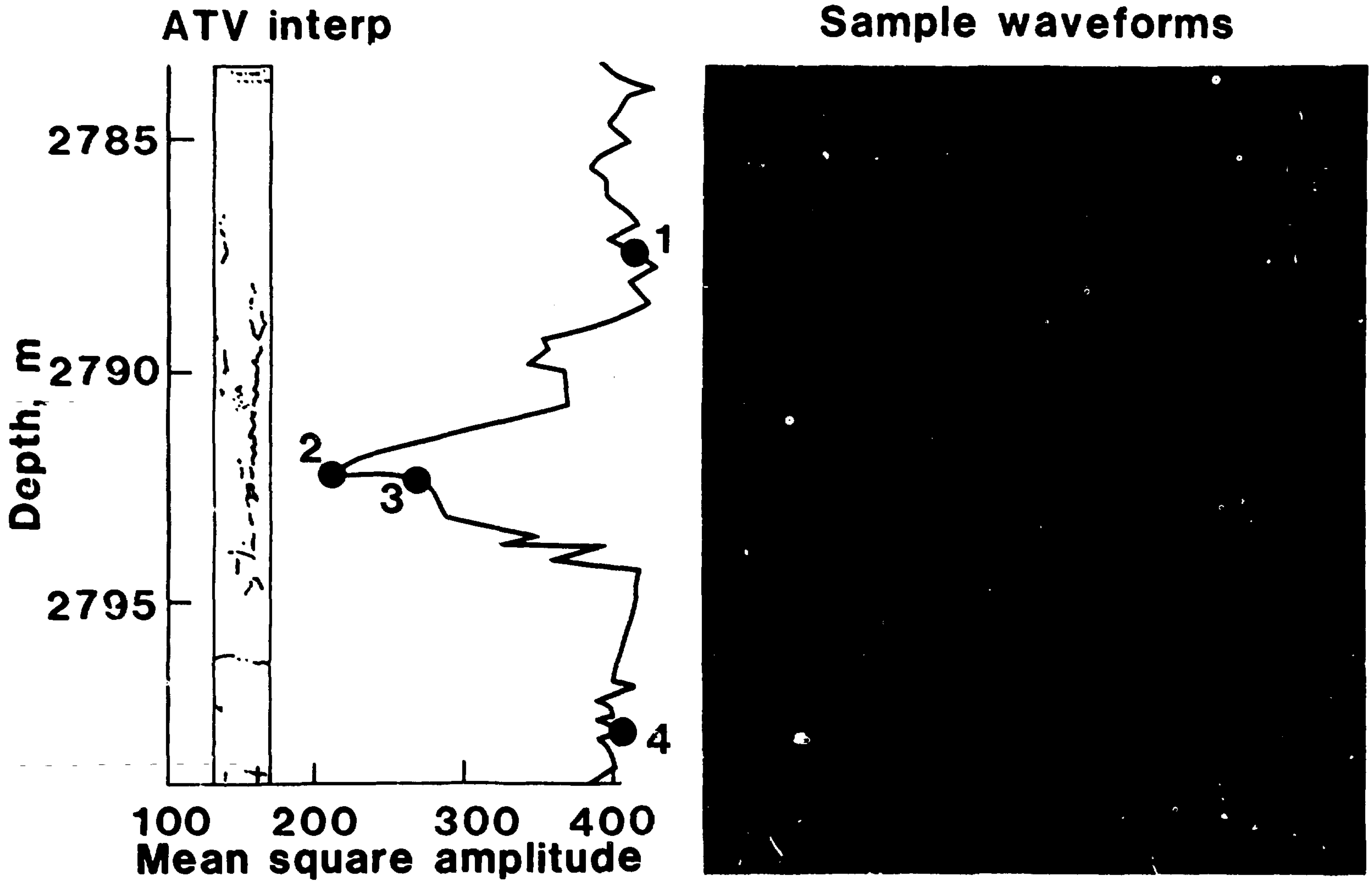

Fig. 2. Acoustic-waveform amplitude anomaly associated with permeable fracture in a deep limestone reservoir.

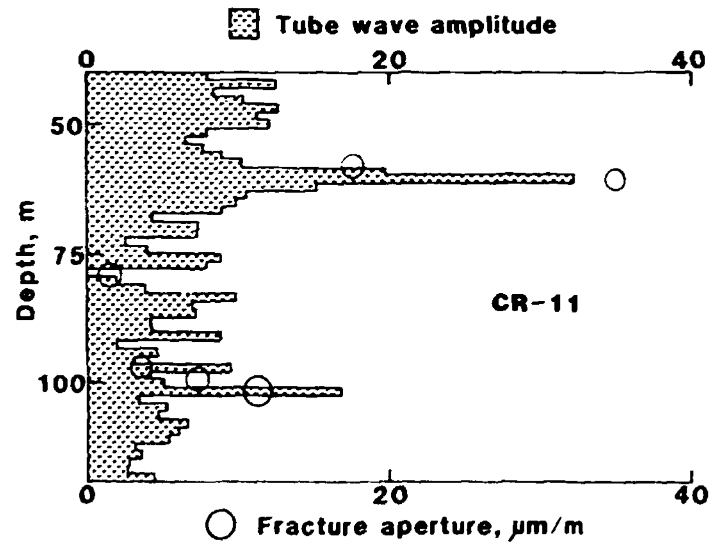

Fig. 3. Comparison of tube-wave amplitude-deficit log with permeability measured during packer isolation and injection tests in gneiss and gabbro at Chalk River, Ontario, Canada

IN SITU ISOTOPE QUANTIFICATION USING GAMMA SPECTRA

The quantitative interpretation of gamma-energy spectra produced by radioisotopes in the vicinity of the borehole offers the possibility of measuring the in situ concentration profiles for natural and man-made isotopes. Earlier attempts to produce quantitative results have included errors due to the complex geometrical effects associated with the borehole and the gamma detector. The theory required to account for these geometric effects has recently been developed in the form of correction curves to include the effects of finite-detector size, finite-sample volume, borehole diameter, and so forth (Schimschal 1980a and 1980b). Typical correction curves are illustrated in figure 4. The mathematical model used to produce the correction curves has been documented (Schimschal, 1981a). The correction curves and model theory also have been verified in the laboratory, using uniform distributions of known isotope concentrations and in calibration test pits at Grand Junction, Colorado (Schimschal, 1980b). All the various corrections have been shown to produce sizable corrections to the actual measurements in at least some situations, explaining many of the earlier problems encountered in the quantitative interpretation of gamma spectra. The improved spectral-analysis methods will be applied to gamma-spectral data obtained from existing waste-disposal sites, and from other locations where conditions are similar to those at many prospective low-level, radioactive-waste disposal sites. Primary emphasis, however, will be placed on analyzing data from sites where corroborative measurements and relatively simple geologic conditions permit careful testing and verification of the existing theory.

FLOWMETER ANALYSIS OF PERMEABILITY DISTRIBUTION

Flowmeter logging offers a direct means for the identification of permeable zones within boreholes that are stressed by pumping or injection. An analysis of flowmeter logs for a site in Idaho (fig. 5) shows that flowmeter data can give a good representation of the permeability as a function of depth (Schimschal, 1981b). A major difficulty associated with flowmeter logging is the inaccurate performance of existing flowmeter systems at minimal flow rates obtained in relatively impermeable rocks. This problem is being addressed by studying various flowmeter techniques that might be especially effective at minimal discharges. The most promising flowmeter concept considered so far involves the detection of thermal pulses traveling with the borehole fluid. Initial tests of such system in the laboratory indicate that thermal-pulse tracking can give useful and consistent results at minimal fluid velocities.

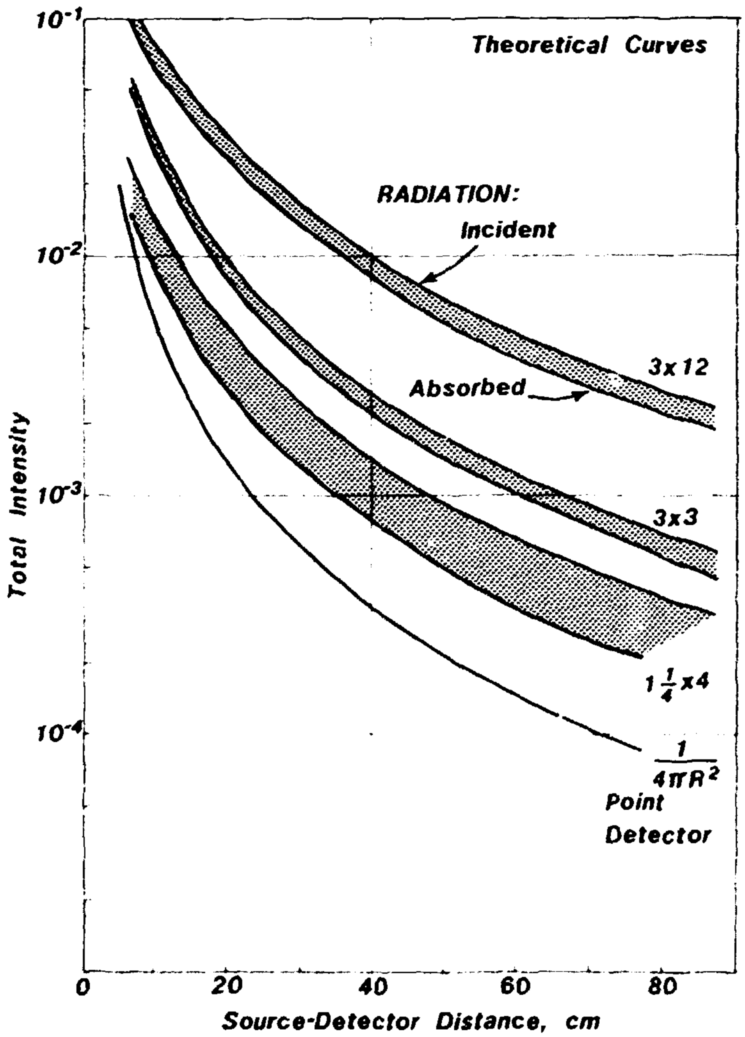

Fig. 4. Typical correction curves required to account for finite size of scintillation detector in the interpretation of gamma-spectral data

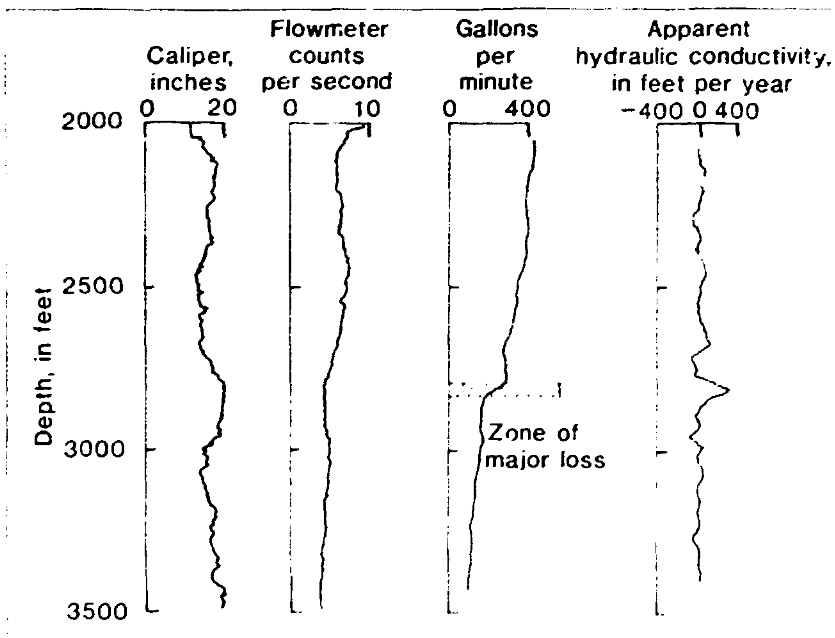

Fig. 5. Log of hydraulic conductivity obtained during fluid-injection testing in a well in Idaho (Schimschal, 1981b)

WELL-LOG RESOLUTION

One of the most important applications of borehole geophysics is the definition of hydrogeologic constants for use in model studies used as part of the disposal-site assessment process. This indicates that the relationship between well-log resolution and overall model performance needs to be studied in detail. The extent of log resolution may, for example, determine how many different types of logs should be run, or in what ways the geohydrological information obtainable for a given expenditure can be maximized. An important consideration is the degree to which the log-inversion equations simulate a closed system. There are almost always many more geologic unknowns than possible borehole measurements, so the number of unknowns usually exceeds the number of available equations. There thus remains a definite limit to the resolution available with the logging data. This degree of resolution is further decreased by the inherent limitations of the calibration process. There also are questions about the relationship between depth-averaged properties determined from log data and bulk-aquifer properties due to the large horizontal-scale differences between logging sample volume and ground-water model element. The relation between log resolution and model prediction is, therefore, extremely complex but clearly deserves detailed investigation. This topic is being addressed through two parallel approaches: application of formal uniqueness theory to the log-inversion process, and tracking of various sources of uncertainty and error as in the generation of hydrologic constants for model studies. Project personnel also are testing, at a number of sites, a new type of compensated neutron probe that appears to provide more accurate porosity data.

SUMMARY

The U.S. Geological Survey has formulated a broad approach to well-log interpretation for hydrogeologic applications. Much of this technical effort can be directly applied to the characterization of proposed low-level, radioactive-waste disposal sites and to the monitoring of conditions within established waste-disposal areas. Several specific areas of studies have been identified as offering the possibility for important progress in the ability to characterize the hydrogeology of geologic formations especially suited for low-level, radioactive-waste disposal. In addition, the interrelationship between log resolution and model performance also is being addressed in at least one case study.

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Lump

SHALLOW LAND BURIAL HANDBOOK

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INTRODUCTION

Milestone C is one of the major technical milestones for the DOE Low-Level Waste Management Program; and is defined as providing the documentation required to support the locating of a Shallow Land Burial Site in the United States. One of the sub-milestones included is the development of a Handbook or manual which provides a review and evaluation of current defense and commercial waste practices and a description of the state-of-the-art technology for shallow land burial of low-level radioactive wastes. Current plans envision completion of an initial draft of the Handbook by the end of FY 1981, followed by a detailed review and issuance of a final draft version by the end of FY 1982. Additional research results produced in future fiscal years may be incorporated into further revisions of the Handbook.

One of the major concerns in the preparation of such a document is a determination of the intent of the Handbook, its potential users, and the depth or degree of coverage to be achieved. For purposes of the initial draft it was assumed that the Handbook would attempt to inform the reader of the current way in which low-level wastes are being handled, to outline the legal and institutional problems that would be involved in developing and licensing such a facility, and to describe in some detail the considerations and data needs for siting, designing, operating, and closing such a facility. As a result, the initial draft is not a Handbook that provides answers to all questions, nor insures that following the steps detailed in the Handbook guarantees that the facility will be licensed; it does, however, illustrate the types of actions that must be considered and the types of information required to achieve successful operations.

It must be pointed out that the initial draft is more suited to utilization by decision makers concerned with how one goes about siting and operating the shallow land burial ground than as a source book for scientists and engineers concerned with technical details necessary to insure compliance with licensing regulations. At this time it is not clear if one handbook can adequately meet the goals

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suggested in Milestone C and still provide the necessary guidance for the diverse audience that might use the Handbook in the future.

SHALLOW LAND BURIAL HANDBOOK

Once the purpose of the handbook was developed, it was then possible to develop an outline of the material and subjects to be included. The suggested outline for the first draft is given in Table 1, and shows that the draft is composed of seven Chapters and two Appendices. A brief description of each of the Chapters follows.

1. Introduction

The major function of this Chapter is to briefly define the term low-level wastes, indicate where they are generated, provide some indication of the magnitude of the disposal problem and the current and future need for such facilities, and outline current practices and alternatives. The material presented in this Chapter is directed mainly at the reader who has heard about low-level wastes, but is essentially uninformed about the technical aspects of low-level wastes.

2. Case Histories

Chapter 2 summarizes pertinent information on existing shallow land burial grounds in both the defense and commercial sector. These summaries indicate the location of the disposal site, its ownership, who operates it, how it is operated, and any problems resulting from operations. In the initial draft most of this information is extracted from published sources; it is anticipated that visits will be made and discussions held at all of the sites during the review and revision period in an attempt to obtain the latest information on the sites, and obtain consistent information for each of the burial grounds. This Chapter would then represent a summary of the state-of-the-art in technology for shallow land burial of low-level wastes.

3. Legislation and Regulation

Location of a shallow land burial ground requires compliance with Federal, State, and local laws and regulations. Chapter 3 briefly outlines the Federal laws and associated regulations that impact development and siting of low-level waste facilities. Federal agencies other than those involved in developing standards or regulating and licensing facilities are also identified. In the case of State involvement, the agencies are less clearly defined than on the Federal level, however an attempt has been made to describe the types of agencies that should be consulted. The importance of local involvement is also discussed in general terms. Finally, licensing procedures (as described in the proposed 10 CFR 61) are described. Table 2 presents a detailed outline for Chapter 3.

Table 1. Outline of the Shallow Land Burial Handbook

1. INTRODUCTION
   - A. What are Low-Level Wastes?
   - B. Sources and Amounts of Low-Level Wastes
   - C. Need for Low-Level Burial Grounds
   - D. Current Practices and Alternatives
2. CASE HISTORIES
   - A. Commercial Burial Grounds
   - B. DOE Burial Grounds
3. LEGISLATION AND REGULATION
   - A. Major Federal Laws
   - B. Major Federal Regulations
   - C. Regulatory Responsibilities for Low-Level Radioactive Waste
   - D. Other Federal Involvement
   - E. State Involvement
   - F. Local Involvement
   - G. Licensing Activities
4. SITE SELECTION
   - A. Meteorology and Climatology
   - B. Geology
   - C. Hydrology - Surface and Ground Water
   - D. Topography
   - E. Proximity to Population Centers
   - F. Geographic Distance to Waste Sources
   - G. Summary of Site Selection Process
5. SUGGESTED DESIGN PRACTICES
   - A. Site Layout
   - B. Trench Design
   - C. Environmental Control Features
   - D. Monitoring Systems
6. OPERATING PROCEDURES
   - A. Receiving and Initial Handling of Waste shipments
   - B. Waste Placement
   - C. Covering and Revegetation
   - D. Monitoring Program
   - E. Record Keeping
7. CLOSURE AND POST-CLOSURE
   - A. Stages of Closure and Post-Closure
   - B. Post-Closure Land Use Planning
   - C. Post-Closure Land Use Controls
   - D. Monetary Considerations
   - E. Closure and Post-Closure Monitoring
   - F. Closure and Post-Closure Maintenance

APPENDICES
   - A. Glossary
   - B. 10 CFR 61

Table 2. Detailed Outline of Chapter 3 of the Shallow and Burial Handbook

3. LEGISLATION AND REGULATIONS

3.1 Major Federal Laws

3.2 Major Federal Regulations

3.3 Regulatory Responsibilities for Low-Level Radioactive Waste
- 3.3.1 U.S. Environmental Protection Agency
- 3.3.2 U.S. Nuclear Regulatory Commission
- 3.3.3 U.S. Department of Energy
- 3.3.4 U.S. Department of Transportation

3.4 Other Federal Agency Involvement
- 3.4.1 U.S. Geological Survey
- 3.4.2 Council on Environmental Quality
- 3.4.3 State Planning Council on Radioactive Waste Management
- 3.4.4 National Governors' Association
- 3.4.5 National Conference of State Legislatures

3.5 State Involvement
- 3.5.1 Executive Office
- 3.5.2 State Agencies
- 3.5.3 Legislature/General Assembly

3.6 Local Involvement

3.7 Licensing Activities
- 3.7.1 Preoperational Phase
- 3.7.2 Operational Phase
- 3.7.3 Disposal Site Closure Phase
- 3.7.4 Post-Closure Observation and Maintenance Phase
- 3.7.5 Institutional Control Phase

3.8 References

4. Site Selection

Chapter IV describes the type of information required and suggested methodology for selecting a site for a shallow land burial ground as currently practiced. Included are such topics as meteorology and climatology, geology, hydrology, topography, distance from population centers and waste sources, etc. This Chapter presents this material in a generic sense since criteria for site selection have yet to be finalized by either DOE or NRC. When criteria become available they will be incorporated into the Handbook. Both DOE and NRC currently appear to be developing "performance" type criteria which means that the site selection process will be directed at meeting certain performance objectives and not numerical values. If this type of criteria is selected for final rulemaking, revisions to Chapter 4 may be minimized.

5. Suggested Design Practices

This Chapter is structured to present information on the design considerations that should be utilized in designing a shallow land burial facility. Since each facility presents specific design problems, the approach utilized attempts to discuss what is needed and what factors should be considered by the designer. Numerical design information is not included, however examples of trench dimensions, cover thickness, and equipment are supplied for guidance. Discussion is presented regarding methods utilized to minimize the entrance of surface and ground water into the trenches. A detailed outline for Chapter 5 is shown in Table 3.

6. Operating Procedures

Operating procedures are described which are necessary to meet licensing requirements and insure that proper waste placement, covering, and monitoring are carried out. The new waste classification criteria proposed by NRC is described in this Chapter. Monitoring programs required to insure compliance with Federal regulations are discussed. Finally, requirements for keeping records both during and after operations cease are described

7. Closure and Post-Closure

The final Chapter describes the requirements for closing the burial ground and outlines the steps proposed by NRC for post-closure care. Also included is a section on monetary requirements for closure and post-closure and methods acceptable to NRC for guaranteeing availability of funds. Monitoring and maintenance activities required during these time periods are also discussed.

Table 3. Detailed Outline of Chapter 5 of the Shallow Land Burial Handbook

5. SUGGESTED DESIGN PRACTICES

- 5.1 Site Layout
  - 5.1.1 Buildings
  - 5.1.2 Equipment
    - 5.1.2.1 Scales
    - 5.1.2.2 Excavation Equipment
    - 5.1.2.3 Monitoring Equipment
    - 5.1.2.4 Fire and Safety Equipment
    - 5.1.2.5 Volume Reduction Equipment
    - 5.1.2.6 Waste Handling Equipment
  - 5.1.3 Access Roads
  - 5.1.4 Trench Space
  - 5.1.5 Buffer Zone
  - 5.1.6 Security Provisions
- 5.2 Trench Design
  - 5.2.1 Trench Depth
  - 5.2.2 Trench Width
  - 5.2.3 Trench Length
  - 5.2.4 Relationship to Water Table
  - 5.2.5 Permanent Trench Markers
- 5.3 Environmental Control Technology
  - 5.3.1 Surface Water Diversion
  - 5.3.2 Covers
  - 5.3.3 Ground Water Diversion
  - 5.3.4 Liners
  - 5.3.5 Leachate and Gas Production
- 5.4 Environmental Monitoring
- 5.5 References

Appendices

Two appendices are currently included in the initial draft of the Handbook; these are a Glossary and a copy of 10 CFR 61 as published in the Federal Register on July 24, 1981.

SUMMARY

The initial draft of the Shallow Land Burial Handbook has been prepared and submitted to the DOE Low-level Waste Management Program for review and comment. Current planning envisions a peer review of this draft, followed by a workshop to discuss in greater detail the content of the next draft. Reviewers of the draft are being asked not only to comment on the usefulness of the material included, but also to comment on the depth of coverage required. This material and new research results available during the review and revision period will be considered for incorporation into the next version of the Handbook. Reviews will be requested from Federal and State Agencies, burial ground operators, consultants, and environmental groups. This review procedure has been developed in an attempt to produce a Handbook that will be of maximum utility to all individuals and groups concerned with disposal of low-level wastes.

ENVIRONMENTAL MONITORING FOR LOW-LEVEL WASTE DISPOSAL SITES

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ABSTRACT

The progress made in FY 1981 on a generic handbook (or guide) for environmental monitoring of low-level waste disposal sites is described, together with the plans for completing the work in FY 1982. A draft of the handbook was prepared which discusses the information needed to design a monitoring program, recommends programs for the preoperational, operational, and post-closure phases of a burial site, and describes sampling and measurement methods, quality assurance, and other components of a complete environmental monitoring plan. The contents of the handbook are reviewed briefly, and the sections on the use of statistics in designing a program and on applicable standards are discussed in more detail.

A report on the unmet needs and technology gaps in environmental monitoring of low-level waste sites was also prepared. The currently available monitoring techniques are considered adequate. No significant needs or gaps were found, although some areas were identified in which additional work would be profitable.

INTRODUCTION

The primary objective of this project is to develop environmental monitoring techniques and plans for future sites disposing of low-level radioactive waste by shallow-land burial. The product will consist of guidelines, recommendations, and instructions for establishing an environmental monitoring program and will take the form of a guide or handbook. The handbook is generic in nature, but will be applied to specific sites in the future. A secondary purpose is a determination of any needed, but unavailable, technology and knowledge in the monitoring of low-level waste sites.

There is an extensive literature on radioactive waste disposal. Many reports are available on the history of the present waste sites, both closed and operating, on their monitoring programs, and on their problems, from which needs can be inferred. Few attempts have been made to prepare generally applicable monitoring programs for waste sites. Two studies address groundwater monitoring for ERDA sites only.(1,2) A guide on environmental surveillance(3) contains excellent useful information on this topic, but is not meant for waste sites.

No publication is available which addresses this question in the comprehensive manner we have attempted. Our intent is to place in one document all the essential information, or in areas where this is not practical, all the information sources, needed to design, plan, and conduct an environmental monitoring program.

Visits to existing disposal sites, a literature study, discussions with individuals from state and federal agencies who are concerned with radioactive waste disposal, and other information gathering activities were conducted to collect the material for the handbook. The evaluation of unmet needs and technology is a natural by-product of these activities, and is intended to provide the NLLWP management with a planning tool.

The tangible results in FY 1981 have been reports on the information collected from the literature survey and site visits (Current State of Knowledge), on unmet needs (Needs Assessment), and on monitoring (Generic Handbook on Environmental Monitoring for Low-Level Waste Disposal Sites).

HANDBOOK CONTENTS AND PREPARATION

The topics treated in the Handbook are evident from the condensed outline in Table 1. A feature of the Handbook that can be noted from the outline is that it includes considerably more than environmental radioactivity monitoring.

The Handbook first describes the background information needed to design a monitoring and surveillance program - the geohydrological site characteristics, the climatology and meteorology, the waste characteristics as they may influence the monitoring program, the pathways from burial site to people, and the related radiation dosimetry. Much of this information will have been collected in the process of selecting and evaluating the site and in obtaining the operating license. Some information on regulations and standards is included, but since they have not been issued in final form, this material must be considered as tentative. The Handbook then discusses environmental sample collection and measurement, selection of sampling locations, types of samples and measurements, and provides statistical guidance on the numbers of samples and measurements needed for a given reliability. Detailed monitoring programs for the preoperational, operational, and post-closure phases of the low-level waste site are described, and guidance is provided on quality assurance and reporting.

To determine if this treatment will result in a suitable document, it is useful to review the objectives of environmental monitoring, which are:

- measure the radioactive content of the environment.
- identify source and causes of any changes.

Table 1. Condensed Outline - Generic Handbook on Environmental Monitoring for Low-Level Waste Disposal Sites

1. Introduction

    1.1 Purpose of Handbook
    1.2 Historical Background Information
    1.3 Purpose of an Environmental Monitoring Program
    1.4 Parameters Which Must be Monitored
    1.5 Overview of Literature

2. Information Required to Design a Site Monitoring Program

    2.1 Geologic Site Characteristics
    2.2 Hydrologic Site Characteristics
    2.3 Atmospheric Site Characteristics
    2.4 Waste Characteristics
    2.5 Pathway Analysis and Dosimetry
    2.6 Applicable Standards

3. Sampling and Measurement Techniques

4. Monitoring and Sampling Strategy

    4.1 Statistical Considerations
    4.2 Statistical Methods

5. Preoperational Program

    5.1 Meteorology
    5.2 Geology
    5.3 Hydrology
    5.4 Radiological
    5.5 Chemical Pollutants

6. Operational Program

7. Post-Closure Program

8. Quality Assurance

9. Data Interpretation and Presentation

10. Appendices

- detect releases from the site.
- monitor site performance, adequacy of controls, trench integrity, and other operations.
- demonstrate the degree of compliance with standards and regulations.
- provide public reassurance that operations pose no undue hazard.

In comparing the Handbook with this list, it is apparent, for example, that a comprehensive geohydrological characterization of the site is necessary before one can determine the locations and depths of the monitoring wells that will meet the objectives. Similarly, the potential exposure pathways must be evaluated to establish sampling and measurement locations, and reports must be prepared to show compliance with standards and provide the public with the information they should have. The preoperational program (Chapter 5) also requires much more than radiological monitoring. Before a disposal site is placed in an area, it is necessary to know wind directions, water flow direction - both surface and subsurface, and similar information. Geography, demography, topography, and transportation routes can also be added to this list.

Because the subject matter of the report covers several scientific disciplines, appropriate sections were written by individuals with specialized knowledge, including a geologist, hydrologist, meteorologist, radiological biophysicist, health physicist, statistician, chemist, and biologist. In an attempt to maintain uniformity, guidelines for writing were prepared. These are summarized in Tables 2 to 4. Table 2 describes the purpose and content, and contains excerpts from the "preliminary negotiations data sheet" which initiated this project. This document describes very well the items desired. Table 3 describes the audience and Table 4 the desired characteristics and properties of the Handbook.

In practice, an environmental monitoring program must be tailored to a specific site, but there is a common set of knowledge and criteria that is relevant to all sites. Thus, the contents of the Handbook are applicable generally - the emphasis placed on different aspects will naturally be site-dependent. The project was approached with the belief that present knowledge is adequate for the purpose, and nothing was found to change this. As in all technical fields, however, improvements in environmental monitoring are to be expected in the future, and should be incorporated as soon as practicable.

It is not possible in the available time and space to discuss the Handbook in detail. It would be more beneficial to review briefly two important sections - Monitoring and Sampling Strategy (Statistics) and Applicable Standards and Regulations. In some respects the two are related, since decisions on sampling are based in part on the standards to be met.

Table 2. Purpose and Content - Excerpts From the Preliminary Negotiations Data Sheet

- Develop generic environmental monitoring techniques and plans for establishment, operation, and close-out of shallow-land burial facilities for low-level radioactive wastes.

- Purpose, to provide operators of low-level waste disposal facilities with the information necessary to design and develop environmental monitoring programs for their sites.

- Address (but not limited to):

  - current state-of-the-art
  - identify gaps
  - review monitoring equipment, techniques, and systems
  - review statistics and design of monitoring networks
  - preoperational monitoring - baseline data
  - operational monitoring - evaluate impacts
  - post-closure monitoring - evaluate long-term impacts
  - data and information collection systems, including format
  - determine R&D needed
  - prepare technology transfer document - a guide for operators... updated as necessary

Table 3. Background of the Handbook User

- Assume the user to have a level of knowledge equivalent to a Bachelor's degree in a technical field; that is, college level courses and knowledge in basic sciences, including calculus.
- Individual with B.S. degree in science or engineering and no experience, could set up and operate the program - although he might have to ask questions and read manufacturer's and technical literature.
- He may need to consult a hydrologist/geologist, health physicist, or radiochemist, but would know from the Handbook, what to ask and be familiar with the terminology.
- He would not be expected to have education or experience in specialized technical fields as hydrology or meteorology.

Table 4. Guidelines for Writing the Handbook

1. Scope and objective of the Handbook must be clear.
2. Must provide practical information and specific guidance on parameters which must be monitored and how they are monitored.
3. A level of detail such that the operator can proceed with little additional study.
4. The Handbook is to be practical, so judgement must be exercised in the length and complexity of the material.
5. Must be organized in a logical manner and give the sequence of required actions.
6. Must be easy to use. It should have descriptive headings, an index, bibliography, etc.
7. Reason for assumptions must be explained.
8. Must suggest specific equipment and typical costs.
9. Must discuss type of personnel needed and typical person-years to maintain the program.
10. Must deal with documentation, interpretation, and presentation of data.
11. Must be clear about what information is needed but is omitted in the Handbook. Must give user guidance on where and how to obtain the other information needed for a successful program.
12. The Handbook must have continuity, given an impression that it was written by one person.
13. Detailed procedures should be in appendices rather than in the body of the text. This way, appendices can be written by different people yet maintain continuity in the text.
14. Must discuss potential traps, problems, unknowns.

USE OF STATISTICAL CONCEPTS IN MONITORING AND SAMPLING

Probability and statistical principles can be useful in reducing monitoring costs and determining the reliability of results. In monitoring for pollutants a background or ambient level or concentration and its standard deviation must first be established. Three cases can be distinguished. In two of them - levels that are sufficiently high (e.g., radon in air, uranium in soil) or sufficiently low (e.g., plutonium, technetium-99 in water) and thus not detectable in all samples except by heroic means - establishing the background presents little difficulty. In the third case, positive results are obtained in some but not all samples (e.g., tritium in well water) and the mean background cannot be readily obtained. The problem is one of handling "less than detectable" and positive results together, a common problem in trace measurements. We present a simple numerical method based on the assumption that the results are randomly and symmetrically distributed about the mean, and that the lower, but unknown end of the distribution curve has the same shape as the upper, known end. The procedure yields an average concentration (M) and its standard deviation (S), both of which are needed in evaluating subsequent results.

From these values, we recommend that an "operating background level" (OBL) be chosen equal to M + S, and further that a control limit (CL) be chosen such that $CL = OBL + aS/n^{1/2}$, where n is the number of samples and a is the constant that determines the confidence level. At the control limit, some action is taken as described below. For n = 4 and a = 3, the probability of obtaining an average result greater than the CL when the true value is at the OBL (i.e., a false alarm) is one out of a thousand. The rationale for establishing these levels is that small releases from a disposal site are to be expected and an attempt should be made to avoid unnecessary false alarms. The effort and cost involved in identifying the cause of small increases above background can be relatively large at the OBL. Decisions on acceptable probabilities and levels at which special attention is required are administrative and depend on many factors, particularly the purpose of the monitoring and the standards, but once these decisions are made, the above procedure is useful in keeping sample collection to a minimum. It is convenient to summarize the data in the form of a control chart, illustrated in Figure 1 for tritium in monitoring wells from a low-level waste disposal site.

In addition to false alarms (wrongly deciding that a result indicates contamination or leakage), a second type of problem results from deciding a result is normal when it is positive. This means that a required action is not taken. The probabilities of making the two types of errors should be balanced by modifying the control limit based on experience at the site. Guidance on this aspect is given in the Handbook. The probability of detecting a shift from normal as a function of sample size and the control limit is illustrated in the operating characteristic curve shown in Figure 2. The curves for each sample size show the probability that an observed average of n samples actually exceeds the OBL.

Figure 1.

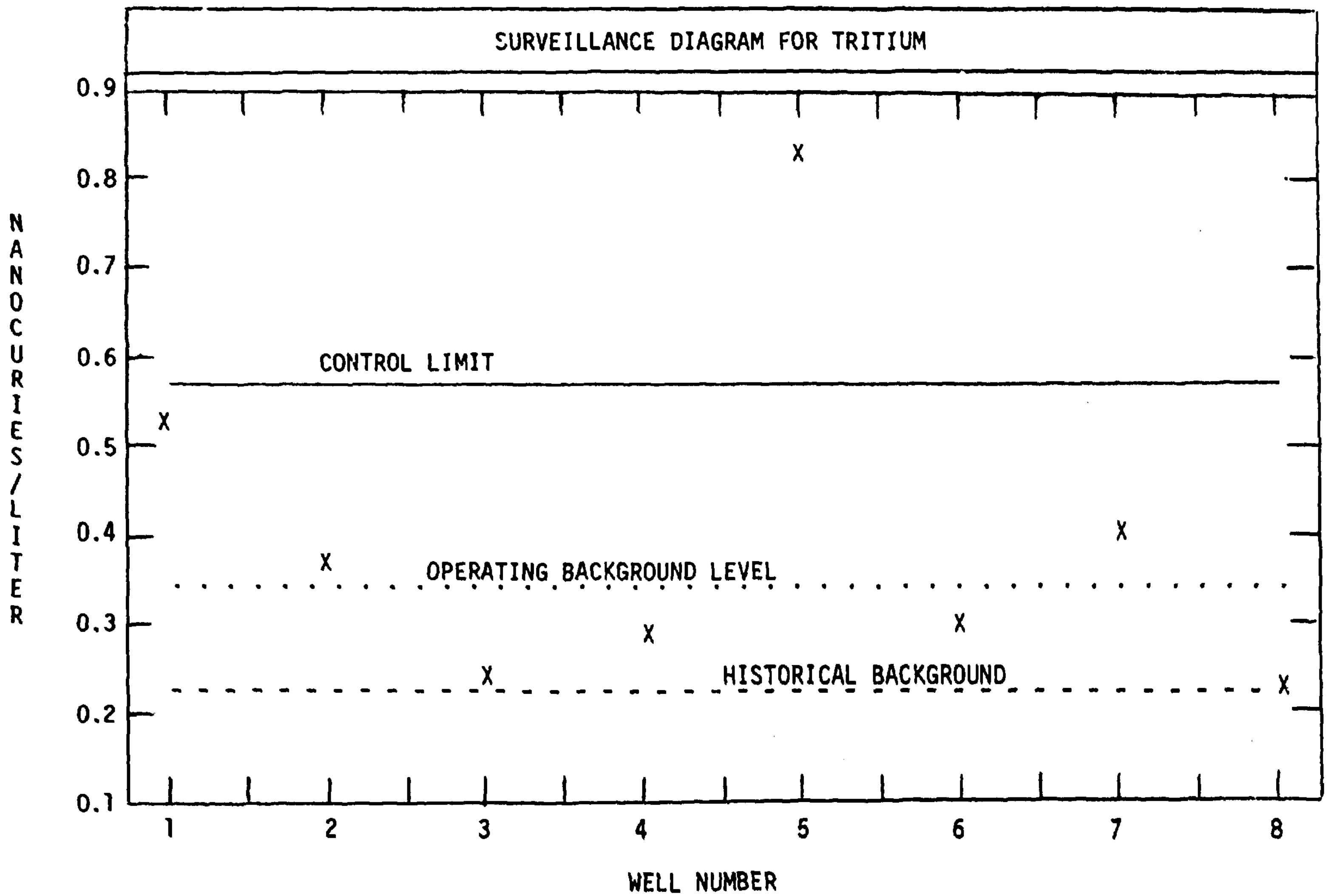
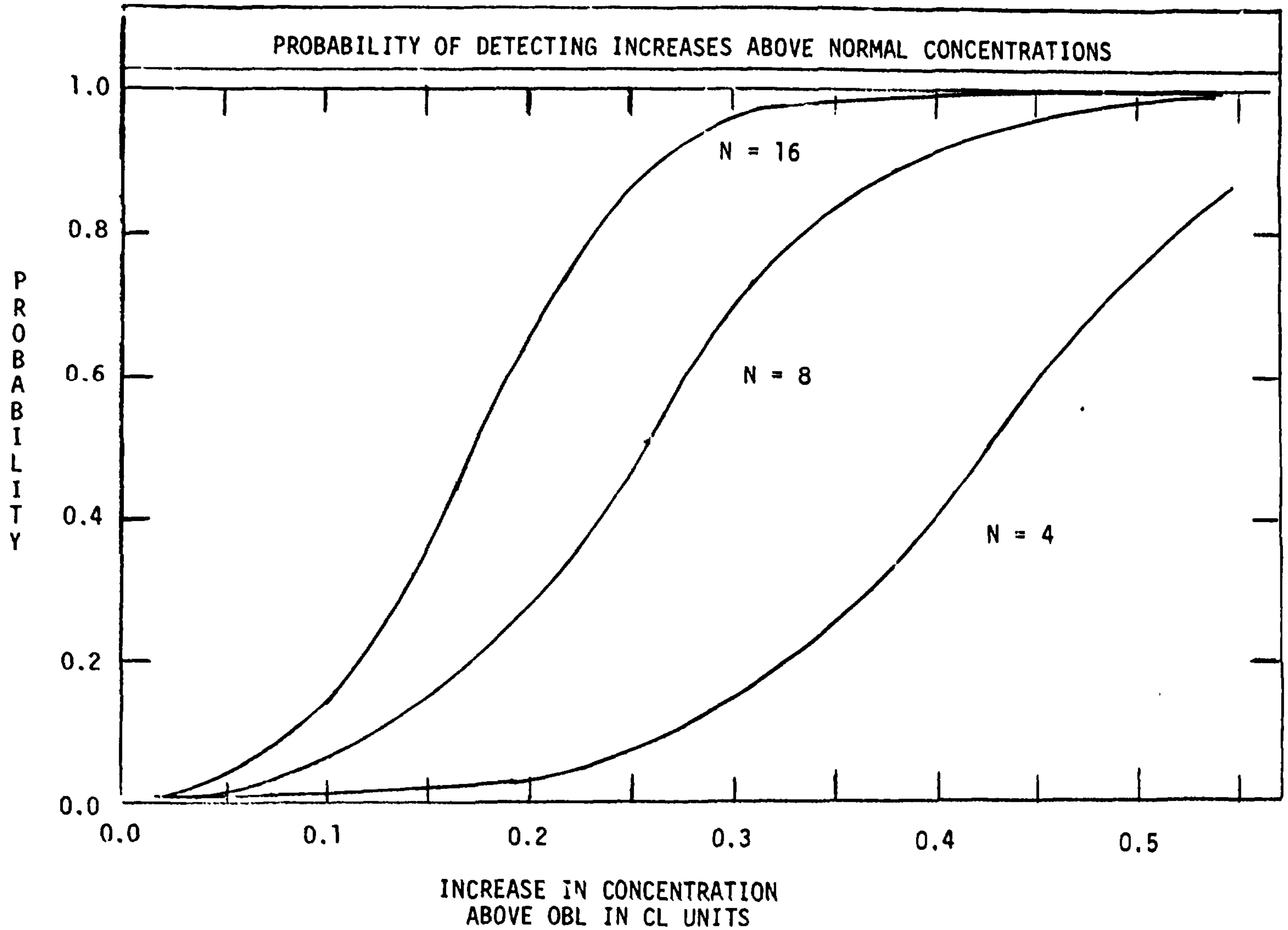

SURVEILLANCE DIAGRAM FOR TRITIUM
NANOCURIES/LITER
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
CONTROL LIMIT
OPERATING BACKGROUND LEVEL
HISTORICAL BACKGROUND
1
2
3
4
5
6
7
8
WELL NUMBER

Figure 2.


PROBABILITY OF DETECTING INCREASES ABOVE NORMAL CONCENTRATIONS
PROBABILITY
1.0
0.8
0.6
0.4
0.2
0.0
N = 16
N = 8
N = 4
0.0
0.1
0.2
0.3
0.4
0.5
INCREASE IN CONCENTRATION
ABOVE OBL IN CL UNITS

Another means of determining the minimum number of samples is shown in Figure 3. These curves are based on a log-normal distribution of the pollutant concentration with a geometric standard deviation of 2 (a frequently observed standard deviation), and give the number of samples required to be 95% confident that a result exceeds the background by the ratio indicated. Similar curves can be constructed for other standard deviations, other distributions, and other confidence levels.

An additional application of statistics in the Handbook is an economic model, similar to that used in industrial quality control. This model can be expressed by the equation:

$$T = B/N + NC$$

where

B is the expected increase in costs from failure of a sampling period to detect leakage or releases,

N is the number of sampling periods per year,

C is the cost of sampling and analysis per sampling period, and

T is the total cost per year from B and from monitoring (NC).

It is shown that the optimal sampling frequency is $(B/C)^{\frac{1}{2}}$. Thus, if the costs, economic or other, can be evaluated for the failure of the monitoring program to detect a problem in the operations that should be corrected, then the question of "how much sampling is needed" can be decided on a statistical and presumably realistic basis.

In summary, if statistical considerations can be used as the principle determining factors in the monitoring program, then

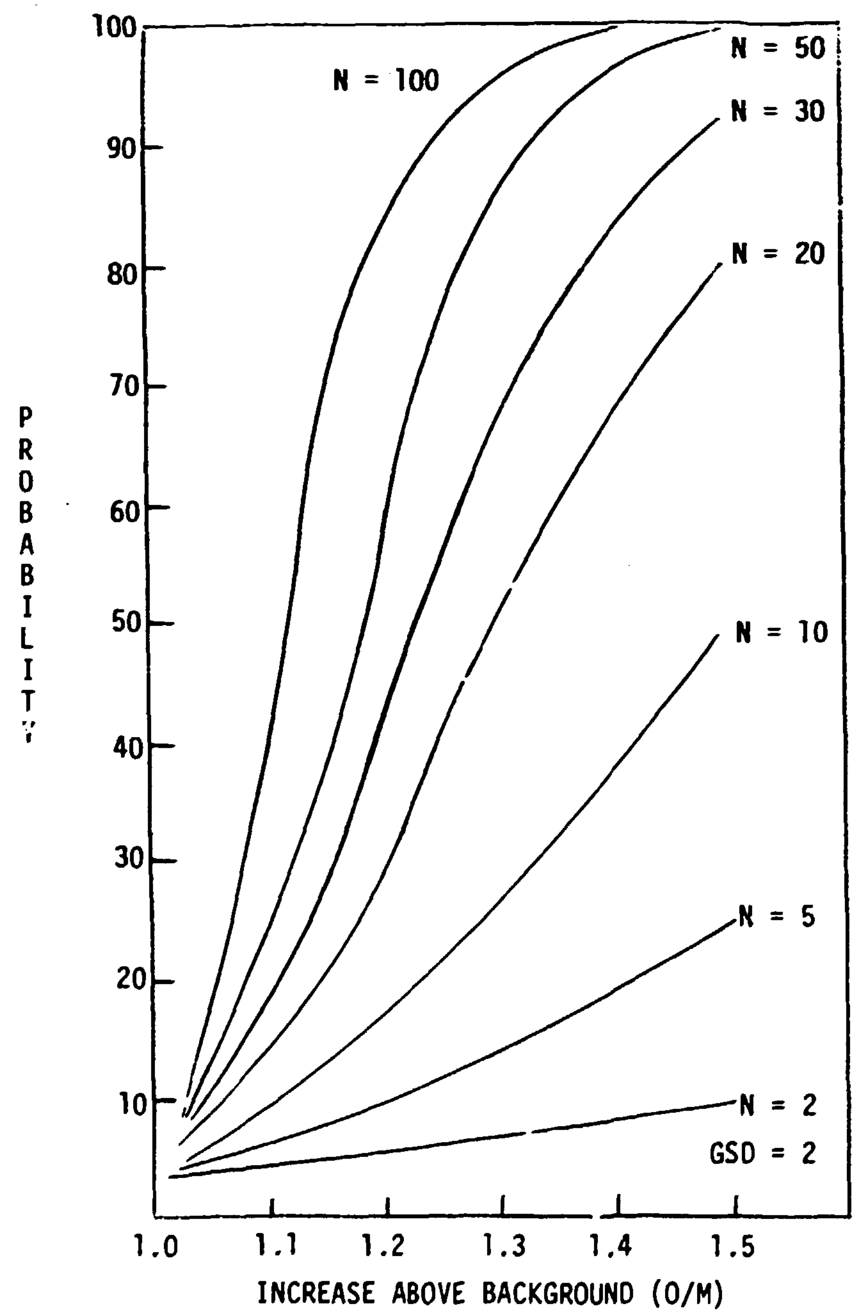
1. Choose a minimum number of samples or number of sampling locations equal to 4 for each sample type, and a sample frequency of approximately $(B/C)^{\frac{1}{2}}$, where B and C have the meanings described above.

2. Prepare control charts for each sample type and location as described.

3. When an average above the control limit is obtained, an effort is made to identify a trend in past observations. If one exists, some action is indicated. If not, action is postponed and additional sampling is done at half the regular sampling interval. This is continued until the question of abnormal results is resolved.

Figure 3.

PROBABILITY OF DETECTING
INCREASES ABOVE BACKGROUND



LEGEND:

O - OBSERVED GEOMETRIC MEAN

M - BACKGROUND GEOMETRIC MEAN

GSD - GEOMETRIC STANDARD DEVIATION

STANDARDS AND REGULATIONS

A section in the Handbook gives some guidance on standards for low-level waste disposal sites. At present, the only applicable standards are those in the Nuclear Regulatory Commission proposed rule 10CFR61 (July 24, 1981) and the accompanying Draft Environmental Impact Statement (EIS) (September, 1981). This regulation provides:

> "61.41 Protection of the General Population From Releases of Radioactivity
> Concentrations of radioactive material which may be released to the general environment in groundwater, surface water, air, soil, plants, or animals must not result in an annual dose exceeding an equivalent of 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the public. In addition, concentrations of radioactive material in groundwater must not exceed the maximum contaminant levels established in the National Primary Drinking Water Standards (40CFR Part 141) at the nearest public drinking water supply (a limit of 10 pCi/l above background must be used for uranium and thorium)."

An additional explanation of this paragraph is provided in the summary of the rule:

> "...the Commission has selected an objective that requires that any movement of radioactivity not result in calculated doses exceeding 25 mrem/yr to an individual at the site boundary or cause the EPA Drinking Water Standards (40CFR Part 141) to be exceeded at the nearest public drinking water supply..."

It appears there are two different sets of standards for which compliance is required, depending on where the dose is delivered.

We have found these statements difficult to interpret, and believe clarification is in order. The pathways may be such that larger doses could be delivered at other locations than at the site boundary, and the nearest drinking water supply may not be the one that is most likely to be contaminated by the waste disposal site. Some explanation is given in the Draft EIS for the rule, which states that an annual exposure limit of 25 mrem (75 mrem to the thyroid) to the maximally exposed individual at the site boundary coupled with an annual population limit of 4 mrem at the nearest public drinking water supply was selected as the preferred performance standard.

The standards in 10CFR61 are not likely to be exceeded by any low-level waste site - but they should be readily understood and applied. These performance standards will be superseded by the EPA standard for low-level waste sites when it appears, but it is doubtful if the final standard will be significantly different.

The EPA drinking water standards are easy to apply, since they are concentrations, and measurements to ascertain compliance are readily made. However, they are also easy to misuse, that is, to apply them to water that is not a public drinking water supply as defined by the EPA. This should be resisted.

Concentrations in other environmental media, including non-drinking water, that must not be exceeded to avoid doses greater than the annual limits, are more difficult to determine. They must be computed from transport and pathway analyses based on a model for the movement of radionuclides from burial site to man.

It remains to be seen how compliance with these standards will be demonstrated. We do provide in the Handbook calculated radioactivity in air concentrations that will deliver the annual dose limit, 25 mrem/year, and these can be used to compare with concentrations measured at a point.

The EPA drinking water standards are based on NBS Handbook 69, which is now outdated if the new ICRP recommendations are to be accepted. The most recent recommendations of the ICRP do not address the question of standards for environmental radioactivity directly. The Commission, in ICRP Publication 26, emphasizes that each man-made contribution to population exposure has to be justified by its benefits, and in ICRP Publication 29, which discusses dose assessment from environmental release of radionuclides, reiterates its recommendation that exposures be as low as reasonably achieveable (ALARA), economic and social considerations being taken into account. ICRP Publication 29 also states that "national and regional authorities must set limits on deliberate releases of radioactive materials into the environment and plan interventions after accidental releases."

Since the ICRP recommendations are usually adopted by the regulatory agencies, the operation of a burial site should be based on the ALARA principle. This concept implies that environmental concentrations and doses should be significantly less than the standards during normal operations.

In recent ICRP reports, the annual dose limits for both occupational and public exposure have not changed from their earlier recommendations. Based on these dose limits, annual limits of intake and derived air and water concentrations are calculated. The latter replace the older maximum permissible air and water concentrations. Their adoption will not significantly change the models used in pathway and environmental transport, and will not require any important change in environmental monitoring programs.

One of the difficulties in the use of measurements or calculations to determine compliance with a standard is that the former are distributions and have an uncertainty associated with them, while the standards are given as single point values without uncertainties, regardless of the validity of the data on which they are based. The standard itself, at least for radioactivity, is based on a risk analysis and judgement, which in turn have a large uncertainty. A more sensible way to state a standard would be to give a value, and indicate the measurement uncertainty allowable in meeting the standard. Thus, since the drinking water standard for radium-226 and -228 is 5 pCi/l, a measurement of 6 ± 1 pCi/l might be considered as meeting the standard. A related point, in comparing with a standard such as 25 mrem/year at the site boundary, a calculation based on a model may be needed. In this case, the calculated dose and the probability of delivering that dose should be given, and the standard should include the desired probability.

NEEDS ASSESSMENT

To assist the NLLWMP in setting priorities, we prepared a report on unmet needs, or lack of knowledge and technology in environmental monitoring for low-level waste sites, as determined from our site visits, discussions, literature study, and the Handbook. The principal conclusion was that current monitoring technology is adequate, and if properly applied, should not be a determining factor in the operation of current or future disposal sites. Although improvements are desirable, they are not essential.

Needs were identified for the following purposes:

1. assuring the quality of environmental monitoring programs and increasing confidence in their results, thus increasing the acceptability of waste disposal sites.

2. improving monitoring technology and services.

3. increasing the basic understanding of the behavior of buried waste, particularly as it affects monitoring.

4. studying the environmental monitoring needs of the expected new technologies in low-level waste processing.

Specifically, we propose the following needs and activities:

- Quality Assurance
  - Central QA/QC laboratory for low-level waste sites.
  - National review committee for environmental monitoring programs.
  - Compilation of standard, validated procedures for sampling and analysis.
- Technical Improvements
  - *In situ* remote sensing monitors (especially for post-closure).

. Gaseous radioactivity measurements.

- Basic Science and Technology

  . Site characterization methods.

  . Waste migration.

  . Dose estimation.

- Environmental Monitoring of Waste Processing Facilities

Some of these items are intended to help restore public confidence in our ability to dispose of radioactive wastes safely, and are not primarily for technical or scientific purposes. Others are for the purpose of improving monitoring data and reducing costs.

PLANS FOR FY 1982

The next step in producing the final version of the Handbook is to edit and revise the present draft into a uniform document. A principal purpose of the revision is to balance the emphasis given various subject areas and integrate several topics, particularly the application of statistics and geohydrological findings to the detailed monitoring programs.

Following this the Handbook will be subjected to critical peer review by a group of qualified individuals who will represent different viewpoints, expertise, and experience; for example, commercial waste site monitoring, government-supported waste site monitoring, geohydrology, health physics, and radiochemistry. We consider this to be a critical part of this project, since experts not involved in the preparation of the Handbook can find areas and errors those of us close to the work may overlook. This process will improve the chances of producing a truly useful document.

Following this review, the final version of the Handbook will be prepared and the design of site-specific monitoring programs will begin. A candidate or potential location for a new low-level waste disposal site will be chosen, the needed characteristics collected, if available, or inferred if not, and the generic programs applied to that site. This will serve to validate the generic plan and indicate to operators of new sites how to apply the generic program to their specific location.

SUMMARY AND CONCLUSIONS

The draft Handbook describes in detail the steps needed to plan and execute an environmental monitoring program for a low-level waste disposal site. First, the background information needed to design the program is given. Detailed programs for the three phases of a disposal site are provided, together with supplementary material needed to support a program, e.g., quality assurance and the application of statistics to program design. We believe that good environmental surveillance programs are a necessary, but not a sufficient condition for the satisfactory operation and post-closure phases of a site. Adequate monitoring coupled with good site selection and operation will make it possible to maintain a site for its expected lifetime. Public acceptance of the site will also depend on frequent and proper reporting of the monitoring results.

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OVERVIEW OF REMEDIAL ACTION TECHNOLOGY DEVELOPMENT MILESTONE D

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INTRODUCTION

The work on remedial action technology development has the same general bases as that on improved shallow land burial technology development (1). A number of the issues identified by the Shallow Land Burial Steering Committee are related to remedial action as well as to improved disposal technology and these are considered in the current program on remedial action. A state-of-the-art survey report (2) was prepared by Evaluation Research Corporation at the request of the ORNL office of the Low-Level Waste Management Program and a draft was issued in June of 1981. The survey showed that the major problems in shallow land burial were the ones that are being addressed in the efforts to develop improved shallow land burial technology. The major components of work aimed at remedial action technology development involve the following general problem areas:

1. Water Movement
2. Subsidence
3. Erosion
4. Intrusion
5. Radionuclide Migration

Operated by Union Carbide Corporation under contract W-7405-eng 26 with the U.S. Department of Energy.

Each of these components will be addressed in terms of its content and the ongoing research, development and demonstration work in the following paragraphs.

Water movement is concerned with controlling groundwater and surface water movement. The principal activities in the groundwater control area involve studies of perched water at the Savannah River Laboratory (SRL) site and evaluation of grout curtains and passive drains at Oak Ridge National Laboratory (ORNL). The principal efforts in surface water control are the trench cap studies at Los Alamos National Laboratory (LANL) and surface drains and systems effects studies being carried out at ORNL.

Subsidence studies involve the evaluation of methods to measure and control or remedy the effects of subsidence at closed sites. Monitoring instrumentation for subsidence was evaluated at the Rockwell Hanford Operation (RHO) during 1981. Grout injection studies are in progress at ORNL. SRL is in the process of evaluating and quantifying subsidence phenomena at their site and work at LANL will involve the effects of subsidence on burial systems.

Erosion studies are being carried out principally at LANL where vegetation effects are being evaluated. Some work is also underway through the Nevada Operations office at the Nevada Test Site where revegetation of that very arid region is being studied.

Intrusion of plants and animals is primarily a concern in the arid regions of the country. The major effort on this problem at this time is being carried out at LANL where gravel and cobble plant and animal barriers are being evaluated.

The control of radionuclide migration involves, in this connotation, the methodology for intercepting the radionuclides themselves after they have begun to move from their burial location through the geologic media of the site. Treatment in this category would generally be considered as a temporary fix to reduce the movement of radionuclides while a more permanent solution to the problem was being implemented. The principal current activity in this area is a study at ORNL of the effects of chemical treatment of soils to increase their sorptive capacity for radionuclides.

The four principal sites active in the remedial action technology development work of the Low-Level Waste Management Program are summarized on Table 1 along with their participation in the various components of the work.

The final remedial action manual is to be prepared by December of 1984 and therefore the necessary research and development work must be

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Table 1. Principal participants active in the Remedial Actions Technology Development effort of the Low-Level Waste Management Program.

PROGRAM COMPONENTS	LANL	ORNL	SRL	RHO
GROUND WATER CONTROL	X	X	X	
SURFACE WATER CONTROL	X	X		
SUBSIDENCE CONTROL	X	X	X	X
EROSION CONTROL	X			X
INTRUSION CONTROL	X			
RADIONUCLIDE MIGRATION		X		

brought to a close by the end of fiscal year 1983. Typical important deliverables for this activity are as follows:

1. Draft State-of-the-Art Remedial Action Manual - ORNL - 6/81
2. Draft Remedial Action Criteria - ORNL - 9/81
3. Report on Barriers - LANL - 9/83
4. Report on Water Management - ORNL - 9/83
5. Reports on Subsidence Studies - LANL and ORNL - 9/84
6. Final Remedial Action Manual - ORNL - 12/84

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COVER INTEGRITY IN SHALLOW LAND BURIAL OF LOW LEVEL WASTES: HYDROLOGY AND EROSION

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ABSTRACT

Applications of a state-of-the-art technology for simulating hydrologic processes and erosion affecting cover integrity at shallow land waste burial sites are described. A nonpoint source pollution model developed for agricultural systems has been adapted for application to waste burial sites in semiarid and arid regions. Applications include designs for field experiments, evaluation of slope length and steepness, evaluation of various soil types, and evaluation of vegetative cover influencing erosion rates and the water balance within the soil profile.

INTRODUCTION

To evaluate a broad range of cover systems for waste burial sites a procedure is needed to simulate, based on long term climatic data, soil erosion and water balance within the soil cover profile. To maintain cover integrity, erosion rates should be less than the soil tolerance level required to maintain a soil profile above the buried waste material. Moisture flux below the cover profile should be minimized to minimize leaching into the waste material. Because sediment transport rates are strongly related to surface runoff rates and because seepage or percolation below the cover material is strongly related to soil moisture in the cover material, it is necessary to simulate a water balance.

Therefore, to analyze the hydrologic processes affecting cover integrity, procedures are needed to estimate runoff, infiltration, percolation, evapotranspiration, soil moisture, and erosion. Because these processes are related and are functions of the climatic inputs, a continuous simulation model is required to maintain an accurate water balance.

In response to these needs we have applied a reasonably simple simulation model that incorporates fundamental principles of hydrology, hydraulics, erosion, deposition, and sediment transport mechanics. The model is intended to be useful without calibration or collection of extensive data to estimate parameter values. Therefore, established relationships, such as the Soil Conservation Service Runoff Equation and the Universal Soil Loss Equation, were modified and used in the simulation model.

BRIEF OVERVIEW OF THE CREAMS MODEL

Several procedures or models are available to estimate infiltration, runoff, erosion, and sediment yield. Knisel (1) summarized several of these and described the hydrology, erosion, and chemistry components used in each as well as their intended scale of application [e.g., see Table 1, p. 147, Knisel (1)]. Each of these models have their strengths and weaknesses and applications in which they are expected to perform well.

In 1978 the U.S. Department of Agriculture recognized the need to develop improved, physically based, mathematical models to evaluate nonpoint source pollution from agricultural lands. A group of some 50 scientists were assigned to the task of developing a field-scale model including hydrology, erosion, and chemistry components (2). The resulting model, entitled CREAMS, A Field Scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems, was described in a USDA Conservation Research Report (3).

Because the CREAMS model was developed using state-of-the-art technology, we feel that it has potential for applications in waste management. Many of the physical factors and management options involved in nonpoint processes on agricultural lands are common in waste management, particularly in shallow land burial of waste material. Therefore, we briefly describe the hydrology and erosion/sediment yield component of the CREAMS model.

The Hydrologic Component

The hydrologic component consists of two options. The first, a daily rainfall model based on the Soil Conservation Service runoff equation (4) and the second, an infiltration model based on the Green and Ampt infiltration equation (5). These options are discussed in detail by Smith and Williams (6).

The soil profile, to the plant rooting depth, is represented by up to seven layers, each with a representative depth or thickness and a water storage capacity. The evapotranspiration calculations are based on a procedure developed by Ritchie (7) and include soil evaporation estimates and plant transpiration estimates based on a leaf area index. Flow through the root zone is computed using a soil storage-routing technique based on the depth of the soil profile, the existing soil water content, and the saturated hydraulic conductivity. Although this procedure only computes saturated flow or percolation below the root zone, a soil water balance is maintained.

Soil water storage in each of seven layers is subject to evapotranspiration (ET) losses based on the rooting depth and the water use rate in the surface layer. The result is an estimate of ET as a function of the total rooting depth and as a function of the roots in each soil layer.

In summary, the hydrologic model predicts runoff and infiltration and maintains a soil water balance by simulating ET and percolation. In addition, estimates of runoff volumes and rates are used in the erosion/sediment yield component to compute sediment transport capacity. Results of model testing and validation for surface runoff, evapotranspiration, and percolation are summarized by Smith and Williams (6).

The Erosion/Sediment Yield Component

The erosion/sediment yield component computes detachment, sediment transport, and deposition on a storm-by-storm basis. Inputs from the hydrologic component include rainfall erosivity, runoff volume, and a maximum runoff rate for each storm. Sediment is routed through overland and concentrated flow (channel) areas (8,9,10).

Slope length, steepness, and shape are used to construct representative slopes for overland flow. Interrill and rill detachment rates are computed using runoff volume and peak rate together with a modification of the Universal Soil Loss Equation (USLE) which is described by Wischmeier and Smith (11). Sediment routing is by particle size classes using a modified form of the Yalin (12) sediment transport equation for primary particles and soil aggregates.

The concentrated flow element computes erosion, sediment transport, and deposition in natural channels, grassed waterways, terrace channels, and diversion channels. The spatially varied flow equations (increasing discharge) were normalized and solved for a variety of flow conditions. Third order polynomials were fitted to these solutions and are used to compute friction slope as a function of position along the channel. Channel erosion is computed using an excess shear stress equation and the modified Yalin equation is used to compute transport capacity.

In summary, the erosion/sediment yield model computes erosion, transport, and deposition of sediment in overland flow and in concentrated flow. Gross erosion and sediment yield are computed by sediment particle size classes. Results of model testing and validation are summarized by Foster, Lane, and Knisel (8) and Foster et al. (9).

Scientific Basis and Source Material

The scientific basis for the CREAMS model is documented in the recent Conservation Research Report No. 26 (3). This report consists of three volumes. Volume I, model documentation, describes each model component and includes a sensitivity analysis. Volume II, user manual, describes model applications and presents material to aid in the selection of appropriate parameter values. Volume III, supporting documentation, provides additional data and explanatory material.

Basic source material providing the basis for the components included in the CREAMS model are summarized in Table 1. The original formulations are described in the references listed in Table 1 and subsequent modifications are described in Volume I of Conservation Research Report No. 26 (3).

APPLICATIONS

Although the state-of-the-art technology described earlier is intended for applications across broad climatic and land resource regions, the emphasis in this paper is on semiarid regions of the western United States. As parameters for the CREAMS model were, for the most part, derived for cultivated agricultural lands, less information is available for rangelands in the

Table 1. Basic source material for the CREAMS model.

PROCESS	COMMENTS	REFERENCES
Surface Runoff		
Option 1	Daily rainfall model Modified SCS procedure	SCS (4) Williams and LaSuer (13)
Option 2	Breakpont rainfall model Modified Green & Ampt infiltration equation	Green and Ampt (5) Smith and Parlange (14)
Evapotranspiration	Soil evaporation Plart transpiration	Ritchie (7)
Percolation	Daily percolation below the root zone	Williams and Hann (15) Smith and Williams (6)
Sheet & Rill Erosion	Modified USLE	Foster, Meyer, and Onstad (16) Wischmeier and Smith (11)
Sediment Transport and Deposition	Modified for particle size distributions in overland and open channel flow	Yalin (12) Einstein (17)
Channel Erosion	Excess shear equation for cohesive soil	Foster et al. (9) Lane and Foster (18)
Impoundments	Sediment deposition in ponded water	Laflen et al. (19)

West. However, many of the physical processes are common to humid and semiarid areas. Therefore, the CREAMS model can be used in experimental design. For example, simulation studies can be used to reduce the number of factors to be evaluated by field experiments. The experimentally evaluated factors could be limited to those showing gross differences between humid and semiarid areas.

Site Selection

As the model can be used to estimate soil erosion and water balance in the soil profile, it can be used to aid in site selection. That is, estimates can be made based on site-specific climatic, soils, and vegetation data but also using generalized information within land resource areas as defined by soils, topography, climate, and land use. This approach was illustrated by Krisel (2) in a schematic of water balance for selected locations in the United States.

Screening Management Alternatives

Management alternatives might include soil properties, slope steepness, slope length, vegetative cover (such as plant seeding and maintenance), and depth of the cover material. Based on simulation studies, initial screening of combinations of these factors could suggest viable management alternatives to control erosion and percolation below the cover material. For example, at a given location with known climatic features and soil erodability, maximum slope steepness (to prevent erosion in excess of the tolerance values) could be determined as a function of slope length and vegetative cover.

Remedial Actions

Erosion rates and soil water balance can be estimated to evaluate existing systems and to rank or select proposed remedial control systems. The soil loss criterion can be used to rank the proposed remedial action systems with respect to erosion and the percolation criterion can be used with respect to soil water penetration. By simulating on a continuous basis, based on long term climatic records, systems can be evaluated with respect to the interactive criteria of soil loss and percolation.

Finally, the ratio of actual to potential transpiration can be related to the ratio of actual to site potential herbage yield (20). This suggests that the CREAMS model, which computes actual and potential plant transpiration, can be used in vegetation studies at semiarid waste burial sites. Yield estimates together with soil water estimates can be used in plant establishment and maintenance studies.

Example

To illustrate an intended application of the model we considered soil loss and the water balance for a particular soil and climate. Characteristics of the input data for the example are summarized in Table 2. Climatic inputs consisted of mean monthly temperature and solar

Table 2. Characteristics of soil, vegetation, climate, and topography for the example application.

ITEM	CHARACTERISTICS	COMMENTS
Climatic Inputs	Average monthly temperature Average monthly solar radiation Daily precipitation	Observed data at Los Alamos, NM
Cover Material	Top soil: 15 cm, sandy loam Backfill: 76 cm, crushed tuff	Nyhan et al. (21) provide descriptions
Vegetation Cover	Bare soil Short range grasses Alfalfa pasture	
Topography	Uniform, 22 m slope length	Standard erosion plot dimensions

radiation for Los Alamos, New Mexico and recorded daily rainfall at Los Alamos for the 20 year period 1951-1970. The cover profile consisted of 15 cm of a sandy loam topsoil and 76 cm of sandy backfill material. Vegetation varied from none (bare soil), to sparse rangeland grasses, to a dense alfalfa cover. Simulations were made for a uniform slope 22 m long with a slope steepness of 5%.

The results of the simulation study are summarized in Table 3. The values shown in Table 3 represent average annual values for the three vegetation conditions. The ET values represent the estimated average annual evapotranspiration. For the bare soil this represents soil evaporation only, while for the surfaces with vegetative cover the ET values represent soil evaporation and plant transpiration. The influence of vegetative cover on the soil water balance is illustrated by the data shown in Table 3. As the density of vegetative cover increases, evapotranspiration increases at the expense of runoff and percolation. This is because the infiltration rate is increased by vegetation, but, at the same time, evapotranspiration is increased. Although more precipitation infiltrates, more water is transpired: the result is less runoff and less percolation. The actual relationships between these processes is dependent upon the climate, soils, and vegetation characteristics and are thus somewhat site specific.

The last row in Table 3 is the ratio of soil loss for the particular vegetation cover to soil loss from the bare soil surface. These data illustrate, under the assumed conditions, the relative influence of vegetative cover in reducing erosion and sediment transport. The primary mechanisms involved in this example are reduced raindrop impact at the soil surface decreasing the interrill erosion, increased soil stability decreasing the rill erosion, and reduced runoff and increased hydraulic roughness which reduce the sediment transport capacity in overland flow.

Although the dense cover provided by alfalfa would significantly reduce the erosion and sediment transport rates, this example is probably unrealistic under climatic conditions at Los Alamos. Analysis of potential evapotranspiration rates under an alfalfa cover and actual rates (reduced due to limiting soil water) suggests that it would be difficult to establish and maintain a dense alfalfa cover without supplemental irrigation.

Table 3. Summary statistics for the influence of vegetative cover on soil loss and water balance for the example application. Average annual values in mm for 20 year simulation.

	mm		
ITEM	BARE SOIL	RANGELAND	ALFALFA
Precipitation	468	468	468
ET	367	451	460
Runoff	46	17	7
Percolation	56	5	6
Soil loss[1]	0.78	0.073	0.002
Relative soil loss[2]	1.00	0.094	0.0022

[1]Based on an assumed bulk density of 1.6. Does not include channel erosion. Uniform 5% slope, 22 m in length.
[2]Ratio of soil loss under vegetative cover to soil loss from bare soil.

FUTURE CONSIDERATIONS

Although the CREAMS model can be directly applied to the problem of cover integrity at shallow land burial sites, additional research is required to quantify the model parameters under semiarid conditions. Also, additional research is needed to quantify parameters under unique conditions such as wick systems or plant and soil water barriers installed within the cover soil profile. Toward this end, experiments are being planned at Los Alamos, New Mexico, Tombstone, Arizona, and Boise, Idaho. These experiments should provide information on parameter values at locations representative of large areas of the western United States.

DISCUSSION

The CREAMS model, although developed for agricultural systems, appears to explain many of the physical processes important in maintaining the cover integrity at shallow land waste burial sites. An example application, at a semiarid waste disposal site, illustrates typical applications. Even though the CREAMS model, in its present form and with existing parameter values, can be applied to the cover integrity problem, improved estimates might be obtained by experimentally determining parameter values under semiarid conditions.

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ARID SITE REMEDIAL ACTION TECHNOLOGY DEVELOPMENT AT THE LOS ALAMOS NATIONAL LABORATORY

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INTRODUCTION

The program goal for Arid Site Remedial Action Technology Development at the Los Alamos National Laboratory is to design and field test methods that could be used to correct actual or anticipated problems with a closed SLB site in an arid environment. These problems might include, but are not restricted to, contaminant uptake by plants and animals, surface water infiltration, surface erosion by wind or water, subsidence, and the upward migration of radionuclides due to moisture cycling. The major accomplishments during FY-1981 were the emplacement of the biointrusion barier testing experiment, the design, emplacement, and data collection from the moisture cycling experiment, and the application to SLB problems of the CREAMS model.

This paper will describe the moisture cycling experiment and the work planned for FY-1982. The biointrusion barrier testing has been described earlier in these proceedings in a paper by T. E. Hakonson, and the CREAMS model and application has been described in a paper by L. J. Lane.

MOISTURE CYCLING EXPERIMENT

The driving force for the flow of water under unsaturated conditions is the hydraulic head gradient, which includes matric, osmotic, and gravitational components. If, due to drying of the surface, the matric potential difference tending to drive water back toward the surface is greater than the gravitational potential tending to drive the water down from the surface, it is possible for water to be transported up to the surface of the ground. In an arid environment this possible upward movement of water could mobilize and bring contaminants back to the surface of a closed burial pit. To determine whether this is an important process, and to determine if it requires remedial action, a moisture cycling experiment is in place and producing experimental data at the Los Alamos Experimental Engineered Test Facility. Some important variables for this experiment are tracer or contaminant depth, average moisture content, temperature and temperature gradients, and the presence or absence of plants on the facility.

This experiment is being performed in sixteen experimental units as illustrated in Figure 1. These units are galvanized corrugated metal pipes about 66 cm in diameter and about 153 cm deep with welded but not sealed steel bottoms. Copper-constantan thermocouples are placed in the soil profile as shown in Figure 1. The spacings between successive thermocouples, starting at the surface, are 1 cm, 2 cm, 4 cm, 8 cm, 16 cm, 32 cm, 64 cm, and one at the bottom of the unit. An aluminum neutron moisture probe access tube is placed in the approximate center of each unit.

The important variables are distributed among the experimental units. Half of the units, eight, have plants on them and the other half have no plants. Except for the plants, the experimental configurations of each set of eight units are the same. Four of them have an average moisture content of 25% saturation, and the other four have an average moisture content of 50% saturation. For each moisture content, in two units the top of the tracer layer is 30 cm from the surface of the unit and for the other two units the top of the tracer layer is 60 cm from the surface. This results in having two experimental units at each average moisture content, with the top of the tracer layer at each depth, and with and without plants.

Each unit was filled with crushed tuff screened to −1.2 cm. The crushed tuff was mixed with an appropriate amount of water in a cement mixer and placed in the units in layers which were compacted while being filled. The tracers were emplaced in solution and included cesium, strontium, cobalt, and tritium in the form of tritiated water. After filling, approximately 1-2 cm of topsoil was placed on the eight units in which yellow clover, alfalfa, and barley were planted. In addition to natural rainfall (identical for all units), equal amounts of water were added to all of the experimental units.

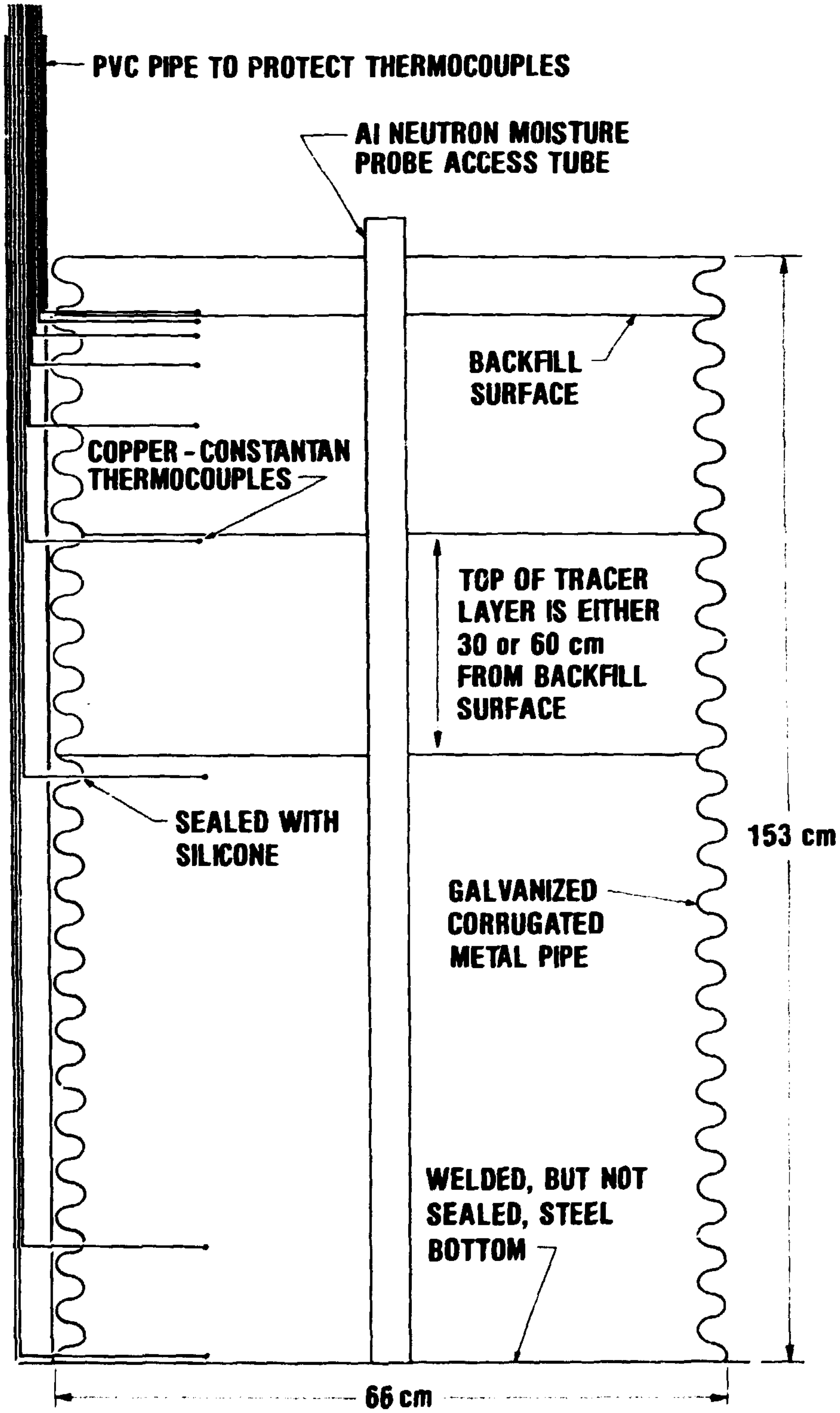

Figure 1. Moisture Cycling Experimental Unit

Temperature and moisture measurements with a neutron moisture probe are being made on a regular basis. In early summer of 1982, after the dry, warm, windy spring typical of this area, the experimental units will be destructively sampled and the soil profile analyzed for the tracer elements placed in the units. Preliminary analysis of the moisture measurements made to date indicates that a significant amount of moisture added to the experimental units is being transported back to the surface of the units. At the end of the experiment, the movement of the tracers, if any, will be correlated with the moisture movement in the units.

Based on the results of these experiments remedial actions to prevent moisture cycling, if necessary, will be designed and field tested.

A photograph of the experimental units with the plants growing well is included as Figure 2.

WORK PLANNED FOR FY-1982

The Arid Site Remedial Action Technology Development experiments planned for Fiscal Year 1982 are divided into five subtasks:

1. Identification and evaluation of erosion control technologies.
2. Second generation biointrusion barrier testing.
3. Microbial mobilization.
4. Moisture cycling.
5. Subsidence effects on system components.

Subtasks 1 and 2 are described in other papers in these proceedings.

For the microbial mobilization experiments, forty 46 cm by 2.75 m PVC pipes will be placed inside one of the large caissons. Within each pipe, tuffacious earth mixed with varying amounts of organic matter and moisture will be maintained under either aerobic or anaerobic conditions, to determine optimum conditions for organic matter volatilization. Gaseous effluents will be characterized using routine chromatographic techniques.

Three organic matter concentrations (3, 9, and 27%, w/w) and three moisture regimes (50, 75, and 100% moisture holding capacity) will be duplicated under either aerobic or anaerobic

Figure 2. Moisture Cycling Experiment

conditions. For both conditions 18 pipes will be needed (36 total); therefore 2 anaerobic and 2 aerobic controls (no organic matter, 75% moisture) will also be employed, making a total of 40 pipes. The caisson will be divided into two sections, one above the other. The lower section will contain the anaerobic pipes, while the upper section will house the aerobic columns. Tuff will be used as the soil material and an appropriate material will be used as the organic substrate. The soil and organic material will be mixed to yield the aforementioned organic matter concentrations. Individual mixtures will be placed in separate pipes and then each pipe will be lowered into the caisson. Once in place each column will be brought to its respective moisture concentration. The top of each pipe will be capped with covers equipped with as sampling ports and one-way exhaust valves. The anaerobic and aerobic columns will be flushed with N_2/CO_2, and air, respectively, for approximately one week. After anaerobic and aerobic conditions have been established, effluent gas sampling will then be initiated. Carbon dioxide and methane volumes and concentrations will be monitored biweekly, using standard chromatographic techniques.

Fiscal year 1982 work on moisture cycling will consist of continuing to monitor the experiment, destructive sampling and analysis at the beginning of the summer of 1982, and the compilation of the experiment results. If necessitated by the results, remedial action technologies will be developed and field tests started.

During FY-1982 experiments to determine the effects of subsidence on system components such as biobarriers, wick systems, and liners will be designed and emplaced in the field.

SUMMARY

Good progress was made in FY-1981 on the design and emplacement of remedial action experiments. Based on this good start, the continuing experiments and the new experiments planned for FY-1982 will provide the required experimental data on which to base the arid portion of the Remedial Action Technology Handbook.

REMEDIAL ACTION TECHNOLOGY DEVELOPMENT FOR HUMID SITES[1]

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ABSTRACT

Results of three separate field-scale remedial actions are described and their effectiveness evaluated. The placement of segmenting dams within a burial trench, coupled with a PVC subsurface cover, resulted in the enhanced hydrologic isolation of its buried waste and led to a significant reduction in the ^{90}Sr discharge from Solid Waste Disposal Area (SWDA) 5 at Oak Ridge National Laboratory. Hydrologic studies of SWDA 4 have indicated that 57% of the ^{90}Sr transport from it is associated with storm runoff events. This has indicated that a surface runoff diversion plan for SWDA 4 would result in an 80% reduction in its ^{90}Sr discharge. Treatment of a burial trench in SWDA 5 with caustic soda has resulted in a two order of magnitude reduction in the concentration of ^{90}Sr in its interstitial water. Such chemical treatment could prove to be a valuable remdial action for problem burial trenches.

INTRODUCTION

The remedial action technology development program has the primary goal of developing and demonstrating remedial techniques for application to sites where radionuclide migration from buried low-level waste reaches undesirable levels. Two basic strategies have, and continue to, underlie this program. Firstly, techniques are evaluated to hydrologically isolate buried waste from the dynamic surface and ground water system. This strategy involves two modes: one where surface and ground water is diverted before entry into the environs of the waste and another where the waste itself is hydrologically sealed from potential intrusion of ground and surface water by such barriers as surface seals, liners, covers, and grouts. The second basic strategy encompasses techniques which fix or immobilize radionuclides in the waste or its immediately surrounding soil without necessarily

[1]Research sponsored by U. S. Department of Energy under contract W-7405-eng-26 with Union Carbide Corp.

perturbing the surface and ground water flow regime. In the latter case, particular attention has been paid to radiostrontium as the comparatively more mobile and hazardous radionuclide ubiquitously present in the low-level solid wastes of our experience. Chemical treatments of waste and its surrounding soil with caustic soda and soda ash has been observed to immobilize ^{90}Sr from subsequent leaching by moving ground water.

HYDROLOGIC STUDIES

Trench Seal Evaluations

In 1975, remedial action was taken on a trench in Solid Waste Disposal Area (SWDA) 5 which had been observed to contribute a major proportion of the ^{90}Sr discharge from that area (1). The topsoil cover of this trench and three surrounding trenches was removed and the continuity of its 100 meter length was interrupted with a concrete dam at 55 meters and a shale-bentonite dam at 82 meters from its lower end, respectively. These barriers were designed to alleviate the often cited 'bathtub' effect where a long sloping trench tends to accumulate water in its downslope region leading to inundation and leaching of the waste especially when the lower end overflows. The group of four trenches was then covered with a 10 mil thick PVC sheet followed by 0.6 meters of topsoil and reseeding to grass. This impermeable trench cover was designed to prevent the infiltration of precipitation.

For the three years prior to this remedial action, the discharge from the tributary receiving the ground water discharge from SWDA 5 averaged 1.58 ± 0.48 Ci/year. For the three years following this remedial action, this same discharge averaged 0.57 ± 0.09 Ci/year. Discharges from other areas, which were not treated, showed no difference between the three year periods preceding and following this remedial action. The conclusion that this remedial action caused a reduction in the SWDA 5 ^{90}Sr discharge is supported by these observations. SWDA 5, however, contains hundreds of additional trenches, many of which contribute to its ^{90}Sr discharge although none are, apparently, of the magnitude of this remedied trench.

Strontium-90 Migration from SWDA 4

Examination of monitoring results indicated that nearly 50% of all ^{90}Sr releases from White Oak Creek drainage can be attributed to migration from SWDA 4 in an average year(2). Any efforts to reduce or eliminate ^{90}Sr discharges from White Oak Creek drainage must, therefore, focus on SWDA 4. Surface runoff originating from upslope areas outside SWDA 4 has been diverted since 1975 over SWDA 4 through a series of asphalt-lined channels. These conduits were designed to prevent the infiltration of this surface runoff into the interred waste by channelling it directly into the tributary south of SWDA 4. However, this surface water diversion scheme has not resulted in a detectable reduction in ^{90}Sr discharge from SWDA 4.

Temporary stream gaging stations were established along the tributary draining SWDA 4 and, at its confluence with White Oak Creek, a Parshall flume was equipped with a flow-proportional sampling system. Analysis of the resulting continuous hydrograph and associated ^{90}Sr concentrations showed that 57% of the ^{90}Sr transport occurred during storm events even though these storm events occupied only 32% of the time (Figure 1). Furthermore, there was no significant lag time between the onset of storm runoff and accelerated ^{90}Sr transport. This situation is not indicative of a ground water dominated streamflow regime. The uncontaminated runoff is carried across the disposal site by the diversion channels and discharged at the lower end of SWDA 4. However, the area below the diversion channels but above the tributary exhibits the highest concentrations of ^{90}Sr in the ground water and its associated seeps. Thus, it appears that ground water migration from the disposal trenches over the last 25 years has brought the ^{90}Sr to a point where it is available for accelerated transport or flushing during storms. Had this ^{90}Sr not migrated since its interment, the present surface runoff diversion channels might well have functioned in preventing this migration. However, it now appears that diversion of this surface runoff laterally into White Oak Creek, rather than across SWDA 4 into its tributary drainage, could overcome much of this storm-associated ^{90}Sr discharge. Additionally, such a scheme could decrease the non-storm discharge by preventing ground water recharge in the contaminated area immediately upslope from the tributary.

Engineered Ground Water Barriers

Often a group of burial trenches in a disposal area is situated in a topographic setting where the water table is maintained by lateral inflow of ground water from upslope recharge areas which are not employed for waste disposal. In such situations, it is extremely advantageous to intercept and divert this lateral ground water to effect a reduction in the water table elevation in the area of the burial trenches. A great deal of ground water interception and diversion technology exists in the civil and agricultural engineering disciplines but has not often been applied to radioactive waste management.

An area of burial trenches in SWDA 6 was selected for such a ground water interception and diversion scheme because it was a typical situation as described above and because a comprehensive history of water table elevation measurements exists for this area. A large selection of engineering design options were considered including French drains, slurry trenches, drilled concrete piers, and steel sheet pile cutoff walls. Each of these basic options had several variations in particular designs and combinations with other options which

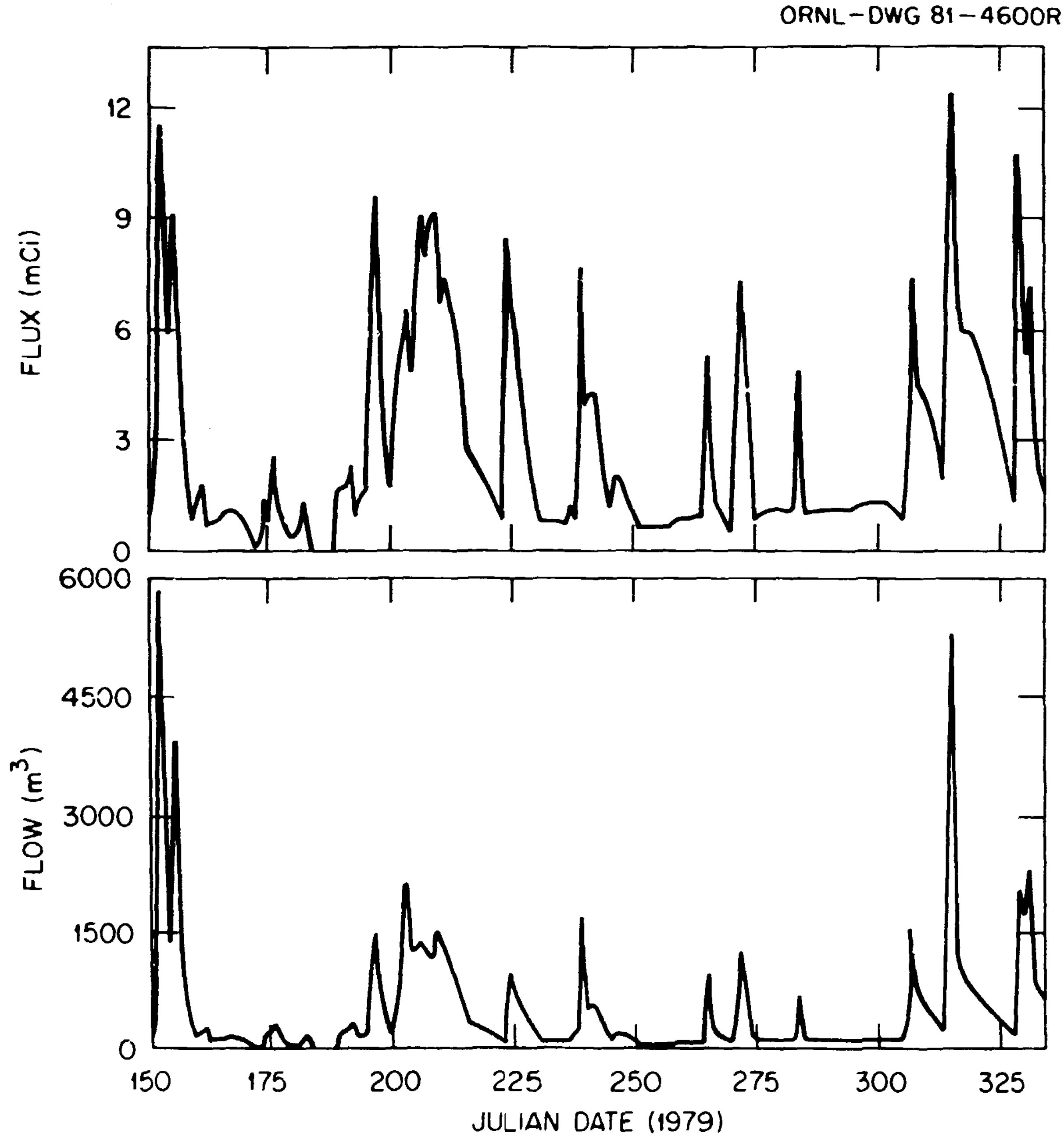

Fig. 1. Daily flow hydrograph and associated flux of ^{90}Sr of tributary draining SWDA 4.

resulted in quite a range of costs. The basic French drain option was selected as the most cost effective and construction has tentatively been scheduled for 1982.

CHEMICAL TRENCH/SOIL TREATMENTS

Laboratory investigations have established that treatment of soil with soda ash and/or caustic soda can effectively immobilize ^{90}Sr (3,4). The chemical basis for this effect is outlined in Figure 2. In the unperturbed or natural situation, ^{90}Sr behaves identically to soil Ca which is partitioned between a soluble or mobile phase as the bicarbonate and an adsorbed phase as an exchangeable cation. When this situation is perturbed by the addition of caustic soda or soda ash, additional cation exchange sites result from the ionization of surface hydroxyl sites;these new cation exchange sites are saturated with Na creating a situation very selective for ^{90}Sr and Ca adsorption. Moreover, the presence of carbonate anion at the resulting high pH, leads to the coprecipitation of ^{90}Sr on $CaCO_3$; this phase is particularly good at immobilizing or fixing ^{90}Sr. When columns of radiostrontium labelled soil are treated with various precipitating Na solutions, soda ash can immobilize up to 70% of the radiostrontium from the leaching action of a simulated groundwater (Figure 3).

A considerable effort has been made to demonstrate the field-scale effectiveness of such chemical treatments. A burial trench in SWDA 5, known to contain a significant inventory of ^{90}Sr, was treated with soda ash and caustic soda. The interstitial waters of this trench were treated with 3,800 L of 25% NaOH through a series of gravity-feed injection wells placed along the trench (wells 3, 4, 10, 11 in Figure 4). Subsequently, these same wells and others were injected with 800 Kg of soda ash dissolved in a minimal amount of water. A year after initial treatment, all old wells and several new wells were again injected with 4,600 L of 50% NaOH to achieve a thorough distribution of the chemical within the trench. This equitable distribution had apparently not been achieved with the previous injections due to the inherent vagaries of the void space distribution, with its associated effect on the channelling of chemical flow, within the trench.

Radiostrontium concentrations in well 1 exhibited a two order of magnitude drop from 125 to <1 Bq/mL following chemical treatment (Figure 5) and this effect has continued up to the present. In the small sump pictured in Figure 4, ^{90}Sr concentrations have fallen off gradually over this time period from over 100 to less than 25 Bq/mL. This is interpreted as a cutoff at the source of this sump's ^{90}Sr input from the trench. Thus, the chemical treatment now looks promising as an effective remedial measure for ^{90}Sr leaking trenches. Well water sampling will continue on a regular basis to evaluate the longer term behavior of this treatment.

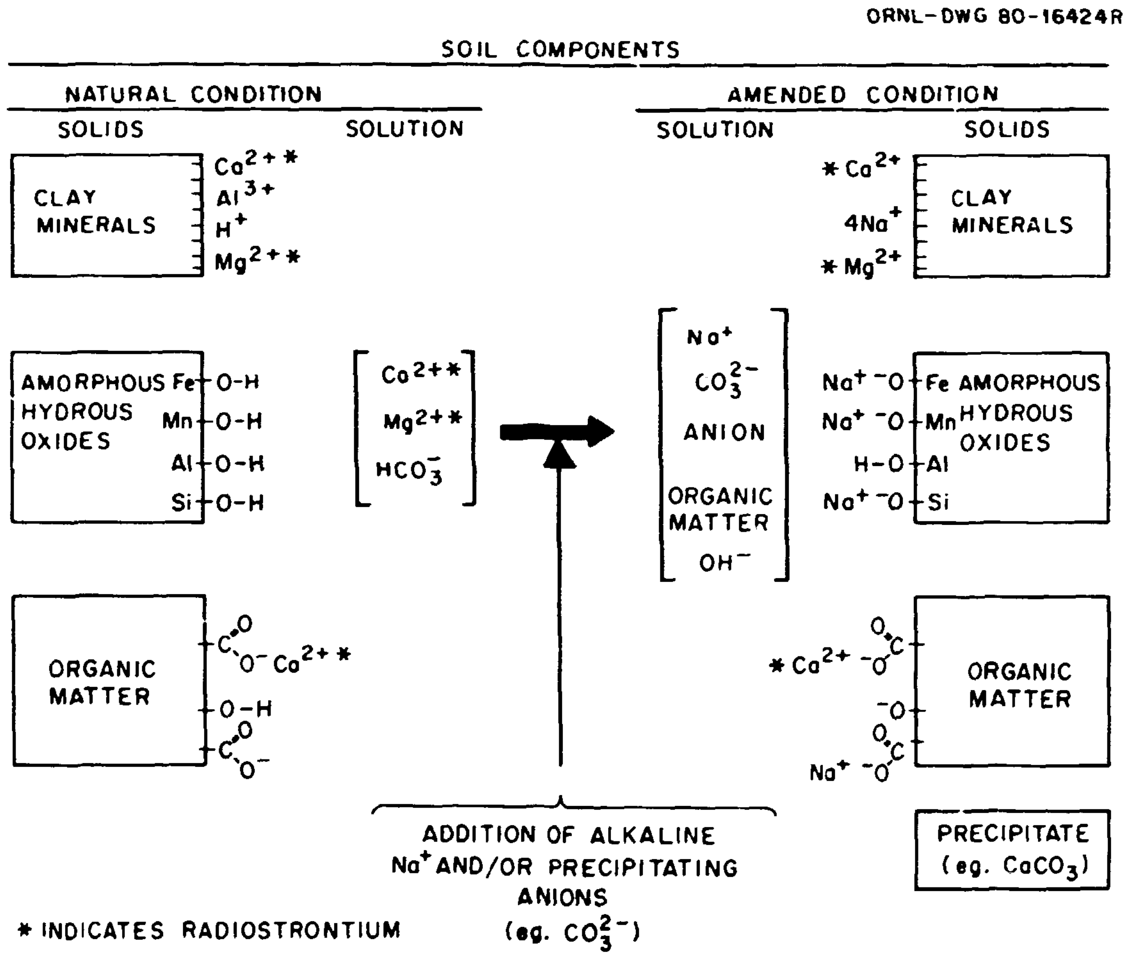

Fig. 2. Conceptual diagram of the chemical behavior of Ca, Mg, and ^{90}Sr in soil under natural and chemically-modified conditions.

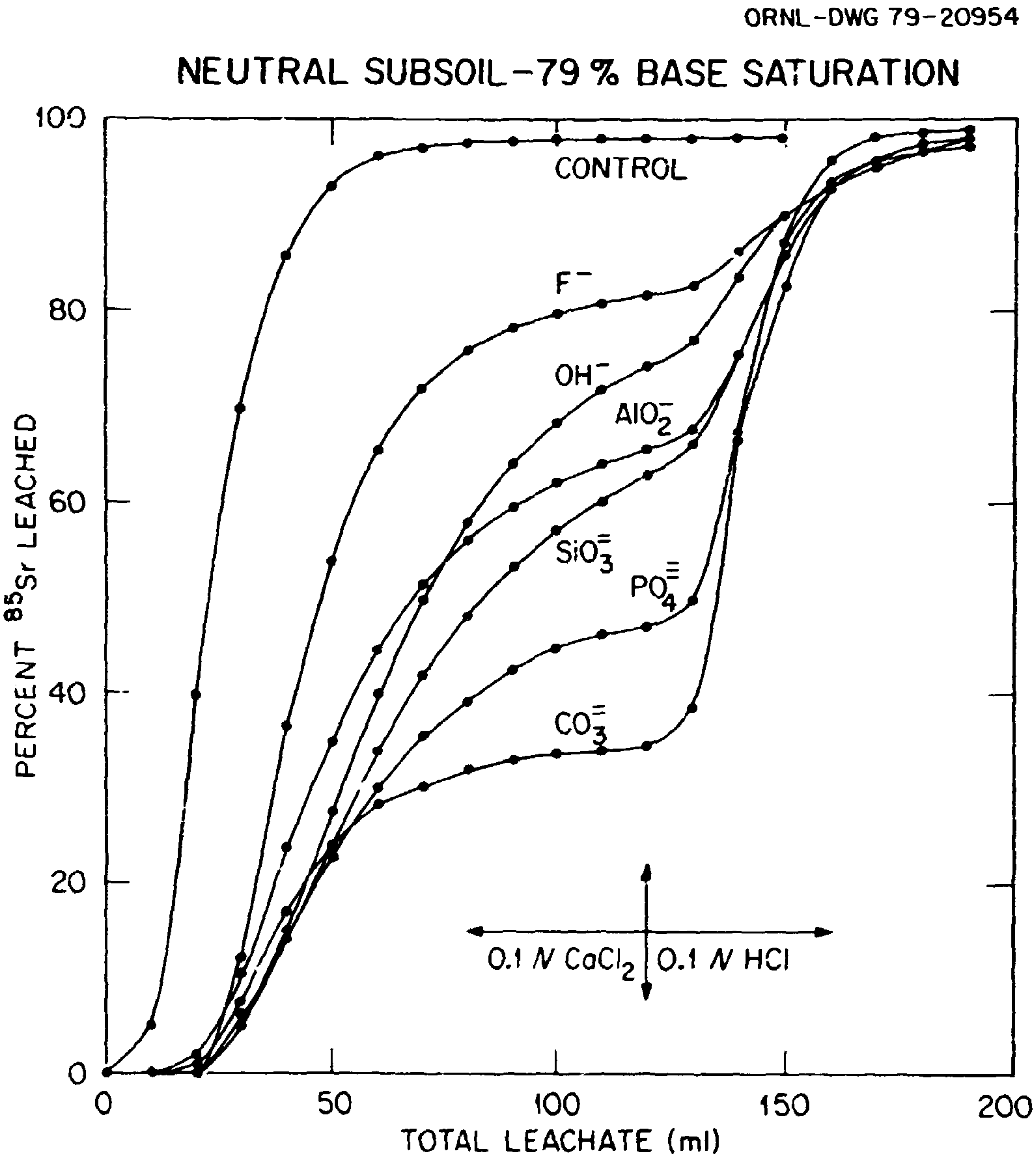

Fig. 3. Elution of ^{85}Sr from soil columns with 0.1N $CaCl_2$ following chemical treatment.

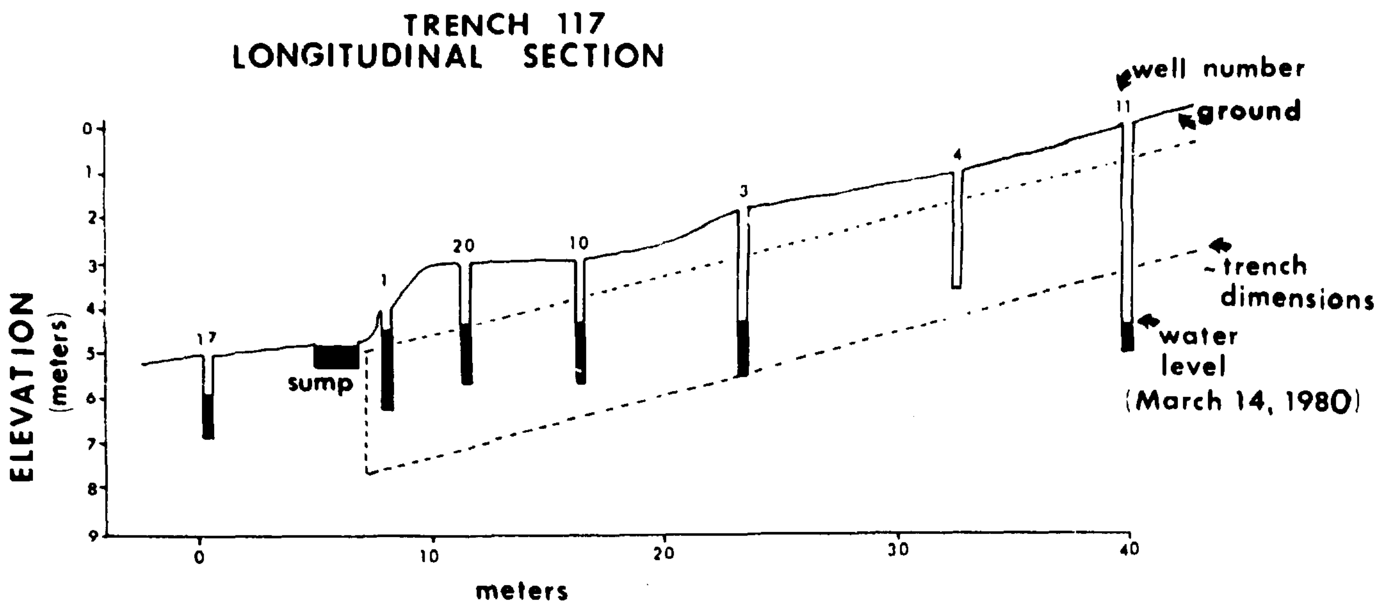

Fig. 4. A longitudinal cross-sectional view of a chemically-treated trench in SWDA 5 indicating well locations and water table.

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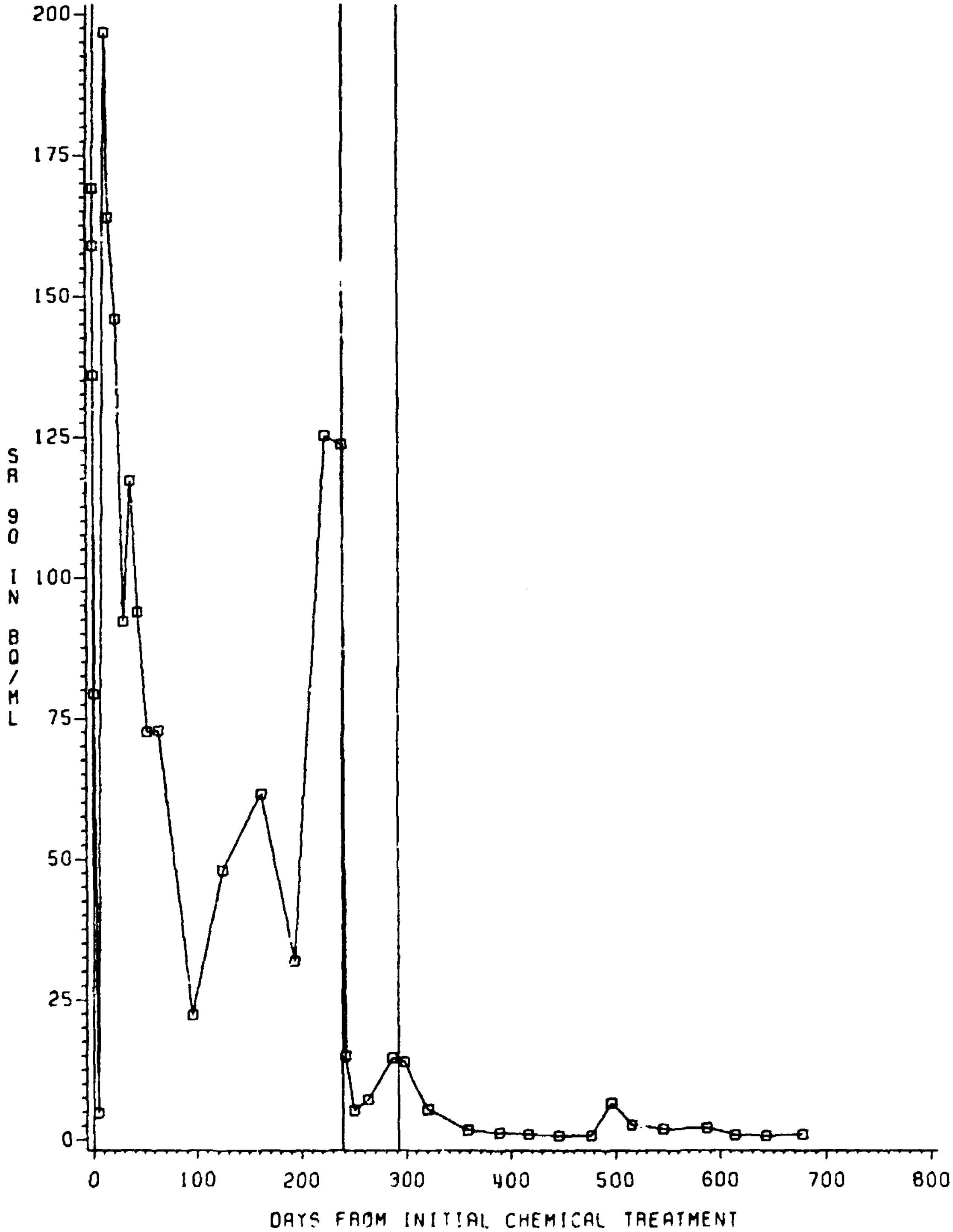

Fig. 5. Concentration of Sr in well 1 of a burial trench in SWDA 5 following chemical treatment. Vertical lines indicate times when chemical was added to the trench.

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LOW-LEVEL WASTE DISPOSAL SITE, SUBSIDENCE AND EROSION CONTROL/MONITORING/ DEMONSTRATION: A FIELD TASK SUMMARY FY 1981

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ABSTRACT

Rockwell Hanford Operations has conducted initial investigations relative to the development of safe, viable, and cost effective technologies to control and monitor geotechnical subsidence and erosion at low-level radioactive waste burial sites. These investigations have been completed in preparation for field testing and demonstration activities. This paper summarizes: i) engineering evaluations of methods to control burial structure subsidence and erosion, ii) evaluation of methods and instrumentation, and iii) conceptual engineering and construction activities completed to test and verify the applicability of control methods for these sites.

INTRODUCTION

There are numerous radioactive waste disposal sites within the United States wherein significant quantities of low-level wastes have been interred. The principal function of these sites is to confine waste materials, within release limits, such that nuclide transport to the biosphere and radiological exposure is minimized. The performance of each site is related to a myriad of interrelated physicochemical and environmental processes that potentially can act to result in loss of confinement and public exposure. Two important processes that function over time to degrade disposal sites are geotechnical subsidence and wind and water induced erosion. Subsidence and erosion problems have been documented as actual or significant potential problems at both commercial and defense burial sites. (1-10) Currently, subsidence and erosion problems are treated by interim stabilization maintenance procedures. These procedures have been reasonably effective in cases of limited occupational exposure; however, the procedures are quite expensive and may only provide short-term confinement. A need exists to develop "final" stabilization methods to provide a stable waste form, disposal structure, and an environmentally stable site capable of confinement for centuries.

Additionally, methods need to be developed to both actively and passively monitor subsidence and erosion such that evaluation of current, and prediction of future, site performance can be made. In FY 1981, activities sponsored by the Low-Level Waste Management Technology Program (LLWMTP) were initiated to develop subsidence and erosion control techniques and monitoring methods and systems. Reports were issued relative to: i) technology reviews, ii) standards development, and iii) engineering field test plans and construction activities. (11-15) The LLWMTP suspended support of these activities in FY 1982. A brief description of FY 1981 results and activities is given.

Subsidence

Subsequent to trench closure, due to independent or simultaneous processes of, e.g., waste form degradation, waste package collapse, etc., subsidence may occur. Subsidence currently is the principal mechanism whereby loss of confinement of low-level waste burial sites results. Numerous burial trenches at several sites have lost structural integrity wherein the overburden material overlying waste materials has caved in or cracked. This often results in waste materials being exposed to the atmosphere at the ground surface. Subsidence may occur on either a chronic or catastrophic basis. For the case of chronic subsidence, large basin-like depressions may occur over a large portion of a burial structure. Catastrophic failure, conversely, often occurs in localized areas along the periphery of a burial structure or in relatively small diameter steep-sided depressions located randomly over the surface of the burial structure. Ongoing maintenance programs are required to fill depressions, revegetate disturbed areas, etc.. Maintenance programs often include increasing overburden thickness as a remedial action technique. This can, if done improperly, increase rather than decrease the magnitude of subsidence problems. Furthermore, continuous maintenance (assuming current methods) may be required at most sites because subsidence is a recurring phenomenon. Continuous maintenance is not advantageous due principally to occupational hazard, occupational exposure, and cost. Thus, cost effective remedial action technology and performance requirements standards which will result in a physically stable waste site, are required.

Waste transport as a result of subsidence can result in exposure directly or indirectly through all major pathways. For example: i) as materials are exposed to the ground surface, direct exposure to occupational workers or the public may occur, ii) precipitation in the form of rainfall or runoff may infiltrate directly into surface depressions and subsequently result in migration through the groundwater or surface water pathway, iii) plant growth (biomass per unit area) typically increases in surface depressions caused by subsidence and biologic uptake may result, additionally, access to waste materials by animals is also increased and biological uptake and contamination spread may result, and iv) as waste materials are exposed or are transported to the atmosphere, they may eventually be entrained in winds which may ultimately result in occupational or public exposure.

Mechanisms that include subsidence are interrelated and may vary over time and space throughout the hazardous life, and within, different locations in a burial site. Subsidence is principally the result of void filling within a burial structure. Void filling caused by lithostatic and hydrogeologic forces results from complex physical and chemical processes. Where substantial inter and intra package void space or readily decomposable materials exist within a burial structure, significant subsidence problems can be expected.

Numerous geotechnical parameters can be monitored both within burial structures and within overburden materials which will provide quantitative information concerning the occurrence, rate, and magnitude of subsidence. These parameters include, e.g., i) horizontal displacement, i.e., movement caused by lateral tensioning, ii) stress/strain, i.e., the amount of positive (elongation) or negative (compression) ground deformation, and iii) tilt, i.e., the slope of the ground surface. These parameters can be evaluated dimensionally to determine, e.g., the rate of subsidence and the potential consequences. This information can then be used to design and implement remedial action activities.

Subsidence ground deformation parameters can be monitored passively and/or actively using a range of simple manual to semi-automatic or fully automatic data-recording/data-processing systems. Monitoring needs should be determined on a site specific basis dependent on existing or potential expected problems or probable consequences.

Several control techniques may be used to perform remedial actions on burial structures experiencing subsidence problems. These techniques are modifications of standard civil engineering or mining engineering methods. The most promising and cost effective of these are: i) dynamic consolidation, i.e., impinging a large falling mass on the burial ground structure to impart compaction with depth, ii) pile driving, i.e., driving piles through waste materials and leaving the piles in place, or backfilling and removal of the piles to provide preferential drainage paths for infiltrating waters, and iii) in-situ incineration, i.e., burning and combustion of compactable waste materials in place and subsequent compaction. These subsidence control techniques have not been tested or demonstrated at low-level disposal sites, thus, the occupational safety and exposure potential, etc., has not been demonstrated.

In summary, subsidence is the principal mechanism whereby loss of waste burial structure confinement has resulted. This has occurred at several sites. Subsidence may increase waste transport in all pathways and result in exposure. Technologies and methods to control and monitor subsidence are required, and testing and demonstration of these are necessary to evaluate safety and long-term performance.

Engineering studies, design, and construction activities were initiated to test, under controlled experimental conditions, monitoring systems and subsidence control alternatives. Materials were acquired and construction was begun at a field test site designed to monitor performance of several waste forms under ambient and stabilized burial conditions. The objective of field testing was to develop a technology to permanently geotechnically stabilize burial sites, i.e., for 500 years.

Water Erosion

The principal function of shallow-land burial of radioactive materials is to effectively confine waste, and as a result, minimize transport to the biosphere. Waste confinement during operations, closure, and post-closure, with respect to water erosion, is required. Waste confinement during post-closure, when site security, monitoring, etc., activities are implemented is especially important. In many cases water erosion effects, as well as mechanisms causing water erosion, will require monitoring. Furthermore, barriers and related structures will need to be developed and used to control water erosion. The functional performance of these barriers, etc., will also require mon toring.

Waste transport as induced by water erosion may result from several factors, e.g., i) overland water/sediment flow, ii) infiltration of precipitation, runoff, etc., iii) saturated/partially saturated groundwater flow, and iv) particulate waste/backfill migration. The water erosion processes influencing the rate and magnitude of denudation of waste burial overburden materials and, ultimately, waste materials themselves include, e.g., i) raindrop impact, i.e., particulate detachment surface crusting by impact and particulate transport by splashing, ii) runoff energy, i.e., water velocity, particulate concentration and surface slope, iii) material erodability, i.e., particulate aggregate structure/texture, profile permeability/conductivity, and profile composition.

Site monitoring of water erosion can involve simple and/or complex evaluations of several parameters. These parameters often are variable in both time and space. Hence, baseline predictive, as well as site performance monitoring, are necessary. Parameter categories requiring monitoring activities include: i) meteorology/micrometeorology, rainfall/rainfall intensity and duration, wind/wind profile magnitude and direction, temperature/temperature profile, potential/actual evaporation, solar radiation, etc., ii) hydrology/geohydrology, e.g., runoff, infiltration, soil moisture content/flow, stream flow, iii) topography, e.g., slope/slope change/structures and length rills, gullies, soil creep slumping, and iv) vegetation, e.g., canopy cover, surface cover.

Parametric monitoring and assessment of water induced erosion may involve data compilation by: i) manual observation and measurement (passive systems/methods), ii) semi-automated field data recording instrumentation, and/or iii) fully automated field data recording and processing. Data accumulation, processing, analysis, etc., for monitoring or predicting site performance may be quite site specific. As a result, monitoring system design and operations should follow site requirements.

Water erosion control structures can be used to minimize erosion. However, water control structures may in some cases cause or increase the potential for waste materials transport if not designed properly or with regard for long-term durability of the structure. Three general water erosion control structures may be used. These include: i) surface covers consisting of natural or synthetic materials, e.g., riprap vegetation covers, ii) drainage and diversion systems, e.g., upgradient watershed diversions, stabilized gullies, vegetation buffer zones, and iii) dams and terraces, e.g., slope/backslope vegetated terraces upgradient natural or manmade dams. Caution must be used if these control structures are used. Surface covers, e.g., asphalt trench covers, if not constantly maintained, will crack or otherwise structurally fail. As a result, surface runoff may be directly channeled into waste trenches and increased water transport will ultimately be realized. Dams or diversion structures within a watershed located upgradient from a disposal site may accumulate significant quantities of water, if these structures catastrophically fail due to design deficiencies or lack of maintenance, increased disposal site erosion, water transport, and exposure may result.

In summary, water erosion may be a significant factor relative to site performance. Site specific water erosion monitoring, control practices, and design may be considered. Furthermore, water erosion processes and control practices must be evaluated as interrelated factors in an integrated low-level waste management site program.

Wind Erosion

During operations, closure, and post-closure of low-level disposal sites, waste transport to the biosphere may occur as a result of wind erosion. Confinement within specific exposure limits of buried waste, especially subsequent to site closure and loss of direct site control is imperative. Hence, the control of erosion by wind erosive forces and site monitoring is required.

Waste transport as induced by wind follows well-known particulate and aerosol meteorologic/micrometeorologic physical principals. Erosion of particulates, i.e., burial site trench soil overburden, however, involves coupled atmospheric and soil transport factors. These include, e.g., particulate transport by creep, saltation, and entrainment. Parameters effecting particulate transport are numerous and interrelated; however, several values relating suspension/resuspension of particulates are often used. These include, e.g., i) fraction velocity, ii) average air velocity, iii) roughness heights, iv) suspension rate, v) drag coefficient, vi) surface shear stresses, vii) surface drag velocity,

viii) particulate shape, density, and concentration, and ix) wind/temperature profiles. The result of wind erosion is typically manifested by removal of successively coarser particules (soil grains) from over a disturbed area, i.e., trench caps, such that deflation basins occur within which waste materials may be directly exposed to the atmosphere.

Monitoring wind erosion forces and actual particulate mass and momentum transfer at a waste disposal site can involve active and/or passive measurement of wind erosive forces or the result of these forces. Depending on actual or potential wind erosion forces, different categories of monitoring systems or methods may be used.

In order to accurately predict site performance as influenced by wind erosion, accurate baseline monitoring may be required. Monitoring methods and instrumentation may range from simple to complex, i.e., simple observation of real time surface denudation can be made using survey techniques, semi-automatic to fully automatic data recording: data recording/data processing systems may also be used. Monitoring systems/methods sophistication will be dependent on site specific needs and site performance consequences.

Control of wind erosive forces or particulate transport may be possible in some instances. Albeit, control techniques specific to mitigation of wind erosion may, e.g., increase water erosion or otherwise exacerbate site performance. Hence, the design and use of wind erosion control structures, barriers, etc., should be done in concert with overall site design and performance requirements. Three general categories of wind erosion control structures may be used depending on site conditions. These include: i) vertical artificial barriers, such as fences located within, or adjacent to, a site in predominant wind directions, ii) surface covers consisting of synthetic or natural materials which overlay burial structures or the disposal site as a whole, e.g., gravel trench caps, and iii) vegetative covers and barriers consisting of flora located directly on a burial structure or barriers located in predominant wind directions, e.g., tree-lined barriers. It should again be noted that use of barriers should be thoroughly evaluated to assure adequate site performance under a variety of site conditions. For example, cobble surface barriers under low wind velocity conditions act to reduce particulate (soil grain) transport; however, in some instances under high wind velocity conditions, particulate transport may increase drastically.

In summary, site performance may be significantly jeopardized by wind erosion. Monitoring and control of wind erosive forces must be considered when evaluating long-term site performance. Additionally, site design and closure/post-closure activities relative to mitigation of wind erosion must be cognizant to interrelated processes that will affect the overall long-term confinement of radioactive materials within a site.

Design and preconstruction activities were completed on a site which will, under controlled experimental conditions, test surface barrier performance. Wind erosion and infiltration resistant barrier tests are anticipated to provide quantitative data such that final design parameters and requirements can be extrapolated from actual valid and technically defensable data. Confinement for 500 years is a design objective of field testing for new waste disposal sites.

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A REVIEW OF REMEDIAL ACTIONS APPLIED AT SHALLOW LAND BURIAL FACILITIES

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ABSTRACT

Evaluation Research Corporation's Oak Ridge Operations office recently completed a review of remedial actions taken to correct problems at shallow land burial (SLB) facililties operating in the U.S. Two staff members from Evaluation Research Corporation's Oak Ridge Operations office recently visited eleven shallow land burial facilities to observe routine operations and remedial actions activities. At each of these facilities, selected problems and remedial actions were identified and documented. The main problem areas for which remedial actions are taken include water management, subsidence, wind erosion, and biological intrusion. In addition, other site management considerations are discussed in the document prepared for the DOE-Low Level Waste Management Program. These include waste packaging, space utilization, physicochemical reactions facilitating migration of radionuclides, gas phase migration, trade-offs, improved practices, and future remedial actions.

The review of remedial actions taken at SLB facilities revealed that the application and evaluation of remedial actions at operating SLB facilities are not well documented. This lack of documentation may be due to two factors. First, operations personnel are primarily involved with the implementation and modification of operating procedures, whereas research-related efforts to identify problems are more likely to find their way into the literature. Second, the recent concerns with problems at SLB facilities may have resulted in recent application of remedial actions.

INTRODUCTION

Evaluation Research Corporation's Oak Ridge Operations office recently completed a review of remedial actions taken to correct problems at shallow land burial (SLB) facilities operating in the U.S. Two ERC staff members visited eleven SLB facilities to observe actual operations and remedial action activities. Six of the facilities (Nevada Test Site, Los Alamos National Laboratory, Hanford, Savannah River Plant, and Oak Ridge National Laboratory) are on sites operated under contract for the Department of Energy. The remaining five (Beatty, Richland, Barnwell, Maxey Flats, and West Valley) are commercial operations which are or have been licensed to operate in their respective states.

The goal of burial site management is to restrict releases of radioactivity into the uncontrolled environment to levels which do not pose a hazard to public health. Absolute isolation by land burial is difficult, if not impossible, but efforts are taken to minimize releases of radioactivity to the extent reasonably achievable, taking into account costs.

The current practice in SLB of low level radioactive waste is to emplace wastes into excavated trenches or pits and cover them with earthen fill. The completed trench or pit functions both as a geologic envelope providing shielding against direct exposure and as an attenuator for migration of radionuclides from the site.

The environment is dynamic and conditions may change over time, especially those conditions which were disrupted by the disposal operations. In most cases, improvements in operating procedures have been developed to reduce the need for remedial actions. However, in some cases problems cannot be completely avoided by improved operating practices and, in such cases, the problems must be corrected by appropriate remedial actions.

To a substantial extent, management practices, including implementation of remedial actions, have evolved independently at the various SLB facilities. The DOE Low Level Waste Management Program (LLWMP) has recognized that an important aspect in developing sound management policy and technology is identification of the actions taken to remedy problems at SLB operations and promotion of the interchange of information on the effectiveness of these actions.

OBJECTIVE

A study was conducted for the DOE-LLWMP to compile information on the application of remedial actions at the major SLB facilities. An attempt was made to document specific remedial actions used at a variety of waste burial facilities to correct problems that have been encountered during past and present shallow land burial operations. We also tried to characterize the degree of effectiveness of remedial actions, when their effectiveness had been evaluated at the site, and to describe how this evaluation was made.

During the planning stages of document preparation, it was anticipated that information describing remedial actions implemented at the various facilities would contain detailed descriptions of methods used. We intended to compile such detailed information into a handbook that could be used by operators for carrying out equivalent remedial measures at their sites. However, current documentation is not sufficient to prepare a handbook of methods and it was not possible to compile the necessary information in the short time period allocated for the initial review.

However, we did compile as much information as possible on the application of remedial actions at operating facilities. Most of the emphasis was placed on operational activities rather than research and development activities. While the resulting document cannot be considered a handbook, it does represent a collection of experience in applying remedial actions.

This document may be useful in the following ways. First, it serves as an initial compilation of experience on how to remedy problems occurring at SLB facilities located in a wide range of environmental settings. Second, it may alert site personnel to problem areas previously overlooked. Third, it lends further credence to the need to review the effects of remedial actions on a holistic basis, rather than just the impact on the specific problem being addressed. Fourth, it provides a body of information for improving waste management, including improved operating procedures and preventive practices, as well as remedial actions for correcting problems. Fifth, it provides documentation identifying where particular remedial actions have been applied. Thus, interested parties would know which sites to contact for further information.

METHOD OF INVESTIGATION

The investigation proceeded by two methods. First, we made a literature search to identify problem areas and attempted remedial actions. The literature contains substantial discussion of problems but very little information describing remedial actions, probably reflecting two factors. First, implementation and modification of procedures is performed largely by operations personnel, whereas research-related efforts to identify and study problems are more likely to find their way into literature. Second, the recent concerns with problems at SLB facilities may have resulted in recent application of remedial efforts. The effectiveness of these may still be under evaluation.

Consequently, it was apparent that we needed direct communication with operational personnel at the facilities to improve and supplement the available information based on remedial actions in shallow land burial. Thus, we made direct contact with personnel at each of the shallow land burial facilities. In addition, we viewed direct communication as an opportunity to clear up misrepresentations or confusion which may have arisen from the literature review, and to allow us to observe first-hand the results of some actions taken.

We sent a letter to the sites stating the purpose of the investigation, the anticipated usefulness of the compiled information to operations personnel, and a "Remedial Action Summary Sheet". In the summary sheet we itemized a variety of important considerations included in the process of taking remedial actions and provided space for written response. We also included an outline of the types of problems reported in the literature to assist operating personnel in recalling the range of remedial actions that may have been attempted at their facility.

Following initial written communications, two ERC staff members visited each of the facilities to observe field operations and to discuss remedial actions with personnel involved with management, engineering, and/or operation of the facilities. Follow-up phone calls were used for further elaboration of information collected during site visits.

RESULTS

The document is a compilation of the information collected from pertinent literature and site visits. Organization of the document is generic with the information categorized by subdivisions according to the following site management concerns: water management, subsidence, erosion, intrusion, and other site management considerations. Information is presented concerning application of remedial actions at individual facilities within each subdivision. At the conclusion of each subdivision, we have provided a summary table of the problems encountered and the remedial actions taken at specific sites.

Water Management (Surface and Subsurface)

The most serious technical problems associated with the disposal of low-level radioactive waste are related to water management. Uncontrolled surface runoff can erode waste trenches and trench caps. Water which contacts waste materials can cause their deterioration and degradation and cause radionuclides to move. The most common ways water comes into contact with the waste are from infiltration of precipitation through trench caps and/or walls or from erosion leading to exposure of the buried waste.

Efforts are made to prevent erosion, ponding, and flooding. These processes have occurred at all the humid, eastern sites, and at some of the arid western sites during periods of intense rainfall. This has resulted in the loss of cover soil, the formation of gullies, and subsidence of trench caps.

Surface depressions in the disposal area and subsidence of completed waste trenches permits ponding or surface water, which allows surface water to soak into the ground and mobilize radioactivity.

The physical location and climatic conditions of the disposal site may make it susceptible to flooding by an adjacent watercourse. Flooding has occurred at the Idaho National Engineering Laboratory (INEL) and steps have been taken there and at the Nevada Test Site (NTS)to protect against future flooding.

At INEL, a diversion system was constructed to reduce the potential for excessive water entering the disposal sites. This system included two dikes and a large ponding area where excessive water could be routed and stored in the event of a flood. The two systems protect the facility from 500 year floods. At NTS, precautionary flood dikes at the radioactive waste management facility are capable of diverting 100-500 year floods. (1, Personal Communication with M. Schletter and M. Marusich, Idaho National Engineering Laboratory, May 1981; and G. Kendall and D. Gillas-Hiller, Nevada Test Site, May 1981)

Common remedial actions taken to control surface water erosion and run-off in the disposal area include: the establishment of a thick, uniform vegetative cover; the filling and regrading of low-lying areas; the construction of ditches to divert water away from the burial area; and the placement of protective covers such as rock and netting to prevent surface water erosion. The control of surface water involves a trade-off. It is desirable to contour the disposal site to slopes which will remove water as rapidly as possible to minimize infiltration. However, slopes and drainage structures which are too steep are more readily eroded and are difficult to maintain. A thick cover of vegetation will help control surface erosion but aids infiltration by slowing the velocity of runoff and increasing the permeability of the top soil layer.

Subsurface water management is usually concerned with minimizing infiltration of water into the ground and preventing contact of groundwater with buried waste. Since subsurface water can cause radionuclide migration from the waste trench, its control is of prime importance in the shallow land burial of low level radioactive wastes. Many remedial actions taken to reduce infiltration are related to surface water control. The enhancement of rapid runoff and the elimination of ponding can reduce infiltration. Control of subsidence helps prevent surface cracks that lead to direct infiltration. Compaction of backfilled materials decreases the permeability of the trench cap. Other attempts to control infiltration include the use of impermeable barriers such as plastic, asphalt, or bentonite clay above or within the trench cap.

At a few of the SLB facilities in the humid east, infiltration has led to accumulation of water in the waste trenches. At Maxey Flats, KY, water is pumped from trenches to storage tanks. The collected water is evaporated to concentrate the radioactive material, and the residues (heels) from the evaporator are solidified and disposed of as low level solid waste. At West Valley, NY, water is pumped into a lagoon and transferred (pumped) to a low-level radioactive waste treatment facility for removal of radionuclides. (Personal Communication with J.P. Duckworth and P. Burn, West Valley, Nuclear Fuel Services, Inc., June 1981; and J. Razor, Maxey Flats, May 1981)

At ORNL, several semi-permanent perched water tables and associated seeps have developed in solid waste storage areas because of the "bathtub effect". Precipitation and runoff from the hillside combine with lateral inflow of groundwater from upslope. As a result, burial trenches and their contents are often in contact with water. (2,3,4, Personal Communication with N. Cutshall, D. Huff, B. Spaulding, E. King, H. Klaus, and T. Grizzard, Oak Ridge National Laboratory, April 1981) ORNL has installed a surface runoff collection and diversion system to ameliorate the problem at Solid Waste Storage Area (SWSA) 4. At SWSA 5, problems were aggravated because of poor trench orientation. Corrective actions included removal of about 0.6 m (2 ft) of overburden from four of the burial trenches and installation of two underground dams (one of concrete and one of bentonite-shale) across two parallel trenches. The stripped area was covered with a PVC membrane and the overburden replaced and seeded with grass to prevent erosion. In addition, a near-surface seal consisting of a bentonite-shale mixture was placed over 14 trenches to prevent excessive infiltration of precipitation. (5)

Subsidence

Subsidence of completed waste trench covers has occurred to some extent at all shallow land disposal sites. Subsidence may lead to ponding and increased infiltration through openings formed on the trench surface, or in extreme cases, to direct exposure of waste materials. Most of the subsidence in a waste trench is thought to occur within one to ten years of its completion, depending on climate and subsurface moisture conditions. Short term subsidence is primarily due to movement of fill materials into voids between waste packages, compaction of the backfill, and the decomposition of organic materials in the buried waste. Long term subsidence may continue well beyond the useful life of the disposal site. Long term subsidence tends to be fairly uniform and results from the continued weathering and consolidation of overburden materials and decomposition of more resistant waste packages and waste.

Control of subsidence is both remedial and preventive. Prompt repair of trench caps is important for preventing further degradation of the waste trench. Most facilities periodically check for surface slumping, and subsidence areas are filled, compacted, and regraded into the contour appropriate for surface water control. Preventive measures include compaction of waste, efficient waste placement, filling void space between waste packages, and compaction of the completed waste trench. At LANL, the current method of burial is to emplace the waste in layers with alternate layers of fill. This has resulted in reduced surface subsidence after the pit has been closed. At Barnwell, sand is used for backfill because it flows into the voids between waste packages without bridging. Operations include backfill and vibratory compaction of sand into voids between waste packages. The top of the trench cap is covered with clay. This method is reported to have decreased the occurrence and extent of subsidence. (Personal Communication with D. Ebenhack and M. Benjamin, Barnwell Chem-Nuclear Systems, Inc., June 1981)

Wind Erosion

In arid regions with sparse vegetation, wind erosion can be a problem. The wind can blow contaminated soil and wastes from open working trenches and the cover from trenches which have been backfilled. Aside from repairing damage which occurs, wind effects management consists primarily of preventive action. At Los Alamos National Laboratory (LANL), trees and other vegetation are left standing between trench excavations to aid in wind and water erosion control and native grasses are seeded on completed trench covers. Gravel is placed over completed trench caps at Richland, Washington, where it is difficult to establish and maintain a good vegetative cover. At Hanford, occasional high-velocity winds are the major cause of wind erosion. Bunch grass is planted on completed trench caps to slow wind erosion. A drill is used to emplace the seeds at the desired depth, where the moisture conditions are better suited for germination. After seed and fertilizer are emplaced, a crimper is used to crimp straw fibers into the soil to protect seeds from being blown away. Bunch grass is a strong perennial and inhibits growth of deep-rooted plants in the trench area. (Personal Communication with J. Warren, S. Powell, N. Wilson, and W. Hansen, Los Alamos National Laboratory, May 1981; V. Apple, Richland, U.S. Ecology, Inc., May 1981; J. Albaugh, B. Heine, S. Phillips, and J. Anderson, Hanford Works, May 1981)

Biological Intrusion

Biological intrusion by plants and animals may result in the uptake of radionuclides from the buried wastes, especially at waste burial sites where insufficient soil cover allows deep-rooted vegetation to contact wastes. Plant uptake of radionuclides occurs both through direct contact with buried materials and with contaminated subsurface water. Remedial actions to control plant uptake commonly involve the removal of deep-rooted plants from trench caps followed by routine mowing and/or herbicide application or by seeding with shallow-rooted plants that can successfully delay the intrusion of deep-rooted plants.

In older burial sites at Hanford, an experimental program has been initiated to test a combination of biological, chemical, and physical barriers to inhibit growth of deep-rooted plants and to eliminate surface contamination. Burial grounds with surface contamination were decontaminated and stabilizied, "bio-barriers" (PVC sheets) were installed and the area was treated with herbicide and revegetated with shallow-rooted plants or covered with rock. "Bio-barriers" have been installed for about 3-4 years and have been effective in preventing tumbleweed growth and root intrusion, but the long-term effectiveness of this treatment is uncertain. (Personal Communication with J. Albaugh, B. Heine, S. Phillips, and J. Anderson, Hanford Works, May 1981)

Rodents and other small animals can burrow into buried waste and spread contamination to the surface. Radionuclide transport is compounded when animals and insects ingest grass and deep-rooted plants that have accumulated activity from buried wastes. Predation of these animals and insects can pass radionuclides through the food chain to animals not normally associated with the disposal site. Remedial and preventive actions taken to control animals at the waste site include placing fences around burial grounds and immediate repair of burrow holes.

Other Site Management Considerations

There are a number of site management considerations discussed in the document prepared for the DOE-LLWMP where problems, or potential problems, were averted by improvements in standard operating procedures. These improvements are not considered remedial actions, but we felt that other operators would be interested in the practices used. These included waste packaging, space utilization, (attempts to reduce radionuclide) migration, and trade-offs in practices to improve overall site management.

DISCUSSION

When problems have occurred at SLB facilities the immediate response has been for the operator to take appropriate remedial actions to correct the problem(s). In most cases, however, the operators have then proceeded to improve operational practices to reduce the frequency or seriousness of the problem, though absolute avoidance of some problems is not possible.

In many cases, there are a number of options for remedial action. The choice depends on the anticipated duration and degree of effectiveness, the immediate cost, and the additional operational costs. Constraints on financial resources may lead to the application of remedial actions which are not the most cost-effective for the lifetime of the facility. More experience and cost information is needed to allow selection of cost-effective practices.

As mentioned earlier, it is important to manage the shallow land burial of low-level radioactive solid wastes in a comprehensive manner, keeping in mind the overall objective of protecting the public from unnecessary exposure to ionizing radiation. This is an important management concept, particularly with respect to implementation of remedial action practices, as practices taken to remedy one problem may aggravate or give rise to other problems. Thus, careful thought should be given to the consequences of applying various remedial action practices and the appropriate balance chosen. This balance generally differs from site to site.

Migration of radionuclides can be reduced by decreasing the permeability of the bottoms and sidewalls of trenches by filling void spaces, cracks, and fissures with impermeable grout. However, this can lead to increased accumulation of water in the trenches, a problem often observed at humid sites where the permeability of the undisturbed formation is significantly lower than backfill used for trench caps.

Larger and deeper trenches improve space utilization, but unless waste receipts are sufficient, much of the advantage may be lost due to frequent covering which is desirable for reducing external radiation exposures and fire hazards.

Cobbles and rocks have been used to create a "desert pavement" type of surface at some arid sites to reduce wind erosion. They appear generally to be effective in limiting wind erosion, but there may be accelerated undercutting at the edges due to turbulence during high winds. Undercutting along edges may occur when rip-rap is placed on gullies for control of water erosion.

SUMMARY AND RECOMMENDATIONS

This review revealed that the application and evaluation of remedial actions at operating shallow land burial facilities is not well documented. Our investigation included a literature review, brief site visits to discuss remedial actions with personnel involved with management of the SLB facilities, and a "Remedial Actions Summary Sheet" sent to each facility to obtain detailed steps taken in applying remedial actions. Unfortunately, the completed document does not provide a step by step account of remedial actions that would allow other facilities to apply remedial actions. However, the document may be useful in familiarizing interested personnel with remedial actions taken at a variety of SLB facilities and allow better communication with operators and researchers of these facilities.

In an effort to improve information exchange on the topic of remedial actions, it may be useful to broaden the written and oral information by conducting a meeting of operators and researchers from various SLB facilities to discuss their experience in applying remedial actions. This would provide a mechanism for the participants to contribute detailed information on methods specific to their site. In addition, such a meeting would allow participants to compare the effectiveness of remedial actions in meeting regulatory requirements. Advantages and disadvantages of specific facility environments, equipment availability, and other conditions unique to the various facilities could be discussed in relation to regulatory compliance.

One of the questions suitable for discussion is whether remedial actions are of generic value or are too site specific to be broadly applicable. By convening people from each site who have been directly involved in shallow land burial, the problems and positive aspects of remedial actions may be discussed by personnel who deal with them on a regular basis. Another question that could be addressed by such a group is the development and/or evaluation of remedial action criteria.

In any case, the document should be carefully reviewed and revised to include more detailed information on methods, procedures, and costs of remedial actions currently being applied at SLB facilities and the status of development of research, development, and demonstration of additional methods. Whether or not it is determined that such a handbook on remedial actions is useful enough to serve all SLB facilities, the information derived from research and operational experience should be updated, evaluated, and reviewed on a regular basis to better monitor the effectiveness of remedial actions at specific SLB facilities.

Groups involved in research, development, and demonstration of remedial actions need to review their results in a comprehensive manner so that all consequences are considered in the evaluation. It is important that correction of one problem does not lead to a different problem which is more serious. Factors such as duration and degree of the effectiveness, immediate costs, and additional operational costs are also important factors to the operator in selecting between alternative remedial actions.

Another major consideration that has not been adequately addressed is "how should the effectiveness of a remedial action be evaluated?" This is a difficult question to address, and I will leave it to the researchers. However, good technical judgement is needed to determine just what measurements are required and the period of time over which they should be made.

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OVERVIEW OF MILESTONE E ACTIVITIES, "GREATER CONFINEMENT THAN SHALLOW LAND BURIAL"

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INTRODUCTION

The objective of Milestone E is to "develop the technology and documentation needed to open a site providing greater confinement than shallow land burial" by March 1986. For the purposes of the LLWMP greater confinement has been defined as "the disposal of LLW in such a manner as to provide greater containment of radiation, reduced potential for migration/dispersion of radionuclides, and greater protection from inadvertent human and biological intrusions in order to protect the health and safety of the public" (1). Greater confinement means greater confinement of radionuclides than provided by conventional shallow land burial.

The need for greater confinement than shallow land burial is predicated on the need to isolate certain higher activity or longer-lived radionuclides found in commercial and defense LLW from the biosphere in order to protect the health and safety of the public. These wastes pose a significant health and safety risk if disposed of by conventional shallow land burial as a result of (1) exposure of the waste by erosion, (2) groundwater or vapor transport of radionuclides, (3) intrusions by plants and animals, and (4) inadvertent and intentional human intrusions. The purpose of greater confinement disposal is to reduce these risks to acceptable limits.

NRC's recently proposed regulations on "Licensing Requirements for Land Disposal of Radioactive Waste" 10CFR61 (2), include a waste classification system which explicitly identifies classes of LLW requiring some sort of greater confinement disposal. Class C Intruder Waste requires the use of 5m of cover or the use of engineered barriers to reduce the potential for intrusion. NRC also identifies a category of waste generally not acceptable for near-surface disposal (depths less than 15 to 20m). The NRC waste classification and disposal scheme identifies two broad categories of disposal: (1) near surface disposal including both conventional shallow land burial (i.e., disposal at depths of up to 10m) and greater depth disposal with at least 5m of cover (i.e., disposal at depths of up to 15 to 20m) and/or the use of engineered barriers to reduce intruder potential and (2) non-near surface disposal (i.e., disposal at depths greater than 15 or 20m).

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As defined by the LLWMP, the DOE definition of greater confinement than shallow land burial is purposely broad to provide the agency with the flexibility required in selecting options for achieving greater confinement in the absence of systematic criteria and standards which identify the wastes requiring this type of disposal. DOE has identified burial at greater depths than conventional shallow land burial (i.e., 10m) and the use of engineered barriers, containment, and solidification as options for achieving greater confinement disposal. Once the DOE waste classification system has been completed, the agency will be able to identify which technological option or options are the most appropriate means for achieving greater confinement disposal for specific wastes.

The preliminary program plan developed for completion of Milestone E consists of four basic elements:

- inventory and preliminary screening of the full range of greater confinement alternatives to shallow land burial,
- selection of technology option(s) to be further investigated,
- development of a plan for identifying and implementing R, D&D requirements for the selected technology option(s), and
- re-evaluation of the selected technology option(s) versus milestone objectives and identification of additional R, D&D requirements.

The program is designed so that these four program elements will be completed within the timeframe of the milestone. Completion of these program elements and issuance of a final report will constitute completion of the milestone.

BACKGROUND

The inventory and evaluation of alternatives providing greater confinement disposal than shallow land burial was an iterative process. Promising technological options were then pursued in more detail. This first round of evaluation or screening was based on such basic issues as:

- technology readiness,
- public acceptance, and
- estimated relative costs.

Both near-term and long-term alternatives were evaluated at the preliminary screening stage. Near-term alternatives considered were (1) greater depth burial, (2) disposal in engineered facilities, (3) disposal in drilled holes, (4) deep well injection, (5) disposal in hydrofractured strata, (6) disposal in cavities, and (7) ocean dumping. Long-term alternatives evaluated were (1) ice sheet disposal, (2) extraterrestrial disposal, (3) subduction zone disposal, and (4) subcrustal disposal. Obviously, all of these options could not be evaluated in the same level of detail because of their state of technical readiness. However, all received at least a preliminary evaluation.

Based on the evaluation criteria, the most promising technological option(s) were selected for further R, D&D funding. While it is true that several of the other alternatives are potentially viable options in the near-term and/or long-term, the limited availability of program funding forced us to focus on the most promising option.

To that end, the option selected for further R, D&D investigations was greater depth burial with or without some combination of solidification, containment, or engineered barriers. Solidification, containment, and engineered barriers were included as options because in some geological/hydrogeological settings, greater depth may not provide greater confinement than SLB, but may actually shorten the pathway to the biosphere by shortening the distance and/or travel time to the groundwater system and ultimately the biosphere.

As indicated previously, the initial program activities focused on identifying and evaluating the full range of alternatives providing greater confinement than SLB. These level one screening activities were performed by:

- Gilbert/Commonwealth: State-of-the-Art Review of Alternatives to Shallow Land Burial of Low-Level Radioactive Waste, ORNL/SUB-79/13837/1, April 1980.
- University of Texas at Austin: Intermediate Depth Burial of Low-Level Radioactive Waste, draft, May 1980.
- University of Arizona, Alternatives to Shallow Land Burial for the Disposal of Low-Level Wastes; Topical Report, Generic Model: Mined Cavities, Vol. 1 through 4, July 1980.
- JRB Associates, Inc.: Assessment of Medium Depth and Deep Disposal of Hazardous Wastes as Related to Low-Level Radioactive Waste Activities, October 7, 1980.
- University of Arizona, Alternatives to Shallow Land Burial for the Disposal of Low-Level Wastes; Topical Report, Generic Model: Engineered Structures, December 1980.

- University of Arizona, Alternatives to Shallow Land Burial for the Disposal of Low-Level Wastes; Topical Report, Time-Tested Underground Structures Suitable for Isolating Low-Level Waste, January 1981.

- University of Arizona, Alternatives to Shallow Land Burial for the Disposal of Low-Level Wastes; Topical Report, Geomechanical Considerations in Siting and Design of Caverns Mined in Limestones of the Midwest, March 1981.

These documents along with the references prepared by NRC and their contractors and other researchers provided the basis for evaluating and selecting the technological options to be advanced to the next level of R, D&D activities.

Once the program determined that the greater confinement disposal task should focus on some combination of greater depth burial, solidification, containment, and engineered barriers, it was further determined that the significant geological and hydrogeological differences between sites located in the arid west and the humid east necessitated the development of parallel programs in these two regimes. The major tasks to be conducted are:

- development of site evaluation and selection criteria,

- identification of waste form effects on leaching rates,

- identification and development of required waste handling equipment, and

- demonstration of the technology to define costs, construction techniques, operational procedures, and monitoring procedures and to document the technical and environmental acceptability of the technology.

Limited funding prohibits the program from completely duplicating these tasks in arid and humid regions. The following activities were funded to accomplish program objectives:

- Ford, Bacon, and Davis Utah, Criteria for Greater Confinement of Radioactive Wastes at Arid Western Sites, prepared for USDOE/Nevada Operations Office, NVO-234, May 1981.

- Ford, Bacon and Davis Utah, Technical Concept for a Test of Greater Confinement Disposal of Radioactive Waste in Unsaturated Media at the Nevada Test Site, draft, June 1981.

- HQ Controlled Milestone LL81.2 "Issue Summary Report Outlining Project Plans, Waste Inventories, and a Monitoring Program for IDB," completed January, 1981.

- o HQ Controlled Milestone LL81.11 Technical Position Paper "Evaluation of the Need for Greater Confinement than Shallow Land Burial of Low-Level Wastes," submitted September 1981.

STATUS

As indicated previously, six major information requirements were identified for the program: (1) development of site selection criteria; (2) identification of waste form effects; (3) identification and development of required waste handling equipment; (4) identification of costs, construction techniques, and operational procedures; (5) identification of monitoring requirements and procedures; and (6) demonstration of the technical and environmental acceptability of the technology. In order to resolve these technology-based questions, the LLWMP has funded and/or plans to fund the activities described in the following sections.

Site Selection and Evaluation Criteria

Criteria development (Ford, Bacon, and Davis, Utah)

The purpose of this task was to identify criteria and standards for the design and operation of a greater confinement disposal facility for the disposal of LLW in the arid west. The task also developed methods for evaluating and ranking the importance of factors affecting site selection, design, and performance. This activity was completed and a final report issued in May 1981.

Waste Form

Waste Form Development (Brookhaven National Laboratory)

The objectives of this task are to (1) identify and investigate potential agents and processes for the improved solidification of LLW, (2) define operating parameters for improved solidification of problem wastes, (3) demonstrate the production of full-scale waste forms, and (4) test and evaluate solidified waste forms, and verify compliance with waste form performance and SLB acceptance criteria and transportation requirements. This work item is divided into five subtasks: (1) survey of potential solidification agents, (2) waste stream selection and definition, (3) collection of physical chemical data on products of the improved solidification of LLW streams and problem wastes, (4) full-scale waste form development, and (5) waste form evaluation. This task was initiated in FY 1981 and will continue into FY 1982. This task attempts to answer many of the questions on waste forms and their behavior.

Waste Handling

Waste Handling Study (Oak Ridge National Laboratory)

The purpose of this task is to assess and evaluate present day practices in the packaging, transport, unloading, and placement into the burial trench of low-level radioactive wastes. A review of the state-of-the-art technology of waste containerization is included in this task. This task was to be initiated in FY 1982, however, the status of funding for this task is uncertain at this time.

Facility Engineering and Construction, Operations, and Monitoring

Greater Confinement Disposal Facility (Department of Energy/Nevada Operations Office)

The purpose of the Greater Confinement Disposal Facility (GCDF) is to demonstrate the economics and technical and environmental acceptability of greater confinement of low-level, higher activity or long-lived, radioactive wastes in order to reduce the potential for biological and inadvertent human intrusions. The GCDF will specifically demonstrate greater confinement in an arid environment by disposal in a drilled hole at the Nevada Test Site. The project consists of six subtasks: (1) technical studies (i.e., systems analyses and evaluations), (2) facility design, (3) facility construction, (4) facility operation, (5) monitoring, and (6) facility decommissioning. Activities on this task were initiated in FY 1981 with construction planned for FY 1982/83 and operation for FY 1983/84. This project will answer many of the technical, economic and environmental questions regarding facility engineering and construction, facility operations, waste handling, and monitoring for a GCDF.

Methods for screening greater confinement disposal sites in humid regions (Savannah River Laboratory)

The purpose of this task is to develop specific methods for selecting greater confinement burial sites in humid regions. Selection criteria will be developed and validated by monitoring a GCF test site to be built at the Savannah River Plant (SRP) in support of the defense high level waste program. Movement of toxic, nonradioactive waste as well as waste radionuclides will be monitored. Competing factors such as degree of isolation (depth) vs operability of the site will be evaluated. This task consists of four subtasks: (1) operating a small scale demonstration facility using nitrate salts generated as a by-product of solidifying SRP HLW, (2) developing specific methods for selecting sites for greater confinement disposal facilities, (3) developing a reference process for design and operation of a GCF, and (4) monitoring of the proposed GCF. Activities on this task were initiated in FY 1981 and are planned to continue into FY 1982.

Technical support non-shallow land burial (Los Alamos National Laboratory)

The purpose of the task is to provide site screening and evaluation models, evaluate SLB site design activities for applicability to non-SLB sites (i.e., define barriers and water management systems), and develop and evaluate post-closure activities for non-SLB facilities (including completing long-term exposure potential analysis for application to arid non-SLB facilities). This information will be made available to NVO during the design and operations phases of the GCDF. LANL researchers will provide technical support for the design and operation of the GCDF. This task was initiated in FY 1981 and will continue into FY 1982.

These tasks will be discussed in greater detail by the individual investigators later in the program.

The planned milestone chart for completion of this program is presented in Figure 1. This schedule graphically indicates how the various Milestone E activities will fit together. There have been no significant changes in the schedule for completion of Milestone E since last years' meeting and the funded tasks are proceeding on schedule at this time.

REQUIREMENTS TO FULFILL THE MILESTONE

The following sections describe planned future activities necessary to complete the R, D&D requirements of Milestone E.

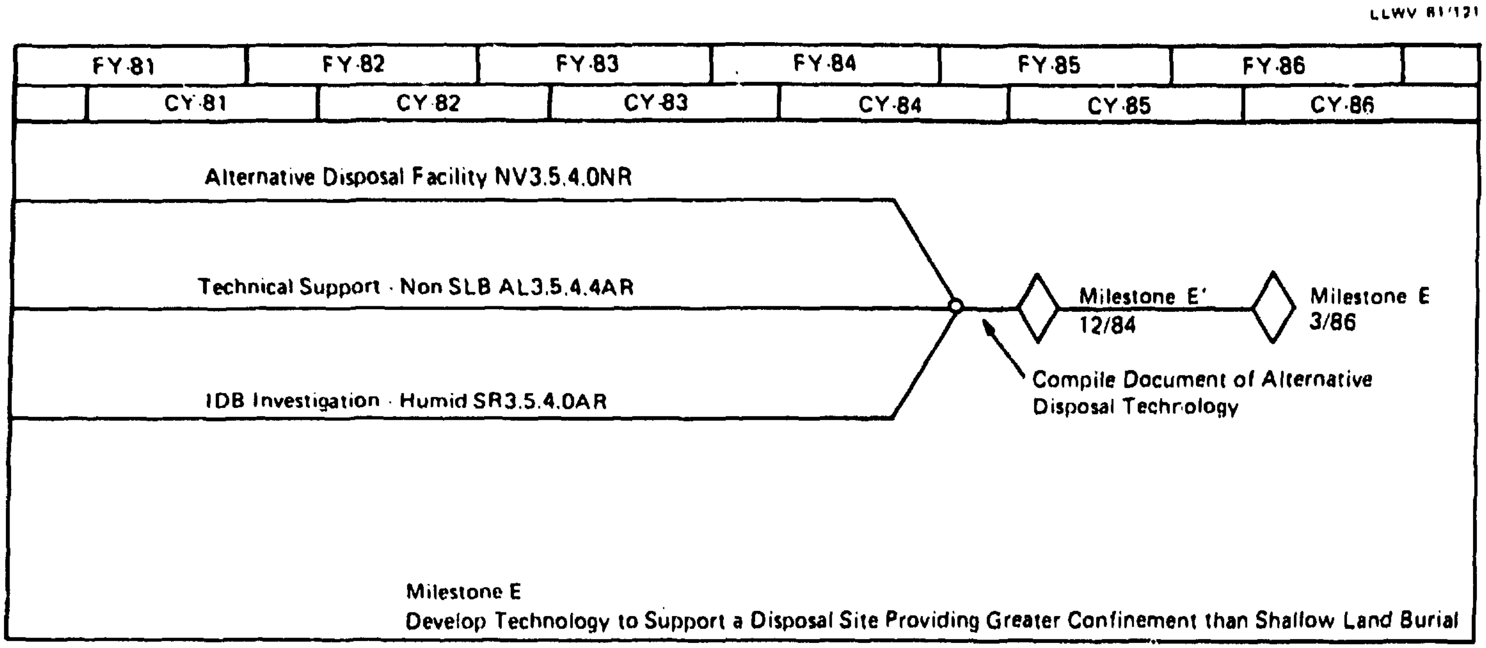

FIGURE 1. Schedule for Milestone E

Site Selection and Evaluation Criteria

Criteria for arid western sites have been developed by Ford, Bacon, & Davis Utah and were issued in FY-1981. SRL is currently developing methods for selecting sites for greater confinement disposal in humid areas and a draft report is due in FY-1982.

Waste Form and Waste Handling

These tasks support Milestone E activities but are actually Milestone G tasks and, therefore, are not discussed here.

Facility Engineering and Construction

The preliminary technical concept plan for the arid GCDF at the NTS was completed in FY 1981 and is currently being finalized. The drilling plan, risk assessment, waste characterization study, and transportation and containerization study will be completed in FY 1982. Engineering and construction activities on the SRL small-scale saltcrete demonstration have been completed. Actual detailed design and construction of the GCDF has yet to begin but is scheduled for late FY 1982.

Facility Operations

The small-scale saltcrete demonstration is currently operating at SRL. The GCDF has yet to become operational.

Monitoring

Preliminary design of the GCDF monitoring system has been completed and is being revised at this time because of changes in budget and technical requirements. Monitoring equipment is to be fabricated and tested during FY 1982. Field emplacement and baseline data acquisition are also scheduled for FY 1982/83.

Final Documentation

ORNL and EG&G Idaho will complete the final documentation necessary to open a site providing greater confinement than Shallow Land Burial in FY 1986 based on the Milestone E funded activities.

SUMMARY

In summary, the objective of Milestone E is to provide the technology and documentation needed to open a site providing greater confinement than shallow land burial. To that end, ORNL has prepared a technical position paper defining greater confinement disposal, options for achieving it, and the need for this disposal technology. In order to meet the objective of the milestones, the LLWMP evaluated the full range of options to shallow land burial and decided to focus on a combination of greater depth solidification containment and engineered barriers. The program identified a series of research needs and then focused program efforts on resolving those needs. These tasks are proceeding on schedule at this time but budget reductions may have an impact on our ability to maintain the schedule.

REFERENCES

1. L. J. Mezga, Technical Position Paper, Evaluation of the Need of Greater Confinement than Shallow Land Burial of Low-Level Wastes, ORNL/NFW 81/29 (October, 1981).

2. Nuclear Regulatory Commission, Proposed Draft Regulations "Licensing Requirements for Land Disposal of Radioactive Wastes," 10CFR61, 46FR38081, Vol. 46, No. 142, July 24, 1981.

INTERMEDIATE DEPTH BURIAL

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ABSTRACT

A second-generation SRP burial site is being developed for use when the current burial ground becomes filled in about 1990. Development centers around the concept of intermediate depth burial because deeper burial will retard movement of radionuclides via upwards paths--the most significant paths according to dose-to-man studies of long-term effects of burial ground operations.

PROGRAM DESCRIPTION

Projected LLW generation rates indicate that the present SRP burial ground will be filled in between 7 and 11 years. The Savannah River Laboratory is looking ahead and evaluating the possibility of going to intermediate depth burial (IDB) for the next-generation SRP burial ground. The current concept of IDB assumes that the waste will be 20-30 ft.(min.) below the ground surface, which compares to the 4 ft. depth used in the current burial ground. Deeper burial puts the wastes further from erosive forces, vegetative uptake potential and from intrusion by man and animals. The concepts which are developed should have general applicability to other humid sites. Some prospecting for IDB sites has already been done. In the current fiscal year this work will be continued with the objective of narrowing down the number of prospective sites. We also plan to develop containment criteria and perform radionuclide migration studies for certain IDB conceptual designs. Comparative cost data will also be developed.

Figure 1 is a map showing the 300 square mile Savannah River Plant. On the map are shown 18 sites which are potentially suitable for IDB. Table 1 provides some data on the area (acres), distance to nearest stream, and depth to water table for each of these sites. From this list about 5 sites will be chosen for more extensive geologic and hydrologic evaluations. These will include ground water elevation, flow direction and velocity measurements. The general geologic strata present on the Savannah River Plant are fairly well known, but these will also be characterized in-depth for the areas of interest.

The proposed IDB site would be excavated into the interbedded and intercalated sands, silts and clays of the upper geologic stratum of

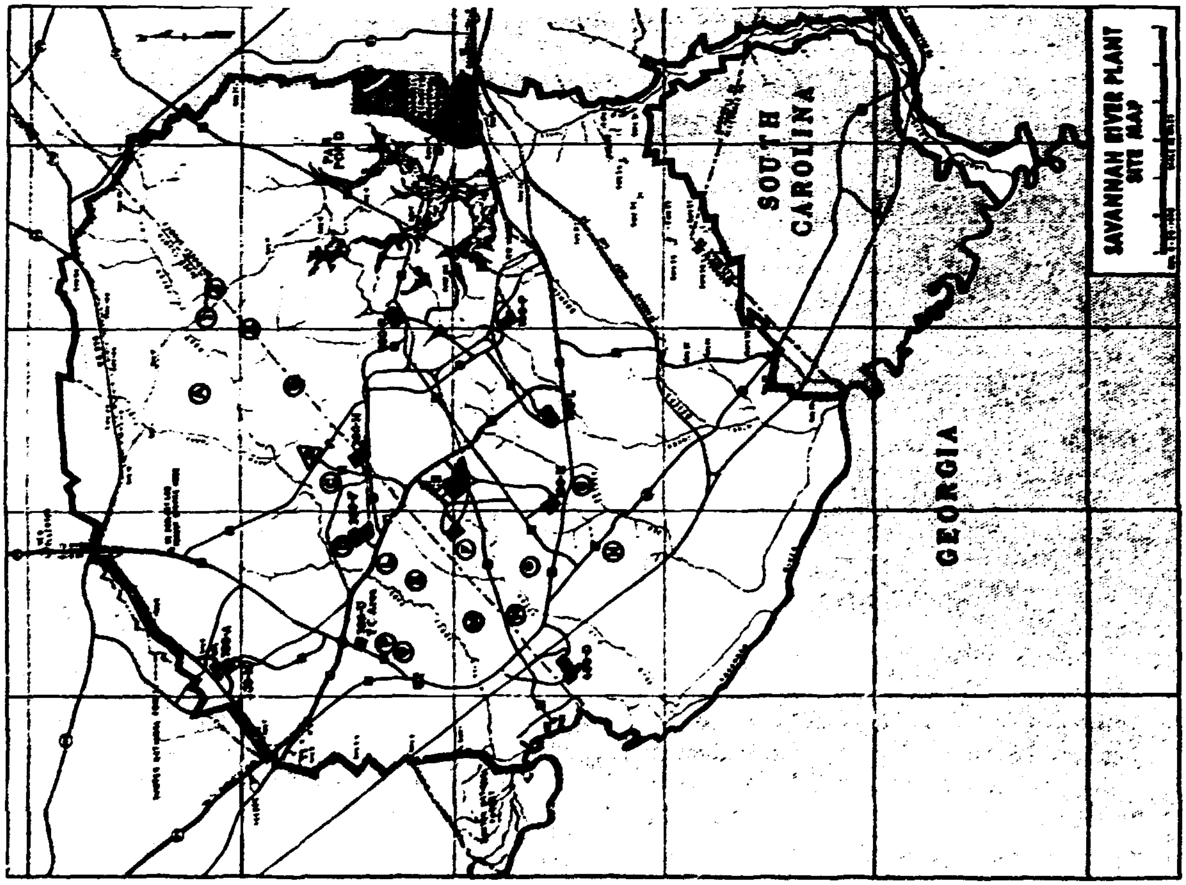


Figure 1. POTENTIAL INTERMEDIATE DEPTH BURIAL SITES

Table 1

Site	Approximately Area (Acres)	Distance to Closest Stream (Feet)	Distance to Closest Marsh or Standing Water (Feet)	Depth to Water Table (Feet)
A	135	2500		>40
B	300	2500 (1000)		40-70
C	90	500		55
D	80	1500 (200)		40-70
E	185	2500*		50-60
F	115	1500	on site	40-60
G	85	1500*		40-50
H	135	3500	1800	50-60
I	215	2000 (500)		
J	220	500-2000 (500)		
K	220	2000 (300)		
L	100	1700*		40-60
M	160	2000 (1500)		
N	210	1500 (500)		
O	225	1000 (400)		
P	240	5000 (1000)		>60
Q	255	5000		>60
Z	35	2000		50-60

( ) indicates distance to intermittent stream.
* At site boundary.

SRP, the Barnwell Formation. Although site design studies have just been started, some initial concepts are shown in Figures 2, 3, and 4. Figure 2 shows the development and use of an IDB which has a bottom clay liner and a clay cap. The initial lined basin is backfilled with a permeable layer (gravel) and the soil which had been removed in order to install the liner. Trenches are then dug and back-filled in much the same way as is current SRP practice. When all available trench space is filled, the burial site is capped with clay which is sloped to minimize perched water. If water should enter the burial space it will collect in the gravel zone at the trench bottoms and be pumped out for processing. This scheme implies long-term surveillance and maintenance of the site.

Figure 3 shows a similar design, without the bottom liner. In this design the amount of initial excavation is minimized (20-30 ft. vs 40-50 ft.). A low permeability cap is placed over the waste which should inhibit (perhaps prohibit, due to capillarity considerations) the movement of percolate water into the waste zone. In this scheme no water collects in the waste zone, so no long-term maintenance is required for monitoring this.

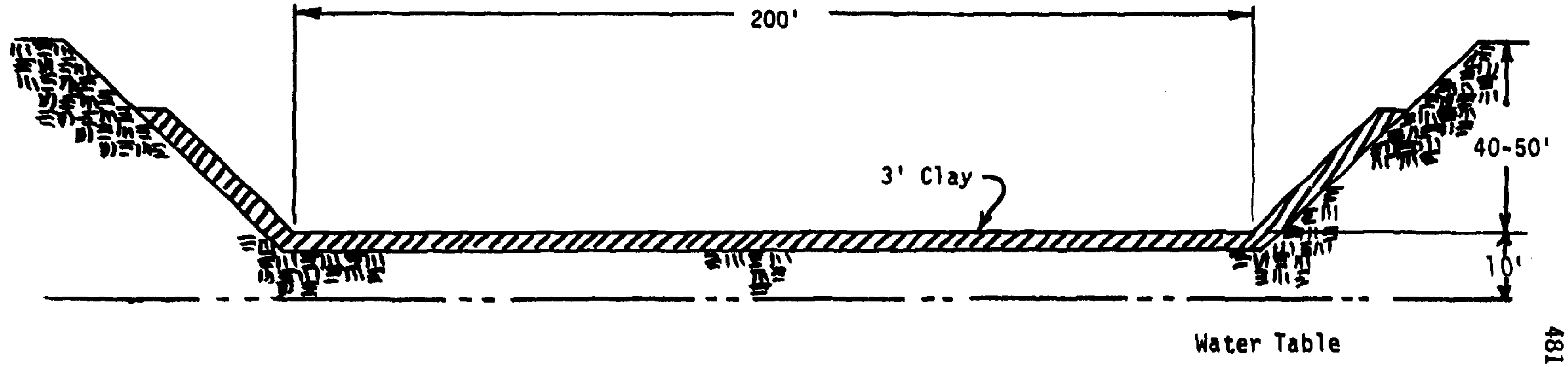
Figure 4 shows a third scheme which utilizes concrete structures to enclose the wastes. Due to economic considerations, this may be used for the highest activity waste only, and conventional shallow land burial (SLB) techniques would be used for the remainder. Incineration may be desirable to reduce waste volume for this case. Incineration can also provide waste form structural stability, which is desirable for the other cases presented.

As mentioned before, the foregoing are only concepts which may be modified or changed entirely to meet the desired criteria. At this time they serve only to illustrate the scope of our program planning.

Criteria will be developed to satisfy all applicable regulations for radioactive waste disposal sites at the Savannah River Plant. As criteria are developed radionuclide migration calculations will be made for selected design concepts, and design details will be varied as necessary to meet the criteria. Cost estimates will also be made for alternative IDB schemes and cost & benefits will be compared to the current SLB mode (plus decommissioning costs).

Figure 2. IDB-Clay Lined & Capped

A. Excavate & Line



B. Add Gravel & Fill

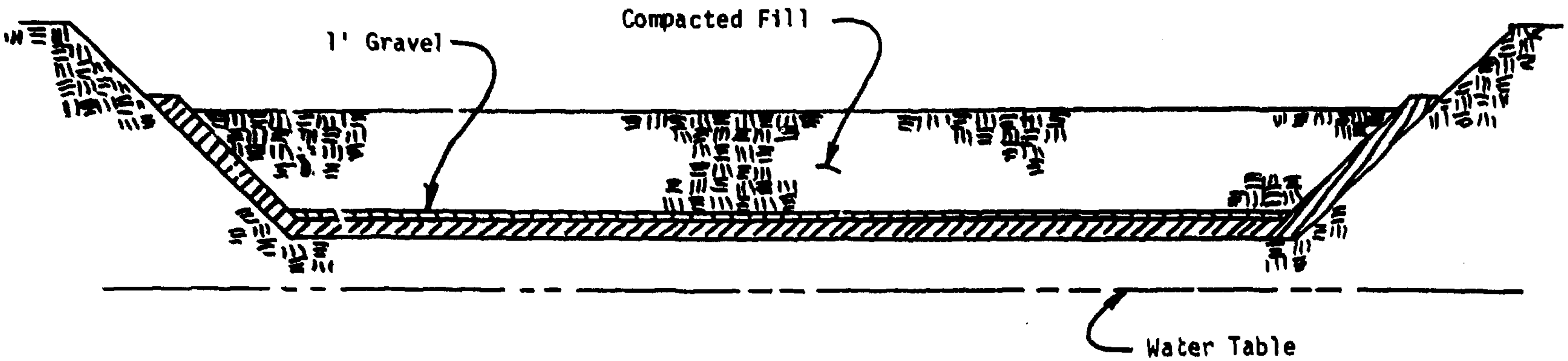
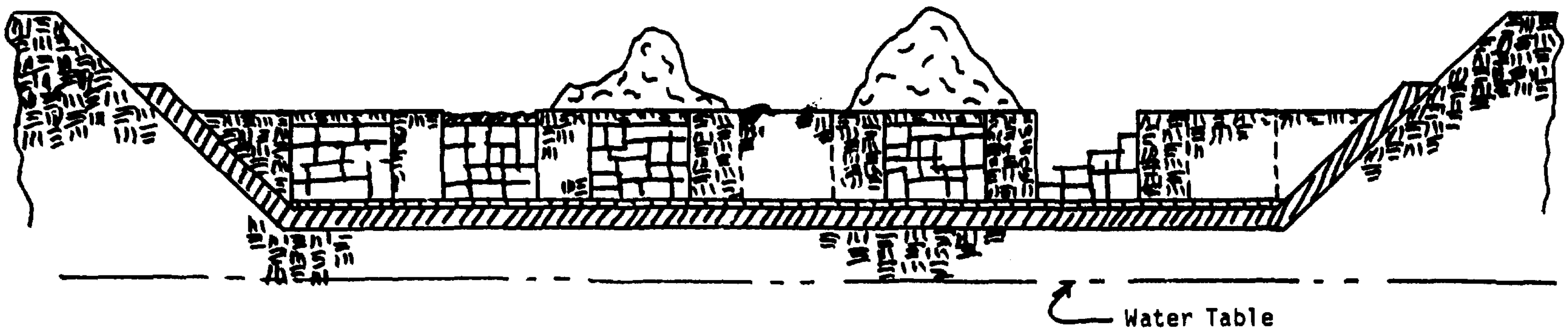


Figure 2. (Cont'd)

C. Dig Trenches - Bury Waste



D. Add Clay Cap & Cover

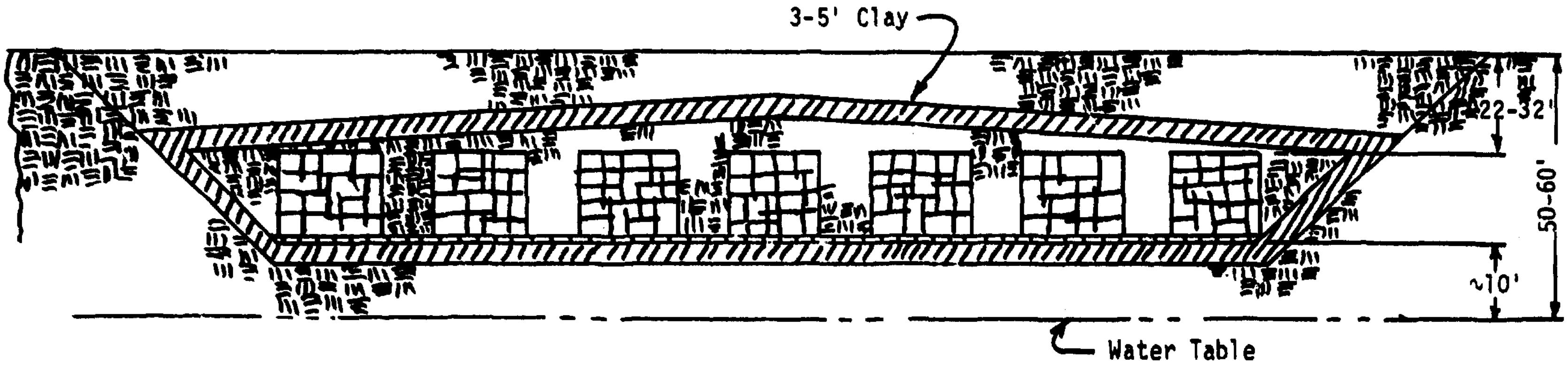
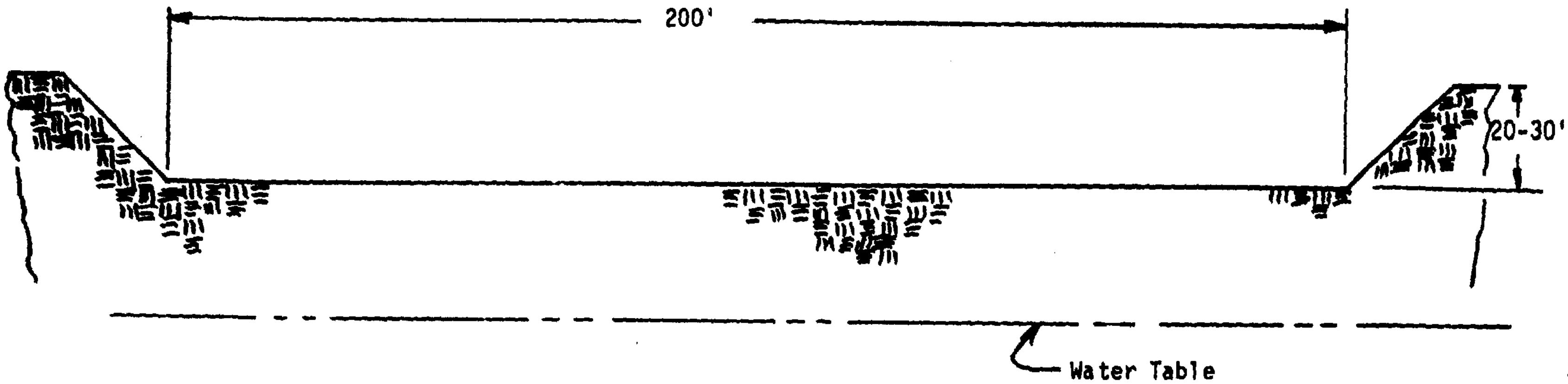


Figure 3. IDB-Clay Capped

A. Excavate



B. Dig Trenches & Bury Waste

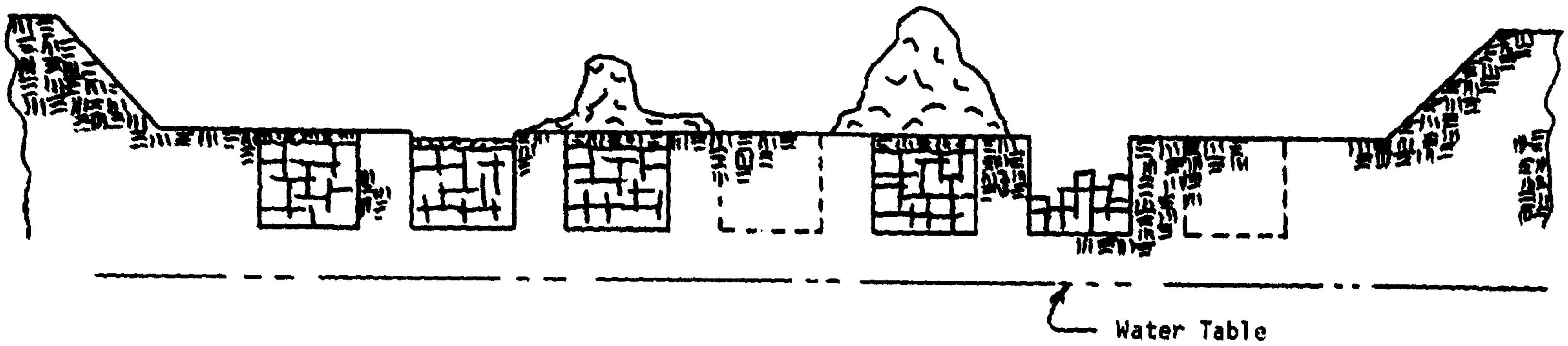


Figure 3. IDB-Clay Capped (Cont'd)

C. Cap & Cover

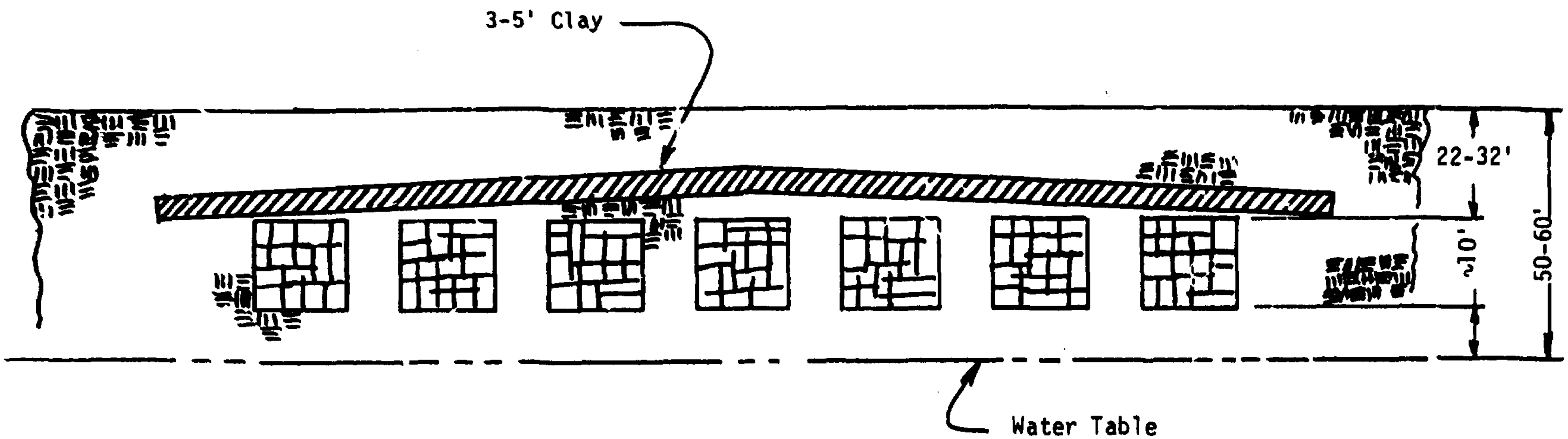
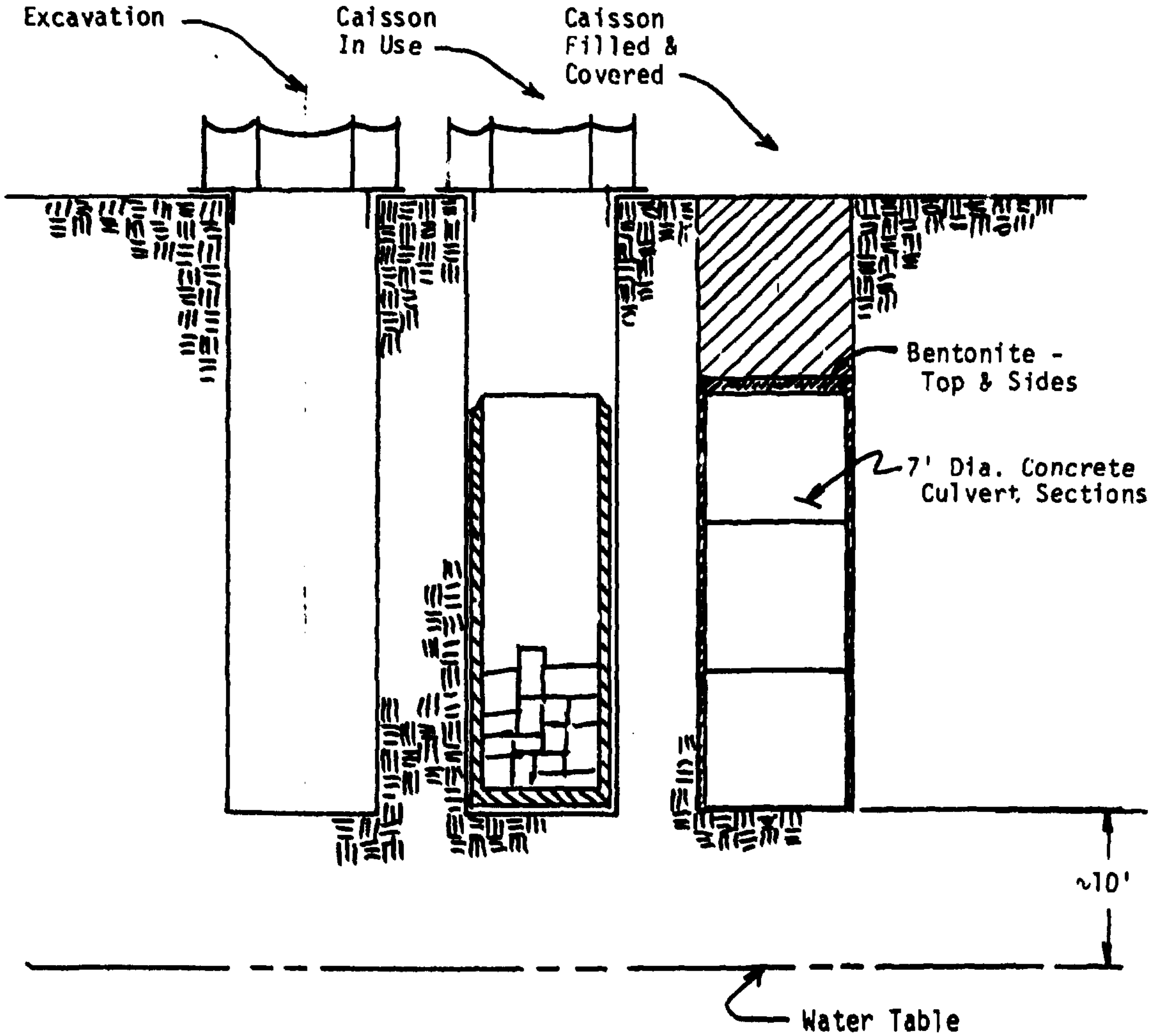


Figure 4. Caisson Burial



GREATER CONFINEMENT DISPOSAL FACILITY: INTRODUCTION

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I would like to briefly describe the Greater Confinement Disposal Facility (GCDF).

In Area 5 of the Nevada Test Site (NTS), a 12 ft. diameter shaft will be bored to a depth of 150 ft. The lower 40 ft. of the shaft will be repacked with alluvium containing packaged tracers, such as tritium or deuterium, which will be released at a later time as an experiment.

As funding permits, we will bore some monitoring holes, placed radially from the emplacement shaft. This will continue until there are 16 monitoring holes exterior to the emplacement shaft. The objective of this construction is twofold. First, to demonstrate the effective geologic containment of low-level waste unsuitable for shallow land burial (SLB), and second, to develop cost effective procedures for handling and disposing of low-level wastes which are unsuitable for SLB.

THE CRITERIA AND TECHNICAL CONCEPT FOR DEMONSTRATING GREATER CONFINEMENT DISPOSAL OF RADIOACTIVE WASTES AT ARID WESTERN SITES

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ABSTRACT

This report summarizes the work of two documents; the "Criteria for Greater Confinement of Radioactive Wastes at Arid Western Sites," NVO-234, March 1981, (within this report, referred to as the "GCDF Criteria Document"); and the "Draft Technical Concept for a Test of Greater Confinement Disposal of Radioactive Waste in Unsaturated Media at the Nevada Test Site," FBDU-343-004, June 1981, (referred within this report as the "Technical Concept for the GCDF").

For the past two years, Ford, Bacon & Davis has been performing technical services for the Department of Energy at the Nevada Test Site in development of defense low-level waste management concepts, including the greater confinement disposal concept with particular application to arid sites.

The investigations have included the development of Criteria for Greater Confinement Disposal, NVO-234, which we published in May of this year; then the draft for the technical concept for greater confinement disposal, published in June; leading up to the point where we are now. The final technical concept and design specifications should be published imminently. The document is prerequisite to the actual construction and implementation of the demonstration facility this fiscal year.

CRITERIA FOR GREATER CONFINEMENT DISPOSAL

As part of FB&DU's first assignment to develop the document which came to be called "Criteria for Greater Confinement Disposal of Radioactive Wastes at Arid Western Sites," or NVO-234, we identified a number of tasks (shown in the following Figure 1). Many of you will remember that we first referred to greater confinement disposal (GCD) as intermediate depth burial (IDB). IDB was eventually replaced after some discussions at last January's San Diego meeting by what was felt by some of us to be a more general yet more descriptive expression of the concept. However, despite the name change, the task remained as part of the development

FIGURE 1

CRITERIA FOR GREATER CONFINEMENT DISPOSAL

- WHY GREATER CONFINEMENT (INTERMEDIATE DEPTH) DISPOSAL?
- GOALS AND OBJECTIVES OF GCD
- ADVANTAGES AND DISADVANTAGES OF GCD VS. SLB
- FACTORS PERTINENT TO SITE SELECTION, FACILITY DESIGN, AND PERFORMANCE
- CRITERIA AND STANDARDS FOR GCD
- DETERMINATION OF WASTES CONCENTRATION ACCEPTANCE STANDARDS (AREA CONCENTRATION LIMITS OR ACLs)
- DETERMINATION OF OPTIONAL DISPOSAL DEPTH
- APPLICATION OF ACLs TO ARID VS. HUMID SITES.

of criteria, to answer the questions: "Why intermediate depth (that is, greater confinement) burial?" and "What are the criteria for disposal at intermediate (or greater confinement) depths?" Well, what is the answer to the question, "Why greater confinement disposal"? The GCDF Criteria Document, as NVO-234 has come to be called, accomplished several objectives.

- It answered the question, "Why Greater Confinement Disposal?"
- It addressed the objective or goals of burial of wastes at intermediate depths to provide greater confinement and described the advantages and disadvantages of GCD compared to shallow land burial.
- It described the concept of a greater confinement disposal facility (GCDF), and discussed and evaluated the various interrelating factors which must be considered in the development of GCDF design and performance criteria, and developed a method for evaluating the importance of these factors.
- It also discussed the criteria and standards for GCD relative to seven major areas:
  - Radiation exposure protection
  - Characterization of waste
  - Transportation and handling
  - Site selection
  - Engineering
  - General facility requirements
  - Administration
- Finally it provided the methodology and analysis to determine the various site-specific waste concentration acceptance standards (in the form of Area Concentration Limits or ACLs) and the optimal or preferred depth of disposal under expected arid site conditions and alternative wet (or irrigated) site conditions.
- An example analysis was also provided for applying the waste area concentration limits at an arid or humid site to determine the allowable waste inventory capacity of a particular site and the loading capacity of a waste disposal cell.

For perspective, let's first answer the question, "Why Greater Confinement Disposal?" (Figure 2)

FIGURE 2

WHY GREATER CONFINEMENT DISPOSAL?

- SHALLOW LAND BURIAL PRACTICES INADEQUATE FOR SOME TYPES OF LLW
- SAFETY "IN DEPTH"
- ALTERNATIVE TO DEEP GEOLOGIC DISPOSAL FOR CERTAIN WASTE TYPES - E.G., TRU, HSA WASTE
- REDUCED COSTS FOR HIGH-SPECIFIC-ACTIVITY LLW WASTE DISPOSAL

As a result of past Federal government operations, nearly 70 million cubic feet of low-level radioactive waste have been accumulated at burial and storage facilities around the country. By the turn of the century, this accumulated volume is expected to exceed over 113 million cubic feet of government-generated waste. At the same time, the generation of low-level waste by commercial sources (fuel cycle, institutional and industrial waste) is increasing at a rate which exceeds the rate of low-level waste generation by the Federal government. The Oak Ridge National Laboratory has estimated that by the year 2000, accumulated low-level waste volume from all sources will exceed over 283 million cubic feet. This volume does not include the high-level, transuranic, and/or the remedial action radioactive wastes which have been and will continue to be generated during the same period.

Radioactivity associated with much of this waste, particularly defense type low-level waste, is made up of mixed fission products, activation products, tritium, and traces of some longer lived transuranic elements. In the past, this waste has been normally stored or disposed of using the shallow land burial concept. However, high-specific-activity wastes and long-lived low-level waste are not suitable for shallow land burial due respectively to their high radioactivity and persistence. Deep geologic repositories, in the past, have been viewed as the most feasible disposal method for these types of waste. However, in the light of the large volume of high-specific-activity low-level waste being generated in the near future, a safe alternative to shallow land burial and an economic alternative to deep geologic disposal is clearly needed. (The concept of GCD is shown in Figure 3.)

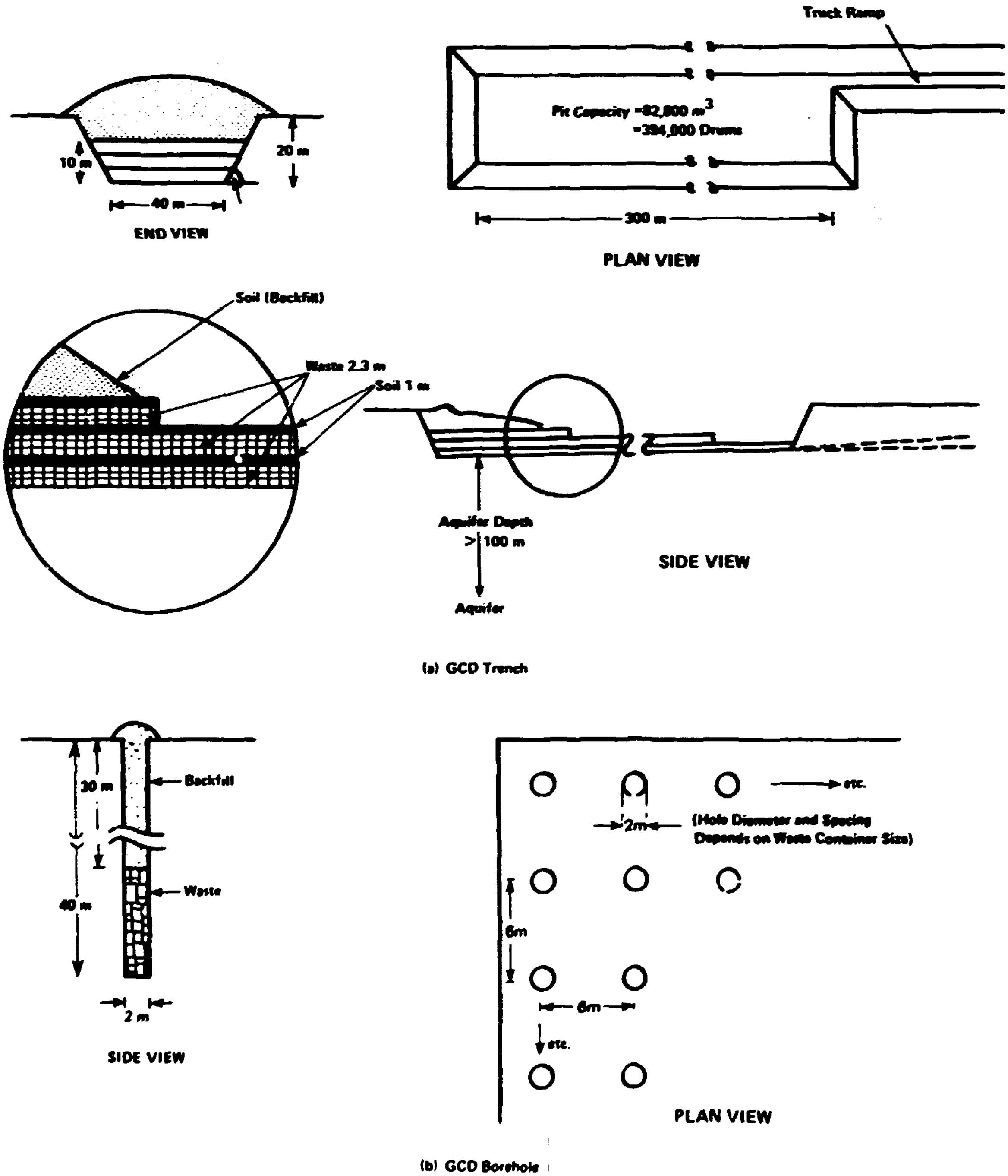
Greater confinement disposal (Figure 4) has been defined by the National LLW Program as the disposal of low-level waste in such a manner as to provide greater containment of radiation, reduce potential for migration or dispersion or radionuclides, and provide greater protection from inadvertent human and biological intrusions in order to protect the public health and safety.

In its application at the NTS, greater confinement disposal (GCD) is seen as an alternative to both shallow land burial and deep geologic disposal (for some types of waste) in providing an economic means of adequately confining (not isolating) and retarding high-specific-activity low-level wastes and transuranics for sufficiently long periods in the geologic media to allow decay to reduce the consequence of release of radioactivity to non-hazardous levels.

The concept of GCD is perceived to have at least three goals or objectives (Figure 5):

(1) The radiological or environmental impacts of GCD shall not exceed the consequences for shallow land burial and shall fall within the guidelines of the current regulations including 10CFR20 and 10CFR61.

(2) The commitment of resources to future generations for continued site maintenance or dedicated site boundaries should be minimized.



SOURCE: REFERENCE 1.3

FIGURE 3. GREATER CONFINEMENT DISPOSAL WITH POSSIBLE DIMENSIONS

FIGURE 4

GREATER CONFINEMENT DISPOSAL

NATIONAL PROGRAM DEFINITION

THE DISPOSAL OF LLW IN SUCH A MANNER AS TO PROVIDE GREATER CONTAINMENT OF RADIATION, REDUCE POTENTIAL FOR MIGRATION/DISPERSION OF RADIONUCLIDES, AND PROVIDE GREATER PROTECTION FOR INADVERTENT HUMAN AND BIOLOGICAL INTRUSIONS IN ORDER TO PROTECT THE PUBLIC HEALTH AND SAFETY.

FIGURE 5

GOALS FOR GREATER CONFINEMENT DISPOSAL

- THE IMPACTS OF GCD SHALL NOT EXCEED THE CONSEQUENCES ANTICIPATED FOR SLB

- MINIMAL RESOURCE COMMITMENT FOR FUTURE GENERATIONS FOR FACILITY MAINTENANCE

- INCREASED RESOURCE COMMITMENT MUST BE JUSTIFIED BY REDUCTION IN IMPACTS, (I.E., LOWER $-REM/CURIE)

(3) The increase in costs of a GCD facility should be justified by a reduction in impacts as measured by a unit FB&DU calls the CDQ ($-rem/Ci) defined as the product of the facility cost, the maximum individual dose impact (after release of institutional control), and the inverse of the inventory disposed.

A recent cost comparison (Figure 6) between SLB and GCD for a postulated low-level waste facility in the State of Utah resulted in a CDQ of 1.73 for SLB and a CDQ of 0.31 for GCD, a reduction of nearly a factor of six.

GCD has several technical advantages (Figure 7), primarily related to the reduction of exposure pathways, e.g., surface phenomena effects, such as erosion, which reduce the material cover over the waste burial location. These effects and other pathways of exposure reduced by GCD include those due to nuclide migration, dispersion, vapor transport to the surface and the effect of plant root penetration and animal burrowing into the waste.

One of the chief advantages of locating a greater confinement disposal facility at an arid site, such as the Nevada Test Site, is the fact that the area is characterized by low precipitation, high evapotranspiration and the presence of leechate or hardpan just below the surface which serves as an aquitard. Such characteristics combine to limit the infiltration of moisture into the unsaturated zone to a depth of but a few meters. As a result, the migration of contaminants out of the site by moisture movement is expected to be negligible.

Perhaps one of the most important pathways which affects shallow land burial is that of human intrusion. Intrusion into a waste site by a human being can take the form of constructing a home on the site, tilling or farming the area, drilling a well through the site or looking for artifacts of value. Greater confinement disposal does not assume to eliminate the human intrusion scenario, but by providing for disposal of waste at greater depths (for example in the range of 30 to 50 meters below the surface, i.e., 150 feet down, the idea is to reduce or minimize the probability of such intrusion as much as practicable.

Burial of waste at greater depths as in the GCDF may also allow the land surface eventually to be released for unrestricted public use much sooner after waste disposal activities cease than can be done with a shallow land burial site. At NTS, of course, the weapons testing program would likely impose restrictions on future land use regardless and independent of waste management activities. The two major disadvantages of GCD, when compared to shallow land burial, are the potentially higher cost (although recent studies by Ford, Bacon & Davis indicate that the cost difference is rather minor, dependent upon geology), and the fact that the waste is located closer to a water table. This latter consideration is why it was necessary as part of the development of criteria for GCD to develop the concept of optimal burial depth (compared in the following Figure 8 for arid and humid sites). (At the Nevada Test Site, of course, this second disadvantage is considered negligible since the aquifer is over 200 meters below the surface. As a result, the difference between the

FIGURE 6

COST COMPARISON (SLB VS. GCD) FOR LLW

$$\text{CDQ} = \frac{(\$\ \text{Cost of Facility})\ \text{X}\ (\text{Max Individual Dose - Rem})}{(\text{Inventory of Waste Disposed - Curies})}$$

CDQ (SLB) = 1.73 $ REM/CURIE

CDQ (GCD) = 0.31 $ REM/CURIE

FIGURE 7

ADVANTAGES OF GCD

- EXPOSURE PATHWAYS REDUCED BY GCD
- EROSION AND SURFACE EFFECTS
- NUCLIDE MIGRATION DISPERSION AND VAPOR TRANSPORT TO SURFACE
- BIOINTRUSION
- HUMAN INTRUSION

DISADVANTAGES OF GCD

- MAY INCREASE NUCLIDE MIGRATION VIA GROUNDWATER TO AQUIFER
- MORE COSTLY THAN CONVENTIONAL SHALLOW LAND BURIAL

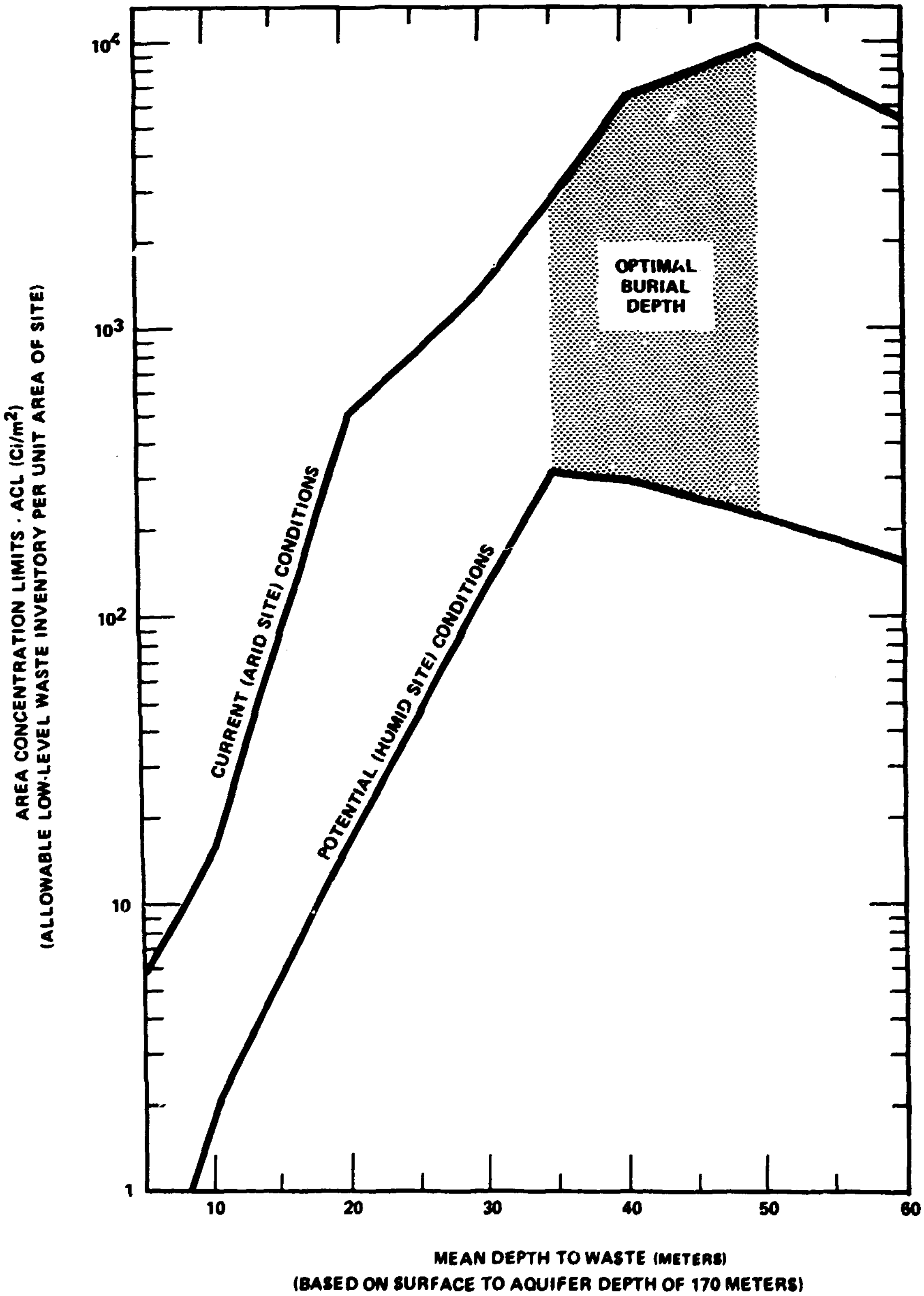


FIGURE 8. ALLOWABLE AREA CONCENTRATION LIMITS FOR DISPOSED LOW-LEVEL WASTE AS FUNCTION OF BURIAL DEPTH

FBDU 417-001

effect of migration from the GCDF to the aquifer, versus that from a shallow land burial facility is not considered of any consequence. This consideration may, however, be important for humid sites or at other sites where a more permeable geology exists in the form of lava tubes, fracture zones, etc.

The resulting reduction in exposure pathways results in a significant increase in the allowable area disposal concentration limits (or ACLs) for most nuclides in a GCDF (Figure 9). The area concentration limits are so called because they represent the amount or inventory (in curies) of waste (represented by the nuclide of concern) per unit area of site (in square meters) dedicated to waste disposal (Figure 10).

Greater confinement disposal has perhaps been most commonly associated with intermediate depth burial as shown in Figure 3.

Other concepts for waste management that may be considered within the definition of greater confinement disposal (Figure 11) include improved shallow land burial (thicker cover and engineered barriers, application of wicking concepts, etc.), and other deeper burial concepts including mining a cavity or tunnel in the side of a mountain or canyon, deep well injection beneath the aquifer, and disposal in hydrofractured strata. The selection or application of any one or more of these concepts would depend, of course, upon the particular waste being considered for disposal and the existing conditions at the site.

What little time there is left, I would like to spend discussing the demonstration test for the GCD borehole concept which was selected for the Nevada Test Site.

GCD BOREHOLE DEMONSTRATION TEST

The objectives of the GCDF demonstration test (Figure 12) are to:

o Evaluate the adequacy of geologic containment of waste at intermediate depths

o Define equipment and procedures required for GCDF operations

o Establish the cost of constructing and operating a GCDF

To accomplish the first objective, three principal experiments have been defined (Figure 13):

o To measure moisture movement, to evaluate and verify models

o To quantify the thermal response of the geologic medium to the buried heat-generating waste (probably strontium-90 and cesium-137)

o To identify and quanity if possible nuclide migration, most particularly tritium

FIGURE 9

AREA CONCENTRATION DISPOSAL LIMITS, ACLs (Ci/m^2) FOR NON-NEAR SURFACE OR GREATER CONFINEMENT DISPOSAL FACILITIES[a,b]
(Reference 4)

	Humid Site[c] Greater Confinement (Limiting Case)	Arid Site[d] Greater Confinement (Expected Case)	Comparison Shallow Land Burial[e]
H-3	940	6,500,000	40
C-14	2.3	3.8	.8
Ni-59	3.7	240	2.2
Ni-63	220	24,000	3.5
Co-60	(f)	(f)	700
Sr-90	36	5100	.04
Tc-99	1.1	1.1	.3
I-129	0.0011	0.05	.008(g)
Cs-135	16	690	84
Cs-137	12,000	13,000	1.0
Ra-226	0.011	6.3	(h)
Th-230	0.0099	0.38	(h)
U-234	14	310	(h)
U-235	0.4	9.3	0.04
U-238	(f)	(f)	0.05
Np-237	0.13	19	(i)
Pu-238	23,000	54,000	(i)
Pu-239	5.5	210	(i)
Pu-240	11	420	(i)
Pu-241	68,000	2,100,000	(i)
Pu-242	4.5	170	(i)
Am-241	2400	7,600	(i)
Am-243	1.4	51	(i)
Cm-242	2,100,000	(f)	(i)
Cm-244	2400	150,000	(i)
Unidentified LLW	330	2,900	---

(a) Minimum Area Disposal Concentration Limits for non-near surface disposal represent the inventory of nuclides in waste (in curies) which can be safely disposed per unit area (in square meters) rather than per unit volume of dedicated site at a mean depth of 35 meters. The limits assume 100 yr container integrity, and are based on Pathway Analysis developed in Appendix A of Reference 4.

(b) Application of ACLs for specific waste forms, is discussed in Appendix M of this document.

(c) Assumes a vertical groundwater velocity of 5m/yr and dispersion of 100 m^2/yr.

(d) Assumes a zero vertical groundwater velocity and dispersion of 0.1 m^2/yr.

(e) Minimum near-surface disposal concentration limits per unit site area are from Reference 10 (column 1), assuming a 1 m waste thickness.

(f) The calculated allowable area concentration limit, ACL, exceeds the specific radioactivity of the nuclide.

(g) Near-surface isotopes concentration limits exceed or may be incompatible with those calculated for greater confinement disposal.

(h) Isotope concentration limit is not listed in Reference 10.

(i) Isotope concentrations are limited to 10 nanocuries/gram under current guidelines (i.e. <0.02 Ci/m^2).

FIGURE 10

CRITERIA FOR GCD DISPOSAL SITE VERIFICATION OF WASTE ACCEPTABILITY

$$F_S = F_0 + \frac{1}{A_S} \sum_{1}^{N} \frac{Q_I}{ACL_I}$$

WHERE $F_S \leq 1$

I = SUMMATION INDEX FOR EACH NUCLIDE

F_S = WASTE LOADING FRACTION FOR SITE

F_0 = EXISTING LOADING FRACTION FOR PREVIOUSLY BURIED WASTE

Q_I = NUCLIDE INVENTORY OF SUBJECT WASTE (CURIES)

ACL_I = AREA DISPOSAL CONCENTRATION LIMIT (CURIES/M^2)

A_S = DEDICATED SURFACE AREA FOR DISPOSAL (M^2)

N = NUMBER OF NUCLIDES CONSIDERED

FIGURE 11

GCD LAND DISPOSAL ALTERNATIVES

	SITE CONDITION	
	ARID	HUMID
• IMPROVED SHALLOW LAND BURIAL (THICKER COVER, ENGINEERED BARRIERS)		X
• INTERMEDIATE DEPTH BURIAL PIT (MUCH THICKER COVER, ARID SITE DISPOSAL)	X	
• GCD BOREHOLE	X	
• MINED CAVITY (ADIT)	X	X
• DEEP WELL INJECTION (BENEATH AQUIFER)	X	X
• DISPOSAL IN HYDROFRACTURED STRATA	X	X

FIGURE 12

OBJECTIVES OF GCD DEMONSTRATION TEST

- TO EVALUATE ADEQUACY OF GEOLOGIC CONTAINMENT OF WASTE AT INTERMEDIATE DEPTHS
- TO DEFINE PROCEDURES AND EQUIPMENT REQUIRED FOR GCDF OPERATIONS
- TO ESTABLISH COSTS OF CONSTRUCTING AND OPERATING GCDF

FIGURE 13

GCDF EXPERIMENTS

- MEASURE MOISTURE MOVEMENT TO EVALUATE AND VERIFY MODELS
- QUANTIFY THERMAL RESPONSE OF GEOLOGIC MEDIUM
- IDENTIFY AND QUANTIFY POSSIBLE NUCLIDE MIGRATION

It should be noted that the waste to be buried in the GCDF will be encapsulated in high integrity containers with expected lifetimes well beyond the five-year duration of the monitoring efforts for the demonstration test. As a result, radionuclide migration from the facility from the actual waste canisters, is expected to be insignificant. Monitoring efforts will thus be concentrated on obtaining moisture movement and temperature response data, and to some degree, nuclide migration data from tracers. The data will be used as input to appropriate models to predict long-term performance.

The following figure (Figure 14) shows the relative location of the selected instruments and their purpose in the experiment. The instruments for measuring moisture movement include a deuterium or tritium tracer, which will be triggered after the waste is emplaced. Soil atmosphere samplers will be used to collect the sample and determine the rate of moisture movement by measuring the ratio of deuterium tracer to the normal water vapor in the sample. Other moisture data will be obtained using thermocouple psychrometers to measure moisture potential, and the neutron scatter probe, which is a portable device to be lowered down an open casing to measure moisture content. The thermal response of the soil media will be measured using thermocouples and/or the thermocouple psychrometers that are permanently emplaced around the borehole. The same thermocouple psychrometers, used for measuring moisture potential, can be used for measuring temperature in the lower temperature ranges at greater distances from the hole.

The occurrence of nuclide migration will be monitored using gamma scintillation probes (Figure 15) that are permanently emplaced around the borehole, which primarily will observe the gamma profile of the waste itself. Also a germanium diode crystal, which again is a portable device, can be lowered down the open casing on an infrequent basis, and take gamma logs which may help identify the existence of possible radionuclide migration. The following figure (Figure 16) shows a plan view of the borehole and the orientation of the instrumentation system. One of the engineering difficulties with instrumenting the borehole is the fact that it is very difficult to drill a small diameter hole through the alluvium without encountering boulders which may deflect the drill shaft, thus causing nonvertical alignment to the borehole.

With regard to emplacement of the instruments, it is currently proposed in the final draft of the GCDF Technical Concept to tie the instrument packages to a steel cable to be lowered beside the borehole or into a temporary casing as appropriate, and then backfilled while pulling up the casing in order to have the instruments in direct contact with the backfilled material. It is expected that the backfilled material will be designed and its density controlled in such a way as to simulate as nearly as possible the natural soil media.

In addition to the instrumentation system surrounding the borehole, a number of laboratory support experiments are recommended (Figure 17) to provide additional support and interpretation of the field data, as well as provide information that can be useful along with field data in

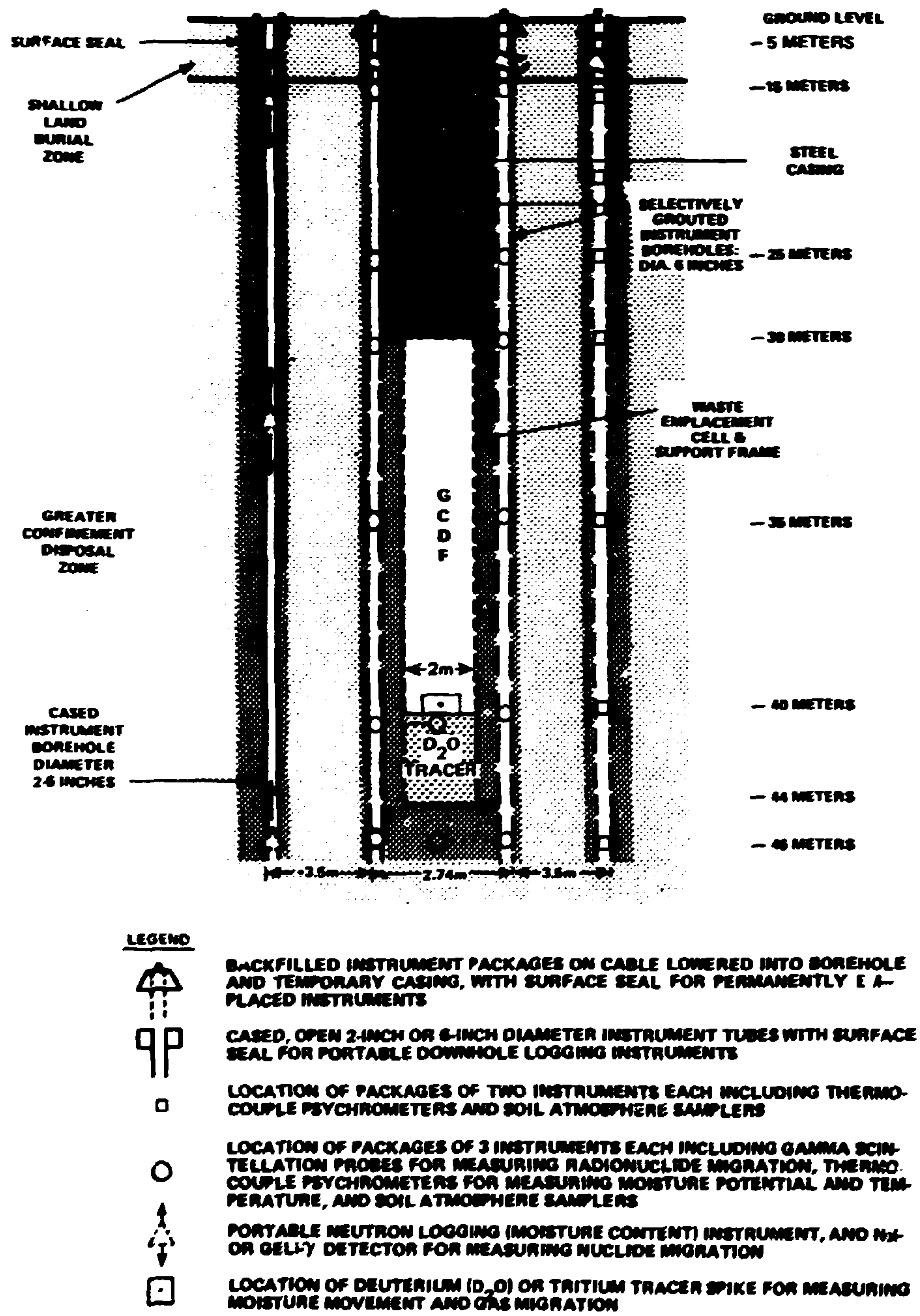


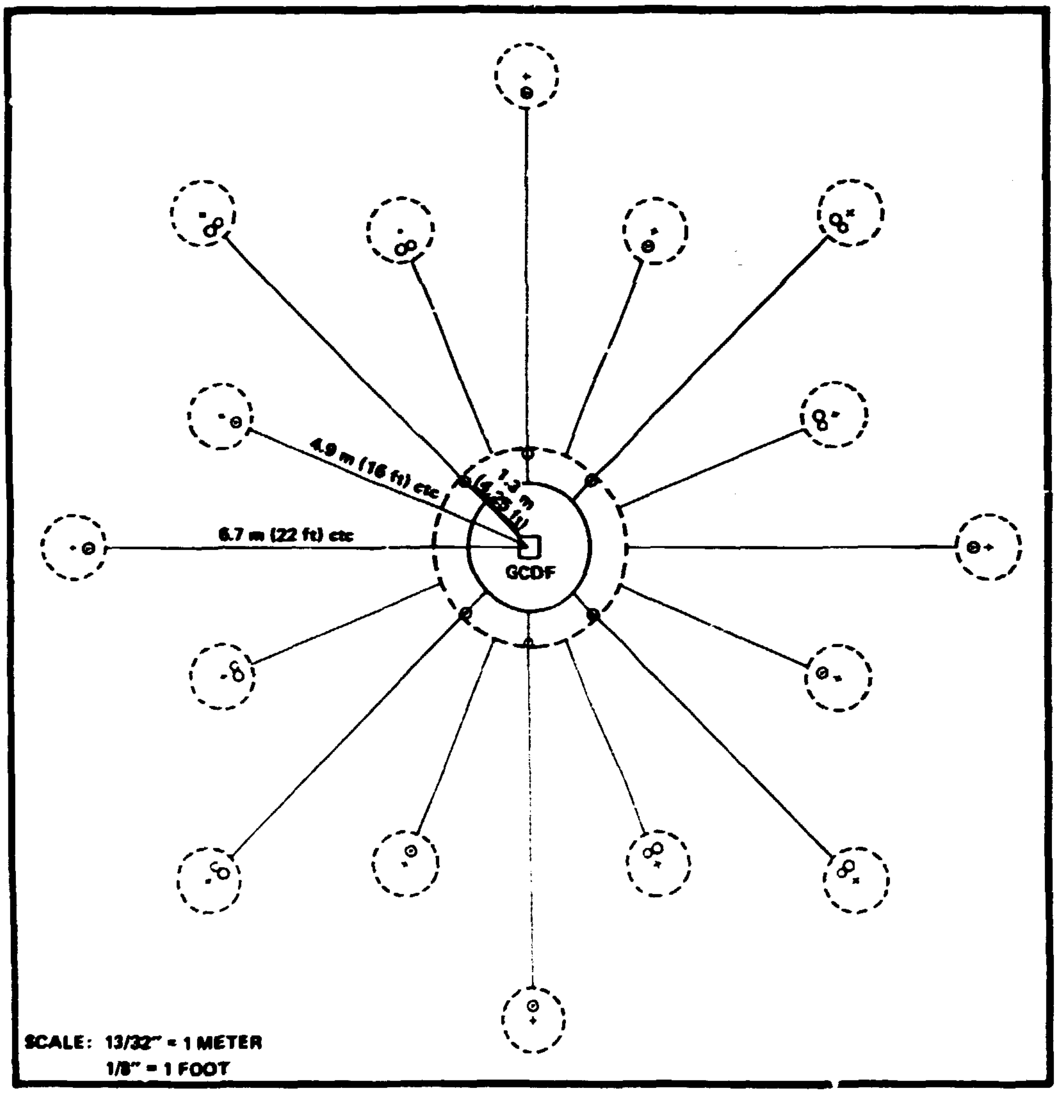
FIGURE 14. ELEVATION VIEW OF INSTRUMENTATION SYSTEM FOR MONITORING GREATER CONFINEMENT DISPOSAL FACILITY
(Not to Scale)

FBDU 343-004

FIGURE 15

GCDF INSTRUMENTS

INSTRUMENT	MEASUREMENT
MOISTURE MOVEMENT:	
TRACER (DEUTERIUM OR TRITIUM) WITH SOIL ATMOSPHERE SAMPLERS	MOISTURE MOVEMENT
THERMOCOUPLE PSYCHROMETERS	MOISTURE POTENTIAL
NEUTRON SCATTER PROBE	MOISTURE CONTENT
THERMAL:	
THERMOCOUPLES (OR THERMOCOUPLE PSYCHROMETER)	TEMPERATURE RESPONSE
NUCLIDE MIGRATION:	
GAMMA SCINTILLATION PROBE	GAMMA PROFILE
GERMANIUM DIODE	RADIONUCLIDE MIGRATION



LEGEND:

GCDF — GREATER CONFINEMENT DISPOSAL FACILITY 2 m (6 ft) DIAMETER BOREHOLE

⊙ — SLOTTED, BACKFILLED AND SEALED 6 INCH DIAMETER INSTRUMENT HOLES WITH POROUS GAS SAMPLERS, THERMOCOUPLE PSYCHROMETERS, AND α AND β NUCLIDE DETECTORS

O — UNSLOTTED 6 INCH DIAMETER "OPEN" ALUMINUM CASINGS FOR PORTABLE GAMMA AND CALORIMETRIC MEASUREMENT

o — UNSLOTTED 2 INCH DIAMETER "OPEN" ALUMINUM CASINGS FOR PORTABLE NEUTRON SOUNDING

(+) — LARGER BACKFILLED 36 INCH DIAMETER INSTRUMENT RECEIVING BOREHOLE

□ — DEUTERIUM D_2O TRACER (LOCATED 4m UNDER GCDF WASTE CELL)

ctc — CENTER TO CENTER SPACING BETWEEN GCDF AND INSTRUMENT HOLE

FIGURE 16. PLAN VIEW OF GCDF BOREHOLE AND INSTRUMENTATION SYSTEM FOR MONITORING GREATER CONFINEMENT DISPOSAL.

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FIGURE 17

LABORATORY SUPPORT EXPERIMENTS

- SOIL MECHANICAL PROPERTY DETERMINATION
- CHARACTERISTIC CURVES
- SOIL CHEMICAL PROPERTIES
- SOLUTE TRANSPORT PROPERTIES
- THERMAL PROPERTIES
- MOISTURE PROBE CALIBRATION
- RADIATION ATTENUATION
- THERMOCOUPLE PSYCHROMETER OPERATION
- TRACER CAPSULE OPERATION
- EFFECT OF SOIL ATMOSPHERE SAMPLER

verifying the performance of the predictive models. While there are many factors (Figure 18), which in some way or another, are being looked at as part of the demonstration test, there are two principal factors which stand out in terms of evaluation of facility performance and for providing figures of merit. These are the thermal response of the facility, and the rate of moisture movement through the soil media. The two parameters are assumed to be coupled. At this time, we have not developed a final judgment as to what the actual figure of merit parameters or values will be. However, we have developed some concepts which we will look at to obtain data to develop that figure of merit. For the thermal response, we have performed an analysis which has given us an expected temperature configuration around the waste cell as shown in the following figure (Figure 19). The monitoring experiment, of course, will make measurements to refine and verify our theoretical calculations.

A possible figure of merit may be that of determining what temperature variance above ambient is acceptable so as not to produce a major effect in the rate of nuclide migration, or in reality in this experiment, the tracer. As shown on the figure, that may be as little as one degree temperature variance or it may be as high as a ten degree temperature variance or greater. We do not yet know that.

With respect to the hydrological figure of merit, most of the data obtained by this experiment will be in the form of moisture data which, through the application of Darcey's law shown in Figure 20, can be used to obtain moisture velocity or solute velocity through the soil. The moisture velocity would be measured directly by the deuterium or tritium tracer experiment with the soil atmosphere samplers. Moisture velocity can also be calculated using data provided by the thermocouple psychrometers and the neutron moisture probe. A possible figure of merit for satisfactory performance of the facility may be to demonstrate that the measured velocity (in meters per year) is much less than what might be defined as the limiting carrier velocity. The carrier velocity is that velocity which is equal to the depth of the facility divided by the number of years equivalent to ten half lives of the nuclide in question such as tritium. The number of half lives represents the amount of time necessary to reduce the initial inventory by a factor of a thousand. This number, of course, is arbitrary and we do not yet know just what value is sufficient to verify the performance of the site. That will be developed by analysis as the monitoring data is obtained. That, in any case, shows the value of the demonstration test and experiment to provide data feedback in the process of validation or verification of the assessment models which were used to develop, as an example, the area disposal concentration limits, defined in the GCDF Criteria Document. As the data is obtained, a national program task should be developed calling for the application of this data, and for the refinement of the GCD criteria.

FIGURE 18

FACTORS AFFECTING GCDF PERFORMANCE

- GEOLOGIC MEDIUM
  - THERMAL
  - MECHANICAL
  - HYDROLOGIC
  - CONTAMINANT TRANSPORT
  - STRUCTURAL
  - HOMOGENEITY

- FACILITY DESIGN
  - EMPLACEMENT DEPTH
  - WASTE VOLUME
  - DEDICATED LAND SURFACE
  - BACKFILL MATERIALS/OPERATION
  - WASTE CANISTER
  - MONITORING SYSTEM

- FACILITY OPERATION
  - OPERATIONS SEQUENCE
  - WASTE EMPLACEMENT METHOD
  - WASTE HANDLING/TRANSFER METHOD
  - SITE MAINTENANCE
  - DECOMMISSIONING

- WASTE FACTORS
  - LEACHABILITY
  - RADIONUCLIDE MOBILITY
  - RADIOACTIVITY INVENTORY
  - THERMAL CHARACTERISTICS
  - PACKAGING
  - HANDLING

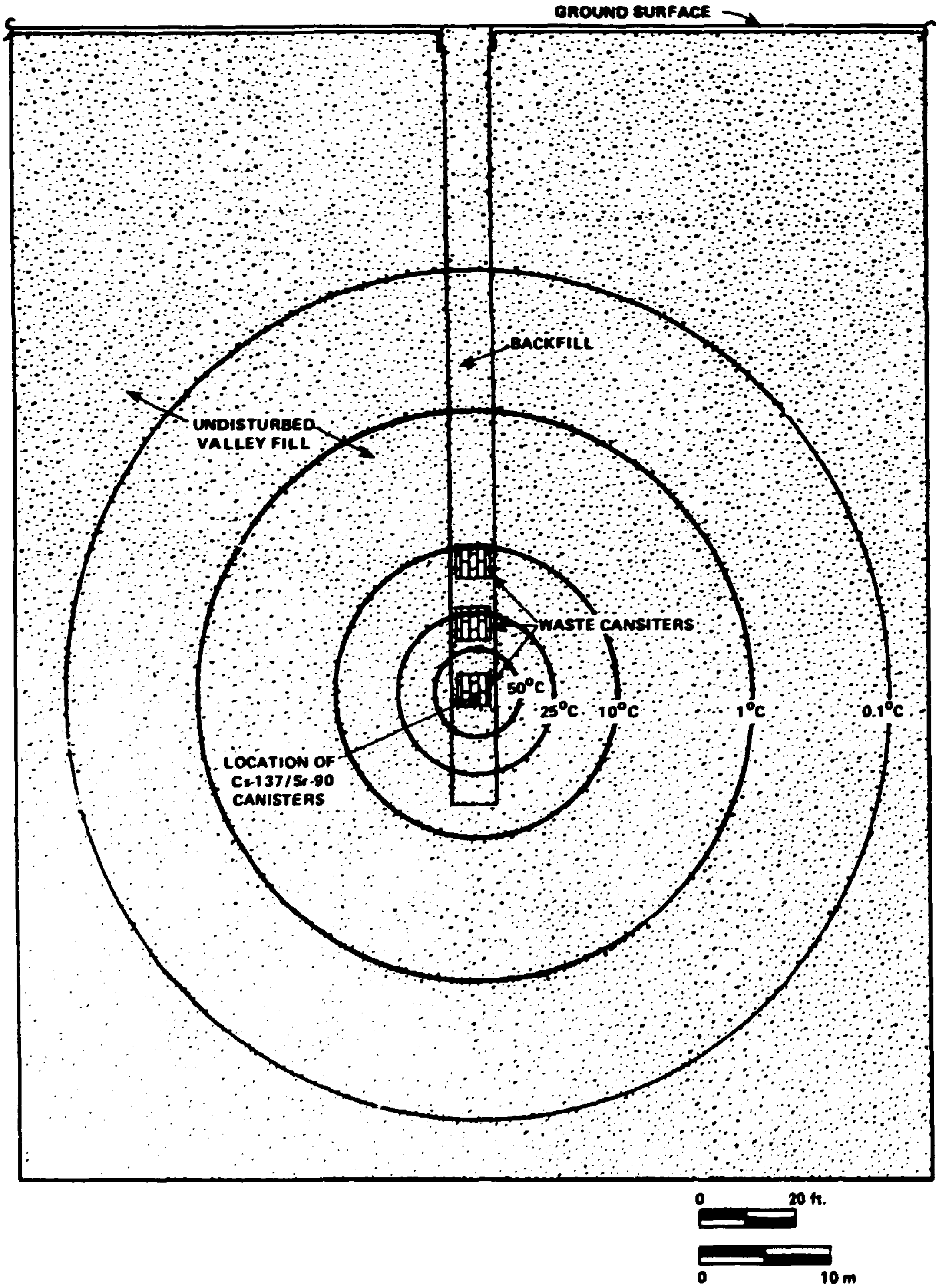

FIGURE 19. GCDF SECTION SHOWING PREDICTED INCREASED TEMPERATURE ABOVE AMBIENT CONDITIONS DUE TO Cs-137 AND Sr-90 DISPOSAL

FIGURE 20

MOISTURE MOVEMENT MEASURED AS DARCY VELOCITY

$$V_X = \frac{-Kx(\theta)}{\theta}\frac{DH}{DX} = \frac{-K(\Psi)}{\theta}\frac{DH}{DX}$$

WHERE

V_X = THE SOIL-WATER DARCY MOISTURE VELOCITY (L/T)

K_X = HYDRAULIC CONDUCTIVITY (L/T)

θ = VOLUMETRIC MOISTURE CONTENT (L^3/L^3)

Ψ = MATRIC POTENTIAL (F/L^2 OR L)

$\frac{DH}{DX}$ = ENERGY GRADIENT AS F (DEPTH, Ψ, TEMPERATURE)

HYDROLOGIC FIGURE OF MERIT

$$V_X \leq V_C$$

WHERE

$$V_C = \frac{D}{10\ (T_{1/2})}$$

AND V_C = LIMITING NUCLIDE CARRIER (MOISTURE) VELOCITY

D = PATHWAY DISTANCE (DEPTH) OF WASTE TO BIOSPHERE

$T_{1/2}$ = HALF LIFE OF DOMINANT NUCLIDE

GREATER CONFINEMENT DISPOSAL FACILITY
PROPOSED DRILLING PROGRAM

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ABSTRACT

Emplacement hole - 132-inch diameter x 6-feet corrugated metal pipe shall be set at 3 feet in a 140-inch diameter hole excavated to 3 feet and the annulus cemented to the surface.

Instrument holes - 34-inch diameter x 5-feet corrugated metal pipe shall be set at 5 feet in sixteen 36-inch diameter holes auger drilled to 5 feet and the annulus cemented to the surface.

A 76-foot diameter concrete drill pad shall be poured. A 120-inch hole shall be auger drilled to 155 feet, and 72-inch I.D. casing installed to 100 feet. Peripheral instrument tubes shall be run and landed around the annulus of the 72-inch I.D. casing. The 26-inch instrument holes shall be auger drilled to 150 feet, and 9-5/8 inch O.D. temporary casing shall be installed in each hole. At a later date, instrument tubes will be run inside the 9-5/8 inch O.D. casing, and the casing shall be stripped out over the instrument tubes. The instrument holes are to be stemmed back to the surface with ground-matching material.

SITE PREPARATION

1. Excavate a 76-foot diameter circular area 6 inches deep for the drill pad.
2. Excavate the large diameter hole 3 feet deep and 140 inches in diameter. Run a 6-foot section of 132-inch diameter corrugated metal pipe and cement it in with Ready-Mix cement.
3. With a construction auger, drill sixteen 5-foot deep, 36-inch diameter holes in the appropriate locations. Run and cement 34-inch x 5-foot sections of corrugated metal pipe in each hole.
4. Construct a cement form along the circumference of the excavated area and pour a concrete pad 6 inches deep (around each casing) inside the circular area. The pad shall be 76 feet in diameter.

(Site preparation estimated to take four 8-hour days.)

DRILLING PROGRAM
DRY WELL AND INSTRUMENTATION HOLES

		8 HRS/DAY
1.	Mobilize large auger rig	1
2.	Auger 120-inch hole to 155 feet	7
3.	Run 72-inch I.D. casing to 100 feet. Run instrument tubes.	2
4.	Auger sixteen 26-inch diameter holes to 150 feet. Run 9-5/8 inch O.D. casing in each hole.	30
5.	Demobilize auger rig	1
6.	Miscellaneous operations and delays	4
	Estimated Total Days	45

CRANE DAYS

1.	Mobilize crane, pick up and run 72-inch casing, demobilize crane.	2
2.	Mobilize crane, run 6-inch and 2-inch instrument tubes, retrieve 9-5/8 inch O.D. casing. Demobilize crane.	10
	Estimated Total Days	12

GREATER CONFINEMENT DISPOSAL FACILITY:COST/BENEFIT

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At the present time REECO is trying to determine the resource requirements for developing and operating a full-scale greater confinement disposal facility (GCDF), especially cost estimates. We have estimated the cost of operations for two different facilities (Table 1). One of the facilities would have a capacity for waste of 10,000 ft^3/yr and the other 100,000 ft^3/yr. We found that the burial costs would be about \$61/ft^3 and about \$25/ft^3 for the 10,000 ft^3/yr facility and 100,000 ft^3/yr facility, respectively. These values were based on the assumption that the GCDF is a part-time facility associated with a shallow land burial (SLB) facility.

We have also looked at risk analyses to study the long term risks from a GCDF as opposed to a SLB facility (Table 2). We found that the NTS is a very good area to bury waste and that there is not a great difference between greater confinement and SLB in terms of safety for almost any environmental scenario (Table 3). However, we did find that there was one big advantage in greater confinement in that the intruder scenario resulted in a factor of about 10^7 reduction in risks to an intruder.

Table 1. Cost Estimate for a Ten-Year Operational Greater Confinement Disposal Facility

Item	10,000 ft^3/year	100,000 ft^3/year
	($K)	($K)
Operating Expenses		
(1) Labor	$285	$475
(2) Drilling and Emplacement	160	1,600
(3) Maintenance	45	175
(4) Monitoring and Surveillance	30	50
	$520K	$2,300K
Cost per ft^3	$52.00	$23.00
Capital/Line Item Funding		
(1) Construction	$300	$500
(2) Equipment	600	1,500
	$900K	$2,000K
Cost per ft^3	$9.00	2.00
OPERATING PLUS CAPITAL TOTAL	$61/$ft^3$	$25/$ft^3$

Table 2. Risk Analysis Summary for a
Greater Confinement Disposal Facility

o <u>SCOPE</u>: Compared long-term (post-closure) risks of GCDF to SLB for scenarios involveing: (1) climatic changes, (2) massive influx of water, and (3) human intrusion.

o <u>WASTE SOURCES</u>:

Isotope	Curies Per Hole
H-3	570,00
Cs-137	370,000
Sr-90	41,000
Pu-239	2
U-233	21
Ra-226	82
TOTAL	981,000

o <u>FACILITY PARAMETERS</u>: Both SLB and GCD facilities contain same volume and concentrations of wastes. SLBF trench is 30-foot deep with a 3-foot cap. GCDF is 150-foot deep with 75-foot backfilled cap.

o <u>CONCLUSIONS</u>:

(1) Disposal of radioactive wastes at NTS either by GCD or SLB has minimal risk

(2) There are no significant differences between GCD and SLB risks for hypothetical environmental changes

(3) There is a significant reduction in risk for GCD over SLB for intrusion scenarios

(4) Of the isotopes considered, only H-3 had any significant contribution to dose

Table 3. Summary of Results of Risk Analysis for a Greater Confinement Disposal Facility (GCDF) and Shallow Land Burial (SLB)

Scenario	Maximum Individual Dose (Rem/Year)	Population Dose (Man-Rem/Year)	Maximum Individual Dose (Rem/Year)	Population Dose (Man-Rem/Year)
BASE CASE	3×10^{-5}	3×10^{-10}	2×10^{-3}	2×10^{-8}
CLIMATE CHANGE	2×10^{-2}	2×10^{-7}	1	1×10^{-5}
INUNDATION	2×10^{-4}	1×10^{-8}	1×10^{-2}	1×10^{-6}
INTRUDER	2×10^{-11}	2×10^{-16}	2×10^{-5}	4×10^{-9}

TECHNICAL SUPPORT NON-SLB FACILITY

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This task has just been started this fiscal year so consequently there is no past history to report. However, this is not to imply that no data and experience are available. Different groups have been working at both Los Alamos and the National Test Site (NTS) for many years gathering useful data in a number of areas which we plan to use. Also, we have several active experiments at Los Alamos that will provide essential information (see DePoorter, Hakonson, Lane elsewhere in these proceedings).

At the present time, the composition of this task is being developed in conjunction with the Greater Confinement Disposal Facility (GCDF), which is the primary non-SLB activity. As the GCDF program is refined, the more specific the activities of this task becomes. In view of this, I would not be surprised if my report at the end of this fiscal year contains some substantial changes from what I am presenting here today.

As a starting point, the goal of the GCDF program needs to be reviewed. It is;

> "To develop the technology and documentation needed to open a site providing greater confinement than shallow-land burial" by March 1986.

I would like to emphasize the work "documentation" because this will be difficult, and it is the area that we plan to emphasize.

To support the GCDF goal, Los Alamos proposes to perform the following subtasks;

1. Data Evaluation Procedures for GCDF Experiment. Los Alamos will assist in the evaluation of the GCDF experimental design to help assure that sufficient data will be collected to allow meaningful comparisons to shallow-land burial simulation experiments currently being conducted at Los Alamos. An assessment of data parameters and needs will be prepared and data analysis procedures documented.
2. Instrument Testing and Calibration. Los Alamos will perform *in situ* testing of proposed sensors, detectors, and other instrumentation under simulated conditions expected in the GCDF. Tests will be conducted in an experimental caisson at Los Alamos and calibration curves/documents will be prepared for the instrument packages. Los Alamos will assist in conducting instrument calibration and testing in a shallow experimental plot at NTS Area 5 to develop data necessary for GCDF and SLB comparisons.
3. Measurement System Design Modifications. Results of the *in situ* testing in subtask 2 will be reviewed to identify potential problem areas in the design of the instrument packages and/or placement of the package. Simulations of the GCDF will be made using data obtained in the instrument testing experiments. Modifications to the measurement system will be identified and simulated.

As indicated in the subtask descriptions above, we plan to establish two field test locations. The first facility will be at NTS where the soil properties will be verified and instrument response will be determined using a pit about 20 feet deep. Local soil and soil obtained from deep drilling will be compared and properties will be defined because we need to know grain size distribtution, density, thermal and hydraulic conductivity, specific heat, etc. for the simulation model.

A second field facility will be constructed at Los Alamos in a caisson 10' x 20'. NTS soil and backfill material will be used along with the GCDF instrument packages in the same geometry as the GCDF to duplicate as close as possible the experiment configuration planned for the GCDF. Since we are dealing with unconsolidated material of varying grain sizes under unsaturated conditions, the interfaces between the different materials (native soil vs backfill) can influnce the flow of heat and moisture. This could cause difficulty in interpreting instrument readings. Also, soil properties, presence of instrument tubes and radiation fields can make neutron moisture probe interpretation difficult. We hope to gain enough insight into instrument response and heat and moisture flow to provide calibration data to the GCDF experiment.

Data from these field experiments and from other Los Alamos experiments will be used to extend the validation of the two-phase, two-dimension unsaturated flow model, which has been developed by the weapons test people at Los Alamos. We expect to be able to demonstrate that the model is valid for near-surface, intermediate depth, and greater depth conditions. With this tool in hand we will then be able to predict the effect of different soil types, heat loads depths and moisture conditions for the GCDF.

The one major data lack is the physical and chemical properties of the waste material that will be buried in the GCDF. Material transport calculations cannot be done properly without this information. I would appreciate hearing from anyone who is working in this area to see if by this time next year we can close this gap.

Supp

INTEGRATED DATA BASE PROGRAM*

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ABSTRACT

The IDB Program provides direct support to the DOE Nuclear Waste Management and Fuel Cycle Programs and their lead sites and support contractors by providing and maintaining a current, integrated data base of spent fuel and radioactive waste inventories and projections. All major waste types (HLW, TRU, and LLW) and sources (government, commercial fuel cycle, and I/I) are included. A major data compilation was issued in September, 1981: *Spent Fuel and Radioactive Waste Inventories and Projections as of December 31, 1980*, DOE/NE-0017. This report includes chapters on Spent Fuel, HLW, TRU Waste, LLW, Remedial Action Waste, Active Uranium Mill Tailings, and Airborne Waste, plus Appendices with more detailed data in selected areas such as isotopics, radioactivity, thermal power, projections, and land usage. The LLW sections include volumes, radioactivity, thermal power, current inventories, projected inventories and characteristics, source terms, land requirements, and a breakdown in terms of government/commercial and defense/fuel cycle/I&I.

INTRODUCTION

The Integrated Data Base (IDB) Program is supported by the Resource Management and Planning Office under the DOE Deputy Assistant Secretary for Nuclear Waste Management and Fuel Cycle Programs. The IDB Program is carried out at ORNL. It provides and maintains current, integrated data on spent fuel and radwaste, including inventories and projections, for these major forms and/or sources:

Reactor Fuel
- o Spent Fuel

Major Waste Forms
- o High-Level Waste
- o TRU Waste
- o Low-Level Waste

*Research sponsored by the Office for Nuclear Waste Management and Fuel Cycle Programs, U.S. Department of Energy, under contract W-7405-eng-26 with Union Carbide Corporation.

Remedial Action Sources
- o Uranium Mill Tailings Remedial Action Program
- o Formerly Utilized Sites Remedial Action Program
- o Surplus Facilities Management Program
- o Grand Junction Remedial Action Program

Other Sources
- o Active Uranium Mill Tailings
- o Airborne Waste
- o Reprocessing Waste
- o D&D of Active Sites (to be added)

The Resource Management and Planning Office also supports two related activities: development of the Federal Plan for Radwaste Management, and Systems Analysis; subcontractors for these two activities are the MITRE Corp. and NUS, respectively.

The IDB is an important component of DOE Waste Management and Fuel Cycle Programs. It is the official DOE data source in its area of coverage. It is used by DOE management for planning and analysis, by field offices and lead sites for overall, integrated data, and by support contractors for generic technical information. It is also used by other agencies, groups, and news media, including:

- Council on Environmental Quality
- Congressional Committees
- State Agencies
- League of Women Voters
- New Yorker and Science Magazines
- UPI articles
- NRC and EPA
- MITRE Corporation
- Kellogg Foundation.

The IDB program includes data collection and evaluation, modeling and projecting, isotopic decay calculations via ORIGEN2, and support activities such as waste management bibliographies and preparation of a radwaste glossary. The major visible results to date have been spent fuel and radwaste inventory and projection reports. The first[1] was issued in 1980 and was expanded and updated in September 1981.[2] The latest version (DOE/NE-0017), distributed under category UC-70:

- o updates inventory data through 1980
- o gives projections to year 2000
- o provides improved data that are
  - integrated
  - reconciled
  - consistent
  - accepted
- o provides more characteristics such as
  - volumes
  - radioactivity
  - thermal power
  - Kg of TPU elements
- o provides references for all primary data.

The last point, referencing of all primary data, is a major improvement over other published inventory compilations. It allows tracing of data back to sources and, therefore, independent verification if required. At present, data transfer is largely manual, by extraction of data from hard-copy printouts. A major objective is to mature into automated data transfer via magnetic tapes. This will allow inventory updating to be done easily, smoothly, and essentially error-free. Once set up and running, it will greatly simplify record transfers between generator sites, lead sites, and IDB. It will also assure a consistent set of data for all of the participants.

APPLICATIONS TO LLW

Integration of LLW data involves many interfaces, including:

- generators/burial grounds/lead site
- site records/SWIMS/State, EPA, NRC records
- direct LLW/secondary LLW/RAP
- Government/commercial (fuel cycle; I/I).

Overall integration of LLW data is, in general, more difficult than data for spent fuel, HLW, or TRU waste because LLW:

- has been around the longest
- is the largest volume
- comes from the most diverse sources
- receives the least controlled handling
- has the least detailed records
- comes from the greatest number of sources.

Integrated Data Base treatment of LLW data covers these areas:

- o Inventories (volume)
  - Burial site
  - State-by-State (to be added)
  - Government, commercial
  - Fuel cycle, I/I (including medical)
- o Characteristics
  - Overall activity
  - Thermal power
  - Isotopics
  - TRU element and HM content
- o Projections
  - Base-case assumptions
  - Alternatives (to be added)
  - To year 2000 (to 2020/2050 in future)

Major data inputs for inventories comes from SWIMS (Solid Waste Information Management System) for DOE burial grounds and from EGG/ID, EPA, NRC, and state agencies for commercial burial grounds. An overall Data Base Management System (DBMS) has not yet been selected, but EGG/ID is testing NOMAD on their own LLW data, and the IDB Program has started an evaluation study of applicable DBMS.

LLW data integration has required reconciliation in a number of areas, including:

- o Data overlap
  - Government vs Commercial
  - Material in transit
- o Incomplete data/estimation basis
  - Front end of the fuel cycle
  - I/I on state-by-state basis
- o Different basis for "generated" vs "buried"
  - Solidification treatment
  - Packaging
  - Gross volume vs net volume
- o Different basis for radioactivities
  - Shipping manifests
  - Decay

In some cases final resolution has not yet been made, pending a more definitive analysis. Projections of future LLW volumes and characteristics involves assumptions in these major areas, among others:

- o Growth estimates
  - Nuclear reactors
  - Nuclear fuel cycle
  - Government (defense)
  - Institutional/Industrial (I/I)
- o New sources
  - Remedial Action Programs (RAP)
  - Decontamination
  - Decommissioning
- o Secondary sources
  - Waste Isolation Pilot Plant (WIPP)
  - Transportation
  - Defense HLW treatment
- o Future regulations
  - NRC classes A, B, C
  - Disposal other than SLB.

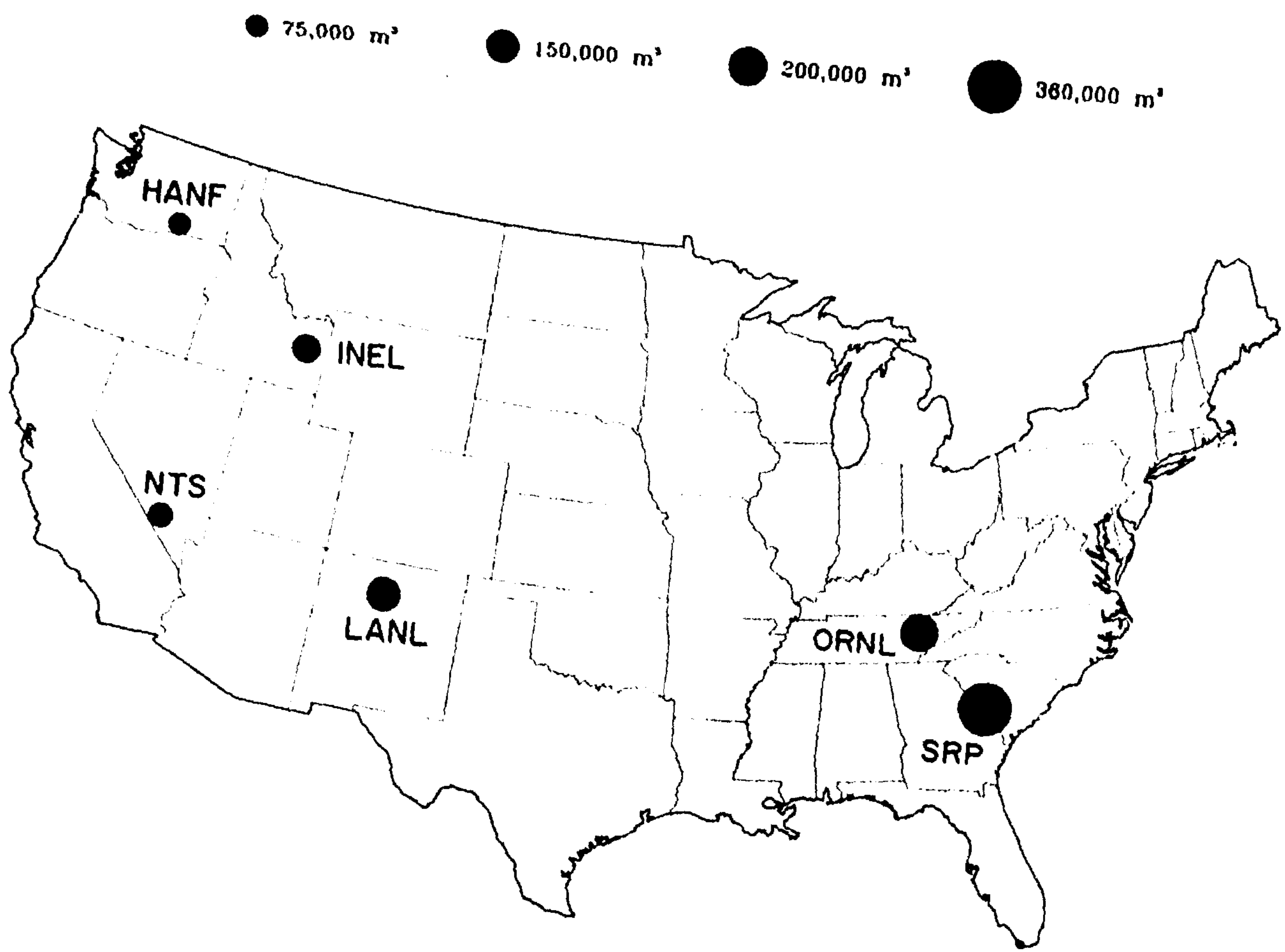
Report DOE/NE-0017 presently includes maps (Figs. 1 and 2) and pie charts for each major waste category. Future editions will have more graphics. Chapter 6 and Appendix D of this report deal with LLW. A list of the tables given in these two sections is shown in Tables 1 and 2. Again, additional information is planned for future editions.

SUMMARY

For FY-1982, in addition to assembling and publishing a third edition of inventories and projections, the IDB program will also address these areas:

- o Automated data handling (via magnetic tapes) and data Q/A
- o Data base management system selection
- o Increased Steering Committee input
- o Expansion of interaction with DOE programs and contractors.

Fig. 1. Location and accumulated volume of LLW at principal DOE sites through 1980



ORNL DWG 81-6758R

Fig. 2 Location and accumulated volume of LLW at commercial burial sites through 1980

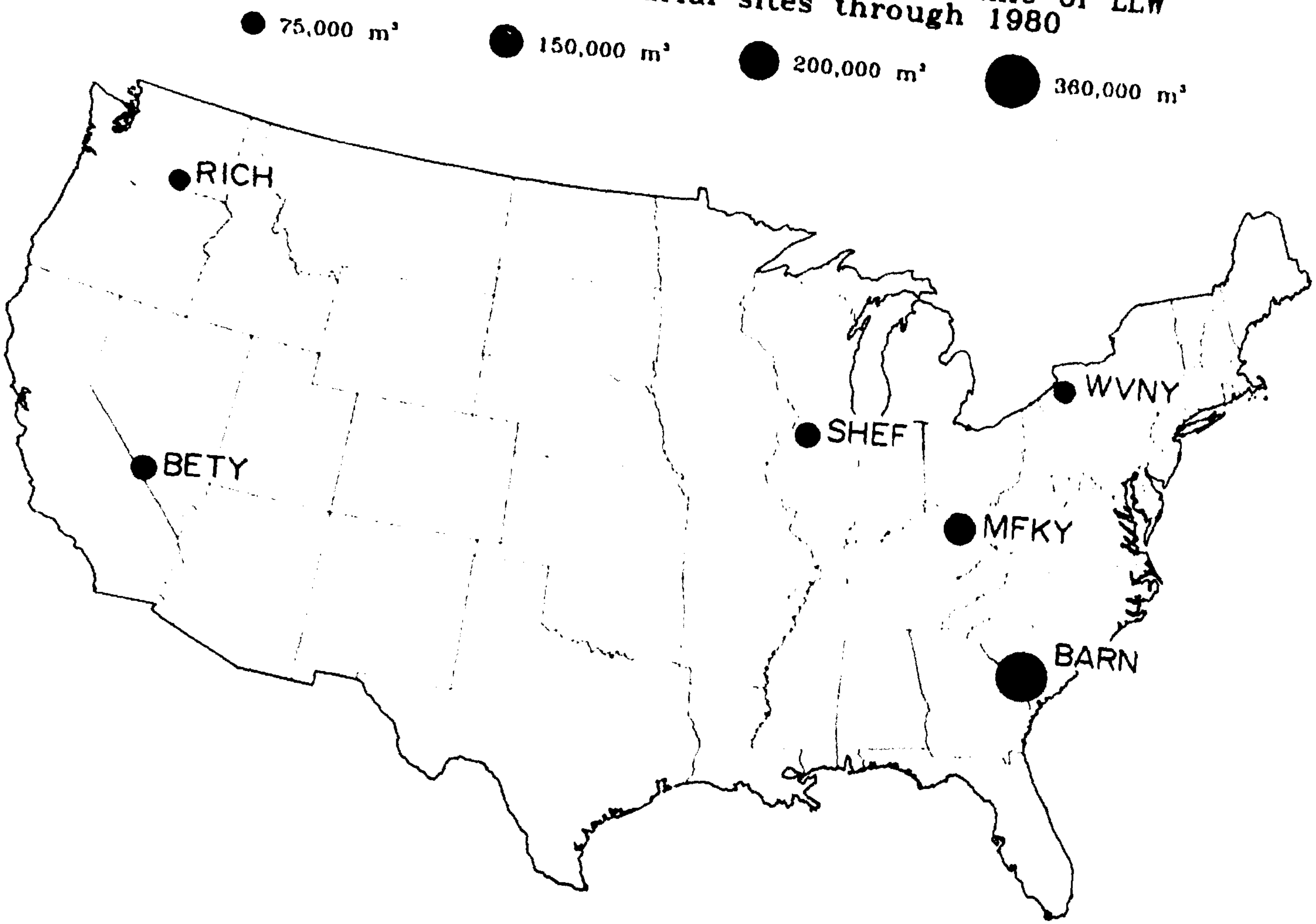


Table 1. LLW data in DOE/NE-0017, Chapter 6

Table 6.1.	Average characteristics of LLW from LWRs per 1000 MW-yr of electricity generated.
Table 6.2.	Volume of institutional and industrial LLW generated in 1979.
Table 6.3.	Inventory of LLW buried at commercial burial grounds at the end of 1980.
Table 6.4.	Inventory of buried DOE LLW at the end of 1980 by Operations Office.
Table 6.5.	Accumulated volume and radioactivity of LLW buried at specific DOE sites through 1980.
Table 6.6.	Projected amounts and characteristics of LLW from commercial fuel cycle operations.
Table 6.7.	Projected amounts and characteristics of institutional and industrial LLW.
Table 6.8.	Projected annual additions of buried LLW at DOE sites.
Table 6.9.	Status of commercial burial sites at the end of 1980.
Table 6.10.	Status and projected DOE burial site land usage.

Table 2. LLW Data in DOE/NE-0017, Appendix D

Other IDB program activities of interest are summarized in the following paragraphs.

The IDB Steering Committee provides generic guidance and includes both programmatic and technical representatives from each major radwaste lead site or function (Table 3). At the October 1981 meeting of this Committee, four subcommittees were formed, to address these areas:

- o Timely input of spent fuel discharge data
- o Format and basis for projections for the next Inventory/Projections report
- o Improved data flow from generator and lead sites
- o Long-term data needs and management-type questions.

Radioactive decays are computed via the ORIGFN2 code.[3,4] This code is the most widely used of all the isotopic generation and depletion codes, and is well documented. In general, this code is most used for the isotopics of spent fuel and HLW, but it is equally applicable to TRU waste and LLW.

Two radwaste bibliographies have been published by the IDB program.[5,6] In addition, related bibliographies have been issued by the Information Center at ORNL.[7-9] All of the reports in these bibliographies are in the report data base at ORNL and can be machine-searched via the standard indexing methods and by key words.

Table 3. Steering Committee for the Integrated Data Base[a]

Functional responsibility	Committee member	Technical contact	DOE office
Chairman and Technical Manager	K. J. (Karl) Notz, ORNL	C. W. (Chuck) Alexander W. L. (Lloyd) Carter C. W. (Charles) Forsberg A. H. (Arlene) Kibbey G. W. (Wayne) Morrison	D. E. Large, ORO
DOE/HQ/NE	E. F. (Ed) Mastal, DOE/NE	-----	E. J. Wahlquist, DOE/NE
High-Level Waste	W. R. (Will) Cornman, SRL	W. R. Cornman	T. B. Hindman and E. S. Goldberg, SRO
Low-Level Waste	G. D. (George) Levin, EG&G/ID	Tom Meyer, EG&G/ID	J. B. Whitsett, IDO
TRU Waste	L. J. (Larry) Smith, RI/RF	R. T. Jensen, RI/RF	A. L. Taboas and D. M. Lund, ALO
Airborne Waste	R. A. (Russ) Brown, Exxon/ID	T. R. Thomas, Exxon/ID	J. B. Whitsett, IDO
NWTS	T. I. (Tom) McSweeney, ONI	T. I. McSweeney	J. O. Neff, RL-Columbus
Transportation	E. W. (Bill) Shepherd, Sandia	E. W. Shepherd	R. Y. Lowrey and Kathy Carlson, ALO
Spent Fuel	N. D. (Natalie) Ferguson, SRP	N. D. Ferguson, SRP	M. C. Kirkland, SRO
Waste Mgmt. Support	J. V. (Jack) Robinson, PNL	J. V. Robinson	Liz Bracken, RL
SFMP	D. H. (Dave) Doerge, UNC-NI	D. H. Doerge	J. L. Landon, RL
UMTRAP	R. H. (Richard) Campbell, ALO	M. S. (Mark) Matthews, ALO	R. H. Campbell, ALO
FUSRAP	E. L. (Lee) Keller, ORO	J. D. Mahler, ORO	E. L. Keller, ORO
Systems Integration	N. B. (Barrie) McLeod, NUS	Y. M. (Yong) Park, NUS	E. F. Mastal, DOE/NE

[a]Additional technical contacts who were especially helpful are:

H. M. Batchelder, EG&G/ID
M. D. DeWitte, Sandia
J. J. Fiore, DOE/NE
G. E. Lohse, Exxon/ID
S. P. Schneider, DOE/NE
R. L. Nebeker, Exxon/ID
W. G. O'Quinn, SRO
J. Themelis, GJO
R. A. Watrous, RHO
D. D. Wodrich, RHO

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5b. C. A. Johnson, Radioactive Waste Management Integrated Data Base A Bibliography, ORNL/TM-7385/V2 (Annotated Abstracts) (September 1980).

6. C. A. Johnson, Radioactive Waste Management: A Bibliography for the Integrated Data Base Program, ORNL/TM-7385/V3 (1981 Edition) (October 1981).

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LLWMP TECHNOLOGY PROGRAM DIRECTION

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This is the time of the meeting when some housekeeping items must be addressed. First of all, the person responsible for setting up the meeting and the logistics was Leroy Stratton. Norma Callahan, the conference coordinator at the Oak Ridge National Laboratory (ORNL), set up the logistics with the Hyatt Regency. Thelma Patton and Pat Viles handled the registration, kept track of the meeting's attendees, compiled the attendee list, and provided assistance to attendees.

Some of you have asked me who on our staff is responsible for the milestones. Bob Fitts handles Milestone A and is coordinator for the contractors at Richland. Jim Vath handles Milestones B and G and maintains the contacts with Brookhaven National Laboratory (BNL), EG&G Idaho, Mound Laboratories, and Rocky Flats on the technology activities. Lance Mezga handles Milestones C and E, and maintains contacts with Los Alamos National Laboratory, Nevada Test Site (NTS), ORNL, and Savannah River Plant (SRP). Leroy Stratton follows Milestone D activities and the work at Argonne National Laboratory (ANL).

We will be conducting site visits in the future, but we hope to do this over a longer period of time -- probably starting in February and ending in June. We want to visit for a longer period of time so that the site review team can visit the site, discuss the status of the work, make an evaluation, and discuss the evaluation with site personnel.

Headquarters milestones are extremely important and are completed only when there has been an officially transmitted report to Headquarters. The official transmittal is made through the Idaho Operations Office (IDO). Procedures will be issued shortly providing the schedules that will have to be met in order to complete Headquarters Milestones.

We appreciate the prompt submission of monthly reports to IDO, the Oak Ridge Operations Office, EG&G, and ORNL.

We hope to have the meeting proceedings published and sent to all attendees by the first week in January. Therefore, the last date that we will accept camera ready copies is November 13.

PANEL WORKSHOP A, B, & G REPORT

J. H. Kittel, ANL
M. J. Schliebe, PNL

INTRODUCTION

This workshop addressed three milestones, A, B, and G. The objectives of these milestones are:

- Milestone A - To develop technology for waste generation reduction by September 1984.

- Milestone B - To develop technology for waste treatment, handling, and packaging for shallow land burial by March 1984.

- Milestone G - To develop technology for waste treatment, handling, and packaging for greater confinement than shallow land burial by September 1985.

Prior to the workshop the co-chairmen prepared handout material to stimulate and focus the discussion of the workshop. The handout stated the milestone objectives, identified the current status of the DOE-LLWMP, and suggested issues and problems for discussion.

MILESTONE A - LLW GENERATION REDUCTION

Discussion

Discussion on Milestone A focused on five main topics:

1) Balance of efforts to achieve optimum reduction in cost and conforming to "as low as reasonably achievable" (ALARA) requirements.

2) Site specific nature of waste generation reduction.

3) Requirement for identification of specific waste streams in order to evaluate the effectiveness of waste generation reduction efforts.

4) Providing incentives for reducing waste generation.

5) Pursuing establishment of _de minimis_ levels for noninstitutional wastes.

Reduction in waste generation can significantly reduce disposal costs. However, selecting appropriate methods must be balanced with other considerations, namely ALARA considerations. Segregation of nonessential material from potentially contaminated material should be highly emphasized since it is an effective method which basically requires no additional facilities and minimal preliminary evaluation of affected material.

Obviously, waste generation is site specific. Individual generators are in the best position to identify the peculiarities of their waste generation and select the most appropriate methods to reduce generation rates.

In order to provide a method for evaluating the effectiveness of waste generation reduction methods, sufficient waste stream details should be established. The actual generation location and qualitative and quantitative details are needed prior to implementing a generation reduction method. Different operating modes should be correlated with generation rates to further pin-point waste generation areas which should be addressed.

Certainly, assurance of the success of waste generation reduction techniques is of key importance. An effective mechanism is by providing incentives for reducing waste generation rates. Individuals instrumental in the continued success of reducing generation rates should be proportionally rewarded for their efforts; however, unavoidable waste generation and subsequent disposal costs should be passed on to waste generators and not simply absorbed by overhead funding.

Recommendations

Continuing emphasis should be placed on establishing de minimis levels for release of noninstitutional low-level waste. This will be a substantial step in the right direction, providing additional relief for LLW disposal.

MILESTONE B & G - WASTE TREATMENT FOR SLB AND FOR GREATER CONFINEMENT

Discussion

Five principal issues were discussed:

1) Volume Reduction

2) Impact of 10 CFR Part 61

3) Applicability of Experimental Approaches

4) High-Integrity Packaging

5) Support from Interim Operations Program

Volume Reduction

Issues Discussed

Incineration was the principal volume reduction topic discussed. There are potential advantages in locating large incinerators at sites away from waste generators because of more favorable environmental regulations. For example, the incinerator might be located at a LLW disposal site, or in one state that is part of a compact. This approach would save capital costs for small generators who cannot afford an incinerator facility.

However, no savings in transportation would result. The main long-term advantage to the nation as a whole would be extension of the lifetime of burial capacity.

High-density compaction is being developed abroad, principally in Germany.

Recommendations

1) Cost/benefit studies are needed to evaluate usefulness of large central LLW incinerators.

2) More information is needed on high-density compaction developments abroad.

Impact of 10 CFR Part 61

Issues Discussed

It's not clear at this time to what extent DOE-owned facilities will be expected to comply with proposed rule 10 CFR Part 61. A double standard with which commercial facilities must comply but comparable DOE facilities would not would be undesirable. It was pointed out that this would not only lead to public relations problems, but would provide unfair cost advantages to DOE-owned operations that compete with privately-owned facilities. Weapons components manufacture is an example. Uranium metal waste is generated that may exceed Class C waste.

Recommendations

1) DOE operations should comply with 10 CFR Part 61 if there are parallel activities in the commercial sector which must comply.

Applicability of Experimental Approaches

Issues Discussed

Industry representatives questioned the applicability of some of the LLW experimental studies on a laboratory scale, in which tracer radioisotope amounts are used to model behavior of high-activity systems. The extrapolation of these results to power plant activity levels seems particularly uncertain. Also, some LLW migration studies do not appear to have had sufficient time to reach equilibrium conditions.

Recommendations

1) Laboratory tracer level experiments intended to model high-activity systems, such as spent resin treatment and disposal, should be reexamined for their veracity in predicting actual conditions in the field.

High-Integrity Containers

Issues Discussed

It was noted that industry is actively developing high-integrity containers. The DOE program doesn't appear to be fully informed of these developments, due in part, at least, because proprietary interests are involved. Some of these containers may serve adequately as meeting Greater Confinement criteria. The availability of these containers may alter DOE R&D program needs and priorities.

Recommendations

1) Improved contact between the DOE Greater Confinement and Waste Packaging activities, and the private sector is desirable to factor into the DOE program the developments in industry.

Interim Operations Program Support

Issues Discussed

The smaller DOE-owned facilities have not been part of the Interim Operations Program, although many of their waste management problems are comparable to those of the large sites. Extension of Interim Operations Program funding to the smaller facilities would provide them with information developed at other sites on treatment of wastes that are common to both large and small facilities.

Recommendations

1) Consideration should be given to urging the Interim Operations Program in providing funding to small DOE-owned facilities to help them solve their waste treatment problems.

PANEL WORKSHOP C REPORT

J. M. Latkovich, PNL
W. J. Boegly, ORNL

INTRODUCTION

The objective of Milestone C - Shallow Land Burial is to develop technology and documentation required to open a shallow land burial site. The scope is to focus on the development, demonstration, and documentation of the technology for site selection, site design, site operation, and closure and post-closure management.

Prior to the workshop the co-chairmen prepared handout material to stimulate and focus discussion in the workshop. The handout stated the milestone objective, identified current program activities under the milestone, outlined some of the key requirements of the U.S. Nuclear Regulatory Agency's proposed rule 10 CFR Part 61, and suggested topics for discussion.

We've heard during the past two days that technology exists. Empirical evidence suggests that it does. However, it has not yet been established that a scientifically defensible argument could be submitted and sustained in applying for a license to operate a near-surface radioactive disposal facility. Perhaps a more accurate connotation of the milestone's efforts would be conveyed were the milestone titled Develop "improved technology" or "Refine the technology required...." At any rate, the purpose of our workshop was to evaluate the status and provide recommendations for technical scope to be initiated or modified.

DISCUSSION

The first topic addressed was that of what would be the most beneficial use of the technical information derived. How do we effect an optimum transfer of technology? The consensus was that a demonstration of improved SLB technology was of most use. It was maintained that a siting demonstration at an actual site should be employed, as this would impart the most credibility to the exercise, that it should not be looked upon as another "simulation." This would be an effective way to get the public involved. The effort should also be thoroughly documented, which would serve not only as a historical, but also an educational, function.

DOE's role in this endeavor was also discussed, and many mechanical problems relative to implementation were posed. For example, as an actual case, the role of DOE in providing the technology aspect, NRC the regulatory aspect, and the states or some private function performing the political aspect, would probably reflect the real world in terms of the dynamics of implementing the course of action. DOE was also perceived as providing a key role, through this effort, by stimulating a group or groups of states or possibly by reviewing the application. This demonstration would serve as a mechanism for opening one or more sites.

Also discussed as how to provide a benefit was that of DOE acting as an independent consultant vis-a-vis the state-federal-operator and regulator-promotor relationships. The importance of personal assistance versus simply providing documentation was stressed as being a much more effective contribution.

The specific technology gaps or issues were addressed relative to each of the functional areas (e.g. site selection, stabilization and post-closure, etc.) In site selection, the main discussion centered around the required predictive capability. The DOE efforts have focused on component models, essentially confirming projected system dynamics. NRC has applied a performance assessment, including both the hydrologic and dose portions, to a humid site and will do so this year for an arid site. Data limitations such as source term or the homogeneity of the geohydrology were questioned as issues, but the discussion centered around the conservatism that would be incorporated by the overall analysis, where a weak facet of the analysis could be conservatively estimated or buttressed by some other segment of the system. It was observed this work should focus on site applications related to licensing, with a specific case study needed to identify gaps.

In the Improved Burial Technology, the need for better definition of what constitutes an engineered barrier was observed, particularly as it relates to or implies greater confinement. Engineered barriers have been related to intrusion barriers. Whether liners are considered engineered barriers and the need for them in the overall scheme of water management and solute transport should be determined. The importance of biologic intrusion was questioned, with a need for sensitivity analysis as to its real impact identified as being needed. The principal impacts could be on site stability or public ramifications rather than on dose to man.

In the stabilization and post-closure area, a sensitivity analysis relative to the importance of subsidence was suggested. The NRC waste classification standards could make the issue moot.

No gaps or issues were identified in the Geohydrologic Site Characterization area. In the Environmental Monitoring area, the question of considering advanced statistical techniques in the Generic Environmental Handbook was raised.

In looking at the Migration Mechanism efforts, it was suggested that sampling below closed trenches could yield data to validate predictive models.

A question raised when reviewing those efforts associated with the Radionuclide Transport Data Base was focused on whether further work should be expended on determining source term characteristics of existing wastes. It was felt this was not necessary, unless for remedial actions, and it was, in fact, suggested the DOE Waste Classification effort be terminated, since NRC issuance of their classification standards has resolved the issue.

A discussion centered around what should be contained in the Milestone C handbook and to what audience it should be directed. While there was no firm consensus, the general opinion expressed was that it should be a document aimed at providing general guidance at the state level. It should not contain significant detail. One analogy offered was that it should emulate a textbook, providing general guidance with extensive references and examples. Another opinion expressed was that the best method of transferring this technology was by training or assisting staff that would be applying the methodology and that the utility of any handbook was questionable.

CONCLUSIONS AND RECOMMENDATIONS

- An actual demonstration of improved SLB technology, particularly on actual site selection, with DOE, NRC, and the state and private sectors involved, would provide an optimum way of transferring technology.
- The Milestone C handbook should provide general guidance with references and examples to be of the most value.
- Direct staff assistance and interaction in technology transfer is considered more effective than extensive documentation.
- Efforts directed toward evaluating long-term predictive capabilities should employ specific case studies in order to identify gaps requiring further development.
- Sensitivity analysis should be applied to determine the real impact of subsidence and biointrusion.

PANEL WORKSHOP D REPORT

Gerald L. DePoorter, Los Alamos
N. H. Cutshall, ORNL

INTRODUCTION

The objective of Milestone D in the DOE Low-Level Waste Management Program (LLWMP) is to develop and document remedial action technology for shallow land burial (SLB) sites. The purpose of the workshop was to evaluate the ongoing and planned research on remedial action technology to determine if this milestone can be met, and if not, why not?

The co-chairmen prepared handout material prior to the workshop to stimulate and focus discussion on the major issues. The handout discussed the purpose of the workshop, stated the objective of Milestone D, identified relevant reseach and development activities, and suggested critical issues and questions for consideration by the workshop.

This report summarizes the discussions in the workshop. One definition is necessary before the workshop summary will be presented. To focus the discussions, remedial actions were defined as the actions taken by the site operator when the site does not meet performance objectives.

CRITICAL ISSUES AND QUESTIONS

The critical issues in remedial action technology relate to water movement, subsidence and subsidence effects on system components, erosion, intrusion, radionuclide migration, and microbiological processes. Except for the last one, this is the same list as presented by R. B. Fitts in his summary of Milestone D.

Although microbiological processes are not remedial actions they are listed as an issue for the following reasons. The effects of microbiological activity such as gas generation, water production, subsidence as a result of the decay of organic matter, and enhanced mobility by the chemicals resulting from microbiological activity will appear most obviously once the site has been closed. Information on the scope and magnitude of the effects of microbiological activity will allow the operator to determine if the effects mentioned above result from this or other causes. The concensus of the workshop participants was that this listing of critical issues and questions was adequate.

RESEARCH NEEDS

The concensus was, as stated above, that the problem areas for remedial action technology research and development are adequately identified and that ongoing and planned work will cover most of the problem areas. Except with respect to documentation, to be discussed below, there were no specific recommendations for improving the DOE-LLWMP in the area of remedial action technology research and development. The area in which improvement is necessary is documentation.

DOCUMENTATION REQUIREMENTS

All aspects of remedial action applications need better documentation. The process of choosing a remedial action, including alternatives considered and the reasons for choosing the particular remedial action used, should be documented. If a remedial action technique is tried and does not work, this fact should be documented to help prevent someone else from using the same or a similar ineffective remedial action.

Considerable discussion revolved on the issue of the credibility of remedial actions with the general public. Some participants thought that the publication of the results of the research and development in peer reviewed technical journals might help with public acceptance. Also, some effort should be made to place the information in "lay" publications, or at least be written so the general public can understand the material presented.

FUTURE RESEARCH NEEDS

Although the present research areas adequately cover the identified remedial action problems, the workshop identified a need for Program commitment to remedial action evaluations that span a 5- to 10-year interval. In order to ascertain the impact of remedial action on a target problem two or three years of information before and after implementation may be required.

Attention was also given to the need for failure mode analysis, both to determine the factors that initially caused the need for remedial action as well as to assess the shortcomings of remedial actions that are themselves inadequate. The efforts on failure analysis must be closely interrelated to site monitoring or surveillance, particularly during the post-closure period. Surveillance should be designed so as to provide the earliest warning of remedial action needs since the cost of most actions escalates severely if implementation is delayed. Furthermore, the failure mode analysis should provide useful guidance in surveillance system design by highlighting key processes.

Another related area that is important to remedial action implementation is the development of a framework of performance objectives, action levels, and plans for reaction to the recognition of monitoring results which signal failure to meet performance objectives. Without this framework, remedial actions may not be implemented at the optimum time and, when they are implemented, they will have the appearance of reacting to an out-of-control situation.

The best remedial action is considered to be prevention. Once failure analysis has highlighted key problems, operating procedures should be upgraded to prevent recurrence of failure at new sites. Factors that are critical in preventing the need for remedial action include: 1) Waste packaging and waste forms that are resistant to leaching and that are structurally sound; 2) Trench filling and compaction practices that eliminate void spaces in or between packages; 3) Proper siting.

Remedial actions must be applied with a consideration of the entire burial ground environmental system. A system approach is essential to assure that the action will both fix the correct problem and avoid the creation of a secondary problem. A clear example is the need to consider the impact of infiltration control on surface runoff and erosion. In some systems infiltration control may cause a more significant erosion problem than the leaching problem it solves. The soil, water, plant, animal relationships must be considered in remedial action design.

A system approach to remedial action will also be more likely to result in actions to "cure" the problem rather than treat the symptoms. For example, by determining the sequence of events that leads to trench subsidence the operator is likely to consider void space minimization and waste stabilization at the time of disposal rather than simply to fill in the space and wait for another collapse.

Progress toward Milestone D will be enhanced by a dual generic and site-specific approach. The application of fundamental, generic principles should guide the design of remedial action for any given site. This basic approach will ensure that a system consideration guide the planning and implementation of remedial action. Local parameter values for the site will, of course, be necessary. At the same time, the generic systems models for remedial action must be validated through documentation of specific site case histories. In this way the systems models themselves will continuously be checked by "real world" considerations. Figure 1 illustrates schematically this feedback loop between generic and site-specific efforts.

GENERIC AND SITE SPECIFIC EFFORTS

ARE MUTUALLY SUPPORTIVE.

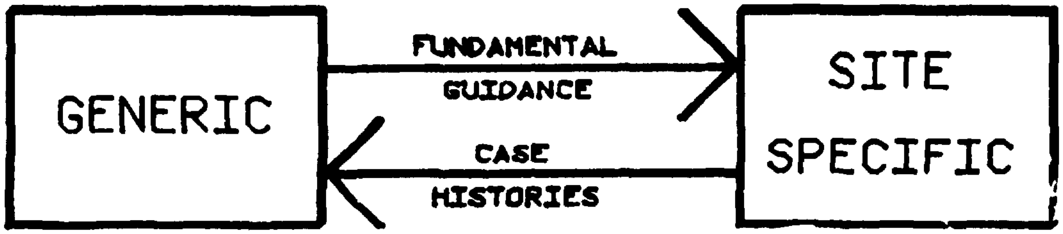

Figure 1

WORKSHOP CONCENSUS ITEMS

The items on which all the attendees at the Milestone D workshop agreed are:

1. Prevention is the best remedial action.

2. A systems approach to remedial action is essential.

3. Documentation of success and failure on a 5-10 year time scale is necessary.

4. A fundamental, generic approach will yield the best long-term payoff.

PANEL WORKSHOP E REPORT

John Wiley, SRL
Preston Hunter, FBD

INTRODUCTION

In the workshop on Milestone E - Greater Confinement, John Wiley and Preston Hunter were the co-chairpersons, and Lance Mezga was the Program Office resource person.

The objective of Milestone E is to develop the technology and documentation needed to open a site providing greater confinement than shallow land burial by March 1986.

Prior to the meeting, the co-chairmen prepared handout material to stimulate and focus discussion in the workshop. The handout stated the purpose of the workshop, discussed how the workshop would be conducted, stated the milestone objective, provided some operating definitions, and listed six focal questions for discussion. The workshop was structured around the six questions relating to greater confinement disposal. The responses to the questions served as a springboard to the workshop discussion. This summary will track the questions asked and responses from the participants in the workshop.

We recognized from some of the responses before the workshop that there may be a problem of definition of greater confinement disposal (GCD), even if GCD is defined as greater confinement than shallow land burial. As an operating definition we chose "greater confinement than shallow land burial and as practiced in a specific site." For example, when we talk about greater confinement disposal at Savannah River we are talking about greater confinement than what is provided by present shallow land burial techniques there . This definition would also hold true for an arid site or any other operating site. In defining GCD in this manner, it should be recognized that a particular waste that might require greater confinement at a humid site might not require greater confinement disposal at an arid site. It should also be recognized that there exists some interface with Milestone C - Shallow Land Burial Technology and our questions were discussed primarily on a technical basis rather than on a programmatic basis.

PROBLEMS OF SLB EXPECTED TO BE SOLVED BY GCD

These are the types of problems that greater confinement disposal might be expected to solve which are potential problems with shallow land burial, at least as it is currently practiced:

- o Biointrusion by plants and animals would be minimized by deeper burial. SRL has plant intrusion and other sites have pocket gophers.

- o Trench subsidence was mentioned as a problem which could be solved by better engineered structures and improved waste packaging.

- o Inadvertant human intrusion as a major problem for shallow land burial sites is difficult to quantify, but deeper disposal would at least reduce the probability of this scenario.

- o Public perception of our low-level waste management practices or "housekeeping" of our sites was mentioned as a principal problem and, for many sites, our "housekeeping" practices are not as they should be. Greater confinement is seen as a way to improve the public perception of low-level waste management. It should be recognized that poor housekeeping can also exist at a greater confinement disposal facility and we certainly want to avoid that.

- o A reduction in nuclide migration may be accomplished by burial of wastes at greater depths. Sites that are marginally suitable might be improved to the level of performance required by application of greater confinement disposal techniques. This may be of particular interest to the states involved in LLW disposal compacts where due to political, site geologic, and other reasons greater confinement disposal may be looked at as an alternative to meeting the states waste disposal requirements.

- o Finally, decommissioning and closure would be improved or facilitated by GCD where possibly we may be able to close a site and release it from institutional control earlier than what would be the expected requirements for a SLB site.

RELATIONSHIP TO 10 CFR PART 61

Another question was related to the impact of 10 CFR Part 61 on greater confinement. Certain types of waste defined in 10 CFR Part 61, such as Class C "intruder waste" which are likely to be handled with difficulty in a shallow land burial facility, could be more easily and practicably handled in a GCDF. DOE sites, while not particularly falling within the guidelines of the NRC proposed rule 10 CFR Part 61, should nevertheless be "comparably maintained."

In establishing criteria for LLW disposal we need to consider the interface between shallow land burial and greater confinement and more input from DOE contractors and industry is needed for the "reserve sections" of 10 CFR Part 61. These sections deal with the operation of low-level waste facilities and consideration of greater confinement disposal concepts should be addresed in these sections.

TYPES OF GCD SYSTEMS

Almost everybody thinks of deeper burial when speaking of greater confinement disposal, but what needs to be emphasized is a "systems approach." The concepts listed below, with the probable exception of ocean dumping, should be considered together as a system for providing greater confinement.

- Deeper burial
- Improved waste form
- Improved containers
- Engineered structures
- Geologic confinement
- Ocean dumping

For example, an improved waste form may, if it is a "super waste form," be sufficient by itself to provide greater confinement. Using only an improved super waste form is not very probable for waste disposal nor very cost effective; what is more probable is a combination of the various concepts as appropriate for a particular site.

The same thing can be said for improved containers. Engineered structures are the primary focus of GCD efforts expected at Savannah River, while geologic containment is the emphasis at the Nevada Test Site. The latter is approaching the concept of isolation as applied to high-level waste disposal. From a technical standpoint, there is not a clear distinction between high-level, transuranic and low-level wastes; geologic containment provides a potentially cost effective alternative, particularly for arid sites.

INFORMATION REQUIREMENTS

For implementation of the various GCD systems, several parameters should be considered:

- Cost is very important, probably the most important parameter, in the selection or implementation of a GCDF at a particular site.

- Waste Characteristics

- Volume of waste and source (or where it is generated)

- Performance objectives relate to understanding the problems that need to be solved.

- Site Characteristics

- Transportation and handling at the site

- Packaging and waste acceptance standards at the site

- Modeling is very important for determining whether or not we need to consider greater confinement at the site and how such a greater confinement disposal facility is going to perform over the long term.

This brings us to the next level of discussion of this question to the "assurance of performance." If we say that greater confinement disposal is needed, how can we be sure it is going to do the job intended? Two primary methods are perceived for assurance of performance:

- Demonstration of concepts. The two concepts that are currently being developed for demonstration include the greater confinement "borehole" facility at the Nevada Test Site and the engineered deeper burial structure at the Savannah River Laboratory. It is the consensus of the workshop that the demonstration of these two concepts is what is minimally required to meet the objectives of Milestone E by 1986. We don't really need to consider optimization of greater confinement disposal with all the concepts mentioned above, but do need to demonstrate the workability of at least one or two of these systems, and do so in a manner which is convincing to the public. So we need to do a good job on the implementation of the demonstration test.

- We would also like to obtain data from the demonstration that verifies that the GCDF is performing as it is supposed to.

TIME REQUIRED

With regard to the question of whether or not there is sufficient time to accomplish the objectives of the milestone and meet the milestone date of late FY 1986, we should consider the following:

- o We need to be concerned with the requirements of the NRC and the timing of publication of their final rule. As mentioned previously, those of us in the program should review the draft rule 10 CFR Part 61 and provide comments to assure that the DOE can maintain "comparability" of criteria and to assure that greater confinement disposal alternatives are considered in the "reserve sections." A coordination of NRC and DOE milestone goals may be helpful in orienting our program to the FY 1986 milestone.

- o It was the consensus of the workshop that the milestone date of March 1986 is sufficient to complete the demonstration of the two GCD demonstration tests at NTS and SRL.

- o In terms of optimizing the overall system, or looking at all the alternative GCD concepts, there is insufficient time. Optimization may not be either cost effective or beneficial to the objectives of the Low-Level Waste Program.

The most important conclusion and consensus to come out of the workshop is to "get on" with the two demonstration concepts and do a good job to convince the public that, if needed, methods to provide greater waste confinement than SLB are available. This can be done by 1986.

RECOMMENDATIONS FOR PROGRAM IMPROVEMENT FROM AD HOC ADMINISTRATIVE MEETINGS

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FIELD OFFICE MEETING (11/4/81)

Technology and Information Transfer

Methods of improving technology and information transfer within the program were discussed. It was agreed that documentation of existing technology should be made available to all interested parties as soon as possible.

Oak Ridge agreed to obtain a bibliography of nuclear low-level waste reports from the Technical Information Center (TIC) and provide the information to the participants. --- Action: D. Large

All field offices participating in the meeting agreed to review all uncleared publications produced by the interim operations program, and provide a copy of the appropriate reports to TIC. ORNL will maintain an updated bibliography for the program action. --- Action: ALL

It was agreed that the milestone system should be expanded to track all reports listed as deliverables in work plans through to publication and distribution. It was agreed that there is a need to expedite publication of reports required to assist the commercial sector, particularly those related to site selection. It was agreed that the level of review should be commensurate with the importance of the document. The Idaho Operations Office will review the milestone reports and other reports with the objective of expediting their publication.

Peer review of documents was discussed. It was generally agreed that some peer review should be accomplished prior to submission of the document to DOE. Peer review external to the participating organization should be established in the milestone review systems and agreed to by affected organization. --- Action: M.J. Barainca

Public Communication

It was agreed that all individuals participating in speakers bureau programs should be aware of and utilize consistent materials. DOE-ID and EG&G will review and update the LLW slide presentation and provide a copy to those DOE offices which do not have a copy of the 35mm LLW standard presentation.

Additionally, the need to provide current public information materials to DOE and appropriate contractors was discussed. DOE Idaho needs to review the cost of upgrading the DOE information program and providing information to a broader public. DOE participation at any meetings which could involve DOE policy issues should be cleared through the lead field office, ID or HQ.

Information from interfacing programs, such as TRU, needs to be provided to participating field offices. The Newsletter may be a good vehicle to provide this information. --- Action: M.J. Barainca

There is a discussion of the need to expand the studies of options to shallow land burial. It was suggested that engineered facilities above and below the ground may be more acceptable in humid regions.

There was a necessity to be more precise in describing technology activities. It was suggested that the term "refinement of technology" be utilized in place of "technology development". This would clarify that the DOE activities were improvements of acceptable technology. It would also demonstrate that technology exists but that DOE's programs are continually being upgraded.

The need to review upgrades of technology in terms of final disposal options was discussed. It should be the objective of the program to safely dispose of waste in a manner that eliminates the need for remedial actions. This would help "break the chain" and minimize the necessity of a series of interim actions which do not contribute to final disposal.

The need to prioritize funding vs. major program issues was discussed. DOE-ID and ORNL will review approaches to this problem.

The need for additional communication to resolve common issues was discussed. Written suggestions received from participants related to this meeting will be evaluated by ID. --- Action: M.J. Barainca

COMMERCIAL SECTOR CONTRACTORS MEETING (11/5/81)

Various areas of program improvements were discussed. Industry participants felt a demonstration of the selection, qualification and validation of techniques applicable to licensing of a shallow land burial site was necessary, and that this should be accomplished on an expedited schedule.

MEETING SUMMARY AND RECAP

D. E. Large, Program Manager
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INTRODUCTION

I have the pleasant, but unenviable task of summarizing the more than 50 excellent papers that have been presented. As you may recall, in summarizing last year's meeting I noted that the workshops revealed a need for improved intra-program communication. I believe that this meeting has provided an excellent forum for information exchange, and we in the Program Offices are pleased to have your comments on how the program is proceeding and how it can be improved.

PROGRAM OVERVIEW

On Wednesday morning Bob Ramsey reviewed the major goal of the DOE Low-Level Waste Management Program, which is to provide an acceptable near-surface waste disposal system by 1986. He also brought us up-to-date on the reorganization within the Department of Energy (DOE) which created separate programs for commercial and defense wastes, under the Assistant Secretaries for Nuclear Energy and Defense Programs, respectively. The Low-Level Waste Policy Act of 1980 gave responsibility to the states for management of low-level radioactive waste from non-DOE sources. The role of DOE is to provide general support to the states in the fulfillment of this law.

Goetz Oertel informed us that a Memorandum of Understanding between the Assistant Secretary of Nuclear Energy and the Assistant Secretary for Defense Programs will define the roles and responsibilities of the two organizations and allow us to retain the present management structure in the field to integrate the two programs.

Phil Hamric pointed out that the Low-Level Waste Policy Act of 1980 has placed an increased emphasis on the commercial program. The objectives of the DOE Low-Level Waste Management Program are to (1) assist states in the development of state plans, demonstrations, and site characterization, (2) ensure that commercial waste responsibility is maintained in the private sector, and (3) maintain a DOE program of consensus development. Phil also provided us with projected budgets for both the commercial and defense programs through 1985. Phil said that participating contractor work is absolutely essential and that he wants feedback from the contractors.

Mike Barainca expressed his view of this meeting as an interactive process and called upon us to provide him with feedback that would help improve the program. In regard to technical progress, he pointed to the need for understanding the system as a prerequisite for developing criteria. He also stressed the need for peer review and "test plans" to provide LLWM Program Offices with the information that would allow justification of the program.

George Levin stated that the program has two basic customers - the states and the DOE facilities - and each has its specific needs. He further reviewed the status of development of the various regional state compacts for siting radioactive waste disposal facilities.

Bob Lowrie reviewed the development of the current program dating from the recommendation of the Shallow Land Burial Steering Committee in the period 1975 - 1979, the Des Moines meeting at which the objectives of the LLWMP were recognized and the major alpha milestones were established, to last year's meeting at San Diego where it was decided that a series of manuals should be developed to facilitate technology transfer. He then reviewed the current technical objectives of the program, their respective supporting milestones, and how they would be addressed during this meeting.

Dale Smith presented an overview of the U.S. Nuclear Regulatory Commission's (NRC) activities in low-level radioactive waste. Most of this work in NRC is in the Division of Waste Management, under the Office of Nuclear Materials Safety and Safeguards. They are supported by the Offices of Nuclear Regulatory Research, Inspection and Enforcement, and State Programs. One of the major and recent activities of NRC has been the development of 10 CFR 61 and supporting technical position papers. The comment period has been extended to January 14, 1982 to permit comments on the Environmental Impact Statement (EIS) which was issued in draft form in October. NRC hopes to have 10 CFR Part 61 and the EIS in final form in about a year. Dale was followed by John Stewart who is also with the NRC. He gave an overview of the technology activities. He reported that information exchanges between NRC and DOE on LLW were highly desirable.

Bob Williams discussed the Electric Power Research Institute's (EPRI) role in serving as a source of reliable technical data for parties who are interested in opening and operating a new low-level waste facility. Bob described EPRI's siting technology and waste processing technology programs.

Russ Stanford of the Edison Electric Institute informed us that the utility Waste Management Group is a group of 39 utilities which interacts with Congress in development of legislation, with NRC and EPA in the development of regulations, and with DOE in the carrying out of programs in which it has interest. Russ urged us to distribute early drafts of our findings since 1986 is nearly upon us and the information we are developing is needed now.

John Deichman stated that criteria are the most important single item needed for guidance in technology development. He sees problems of the waste management operator becoming more complex as more specific waste forms are defined, thus requiring a wide variety of management methods. He expressed his belief that it might be cheaper to combine a number of waste forms and treat them as one.

TECHNOLOGY DEVELOPMENT

On Wednesday afternoon we moved to more specific discussion of the programs conducted to support the alpha milestones.

Waste Treatment

Jim Vath reported on the current status and presented an overview of the objectives of Milestones A, B, and G (waste generation reduction, waste treatment for SLB and waste treatment for greater confinement, respectively). He then introduced other speakers who discussed technical progress. Mike Schliebe projected that the limitation on LLW disposal capacity and the rapidly increasing costs of disposal are providing incentives for reducing the generation of LLW. The handbook he is producing will discuss technical and administrative methods for reducing LLW generation. Other papers in the session by Don Clark, Charlie Abrams, Jack Blakeslee, Ralph Jaegar, John Deichman, Joe Thompson, George Becker, Don Oakley, and Jim Mack discussed methods that are being studied to reduce waste volumes or to treat specific types of waste requiring special handling. Bob Neilson reported progress on efforts to develop solidification processes for various types of wastes.

Shallow Land Burial

Thursday morning was devoted to Milestone C (Shallow Land Burial). Bob Fitts presented an overview of the milestone objectives and the status of the program. The program has been designed to address the major issues identified by the Shallow Land Burial Steering Committee.

Fundamental studies

In the papers devoted to fundamental studies, John Wiley reported that monitoring of the shallow land burial facility at SRP, used from the early 1950's, reveals little movement of radionuclides other than tritium. Tim Jones showed results that suggests there is little concern for upward movement of tritium by evaporation. John Swanson reported the effect of organic complexants on europium, nickel, cobalt, cesium, and strontium. Al Weiss discussed the initial steps taken on a new program at BNL to study the effects of microbial activities on organic wastes in SLB facilities.

Model development and application

In the papers on model development and application, Tim Jones discussed both water and solute transport models. He reported that 2 parameter nuclide transport models fit the data nearly as well as 4 parameter models. Gerry DePoorter described a caisson-type lysimeter experiment with horizontal access tubes for emplacement of measurement devices. Lisa Stinton is applying existing criteria and models to the selection of a site for shallow land burial at the Oak Ridge Reservation. John Wiley has developed and applied dose-to-man models at SRP, which indicate that strontium-90 is the critical radionuclide in the "home farm scenario." Even in the worst-case scenario, doses from plutonium and cesium-137 are low.

Technology, development and engineering scale testing

In technology development and engineering scale testing, Nancy Vaughan found that fluorocarbon tracers can be used to get quick results on important groundwater flow paths. Gerry DePoorter reported that the Experimental Test Facility at Los Alamos has been completed and two experiments (biointrusion barrier and moisture cycling) have been emplaced. Tom Hakonson found that cobble and gravel effectively prevent plant and animal intrusion. Bob Hooker has installed settlement gauges over four SRP trenches to quantify the amount and duration of settling.

Site stabilization and closure

In site stabilization and closure, Norm Cutshall discussed the importance of planning for stabilization and closure of SLB facilities during the course of site utilization or preferably, as a part of site selection.

Instrumentation development and application

Jack Barraclough reported on the 600-ft well at INEL which uses seven specific ion probes to make a variety of measurements and discussed developments in well-logging equipment. Ron Brodzinski described a transuranic assayer that will measure 10 nanocuries per gram in 1 minute in a standard package. Fred Paillet described existing geophysical equipment that can be used for well-log interpretation for hydrogeologic applications.

Documentation

With respect to documentation Bill Boegly and Jake Sedlet reported that initial drafts of the Shallow Land Burial Handbook and the Handbook on Environmental Monitoring for Low-Level Waste Disposal Sites have been completed.

Remedial Action

Under Milestone D, Bob Fitts presented the objectives and current status of activities in Milestone D and then introduced speakers who reported on technical progress. Leonard Lane and Gerry DePoorter discussed remedial actions for arid sites. Brian Spalding reported that installation of engineered barriers in Solid Waste Disposal Area 5 at ORNL reduced strontium-90 discharge from 1.6 to 0.6 curies per year. John Deichman discussed subsidence and erosion control. Don Jacobs reported that an initial draft of the remedial actions document has been completed which indicates that the major problem area is water management.

Greater Confinement

Under Milestone E, Lance Mezga presented an overview of the objectives and the status of the current program. Demonstrations are being planned in the area of greater confinement at SRP and NTS. Bob Hooker discussed the concepts that will be considered at SRL. Bob Boland (Nevada Operations Office), Preston Hunter, Paul Dickman, and Bill Garms reported on the plans for a Greater Confinement Disposal Facility (GCDF) at the NTS. Paul indicated that the GCDF would reduce the intruder risk by a factor of 10 million. Jim Steger outlined the work proposed by Los Alamos to support the Greater Confinement Disposal Facility goal in the areas of, data evaluation procedures, instrument testing, and measurement system design modifications.

SUMMARY SESSION

Karl Notz described the DOE Integrated Data Base and related it to the needs of the DOE Low-Level Waste Management Program. Bob Lowrie made closing comments regarding the technology program and recognized the meeting logistics and personnel responsible for them.

Workshop Summaries

Mike Schliebe reviewed the workshop discussions on Milestone A which dealt with waste generation reduction. It was recommended that segregation of nonessential material from potentially contaminated material be emphasized and that incentives be provided for waste generation reduction. In addition, to provide a method for evaluating the effectiveness of waste generation reduction methods, sufficient waste stream details should be established. He also emphasized that de minimis levels are needed for non-institutional low-level waste.

Howard Kittel summarized the discussion on Milestones B and G. Incineration was the principal volume reduction topic discussed. It was recommended that more information is needed on high-density compaction development abroad and that cost/benefit studies are needed to evaluate the usefulness of large centralized LLW incinerators. It was also recommended that DOE operations should be consistent with 10 CFR Part 61 if they are parallel to activities in the commercial sector.

J. Latkovich summarized the important points discussed in the Workshop on Milestone C. The consensus was that a siting demonstration at an actual site should be employed to establish credibility. In addition, a reassessment of the definition of this milestone was recommended because the connotation of "improve" or "improved" conveys the idea that adequate technology does not already exist.

Gerry DePoorter summarized the discussions in the Workshop on Milestone D. To ensure implementation of remedial actions at an optimum time, it would be helpful to develop performance objectives and action levels for a SLB site. Prevention was considered to be the most effective remedial action. Once a problem is recognized, operating procedures should be upgraded to prevent recurrence of similar problems at new SLB sites. The consensus was that the problem areas for remedial action technology are adequately identified and the current program is addressing most of the problem areas.

John Wiley reported on the discussion dealing with greater confinement in the Workshop on Milestone E. It was suggested that greater confinement would help mimimize biological intrusion and reduce the probability of inadvertant human intrusion. In addition, decommissioning and closure could be improved or facilitated by greater comfinement since a site may be able to be released from institutional control earlier than what would be expected for a SLB site. The consensus of the workshop was to "get on" with the two demonstration concepts and do a good job demonstrating to the public that greater confinement technology can be developed by 1986.

THIRD ANNUAL PARTICIPANTS INFORMATION MEETING
DOE LOW-LEVEL WASTE MANAGEMENT PROGRAM (LLWMP)
Hyatt Regency, New Orleans, Louisiana
November 4-6, 1981

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