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Proceedings of

ALPHA-CONTAMINATED

Waste Management Workshop
Gaithersburg, Maryland
Aug. 10-13, 1982

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PROCEEDINGS OF
ALPHA-CONTAMINATED WASTE MANAGEMENT WORKSHOP

Gaithersburg, Maryland

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FOREWORD

These proceedings are published to provide a record of the oral presentations made at the DOE Alpha-Contaminated Workshop held in Gaithersburg, Maryland, on August 10-13, 1982. The papers are transcriptions of these oral presentations and, as such, do not contain as significant detail as will be found in the reviewed papers to be published in the periodical Nuclear and Chemical Waste Management in the first issue for 1983. These transcriptions have been reviewed by the speakers and some illustrations have been provided, but these contain only the preliminary information that will be provided in the technical papers to be published in the periodical.

INTRODUCTION

Mike McFadden, Department of Energy/Albuquerque

I'm Mike McFadden, the Transuranic Waste Program Manager, and I would like to welcome all of you to the Alpha-Contaminated Waste Workshop. I emphasize the word "workshop." The way it's set up is that people are going to give papers, and we will have enough time after each paper to encourage discussion. We are sponsoring this workshop because of all the activity in the area of defining the lower limit of transuranic (TRU) waste [e.g., the draft 10 CFR 61, 40 CFR 191, and the Department of Energy (DOE) Order 5820]. We felt that if we pulled together all the technical expertise in this area from DOE, the Nuclear Regulatory Commission (NRC), the Environmental Protection Agency (EPA), industry, and participation from other countries, they could assist in defining this limit. We are going to do this by committee. We have a committee that will be analyzing all the papers and discussions, and at the end of the session, they will come up with a conclusion from all the papers. This committee is headed by Marty Steindler. He's with Chicago Argonne National Laboratory, and he will be discussing the format of the sessions, the committee makeup, and a little bit about housekeeping issues. Before he does, I'd like to issue some thanks; first to everybody who agreed to participate in this workshop, some of whom only had about 2 weeks to prepare their papers. We received great enthusiasm from everybody we contacted and that indicates to me the importance of this workshop. I would also like to thank Oak Ridge National Laboratory for agreeing to set up the workshop with such short notice. Special thanks to Herschel Godbee, Ed Frederick, and Carlos Bamberger. I'd like to thank the people who agreed to serve on the program committee. I think they got a shock last night at a committee meeting when confronted with the amount of work involved in serving on that committee. Also, a special thanks to Marty Steindler for agreeing to serve as the chairman of the committee and helping us set up the workshop.

OPENING REMARKS

Martin Steindler, Argonne National Laboratory

I want to emphasize several things about format, give you some housekeeping ideas, and then get off this podium as fast as possible.

The purpose of this workshop is to obtain a scientific and technical discussion on alpha-contaminated waste disposal: The focus is on the 10 nCi/g issue and the topics that surround it. The papers have been structured to give a background, some detail on present practices and on risk analysis, in an attempt to determine whether or not we can come to a consensus on the question of what the alpha-contaminating element concentration could be to meet whatever the standards are. The agenda of the 3-day workshop is not perfect, and it certainly is not complete. The consequence of the deficiency is that you, the audience, are going to be an important part of the workshop. It is absolutely necessary that this be a workshop with a capital "W." We have asked each of the chairmen to make sure that we have as much audience participation as possible. We are interested in obtaining questions, and we hope we can get reasonable answers from the speakers. We are anxious to encourage discussion. We are, in short, trying to air whatever technical and scientific issues there are in the various topics. In the technical sessions, the speakers have between 30 and 45 minutes, followed by about 15 minutes of discussion. The schedule, as in every formal situation, is important, but I would like to emphasize that the schedule is not king. It is much more important to air whatever has to be aired on a technical topic.

We do plan to publish the proceedings, particularly the technical papers. The details of how that is going to be done are not developed.

Let me now turn over the podium to Goetz Oertel, who is the chairman of this session.

WELCOME

Goetz Oertel, Department of Energy/Headquarters

I'm Goetz Oertel from the Department of Energy (DOE), Office of Defense Waste and Byproducts, and I certainly want to welcome you on behalf of DOE to this meeting. I am impressed with how many people did come. The list of participants and speakers reads like a "Who's Who" in this area. I would like to recognize Dr. Charles Gilbert, the Deputy Assistant Secretary for Nuclear Materials including Waste Management, who is here with us today. Chuck, if you'd like to raise your hand so that people know who you are. I'm very pleased that he will be with us for as long as he can. I would also like to mention for those of you who deal with my office that we have a new Director of the R&D and Byproducts Division by the name of John Jicha. John, please raise your hand.

Nuclear waste has been much like the weather; people like to talk about it a lot, but nobody does anything about it. That's changed. As you probably know, nuclear waste is under control, which is more than we can say for many of the non-nuclear hazardous wastes; everything is either being disposed of or it is in safe interim storage. Now, safe interim storage is a noble and important objective, but it is not a solution. We are defining such solutions and, rather than only studying the issues and doing more R&D, important as that may be, we're doing something about it.

The Waste Isolation Pilot Plant (WIPP) is well under way. Two shafts are down to full depth, and they are connected. This facility is now much further along than any other facility of its nature in the world, considering that it is in a new site that has not been previously used for any other purpose. The Defense Waste Processing Facility is being planned. More than that, it is being designed, and the process is already working at Savannah River (with actual waste in the laboratory and also in the engineering test facility) at full or nearly full scale. We are ready to build that facility, and Congress has authorized the project. The commercial repository is being developed, which will also be, in our reference plan, the final resting place for defense high-level waste. Nuclear waste legislation is moving through Congress at an unexpectedly rapid pace. I'm very encouraged by that. Chairman Dingell's committee has reported out H.R. 6598 less than 1 week ago. We have high hopes that Congress will pass a bill for nuclear waste in the House as it already has done in the Senate. We may have comprehensive nuclear waste legislation in this country very soon.

We are not only addressing the inventories of transuranic (TRU) and high-level wastes, we are also looking again at the definitions of nuclear waste so that, as somebody at the Nuclear Regulatory Commission (NRC) once put it, the punishment may fit the crime. Rational definitions are finding their way into the legislation I was talking about: high-level and TRU wastes are being newly defined.

Certain specific numbers will have to be determined by the regulators. Today's meeting is going to help develop what those numbers should be.

Finally I should mention that we are planning to use some of the materials in nuclear waste for those beneficial purposes for which they may be suitable as byproducts. This is not today's subject, but we are very encouraged by developments in that area. We will not treat as waste what we can use.

KEYNOTE ADDRESS

Governor Dixy Lee Ray

Before May 18, 1980, in the State of Washington, I used to use an expression when we really welcomed people, which was that we should be willing to do anything for them, even move mountains. I don't use that welcome anymore, but I do think that the organizers of this workshop must have moved a few mountains to achieve what is being begun this morning. I have been in the federal establishment long enough to know how long it normally takes to get anything done and to organize a workshop of this magnitude and significance in a few days. It is nothing short of a miracle. I'd like to add my congratulations and commendation to those who are responsible and especially to Herschel Godbee from Oak Ridge, who had a major role in this enormous organizing effort. I'm sure the results will be everything that the organizers have hoped for.

The issue at hand is alpha-contaminated wastes and, indeed, I will refer to this in time with a few brief comments. First, I'd like to speak a little bit more broadly about waste. Often, dealing with the subject of waste, and particularly with the subject of radioactive waste, we get defensive. Waste has a negative image. We don't even call garbage "waste" anymore. It is something you put into a sanitary landfill. But we still call the place where you dispose of radioactive waste a "dump." It is the only place now that is called a dump. We do not even dump sewage, which is a waste that can harm the environment. We don't even pay any attention to some wastes--coal wastes, for example. We just scatter them everywhere, and their toxicity lasts forever. We don't worry about those; we just anguish over the ones that are radioactive. Those of us in the nuclear game come to feel that we're carrying a heavy burden. Well, we shouldn't. We should remember that we are dealing with radioactive waste because these materials are the end product of some of the most exciting and uplifting enterprises that the world has ever known. We have radioactive waste because we have a way to make energy for human society without burning fossil fuels. We have radioactive waste because the knowledge that enriches and ennobles the human mind and spirit has grown, and we know much more than in the past.

Those of us who were already adult in the early 1940s remember what it was like before the atomic age, and although I don't feel decrepit yet, I'll be 68 next month. My lifetime has encompassed the birth and growth of just about all our knowledge and understanding in nuclear science. It has been one of the most exciting episodes in the great human enterprise.

The history of western civilization is, to a considerable extent, the history of growing knowledge, the history of unprecedented personal liberty, the history of knowing how to use energy and put it to use for the good of mankind. A little historical perspective is not

bad in starting out a workshop like this one, so let us remember that for 5800 years out of the 6000 years of human civilization, most of the fossil fuels and certainly all of the fission energy lay buried beneath the earth's surface. Only wind, falling water, and the burning of wood augmented human and animal labor. Then 200 years ago, the burning of fossil fuel began to spread throughout the western world, and our knowledge began to develop at an explosive rate. Eighty years ago, the United States population numbered about 76 million persons, and they used 10 quads of energy, which cost them about $4 billion. That 10 quads of energy was equivalent to a per-capita use of about 40,000 kWh thermal. To put it in somewhat starker but perhaps more expressive terms, it was equivalent to the physical labor of 110 human slaves, each one working 8 hours a day, 365 days a year, for every man, woman, and child in the United States and each slave consuming no energy himself and being paid the handsome wage of 0.001 cent per hour.

In the 1980s, we've increased our energy use in this country quite a bit. For a population of 220 million people we now use about 80 quads of energy annually and that, in the same sort of analysis, equates roughly to each one of us having about 300 human slaves under those same conditions. But the costs have gone up enormously. Now we would have to pay them 0.1 cent an hour! How many of you have negotiated labor contracts recently? Can you think of any work being produced at a salary of 0.1 cent an hour except that which comes from the energy we use?

Let's look at our energy use in another way. Everybody has to eat, although I suppose some of us eat more than we need to. In 1910 one United States farmer could feed 7.1 persons. (I always wondered what that 0.1 fellow must have looked like.) Today the American farmer can feed 59 persons. On a worldwide average, one farmer feeds just a little over 5 persons. In 1910, one U.S. farmer with a team of horses could plow 1 acre per day. Today with a tractor he can plow 35 acres per day. In 1910 one acre of land could yield the equivalent of 26 bushels of corn; today the same acre could yield the equivalent of 97. Energy and technical knowledge make the difference. Some people today would have us return to some kind of preindustrial, nostalgic, pastoral time of presumed simplicity and great calm, but they don't know what the past was really like.

Could we return to preindustrial agriculture, without the heavy energy use that we have today? Even with modern agriculture we don't feed the whole world, but just feed the United States and about a quarter of the rest of the world. In 1910, without the energy use of today, 25% of the arable land had to be set aside to grow feed crops for the farm work animals. If we were to produce today's crops with preindustrial technology, imagine the large areas of land that would have to be set aside to grow food for the farm animals and for the 27 million farm workers who would have to take care of them. We would require, in the United States alone, about 61 million horses

and mules. It would take 20 years to breed this number because there are only 3 million alive today, and there is no way you can speed that up. (After all, it takes 9 months to make a human baby. You can't speed it up and still have a full term, normal, human infant. You can't spend more money; you can't hire more physicians; you can't improve the mother's diet; you can't even have the mothers all wishing hopefully that the time would be shortened. It just doesn't work. You can't even get 9 women pregnant and get a baby in one month! It takes time.)

The use of energy in agriculture is important. Eric Rutley, Secretary General of the World Energy Conference, said at the International Conference in Toronto in 1980, "If energy for agriculture machinery were suddenly taken away from us, right now, most of the world's population would have to die, not over the natural span of three score years and ten, but suddenly." Yet there are those who keep telling us we shouldn't use so much energy, that we don't need nuclear energy and all of its problems, that we should return to more labor-intensive activities. What do they really mean?

In 1934 when I was a student in college during the Great Depression, we argued the merits of the Works Progress Administration (WPA). WPA was one of the first of the alphabet agencies. It was a government program for providing jobs, something that is being urged today. The symbol of WPA was a shovel because a great deal of the work was manual labor such as laying pipe for water systems and sewage plants. In my economics class we argued the merits of this program and, being young and idealistic like all young people are supposed to be, I held out strongly for its merits. I pointed out to my professor, whom I thought very dull in this regard, that, after all, the WPA program at least put people to work; it provided jobs. I thought it was a very powerful argument. He looked at me for a few moments and then said in a quiet voice, "Young lady, if the objective is merely to provide jobs and work, why give them shovels? Why not give them salad forks?" It was my first lesson in economics, and I have never forgotten it.

Energy makes things better. Another lesson in labor-intensive work came years later when I was studying at the Zoological Station in Naples, Italy. I took a trip to the place called Cuma, not very far outside Naples. This is where the Greeks first landed on the Italian peninsula and where the Sibyl's Cave is located. To enter it, you walk down a dirt tunnel into an excavated cave. The natural gas flame is still burning. It is eerie. I was not impressed, though, when I looked at the walls of those tunnels. I could see the imprint of the fingers of the slaves who dug that tunnel with their hands. Now that's labor-intensive.

To do things the way we do today, which I'd say is better for everybody, takes energy, not just for production of food and fiber, but for everything else. At the risk of over-simplifying, it's good to remind ourselves occasionally that energy made industrialized

society, not just transportation, possible. Energy powers our agriculture and produces our food and fiber and the pesticides, medicinals, and herbicides that make possible more productivity from the land. Energy is required to operate all commerce, and energy eases domestic living. Energy powers high technology. It runs our communications systems and it controls the computers that seem to order our daily lives. We in western civilization must be doing something right, because despite all of the criticism, despite all of the negativism, we have a kind of life today in our industrialized society that makes it possible for more people to live longer and healthier lives, freer from hard manual labor, sharing more of society's goods and services and comforts, and enjoying more personal liberty than any other society that human beings have ever invented. It isn't perfect, it's just better than any that's ever been known. We must have achieved something; we must have been doing something right to have an average life span of 73 years.

Make no mistake about it, life in industrial society is not an unmitigated good. It has its risks and its problems. But we are surviving those risks and solving those problems better than has ever been done in any other society. The curious thing is that a lot of people today don't seem to think so. They apparently believe that there should be no risk at all. They believe, apparently, that life is full of intolerable risks, and they demand that corrective measures be forced by government at whatever cost. My all-time favorite example of the do-gooding protection by government is the case of the humble hamburger. This ubiquitous meat, so important to so many of us, is controlled by 41,000 regulations, 200 legal statutes, and 161,000 precedent-setting court cases brought on behalf of consumers that make it cost 8 to 11 cents more per pound. And you thought nuclear had a lot of rules and regulations. Doesn't it make you feel well protected when you bite into a hamburger?

To return to energy and particularly to the nuclear activities that generate transuranic (TRU) waste, there is an overwhelming clamor for total protection and complete safety. Can this ever be achieved? No. Is it necessary? No. But the public perceives it otherwise. Apparently, it's not enough merely to point out that other activities also are risky. Automobiles, for example, take 50,000 lives per year; TRU waste takes none. For all their lethal and toxic aspects, nuclear wastes have not killed or even hurt anyone. Despite a massive public education campaign, 50 million Americans have not been convinced to give up cigarette smoking, even though it is well established that cigarettes lead to about 150,000 fatalities per year and contribute to immeasurable suffering from respiratory ailments. Furthermore, an average cigarette smoker contributes about 8000 millirem of radiation directly to his bronchial epithelium. Yet I've often seen people carrying signs that say, "No Nukes!" and smoking. The average smoker gives himself a radiation dose equivalent to about 300 chest X-rays per year, but is anyone more afraid of a cigarette than of a low-level waste storage site, even one 100 miles away?

There is absolutely nothing new about radiation. Mankind has always been bombarded by radiation from various sources. Cosmic rays reach us from outer space. Natural radioactivity is found in rocks and soils and in building materials such as bricks and stones. Within our bodies potassium-40 is naturally radioactive. The air we breathe contains a little bit of radon, a natural radioactive gas. However, some believe that if the radioactivity has been caused by human activity, it is different, somehow more lethal and worse than what has been placed here by the hand of God. Little attention is paid to natural radiation, which in fact we could reduce considerably if we didn't insulate our homes so much or use expensive heat pumps. Only in nuclear wastes and nuclear science activities is there great alarm, even though other sources produce hundreds of times more radiation than nuclear waste and even though all the nuclear waste that we have can increase our radiation exposure not more than a tiny fraction of 1%.

What can we do about this curious situation? I believe there are two things. One of them is just exactly what you're doing--trying to bring more reason, better rationale, and, I hope, a large and generous dose of common sense into our definitions and our rules and regulations about the proper handling of waste and other nuclear activities. Second, we can all benefit from paying more attention to the public's fears and perceptions. It's imperative that this present momentum towards establishing a national policy for the management of TRU waste should be maintained. The public, also, must be informed, unequivocally, that there is a national resolve and that technology is adequate to protect health and safety. Nothing will reassure the public like an early demonstration in a safe site.

Although this task will not be easy, the public must become better informed about relative risks. For example, most people, and even many scientists, believe that any amount of radiation, however small, however low-level, will cause detectable harm. Arthur C. Upton in a February 1982 article in The Scientific American defined the hazard from low-level radiation: "If it is real, is too small to be detected." Out of a million people exposed to low-level radiation, about one might die. This risk is equivalent to travelling about 60 miles in an automobile, smoking one to three cigarettes, visiting for two months in Denver, or working 3 hours in a coal mine. Nevertheless, when asked to rate hazards many people consistently rate nuclear power and the results of nuclear science activities as more hazardous than any other type of exposure, including automobiles, hazardous handguns, smoking, drinking alcohol, or undergoing major surgery. Nuclear power stations are rated as more hazardous than 15 other activities that contribute, by actual record, more deaths per year.

What leads to such perceptions of risks? I remember a professor at the University of Colorado who said recently, "I am a critic of nuclear power. I am one of those people who can listen to

pedigreed scientists give me a list of statistical risks that are hard to refute, and then I turn around and I take the reading of my own gut feelings and I come away disbelieving everything that I have heard." How can logic deal with an attitude like that? It's very difficult. Often after I have responded to objections raised by otherwise intelligent individuals who oppose nuclear power, they finally say, "Alright, I'm sorry, I know you're probably right, but I just don't like it." A representative of one of the active groups opposing everything in the nuclear field recently said, "They (the supporters of nuclear power) want you to use reason and logic. It's time to start using our emotions and our feelings, not reasoning and logic, in making our decisions." These attitudes have profound meaning for those of us who believe that only through rational use of our knowledge can the world be made a better place for human beings. We believe that having sufficient energy is important to human society and requires the use of nuclear power with all of the attendant risks, including the manufacture of waste. We need a better understanding of the perceptions of the public and how to deal with them. Dr. Robert L. DuPont, the behavioral psychiatrist at the Institute for Behavior and Health in Washington, D.C., points out that irrational fear of nuclear things has all the attributes of a phobia, a phobia caused by attitudes toward risk, which in turn are rooted in three simple psychological perceptions, all without any basis in fact. These perceptions are: first, that the individual controls the risk; second, that the risk is greater if it shows up in one big event rather than separate small events scattered over time and space; and third, that the risk is greater if it's unfamiliar.

All of these perceptions are important. Familiar things, no matter how dangerous they are, are just about impossible to fear. Nuclear powerplants and nuclear waste sites are not. The requirements for remote siting, restricted access, and evacuation plans all reinforce in the public mind the emotional fear of the unknown. We have to be more explicit in dealing with the public. We should be understanding of their fears, which are very real, even if the basis for them is not. We should not be drawn into playing their "what-if" games, but consistently and carefully we should concentrate on what is factual. We should work more effectively with health agencies to put both cancer scares and genetic risks into proper perspective and with the news media to try to gain fairer, more unbiased coverage.

One personal experience taught me that to get the public attention, or even the attention of people who ought to be involved, you need to do something drastic. As some of you will recall, in 1979, I was Governor of the State of Washington. For good and sufficient reason I closed the low-level nuclear waste site in the state and kept it closed long enough for wastes to pile up in hospitals. Their storage areas got full, and they began to get worried about what they were going to do. For the first time, the chairman of the Nuclear Medicine Department at the University of Washington said to me, "How can I help?" I said, "Go on TV and tell the public." He did, and he got

a lot of other people to do the same thing. For the first time the average person in the State of Washington began to realize that there is such a thing as nuclear medicine, and that it causes nuclear wastes also, and that those nuclear wastes have to be taken care of.

Every day about 300,000 health and medicine procedures in the United States involve nuclear materials. How many people realize that when a person receives an injection of a radioactive material for a diagnosis or for therapy, 99% of the radioactivity goes into his body? What's left over is stuck in the hypodermic needle, the edges of the bottle, the cotton swab, perhaps, that cleaned the puncture point, the doctor's rubber gloves. All those things constitute nuclear waste, but 99% of the radioactivity is in the person's body. The patient is not a hazard to himself, his family, or his friends. He can deposit that waste in the usual receptacles when it leaves the body, but is is not nuclear waste. when he dies, he doesn't have to take "the old bod" over to a nuclear waste dump. That 99% is beneficial; only that 1% is nuclear waste.

We need a little common sense. Rules may not always be sensible even if they are rational. It's time for us to pay a lot more attention to what is sensible and what is rational in making our rules. We ought to recognize, as a recent publication from the National Council on Radiation Protection did, that radiation is not the most dangerous exposure. This publication compared the permissible body burden for lead and plutonium. "We assume for purposes of illustration that a body burden (for lead) 100 times greater (than normal) will have a relatively high probability in resulting in a fatal cancer and therefore (will be) described as a dangerous body burden. Therefore a waste containing 10 nCi/g of plutonium-230 as compared with lead. . . ." The publication adds, "If a storage battery contains 50% lead by weight and a lethal body burden of lead is taken to be 2.3 g, the battery waste contains about 0.20 of a potentially lethal body burden per gram of battery. We see thus that gram for gram discarded, lead is many times more lethal than plutonium in contaminated waste at a level of 10 nCi/g. The point is that we have had a large amount of experience with the disposal of lead storage batteries and we know that they are a potential hazard; however, we also know that hazards can also be controlled by common sense procedures. We do not inter all the storage batteries in perpetuity in geological repositories."

For nuclear waste disposal, we also have the question of cost and the question of measuring the cost of a procedure against the benefit derived from the procedure. I wish we could think of new terms rather than saying cost-benefit because that has become hackneyed, but cost-benefit does make a big difference. The report on the Council on Radiation Protection says, "The difficulty with any single numerical criterion is that it results in a sharp transition at whatever level is chosen. In this case, speaking of the 10 nCi/g, a sharp escalation occurs in the cost of disposal when the concentration of transuranic waste exceeds the 10 nCi/g. At 10 nCi/g the waste can

be disposed of in shallow burial, which at a reasonably large site is accomplished at a cost of approximately $460/m^3$. Taken literally, if the concentration were to be 11 nCi/g, thus requiring the waste be packaged for retrieval, storage, and ultimate interment in a geologic repository, the cost would sharply escalate to about $20,000/m^3$."

Questions on limits and cost-benefits are some of the difficult and soul-searching decisions that only people like those in this room, knowledgeable in all the technical aspects of the subject, can properly and intelligently discuss, analyze, and evaluate and recommend answers. It is a heavy responsibility, and it means a great deal more than even you perhaps perceive.

Again, despite the negative aspects of dealing with something that has this awful word "waste" attached to it, the problem is of great importance, and it has come about because of important and positive actions. Solving the problems and getting the public to understand will require the kind of enlightened leadership and cooperation that have brought all of you together. American society for too long has been mired in the slough of polarized recrimination and litigation. It's time to return to the concept of the common good and to adopt attitudes like those propounded in Goethe's Faust. Faust, having tested and tasted every kind of human pleasure, became jaded with self-indulgence. He found solace at last in a mundane engineering project. We should remember Goethe's words, "Whosoever aspiring struggles on, for him there is salvation." May all of you who struggle to bring calm reason into this troubled field enjoy Goethe's wisdom and have a taste of Faust's salvation and ultimate triumph. Thank you very much.

Ken Gablin, K. A. Gablin and Associates: Governor Ray, driving up here this morning I had a chance to get almost chopped off in the right lane by a woman driving very fast in a car with New York license plates and two bumper stickers that said, "Use the Solar Solution to Nuclear Pollution," and, "Equal Rights Amendment--Yes." Could you comment on those two bumper stickers?

Ray: I believe that nothing has contributed more to equal rights, to the liberation of women, than use of energy. The most outstanding contribution has been made by electricity in the home. The first big step forward in the liberation of women from bondage occurred sometime between the 11th and 12th centuries in western Europe. It was technology, the invention of a spinning wheel. Before that time, spinning, women's work, was done by taking a stick called a distaff and winding thread on it. Weaving was always done by men. It took six women with distaffs to keep one weaver busy. After the invention of the spinning wheel, one woman could keep nine weavers busy, and for the first time women's work become important in the marketplace. Also at this time, women gained the right to keep any wealth brought into a marriage, to hold property in their own names, and to inherit wealth from their husbands. A woman no longer had

to marry to be supported; the term spinster originated to describe an unmarried woman, particularly one who supported herself. The next big advance in women's liberation took place with three technological developments: the telephone, the typewriter, and the sewing machine. Now, women no longer have to shake down the ashes, chop the kindling, carry the water, and do all of those things that always have been women's work. Electricity has made it possible for women to go out and protest and talk about equal rights. Today, one person with a machine or an engine can do the construction work that once took 565 men to do, and the person pushing the button or moving the levers could be a woman just as easily as a man. The Equal Rights Amendment people ought to recognize that energy has liberated them, and the best, the cleanest, the safest, and the cheapest way to produce energy is nuclear.

HISTORICAL OVERVIEW

Alex Perge, Department of Energy Headquarters

For this talk, I've made a number of notes. I have gone over them a number of times and finally cut out a lot because they might not be very useful in the meeting. I was also concerned about the order of the program, following Dr. Ray. After Dr. Ray's appearances before Congress, it was an easy job to review the transcript of her testimony because the transcripts come out in perfect English; they are in perfect order, well thought out, and need nothing.

The program to produce significant quantities of plutonium started at Oak Ridge National Laboratory (ORNL) and, shortly thereafter, at Hanford. For a number of years, the original program carried the philosophy that "everything had to be recovered." Production was grams and hundreds of grams, and "nothing was lost." Of course, "nothing lost" depended on the ability to measure what you had and to know where it was. Very elaborate systems of accountability were set up and used for transferring materials. One of the largest parts of the work force was made up of analytical people, who carried out tremendous amounts of analyses that had to be done for moving things back and forth.

The wastes that were generated of the trash variety were kept in the vicinity of the facilities that generated the waste, eventually resulting in a large number of disposal or burial grounds at Hanford. One basic concern was measuring the insides of pipes and tanks because they were inaccessible. This resulted in the original concern over the release and disposal of material into the burial grounds.

Eventually, in the mid-1950s, with the advent of eight reactors at Hanford and five reactors at Savannah River, we got to the point where we were accounting for materials in larger total quantities. We were now working with hundreds and thousands of kilograms instead of grams and tens of grams. Accounting for the plutonium moved from milligram quantities to the concept of replacement costs. During this period, the amount of plutonium being disposed of suddenly started to increase. It was too easy in some cases to justify nonrecovery because the replacement costs were much less than the recovery cost.

It was during the mid-1950s that Argonne National Laboratory (ANL), ORNL, and KAPL came into operations with reprocessing pilot plants. These facilities started working with gram quantities in the laboratories. These were the three major sites in the mid-1950s (not including the weapons production program) that were dealing with plutonium. Milligram quantities of material were only disposed of by accident. In fact, with the emphasis on measurement and recovery of material, very extensive efforts went into producing equipment that would make it easier to recover plutonium. Pilot-plant equipment at

these sites even had mirror finishes on the vessels to promote the recovery of plutonium.

During this period, the work in Belgium, the Eurochemic program, started developing. The ideas that were being considered in the Eurochemic plant did have some influence in the United States. The Eurochemic plant is probably, in terms of Hanford, the world's worst site for an operation of that sort. You scratch the surface and you hit groundwater. If you back up too fast, you are in somebody's backyard. You have vegetable gardens all around. So a great deal of effort went into (1) containing all the waste on site, (2) reducing volume, and (3) providing proper packaging.

During this same period, Joe Lieberman headed a group that visited Russia and saw the Russian activities in the treatment and disposal of low-level waste. This had an impact on those who went and on those who heard about the activities because much effort was directed at confining the material and storing it in small spaces. It was also during this period that the Ontario Ordinance Works, which was a site for receiving waste from the northeastern part of the United States, was in a transition phase of closing out and was cleaning up.

The weapons testing program was at its height with above-ground testing, and it was being monitored by many people from our other sites. The Hanford site sent many people to the test site. The test monitoring had an influence on those people because, up until then, they were worried about conserving all of the plutonium they had. They were also concerned about monitoring and reducing exposure to people to the nth degree. Suddenly, they were thrust into a new environment and a relatively dirty one. This had to have an effect on their thinking and also affected the thinking at other sites because (with the advent of the program at KAPL, Brookhaven, and several other sites) Hanford personnel were leaving to work on those programs. When they joined these new programs, these people brought along their thinking. In the latter part of the 1950s there was a lot of concern about uranium-233. There were several programs aimed at producing uranium-233. Some of the uranium-233 produced was not used, and disposal of these contaminants and products was being considered.

There was a series of renovation projects: cleaning up the Harshaw Chemical Plant, renovating the Oak Ridge Gaseous Diffusion Plant, cleaning up of the Destrehan Street Plant. All of these projects were concerned with release of material to the uncontrolled environment. Decisions were being made about what activity levels would be allowed for release of materials. In many cases, there were very conservative guesses made. In other cases, as we have found recently, the guesses weren't conservative enough. Sometimes we've gone back for the third time to clean up something that we thought we'd cleaned up adequately in the mid 1950s. In all of these cases, one of the main decision-making points was to equate the activity of concern with the natural

occurrence of the radionuclides that we were dealing with (e.g. radium).

In the late 1950s we had an accident at the ORNL 3019 building; a plutonium evaporator exploded, causing many concerns and problems. The accident required rethinking of control methods and control values for clean up and material release.

All of these incidents were significant in making us develop criteria for acceptable levels for material released to the uncontrolled environment. In many of these cases, where irradiated fuel elements were handled, plutonium was the controlling factor and the controlling concern. Decisions concerning discrimination levels for disposal on a restricted or unrestricted basis were being made regularly from the earliest days of the program. As the following events show, with the aging or growing maturity of the programs, the needs for guidance, and the guidance itself, became more complex. I must comment here about Goetz Oertels' comment that we are now starting to do something. Bill Lennemann did produce a document outlining the Atomic Energy Commission (AEC) waste management program and another report concerning its isotope recovery program. The AEC did take an interest in publicizing what we were doing and issuing standards, guidelines, and criteria. These were all wrapped around program plans that were made public in most cases.

The commercial burial grounds program was opened in 1963, allowing commercial firms to ship their low-level waste to Oak Ridge and to Idaho. Again, this brought up the question of what was allowed to go into the burial ground because there was concern over the plutonium content. However, the waste from commercial programs essentially carried no plutonium. There were things going through the commercial system that came from some of our own operations, but in most cases, the amount of plutonium being handled was very small and the consequences of error with the guidelines that were used were not significant.

This was also when the ocean disposal program that we'd been carrying out stopped. Ocean disposal was prohibited until a comparison was made between the cost of land burial and the cost of ocean disposal. Again there was the question of what was allowed to be buried and what plutonium contamination levels would be used. Incidentally, in every case where this evaluation was made, it turned out that the cost factors were weighted in favor of land disposal by at least 4 or 5 to 1. These evaluations resulted in a series of volume reductions for a period of 2 or 3 years as a result of people being forced to look a little more seriously at what they were burying and how they were packaging it for burial.

In the mid-1950s because of concern over the spread of plutonium contamination (especially at Hanford) through the burial programs, a cut-back was made of the burial program. At Hanford alone, which had

about 30 burial grounds, the number of burial grounds was cut back to about 3.

The Public Health Service was involved in the cleanup of radium- and thorium-contaminated facilities around the country. They were also trying to withdraw radium from the medical system and to replace it with cobalt-60. Much of this radium was sent to the AEC for disposal in burial grounds. Comparisons needed to be made of the health hazards from these isotopes with those of plutonium. How and where should they be buried?

At the same time, ANL was in the process of developing a burial site for the fuel from the EBR-2, which consisted basically of blanket elements. Again, what was to be done and how it was to be done was the basis of concern about the plutonium content. This was the start of retrievable burial concept. ANL was directed to dispose of the EBR-2 blanket elements in such a fashion that they could be retrieved at a later date in a package that could be retrieved contamination-free.

Los Alamos National Laboratory entered into its large renovation and cleanup program during the 1950s. Numbers were being developed at Los Alamos for control of the decontamination and proper disposal of these old facilities, which consisted of wooden buildings and equipment.

We also had several programs that were beginning to consider the use of plutonium-238. These programs introduced another problem--whether the concern about plutonium-238 should be the same as that about plutonium-239. Two of the sites that handled plutonium-238 did not handle plutonium-239. That made it a little bit easier. However, Savannah River, where most of the plutonium-238 was produced, was beginning to have problems dealing with the two different isotopes.

Several sites may be foreign to most of you: Clarksburg, Granite City, and a site in Baltimore. These were facilities that were part of the weapons materials production program and also part of the very large program for receiving ores from outside of the country. The Department of Agriculture had a very big program, sending food overseas and receiving ores in return. Many of the ores were radioactive (e.g., pitch blend and thorium ores). Rare earths were being stored in conventional warehouses with unconventional storage systems. We had to deal with cleaning these up and had problems agreeing on what would be allowable contamination that could be left behind and what couldn't be cleaned up very easily.

In 1967 at an International Atomic Energy Agency (IAEA) meeting, John Anders of Los Alamos National Laboratory presented a paper on the Los Alamos cleanup program. For the first time, a comprehensive program was presented on the cleanup criteria and was openly discussed. When I say openly, I mean in an environment outside of the AEC's own operations. The cleanup criteria used at Los Alamos for that program

was listed as 1000 d/m over 60 cm^2. I don't remember the type of instrument that was being used, but it was identified. This was the limit that was used for just what could be left behind. This was also the start of serious discussions on issuing comprehensive disposal regulations. We finally realized that operations at one or two of the sites were affecting other sites and that the problem was not localized.

In 1968, the General Manager appointed a task force on AEC operational radioactive waste. This was triggered by a Government Accounting Office (GAO) report that questioned the documentation of some of our practices and the organization of the waste management program. The General Manager asked that the task force report back to him by August 1, 1968. There had been two previous studies on changing the organization of the waste management program in the AEC, but in both cases a decision was made to make no changes. The task force consisted of George Quinn, Assistant General Manager for Production; George Kavanaugh, Assistant General Manager for Research; John Vincegvara, Assistant General Manager for Administration; and John Earlewine, Assistant General Manager for Operations. These people met almost daily and reported to the General Manager weekly. The intent was to develop a report showing what activities had to be factored into the budget cycle for the 1970 fiscal year. Because of the shortage of time and the concern over high-level waste, the study concentrated on Hanford, Savannah River, and Idaho. Their major recommendation was that the solidification of all high-level waste should be completed by the end of December 1975. The report also noted that further study should be made of the low-level waste and plutonium-contaminated waste.

At about this same time, several other things happened that I will mention because they enter into later comments. In 1969, the IAEA had an advisory committee on developing waste categories. One of the points they made was that, for the alpha waste, the measurements and the reporting should be on the basis of curies per cubic meter. Also, transuranic (TRU), the real program at ORNL, was well under way. ORNL had a program that used the term TRU: it was a reactor program for producing TRU elements and became a large program for producing californium.

We had to face up to the issue of returning material from the plane crashes in Spain and in Thule, Greenland. In both crashes, there were problems in determining what could be left behind and what could be shipped back. Because we didn't have acceptable discrimination rules, we wound up with what seemed like most of the soil from Spain being returned to Savannah River. For a while, we felt that all of the ice from Greenland was coming back too.

Another development that occurred at this time, as a result of the GAO report, was the requirement that formal waste management plans be developed by all of the sites. They were to be kept current. Each

type of waste had to be addressed in the plan, with statements about objectives for managing waste, the standards being used for judging performance at the site, and creation of essentially a material balance of the site.

At about this same time, the Rocky Flats fire occurred. This fire resulted in a large quantity of material being shipped to Idaho, which was the Rocky Flats repository from the day the Rocky Flats operation began. The shipment of this large quantity of material to Idaho resulted in the agreement between Seaborg and Church (Dr. Seaborg, chairman of the AEC, and Senator Church from Idaho) that, before the end of the 1970s all of the material resulting from the fire would be shipped out of the State of Idaho. This caused a flurry of activity, and a meeting was held to decide what should be done about getting this material out of Idaho. Joe Liebermann, Walt Belter, and their waste management R&D program had just finished one of the phases of the work at the Lyons, Kansas, mine. They still had about 1.5 years to go before decisions could be made as to whether Lyons could be a repository site. However, the AEC felt, over Joe's objections, that they had had enough time and it was put up or shut up time. Plans were made to expedite the work at Lyons so that plutonium-contaminated waste could be moved to that potential repository.

The General Manager's task force was still meeting periodically, but because of the increase of concern about plutonium-contaminated waste, General Giller and John Abbadessa were added to the task force. General Giller was head of the Military Applications group, and John Abbadessa was controller of the AEC. Additionally, the General Manager insisted that he have evidence of action; it was very interesting to see the AEC's six top men meeting regularly on waste management activities. There were a few times when they felt that they didn't have enough substantive matters to talk about, but they knew they still had to satisfy the General Manager. They asked for some help, and Bill Lenneman, Walt Belter, and I were assigned to work with them. They wanted to know if there were any icebergs in the system and what might be the next area of concern that they should face. Our recommendations, on the basis of this long listing of events that I have given you that occurred over 15 years, was that the problems concerned with plutonium-contaminated wastes and their disposition had to be faced. At that time we still called the problem "plutonium-contaminated waste," and I sometimes feel we should have kept that term instead of changing to "TRU-contaminated waste." In reviewing this program, it became evident that waste volumes had to be reduced, not only in the generation of waste but also after the waste had been generated. The General Manager quickly released a statement to all operations that volumes had to be reduced. Not only that, but he called each of the field office managers personally and required each of the assistant general managers to call their field office and contractor representatives personally. Within a very short time, there was a dramatic reduction in the amount of plutonium-contaminated waste that was generated.

In December 1969, the results of the General Manager's task force came out with a notice that went to all operations: segregation of plutonium-contaminated material had to begin. The discrimination level was simply stated as any plutonium detectable, and isolation of material was required. An example was given based on the Savannah River practice, that 0.5 g/m^3 per 5 ft^3 box (a standard system at Savannah River for measuring plutonium that went to the burial ground) would be acceptable to start with. It was expected that there would very quickly be a reduction by a factor of 10. Then the question arose, how do you measure that? That question is still a problem today. How do you do the measurements? The task force recognized that this project would be costly, and they insisted that a cost evaluation be made of burial versus storage plus processing. The implementation time was 6 weeks. Exceptions were allowed, but only on the basis of written requests to the General Manager. Obviously 6 weeks didn't give much lead time for doing things. Emphasis was given to proper packaging and storage in a contamination-free mode. The statement issued at that time stated that, to improve the AEC posture on its own radioactive solid waste handling, decisions were being made that required a concerted effort by all to reduce the quantity of radioactive solid waste generated. Volume reduction methods (e.g. sorting, compacting, and incinerating) were to be used. This is an important point. This requirement of the General Manager's task force followed the practice in most European countries, that is requiring that some sort of treatment be given to the waste and that an attempt be made to recover or, better stated, to remove, the plutonium in the waste, making the remaining waste a little more amenable to disposal or further storage.

The plutonium or TRU nuclide contaminated radioactive solid waste was to be stored separately and to be retrievable for possible relocation or reprocessing in the future. Although there was no evidence that these radionuclides weren't being satisfactorily retained in the existing burial grounds, their long half-lives and high specific radiotoxicity posed prolonged surveillance problems compared to other radionuclides. This situation was one of the bugaboos of the waste management programs. The question generally asked by Congress or by others who eventually controlled the money was, "Is anything wrong? Has anyone been damaged? Has anyone been hurt?" And the answer always was, "No, everything is safe." And so, "let's wait another year." The General Manager's task force faced up to the open ends in these statements and formed three working groups. One was concerned with sorting, under Harvey Soule. Another one was concerned with compacting the waste, under Ray Walton. The third was concerned with incinerating the waste, under Bill Lennemann. Two of these reports were published, receiving widespread distribution. The sorting report came out about January 1971, and the compaction report in June 1970. The incineration report, as received, was an illuminating and detailed engineering document, but it received less distribution than the others.

The sorting task force report, used to follow up on the discrimination numbers and give further guidance, resulted in the numbers that are now frequently discussed. The 10 nCi/g of waste limit was derived from the upper range of concentrations of radium-266 in the earth. The report stated that this limit was subject to modification based on long-term studies of nuclide migration in soil. The activity density was allowed to be averaged over a larger number of containers and areas. If individual containers were over the 10 nCi/g level, it wasn't considered to be a catastrophe. Plutonium-239 measurements at this activity density were not practical in plant working areas, so administrative controls based on suitable studies were to be used. We deliberately used a per weight basis rather than the previously used per volume (also IAEA-recommended) to reduce potential for abuse (that is, small concentrated contaminants packaged in large volume boxes to reduce per volume values).

The limit of 10 nCi/g was not meant to be a value below which excess material could be unconditionally released. Storage was meant to be contamination-free. I'll go back a little bit here. The intent was to provide a discrimination level for what could be disposed of in burial grounds. The idea was that this discrimination level would release a large amount of material from concern about its burial. Anything above this level would be put aside until a decision was made about more acceptable and broader discrimination levels. At that time, we hoped these levels would be higher by at least a factor of 100 or maybe even higher. Again, the intent was to set a lower limit below which we weren't concerned about what went into our own burial grounds. The storage of material above 10 nCi/g was meant to be in a contamination-free situation. The intent originally was onsite storage before disposal. (The reason for initial onsite storage was to ensure that the people who packaged the waste for shipment elsewhere did a proper job of packaging. We felt if they were forced to keep it for a while, they would do a better job than if they could ship the material immediately.)

Bill Lennemann and I made the decision on how long a period to consider. I wanted 5 years and Bill wanted 50 years, so we compromised on 20 years. We felt the budget cycle was much too long to consider implementation in 5 years, even if developing an acceptable broad-screening level created no problems. Fifty years was too long; it gave the impression that we weren't really concerned about the problem and we were putting it off for some other day. We felt people would forget about the problem. We were already beginning to feel that we had a problem with memory and continuity. Generations, instead of being 10 or more a year, were more like 5 or 6 years in our programs. We felt that even in the government we would be able to develop better regulations in 20 years. The decision was made 12 years ago and we have 8 years to go.

We also considered problems with developing these numbers. The philosophy of each of our sites was different; the programs differed

in magnitude and nature; the possibility of error at each site and even within sites varied; and the consequences of error varied. The intent was to develop guidance figures that would allow decision-making within each of the entities, not to produce across-the-board requirements for everybody. We were influenced by the sizes of our sites. Hanford and Idaho are about a million acres apiece. Oak Ridge is about 70,000 acres, and Savannah River is 225,000 acres. KAPL was about 10 or 15 acres and Argonne was maybe a few hundred. Their locations were different. Their climates were different. Some R&D operations showed the maximum amount of material on some sites was not over a few hundred grams and at other places we had hundreds of kilograms.

About 1970, the Waste Management Division was set up. The intent was to create a waste management group that would be planners, coordinators, evaluators, and reporters. They were not to have money and they had no implementation responsibilities. The restrictions seemed like a handicap to some, but they were compensated for because we worked directly for the General Manager, and the Commissioners showed a great deal of interest in what was happening.

We decided to press the regulatory part of the AEC for numbers. We had decided what our own operations would leave behind in the burial grounds, improving the burial ground situation. However, we wanted input from the AEC on the higher values, and we wanted a decision on what higher values could be used for a commercial program. But we received no response.

Shortly after, the situation in Lyons deteriorated so much that it was decided that we would not go ahead with qualification of the Lyons site. I indicated earlier that the Lyons site was originally meant to satisfy the requirements for disposal of plutonium-contaminated waste, and the high-level waste was a secondary concern although originally it had been the primary interest. After the decision to give up on Lyons, the Commission asked the U.S. Geological Survey (USGS) to review the rest of the country (preferably government-owned land) for a possible repository site. USGS quickly focused on the southwest and eventually on New Mexico. This was natural because the survey had done quite a bit of work for the AEC at the Nevada Test Site in New Mexico and in other western states as a part of the plowshare program, Project Gnome.

We were inundated with offers for abandoned mines. People wanted to give us iron ore mines, limestone mines, and marble mines. We had to give all of these serious evaluation and consideration because each of these proposals came from a favored Congressman or a Commissioner. It became evident that both the location and the waste form were important. Until this time we hadn't considered waste form much beyond the convenience of handling. Again, we asked the AEC for guidance on increasing the value or discrimination level for what could be released because we were now working with land areas that

were not part of our expansive sites. We felt that working in New Mexico or even Lyons was quite different from working in Hanford where we had already spent 15 years, in some people's minds, irretrievably contaminating parts of the site.

Another question concerned the problem of moving burial grounds or exhuming burial grounds. The health physicists who had been involved in the sorting group were concerned about the exhumation problem. Exhuming was something that this group didn't want to do.

We also had a big push to include the National Academy of Science in our review, the philosophy being, as Dr. Ray indicated, to allow the people we were dealing with to have complete involvement in our planning. We were to tell the Academy--everybody who wanted to know--what we were doing. Very often we were telling people what we were doing even when they didn't want to know.

As part of this effort, a public information program concerning the biological environmental research effort resulted in a symposium in Hanford in 1971 on biological implications of TRU elements. Documents were issued on the proceedings of an environmental plutonium symposium. In 1972 the program in another meeting was concerned with the radiobiology of plutonium.

In 1974, at the last major meeting of the Joint Committee on Atomic Energy, Dr. Lieberman promised that a study would be made to replace the 10 nCi/g discrimination number with one having a more scientifically valid basis. Consequently, an assignment was made to the Los Alamos Laboratory which in turn, commissioned a task force consisting of Auerbach of Oak Ridge, Cory of Savannah River, Duguid of Battelle, Garrels of Northwestern University, Merriman and Christensen of Los Alamos, Bruce Owen of Dow, Herb Parker of Hanford, Reinig of Savannah River, and Roy Thompson of Pacific Northwest Laboratoy. Jack Healy and John Rodgers were the two Los Alamos people directing this effort. Bruce Wachholz was the AEC or Energy Research and Development Administration contact on the program.

We issued an environmental impact statement, WASH 1539, in September 1974. It was aimed at management of commercial high-level waste and TRU-contaminated radioactive waste. Also in 1974 the regulatory people issued their regulations that anything over 10 nCi/g would be TRU waste and would have to go into a repository. Because the demise of the AEC was imminent, very little was done. However, Owen Gormley came up with an idea that we took to John Earlewine and Mr. Hollingsworth (the Deputy General Manager and the General Manager), who went to Dr. Ray and asked for permission to go ahead with a program for setting up a repository in New Mexico for plutonium-contaminated waste. The basis of the proposal was that treatment of plutonium-contaminated waste was one part of the operation at Lyons that had never been questioned. We received permission from her to

go ahead with a low-key effort. That was the start of the Waste Isolation Pilot Plant (WIPP) program.

Also at this time we made one more attempt with the regulatory people to come up with a basis for the 10 nCi/g number, which they had adopted. Their response was to wait until the Los Alamos report was released. The Los Alamos report was released internally in 1978, but it sort of died there. It was caught up in the change in administration and the views of the new administration's concern about the way the biological and environmental research program was being operated. Also, Dr. Lieberman was making up his mind and finally decided to leave the organization. The Los Alamos report is available. There were very few copies of it until recently, when I managed to get 50 or 60 copies of it. I started sending it out about 6 months ago. It has been labeled an internal Los Alamos document numbered LA-UR-79-100 and titled, "Limits for Burial of the Department of Energy TRU Waste."

I want to make one last point, one which Dr. Ray also reminded you to keep in mind. We have to use common sense. The rules must be sensible, and pure logic shouldn't always carry the sway. I probably mis-stated her point, but the idea is that we need a little more common sense. We shouldn't be stampeded into things. However, this also can go the other way. We have refused to be stampeded at times and have done very little. It was difficult for me to put all of these things in perspective and the order was difficult. I tried to make some points that were also difficult to make. I hope they will be of some help to you.

Bill Tedder, Georgia Institute of Technology: I noticed as you went over the history of waste management activities, a lot of things seemed to be after the fact. I have also noticed in my personal experience that chemical process people and production people tend to look down on waste managers to a certain extent, and nuclear physicists seem to be totally oblivious to their existence. I wonder if something couldn't be done to elevate the stature of waste management, especially among the waste generators. Specifically has the Department of Energy (DOE) considered the value of using some system of internal pricing? Basically, putting surcharges on the waste generators, it seems to me, might force the generators to consider more carefully the cost of final waste disposal and perhaps even have these costs included in their basic budget proposals before the program is actually initiated.

Perge: On the latter point, I can say that surcharges were made a requirement 10 years ago. I did mention that one of the statements of the General Manager's task force was that all aspects of the waste management cycle had to be costed and added together. One of the basic problems that arose is that this worked very well at some sites where everything was integrated, but didn't work well at the other sites. When you have things coming out of Rocky Flats as a

result of a fire, the last thing you are going to do is press the people to make some of these evaluations. The point you make is a valid one. I think at least two other statements were made following the General Manager's Statement. Jerry Daley was involved with one requiring an evaluation of (1) the full cost, including storage, for a certain period of time; (2) the possibility of retrieving the waste and repackaging it before it was shipped to a repository; and (3) an estimated cost for a repository. That was a requirement for a period of time. One of the problems that has plagued the waste management program, and this has been commented on by a number of people, is the frequent organizational changes. These changes have affected the ability to implement some of the activities. Waste management, in my mind, has to be part of the operation. The basic decisions still have to be made by the people who are in charge of the operations; the decision should be made as close to the problem as possible. However, the operators do need guidance, and some of the problems have arisen because there wasn't enough guidance being given.

Goetz Oertel, Office of Defense Waste and Byproducts Management: Let me add to that as far as defense is concerned. The answer is yes with exceptions.

Perge: I want to add another comment. Another problem is that everybody wants to make somebody else's decision. The health physicist, for a long time, carried the big stick at most of the sites and made the ultimate decisions. Engineers resent having to design something that requires a decision by somebody else. So they are always pressing for black and white numbers when they put things together. Most of our experience has been based on evaluating each specific case on its own merit. It is a serious matter. It was pretty much of a closed house for a while and we could justify spending the effort. Another point is often missed when you consider the regulatory program; our programs have the biological, environmental, and in many cases, the medical sciences working on the same site with the people in charge of the operations, who make use of that expertise. This is quite different from a utility program or a commercial research or medical facility.

Preston Hunter, Ford, Bacon, and Davis, Utah: I'm curious as to whether there was an unstated time line in your discussion on history, because some of the current documents, such as 10 CFR 61 for low-level waste and 10 CFR 60 and NVO 234 for greater confinement disposal, apparently were omitted. Their existence has a direct bearing on limits of TRU waste disposal.

Perge: I decided that those documents weren't history. Most everybody here is aware of that timeframe, and I was only trying to fill in reasons for what had been done in the past, reasons for decisions very few people were involved with.

Jerry Cohen, Science Applications, Inc.: Something you mentioned intrigued me. You mentioned that during this period there was a time when people made their abandoned iron mines and different types of ore mines available to you. You mentioned then that you realized that waste forms were very important. Could you expand a little on the rationale behind that insight?

Perge: These were all wet sites. They were also small areas of land. They were also areas where the environment had been spoiled by the operation. Any such site, to be useful, requires impervious containers and a waste form that would last forever.

Paul Dejonghe, CEN/SCK Boeretang 200, Belgium: Several times you referred to the 10 nCi/g limit; Governor Ray also did. But you didn't say how this value was born. Was there a scientific basis for it? Was there a study leading to that, or was it just a decision? Or was it a consequence of observations? Could you just expand a little bit about it, please?

Perge: When the General Manager's task force wanted a number developed for discrimination, they went further than that: they said we had to have one. Harvey Soule was working for me and I passed the directive on to him. He worked on the blackboard and he talked to a few people like Jack Healy and Bill Reinig, and on his own he roughly equated the hazards associated with radium in one of the high-grade ores out in the West. He came up with that rough equivalence, but to his dying day he never wanted to be associated with that number. He felt that it would denigrate him in the eyes of his profession because there was never enough time to put in all the qualifications. Our intent was to have a rough screening number that we could use immediately. As I mentioned, we were always expecting something better to be developed with a more scientific basis. Our feeling was that having only waste below that level put into the burial ground would be far better than having everything go into the burial ground.

LEGISLATIVE AND POLITICAL ASPECTS OF WASTE DISPOSAL

Ed Davis, American Nuclear Energy Council

What I'm going to attempt to do today is to try to give you an overall perspective of the nuclear waste legislation so that you will have a better understanding of the relationship of the transuranic (TRU) sections to the overall legislation. The American Nuclear Energy Council is an industry-supported organization, with over a hundred companies that are involved or have an interest in nuclear energy in the United States. We have uranium producers, private and public electric utilities, NSSS vendors, architect-engineering firms, and other firms that are involved in the front and back ends of the nuclear fuel cycle. We have, for some time as an industry, been advocating that we need a comprehensive federal program for nuclear waste management. For too long, the opponents of nuclear energy have used the nuclear waste issue to impede the development and use of nuclear energy in this country. Legislation is required to establish a comprehensive program. The development of legislation has not been unlike Homer's Iliad. We started working on this legislation over 4 years ago. As you know, in the 96th Congress, which includes calendar years 1979 and 1980, we were able to get legislation passed in both the Senate and in the House of Representatives. Three committees in the Senate and three committees in the House in the 96th Congress passed legislation. The House acted in the Lame Duck session of that year. That was on December 5th. A conference was hastily arranged with the Senate; however, almost immediately the conferees were confronted with one of the most controversial issues related to nuclear waste legislation--the defense waste issue.

As a result of an impasse over this issue, the nuclear waste legislation was allowed to die in the 96th Congress. When the 97th Congress convened, the Senate was the first to reinitiate consideration of the legislation. The Senate Energy Committee in conjunction with the Senate Environment Public Works Committee introduced a joint bill--S.1662, the Nuclear Waste Policy Act of 1982. It is unique in the annals of Congress when two powerful committees on opposite sides of the spectrum (one committee traditionally responsible for energy, the other traditionally responsible for the environment) join together and sponsor a nuclear waste management bill. It was a first. Because of the impetus and the momentum that ensued from action by the Energy and the Environment Committees, the Senate was able to push through legislation, which was passed in the latter part of March. The Senate legislation is comprehensive. It addresses the issues related to the permanent repository. As such it contains a mandated schedule for the siting, licensing, and construction of a permanent repository. It also includes provisions dealing with the interim storage of spent fuel, something that the utilities feel is an essential element of the legislation. It contains a mechanism to resolve disagreements with states. Lastly,

the legislation provides for private-sector financing of the federal waste management program.

During the time that the Senate Energy and Environment Committees were considering the legislation, the House had also begun addressing the legislation. The first committee to act was the Science and Technology Committee. Under the leadership of Chairwoman Bouquard, the subcommittee acted expeditiously to report a basic R&D bill. Its scope was constrained to consider only the R&D aspects of the repository. Because of interest by many members of the Science Committee who wanted to address the nuclear waste legislation in a comprehensive fashion, the subcommittee worked with members of the full committee and drafted a comprehensive bill that contained not only the R&D aspects but also the licensing aspects of a repository program. The bill, in a minor way, also addressed the interim storage program. That legislation was acted upon and reported around Thanksgiving of last year. The Interior Committee was next to act. At that time Morris Udall wanted to work out a consensus with the Energy and Commerce Committee. Several months went by and many drafts; finally, a meeting took place in Udall's office around the Lincoln Day recess. At this meeting, there were a number of parties present. All the principals were there, and it became very clear to Udall that unless the Interior Committee acted on its own, there was not going to be a waste bill because he wasn't going to get a consensus among all the parties. Udall decided to break up negotiations with these other committees and his other partners (Energy and Commerce) and to move the waste bill on his own. Around March 17th, Udall reported out a comprehensive bill from the Interior and Insular Affairs Committee. Shortly after the action of the Interior Committee, the Energy and Commerce Committee began its consideration of nuclear waste land legislation. Considerations had to start from scratch with the Subcommittee Chairman Dick Ottinger from New York, who has some very strong views with respect to nuclear energy. We worked very closely with Chairman Ottinger. We worked very closely with the leadership on the Republican side, Congressman Broyhill and Congressman Moorehead. It became clear after several weeks of negotiating on a compromise bill that the two sides were not going to be able to agree on a compromise vehicle. Therefore, the subcommittee was presented with two alternatives, two separate substitutes, and the subcommittee had to decide in favor of one or the other. As a result of subcommittee action, the Broyhill-Gramm bipartisan substitute was adopted by the subcommittee and was reported to the full Committee on Energy and Commerce.

On August 4, the Energy and Commerce Committee reported out a comprehensive nuclear waste legislation bill, HR 6598. I must tell you it was a real struggle to get that legislation out. The markup lasted for 4 days, and it makes the action by the other committees almost look like a piece of cake. It was a very controversial markup. Over 18 separate amendments were offered for which recorded votes were demanded. The opponents of the legislation (and there are

opponents of the legislation who were trying to keep the bill bottled up in committee) are now trying to delay consideration by the Rules Committee. As you know, we are under severe time constraints. The House is scheduled to go out August 20 for its Labor Day Recess. It returns September 8 for a few brief weeks and is scheduled to adjourn October 2. There is some talk, as you know, about a Lame Duck session, but that still gives us only a few legislative weeks to complete the process.

What remains now? A bill passed the Senate. We have four House Committees that have already completed consideration of nuclear waste legislation. I failed to mention the action by the Armed Services Committee, which was granted sequential referral to the Interior Committee bill (HR 3809), acted on it, and has reported that bill out with amendments. Four committees in the House have acted. The four House committees of jurisdiction must get together and reconcile their differences in a clean bill. We don't have to have 100% unanimity. Those differences that remain can be offered up on the floor as committee amendments, but at least there must be an agreement on a consensus bill to request a rule from the Rules Committee. We have very little time left, as you know. We are facing some problems from members of the Rules Committee who feel that the legislation does a disservice to their districts. We are now working with those members of the Rules Committee to see if there isn't some way that we can work out their concerns. Overall, I believe that the reconciliation process will take place rather quickly. I'm not prepared to predict the outcome of the Rules Committee action. I think it's premature to do that right now. However, I would note that the Administration, the state and local governments, the industry are behind this bill, and the public is behind this bill. I just feel that, because these interest groups are combining together in a broad coalition, we ought to be able to get legislation through the Rules Committee and on to the floor.

The House of Representatives, as a whole, will have to act on the legislation. Once the House has acted, the legislation will have to go into a Conference Committee with the Senate. The Senate and the House conferees will then have to work out their differences. Once these differences have been resolved, the legislation must go back to both the Senate and the House for endorsement of the conference report. We have a long way to go and not much time, but I think it can be done. We do have somewhat of a safety net in the Lame Duck session, but we don't really want to count on that if we can help it. On the legislation, I have shied away from the specifics because I'm going to leave that to my esteemed colleagues on the panel. I must tell you that I think what we have before us in both the Senate and the House will make a very good bill and a very comprehensive bill. I think the legislation addresses most of the concerns of all the parties involved. It should go a long way to address the issues of concern to the states and localities. The legislation contains a number of provisions for public participation, but at the same time

contains a schedule that allows decisions to be made in a timely manner so that progress can be made on the siting and construction of the repository. This is something that we believe, as a nuclear and utility industry, is the primary purpose of the bill. I would be remiss if I didn't add that there is a lot of controversy with respect to one of the elements of the legislation that the nuclear and the utility industries are concerned about: the away-from-reactor storage provisions of the bill. The Senate came within three votes of eliminating this provision. We have gone a long way to compromise in the House. As it stands now, the legislation contained in both the Interior Committee and the Commerce Committee represents a compromise of what was approved by the Senate. The legislation provides for a limited last-resort offsite storage program at federal facilites. If utilities can show that they have exhausted all their options for storage at reactor sites and have pursued trans-shipment between plants within their own utility system, and are still not able to meet their storage needs on site, they will be able to ship a limited amount of spent fuel to an existing federal facility. We believe that part of the program is an essential element of the bill and hopefully will remain in the bill as the House and Senate move forward to address and resolve their differences.

LEGISLATIVE AND POLITICAL ASPECTS OF WASTE DISPOSAL

Joyce Freiwald, Committee on Science and Technology,
U.S. House of Representatives

Now that the others have described the cumbersome process that you go through trying to get a bill passed, I thought I'd discuss briefly the part most pertinent to this conference, the transuranic (TRU) waste issue.

First, I should comment on Ed Davis' discussion on the Senate bill. In the Senate bill, no language specifically dealt with TRU waste, but some aspects of the legislation other than the specific section on TRU waste are pertinent. The definitions that were used are especially important. In the Senate bill, the definition for high-level waste was based strictly on the source of the waste. High-level waste was defined as the liquids and solids resulting from reprocessing. As I go through some of the other versions of the bill, you will understand the pertinence of that definition. In the past, any high-level waste bill used that reprocessing source definition.

The other terms defined in that bill that are crucial for any legislation dealing with high-level waste are "storage" and "disposal." In the Senate bill, the definition of storage specifically mentioned TRU waste. However, a little quirk, the Senate bill did not include TRU waste in the definition of disposal.

As Ed Davis said, the House versions of the bill started in the Science Committee. Because I'm on the staff of the Science Committee, I got involved over a year ago. A bill takes a long time to be reported, and the bill was formally reported out of the Science Committee on December 15, 1981, as H.R. 5016.

In that House bill, the definition of high-level waste was addressed more carefully, probably because there was some concern that the definition of waste was too limited. Previously, Congress had passed a low-level waste bill that defined low-level waste clearly; I assume most members of this audience are familiar with that definition. But, the Senate definition of high-level waste had left a lot of different types of waste undefined by legislation. The high-level waste definition that the Science Committee reported out still relied on the source definition, but it also included some other categories, such as high-level waste resulting from accidents at nuclear power plants. This definition would allow the high-level waste from the Three Mile Island accident to go into the commercial high-level repository, if one is ever developed. The definition included some spent fuels that the Nuclear Regulatory Commission (NRC) had not designated as suitable for reprocessing. It also included TRU waste and nonfuel materials that were activated by neutron bombardment. The definition also had a caveat that allows the NRC to declare other items to be high-level waste, if the NRC believes that categorization is appropriate. The

Science Committee bill included a separate definition for TRU waste. TRU waste was classified as high-level, and it also had a separate definition, which classified TRU as material with an atomic number greater than 92 and a half-life greater than 5 years. At the very last minute, the definition in the bill was changed. TRU waste was defined as having concentrations greater than 100 nCi/g instead of concentrations greater than 10 nCi/g.

This definition set a limit of 100 nCi/g concentration. At this limit, TRU waste would be required to be put into a high-level waste repository. The limit was added because many industry representatives felt that not all TRU waste must be disposed of as high-level waste. In fact, 15 private companies in research laboratories in the United States now have various forms of TRU waste, most of it less than 100 nCi/g, and the bulk of it is from the decommissioning of nuclear facilities. Other TRU wastes result from private research and development activities and from the manufacture of nuclear heat sources, such as pacemakers. Because no facilities are now available for disposal of this waste, we attempted to address that issue in the Science Committee version. However, as Ed Davis mentioned, the Science Committee version addressed only those parts of a high-level waste bill that have to do with research and development programs.

Next was the Interior Committee bill. Even though I am on staff with the Science Committee, by some quirk of fate I ended up being involved in the development of the Interior Committee bill, and so I have some expertise. In the Interior Committee bill, the high-level waste issue was once again addressed. The definition was still based on source, and again a caveat was added that allowed the inclusion of such other highly radioactive materials and TRU waste as NRC designates. Also, this bill included a definition of TRU waste. Although it was similar to the Science Committee's definition--atomic number greater than 92 and half-life greater than 5 years--it did add "in such concentrations as the Commission would designate." One significant difference between the two bills was that the Interior Committee bill actually addressed what should be done with TRU wastes that do not qualify as high-level wastes. This bill authorized the Secretary of the Interior to make unlicensed federal facilities available for storage of commercially-generated TRU wastes, regardless of their concentration. Note that I said the storage of TRU wastes; the bill said nothing about the disposal of commercially-generated TRU wastes. It authorized the Secretary to enter into contracts with the people who generate TRU waste and to charge reasonable fees to cover costs. In other words, the storage of TRU wastes was included under the trust fund that the bill provided for the interim storage of spent fuel. The bill also specifically stated that National Environmental Policy Act of 1979 requirements or licensing requirements would not be put into force at the Department of Energy (DOE) facilities as a result of DOE acceptance of the commercial TRU wastes. Otherwise, DOE might be required to license its facilities to receive TRU wastes. DOE and NRC have had a long-standing feud over NRC's insistence that

DOE should accept these wastes. DOE had said, "No, we'd like to very politely refuse that because that would mean we would have to be licensed by the NRC. So, we don't want to accept the commercially generated waste."

The Interior Committee bill also specifically set a deadline; DOE would quit accepting any TRU wastes when (1) a repository or some other disposal facility is available or (2) 6 years after the NRC developed regulations for licensing TRU facilities, whichever came first. The Interior Committee bill also required the Environmental Protection Agency (EPA) to develop standards and the NRC to develop regulations, within 2 years of the bill's enactment, that address the licensing requirements allowing facilities to dispose of TRU waste. Although some concern was expressed that the TRU section was a new issue that had not been addressed in hearings, the committee accepted it. Another concern was that the TRU section is part of the subtitle that deals with the interim storage of spent fuel and that part of the bill might be deleted because of the controversy over the AFR issue. The Interior Committee reported this bill out on April 27, 1981.

As Ed Davis mentioned, the Armed Services Committee reported out a version of the bill on July 16, 1981. That version made more changes in the definitions of high-level waste, low-level waste, and TRU waste. The high-level waste definition was changed to consider both the source and the hazards of the waste. This definition allows EPA to determine the concentrations of fission products and TRU elements that require high-level waste disposal. The low-level waste definition also allows EPA to determine concentrations of waste that can be disposed of as low-level. Similar language was used for TRU wastes. As you can see, the definitions have evolved. These versions also indicate a marked shift; instead of having the NRC determine the waste classification, the responsibility was shifted to the EPA. Finally, the Armed Services Committee exempted defense activities. DOE defense facilities would be required to accept and store TRU wastes only if they will not interfere with defense activities.

The Commerce Committee recently reported out its version of the high-level waste bill, and it addressed the three definitions of high-level waste. The Commerce Committee's definitions are like the Armed Services Committee's, except low-level wastes are defined as anything that is not classified as high-level waste, TRU waste, spent fuel, or byproduct materials. TRU waste was defined without any regard to the source or the form of the material. The Commerce Committee bill defined TRU as material contaminated with alpha-emitting radionuclides with atomic numbers greater than 92. Another change required that the half-life be greater than 20 years, rather than 5 years. The definition of half-life included a new phrase, "at the end of the institutional control period." This bill also allowed EPA to decide specific criteria. Congressman Synor offered an amendment that required DOE to accept title to the waste when it was received at the DOE facility, which was a complete change from the Interior

Committee version that specifically stated that DOE could not accept title of TRU wastes. The new language added by the Commerce Committee would require DOE to accept title when the TRU waste arrives at the DOE facility. (Consequently, DOE cannot be held responsible for transporting waste from the commercial site to the DOE facility.) The Commerce Committee version also provided for storage and disposal of TRU waste by DOE, unlike the Interior Committee's approach of allowing DOE to store TRU waste until some disposal alternative is available.

Congress made three important changes regarding radioactive wastes during the past session. First, TRU waste has been included as the waste bill went through the committee process. Second, the waste form definitions were gradually refined. Third, the responsibility for final criteria was shifted from NRC to EPA.

As Ed Davis made clear, there is still much work to be done on this bill. The final language concerning TRU waste will depend on the next series of conferences between the Committees. Right now, I think it is reasonable to expect that the Science Committee will concur with the Commerce Committee and its language and add TRU waste. I also see no major difference of opinion between the Commerce Committee and Armed Services Committee. The controversy about TRU waste may be between those three committees and the Interior Committee. The issue will be whether or not DOE should accept title to waste when DOE accepts it for storage or disposal. When we come to the conference between the House and the Senate, I have to note that the Senate did not have any language dealing with the TRU waste. So, how the Senate will stand on that issue is up in the air.

Hopefully, we can get all the changes together into one piece of coherent legislation that addresses the problem. After a concensus bill is developed, it will go to the Rules Committee and then to the floor. I can only guess that no major issues about TRU waste will develop, but I doubt that TRU waste will be the focus of any opposition.

LEGISLATIVE AND POLITICAL ASPECTS OF WASTE DISPOSAL

Tom Pestorius, Office of Science and Technology Policy

I've been sitting here listening to this and it's all very familiar. Many people have worked on the waste legislation this year and in previous years and the one conclusion I've come to is that you've got to be an optimist. It certainly tires me out just to listen to the story each time and to go through each agonizing detail. There is a story told about an optimist and a pessimist--two young children in the same family. On Christmas morning the pessimist found a room full of toys. He looked very sad and when questioned said, "Well I'm sure that somebody's just going to walk in this door and take these toys away from me." The optimist found a room full of horse manure, and he was gleefully jumping around. When questioned he said, "Well with all this horse manure around there's got to be a pony somewhere." So the job of the people who work trying to get a nuclear waste bill through is to "find the pony."

As most of you know, the President feels strongly about the nuclear option, about using the uranium resources that we have in the United States to benefit the people of the country. And as he said in his Nuclear Policy Statement on October 8, 1981, one of the prime policy considerations of using that uranium is how to deal with the issue. The American people want it dealt with and it's of prime importance to the President. The key step in implementing the policy, of course, is the actual disposal of radioactive waste.

Let me say a few words about the commitment that the Science Advisor to the President, Dr. Keyworth, has to high-level waste disposal. It's important to note that the Office of Science and Technology Policy (OSTP) is a policy office, and we don't usually deal with any single issue in great detail. Nuclear waste, however, is an exception because of the strong commitment to effectively fulfill the federal responsibility for waste disposal. Nuclear waste disposal has high priority. We've worked with Congress, industry, and other groups to facilitate a workable piece of legislation. From listening to Ed's story, you probably think, "All we need is another player on this stage of nuclear waste." OSTP has tried to be constructive. We have dealt with waste legislation in the context of the policy statement that the President made last October. In other words, we have tried to frame legislation regarding waste to encourage the efficient use of the uranium resources that we have in the United States. We're trying to get a workable waste bill.

We're encouraged by what's been happening recently. I'm convinced that there's a real bipartisan commitment to get a bill to the President this fall and I think that we'll succeed in doing that. I know there are many hurdles to get over, but I think we'll make it.

Let me talk a little bit about our approach. As I said, dealing with the waste issue is vital to the nuclear option. Of all the toxics we have to deal with today, nuclear waste is probably the most studied and one of the best understood. The American people want the nuclear waste issue settled, and that is an engineering task we can accomplish. We sent a detailed Presidential message on nuclear waste to Congress. Rather than discuss the details of that message now, I will answer questions about it during the question period. I was involved closely with developing the message. Five hundred of my close friends and I wrote it.

As you know, more is involved in handling nuclear waste than just the legislation. I am not downplaying the legislation, but we also have to set some important standards. Two that we at OSTP have been coordinating are the high-level waste standard and the uranium mill tailings standard. We have worked with the Environmental Protection Agency (EPA), the Department of Energy (DOE), the Nuclear Regulatory Commission (NRC), and the Office of Management and Budget. The high-level waste standard should be out soon. I know some people here can discuss that standard much better than I can, but I do think we will have a workable high-level waste standard out soon. We have met with just about everybody to discuss the uranium mill tailings standard. When we first entered this project, we heard reports that the agencies were not together on this standard, but I don't think the agencies are that far apart. We should be able to set that standard this year also.

OSTP generally deals with policy issues, but we have been involved in a number of the details regarding nuclear waste, which again points to the importance that the President places on this issue. He's a strong believer in the nuclear option and recognizes that you engineers are the ones who will deal with the safe disposal of nuclear waste as soon as the federal government fulfills its responsibilites. I believe this year we will make significant progress towards that goal. That's about all that I had prepared to say. I'll be glad to answer any questions.

Bill Tedder, Georgia Institute of Technology: I am concerned about high-level waste being defined as anything from reprocessing. One of my pet gripes is the way the different waste categories have been defined in the past. For example, I know at one time there was a remote-handled, low-level category, which is basically an oximoron. That's like talking about the crash of silence; it's a contradictory phrase. I feel it's important to get clear, unambiguous, technically relevant definitions of all the waste categories, not only for communications within the nuclear industry, but more importantly perhaps for avoiding public confusion. So if you have a remote-handled, low-level waste, I think you're just setting yourself up for disaster in the public perception of what is going on with the waste program. My question is: what is being done, if anything,

to define waste in a consistent, technically relevant manner that is unambiguous?

Pestorius: That's a good question. When I first came here a year and a half ago, I said, "Boy, anybody can do a better job at passing all these dumb laws than I've seen done before." But after being here, I've begun to understand why sometimes you don't get comprehensible language in legislation. In the legislation being written in the House, the high-level waste definition has evolved, trying to escape that attachment to reprocessing and rather to define high-level waste by using both the source and other criteria. I think the definition in this legislation will be a big improvement over what we started out with. However, that definition will be refined, I believe, as regulations are developed.

I agree with Joyce that the definitions have improved as the legislation has worked through the various committees. The technical community can play a part providing the information that is necessary to put the various waste forms in separate categories. Traditionally, waste had been defined on the basis of origin, not characteristics or hazards, and this has been a problem. DOE has been trying to change the approach to take the characteristics of the waste into account for definitions. This has been a major improvement in the legislation as it has been processed through the House.

Alex Perge, Office of Nuclear Waste Management and Fuel Cycle Programs: I wanted to comment that you also have to be concerned as much about the destination of the waste as about the source and the characteristics. The characteristics tie in with what you do with it. We were often concerned more with, or were willing to put into a burial ground, highly irradiated aluminum, carbon steel, or other material that could not be handled very easily and had to be remotely handled. We were also more concerned about putting in plutonium contamination, which could be handled, and were combining the two thoughts. I don't think you can forget where you're going to put waste.

Bill Lennemann: I have two comments. One of them goes with the definition. I have always been opposed to pat definitions of radioactive waste because a curie of tritium does not equal a curie of strontium, which does not equal a curie of plutonium. I agree with Alex. Although the sources may be the same, the environments where you dispose of any particular material will be different. You have to take into account what is being done with the waste in the end when you define a waste, and that is difficult to do. I will also point out that some high-level waste is called high-level waste, but other high-level waste contains more alpha-contaminated material than any other waste which you're going to handle. You've got to determine when high-level waste really becomes alpha-bearing waste, again posing some difficult questions. Pat definitions of waste seem to tell you what you have to do with waste but often what you do with the waste

in one place is not necessarily what you should do with it in another place, economically or logically. The question I have concerns this legislation about the government providing utilities with storage of fuel elements as a last resort. What is this last resort? Is it defined?

Pestorius: The last resort defined in legislation, both in the Senate and the House, occurs when utilities exhaust onsite storage and fail in efforts to trans-ship fuel from one station powerplant to another within the utility system. Also, utilities must try to use other alternatives to wet storage, such as dry storage and storage casks. Utilities must demonstrate that they have attempted all of these options and only when they demonstrate this can they be granted access to a federal site.

I'd like to make an observation here. The transuranic (TRU) problem is not unlike the problem that utilities are facing. There is now no place to dispose of TRU waste, and the same thing is true for spent fuel. Utilities have no place to ship spent fuel, no federal repository, and TRU waste generators have waste accumulating at their sites.

Anibal Taboas, Department of Energy: Question to Ed Davis first. Who is responsible for bringing the three bills, 6598, 3809, and 5016, to compromise before taking them to the Rules Committee?

Ed Davis, American Nuclear Energy Council: I think the natural leader would be Chairman Morris Udall. He can't do it by himself, of course, and I think he'll have to work closely with his ranking minority member, Emanuel Lujan, and Chairman Fuqua of the Science Committee, Chairman Dingell, and ranking minority member Broyhill from the Energy and Commerce Committee. Mo Udall's leadership in nuclear waste management dates back 4 or 5 years. He has adopted this bill as his own and is pushing aggressively to move the legislation through the rules committee and onto the floor. I think if this legislation passes this year, it will be largely because of the efforts of Mo Udall.

Joyce Freiwald, Committee on Science and Technology, U.S. House of Representatives: I'd like to add a comment on that. The Armed Services Committee marked up Mr. Udall's bill and the Commerce Committee's bill, was basically a marked-up version of Mr. Udall's bill. It's likely that the bill that will be the basis for one comprehensive piece of legislation from the House will be a variation of 3809. It may be more likely to be the Commerce Committee's version, but it's clear that Mr. Udall's bill is the focus.

Taboas: Do you think Armed Services is pretty much guaranteed participation in the conference?

Freiwald: Yes.

Paul Dejonghe, CEN/SCK Boeretang 200, Belgium: I am also concerned about the waste categories, but I have a question of a different nature. Does the bill that is now in the making include any definition of responsibilities and liabilities? We didn't hear anything about that. We hear about characterizing the waste, but who is finally responsible for what and who should be liable for it?

Goetz Oertel, Office of Defense Waste and Byproducts Management: To a large extent that is covered by the Atomic Energy Act of 1954.

Pestorius: To add a historical note, Congress passed a Low-Level Waste Act in 1980 at the end of the 96th Congress. The act gives the states the responsibility of managing and disposing of low-level waste. The responsibility for managing high-level waste the federal government reserved to itself under the Atomic Energy Act.

The legislation that just came out of Commerce also talks about title transfer of the waste in different situations. The user maintains title until the waste is turned over to the depository for permanent disposal when the Secretary of DOE takes title.

Freiwald: As a further point, Ed commented that the federal government is responsible for high-level waste. If you break that down within the federal government, clearly DOE has the main responsibilities (1) for receiving, for instance, the TRU waste; (2) for the last resort interim storage of spent fuel; and (3) for the development program and the management of the repository. NRC is responsible for licensing the repository, and EPA is responsible for developing the standards for NRC to use in doing that. Finally, you do have some additional involvement; the utilities are responsible for financing the cost. So it is a matter of shared responsibilities, but I believe the legislation does define clearly how those responsibilites are divided up.

Lennemann: You've heard the basis for the 10 nCi/g limit of plutonium concentration developed back in 1968. It was simply a desperation figure because no other information was available. Based upon higher radium concentrations in the earth, it was essentially a sort of de minimum quantity, regardless of what was considered otherwise. What is the basis of this 100 nCi/g figure that now is kicking around?

Pestorius: I think that's an unfair question to ask this particular group because, as you know the legislation does not call for a limit by number, but calls for that limit to be established by appropriate regulatory authorities, different ones depending upon which bill you look at. I think that limit is what this workshop is all about.

Freiwald: You are right in saying that in the Science Committee version there was a 100 nCi/g limit, but the definition of TRU that will probably come out in the final legislation will not set a definite number. The basis of that Science Committee number was

some input given, not by the entire technical community but by various people, as being a round number that made a convenient dividing line. I thought earlier this morning when I was listening to the other talks that 100 nCi/g is a peculiar number because it's a nice round even number that doesn't have much basis in fact. But when you're dealing with legislation, you find that it's exceedingly awkward to use specific, carefully defined, well-articulated definitions, first because you have to fight through everybody to explain why you're using that definition and nobody's going to spend the time arguing over it and, second, because only in other realms do you do that kind of careful definition.

Jerry Cohen, Science Applications, Inc.: All three panelists are familiar with deliberations regarding legislation. Are these deliberations mostly motivated by concerns over health detriment to present and future generations or is the concern mainly because of public apprehension regarding nuclear waste?

Davis: I think it's a combination of those factors. The public does perceive there's a lack of adequate protection to public health and safety, that the wastes are being carelessly taken care of. The public seems to believe that the industry has this issue around its neck that needs to be taken care of. I do think the federal government has not done a good job managing these wastes and a comprehensive responsible program is necessary.

Cohen: And the problem will be solved legislatively?

Davis: I think that's the place to start. We've had Let me turn it 30 years now. over to Tom. It's an exercise in leadership, I might say.

Pestorius: I'd agree with that. I'm an engineer by training, and I've never been involved in a project where writing on a piece of paper builds, protects, runs, starts, or stops anything; people and equipment do. In the Science Advisor's office we have tried to keep that concept in mind. As I said, this is an engineering task to be performed, and it can be done. We can dispose of some toxic waste; we can dispose of radioactive waste safely in this country, and we have tried to keep the focus on that. This task is not going to be accomplished by the legislators, and it's not going to be accomplished by the lawyers; it's going to be accomplished by the engineers. We need to keep away from micro management. Nuclear waste issues are not easily characterized in legislation, but we have to recognize that we have outstanding engineers in this country ready to do the job. All we have to do is get a piece of legislation through that sets some solid standard based on health and protection of the environment.

Preston Hunter, Ford, Bacon, and Davis, Utah: I second those comments of Bill Lennemann's. If we were to take a vote, I would vote for him to be helping you on that advisory panel to come up with definition.

But I want to ask one other question of Joyce. Along with the 100 nCi/g limit, how was the five 5-year half-life determined? And as I understand from your statement, there was a 20-year half-life recommended; why not 10 years, why not any other number?

Freiwald: The blunt answer to that question is that the 5-year figure was in last year's bill, or in the last Congress' bill, and so it is here now. I was not involved on the committee when the 5-year limit was changed to the 20-year limit, so I can't tell you what their rationale for that was. I think it was mostly that they felt the 5-year limit was too stringent and they wanted something looser. How they came up with the particular number 20, I can't say.

REGULATORY POLICY OF THE EPA RELATED TO ALPHA-CONTAMINATED WASTE

Glen Sjoblom, Environmental Protection Agency

My first involvement with the definition of transuranic (TRU) waste came within weeks of my assuming the responsibility within the Naval Reactors program for radioactive waste disposal and other related matters. That was in early 1971, when I was trying to understand a proposed Atomic Energy Commission (AEC) Manual chapter having to do with radioactive waste management. The AEC had decided to create a Division of Waste and Scrap Management under Frank Pittman; people involved in that Division included Alex Perge and our departed friend Harvey Soule. I had several discussions with Harvey trying to understand how he was arriving at 10 nCi/g. I think that's been covered, but I just wanted to point out that it's not a subject that is new to me, at least.

I think the definition has served us well as a holding pattern. I think that's one point that was made here, but now we have to decide not what we're going to hold, but what we're going to dispose of and how. As far as the EPA is concerned, our involvement stems from the AEC Act in which we are charged with setting generally applicable radiation standards to protect the public. That particular responsibility is being interpreted by EPA in a standard-setting process, which is about to go into the public phase. We have been working for several years now to try to come to grips with some of the very issues you're talking about here. The high-level waste standard and the TRU waste standard that we're working on are aimed at protecting maximally exposed individuals, as well as cumulative dose to man over very long periods of time. We're looking at a 10,000-year period. The choice of numerical value for TRU waste is important in that it represents the upper bound on alpha-emitting radionuclides that we will be considering in a low-level standard. This represents the dividing line. In working on a standard, we considered not only public health, but achievability in engineering and alternatives, and we also considered the economics that are involved. In about 1979 (in scoping out the definition), a choice had to be made for this number, and a value of 100 nCi/g was chosen based on a simple model, which indicated that, if such material were in the upper crust, resuspension of the material might result in exceeding 500 millirem in a year to a member in the general public. This was a very simplistic evaluation at that time, but you have to start at some point in defining this material.

The high-level waste standards will cover not only the disposal phase (when the material is permanently put away) but also the operational phase of a repository in terms of waste preparation and those operations involving the repository up until the time that it is sealed forever. An existing EPA standard is applicable to the nuclear fuel cycle. This is 40 CFR 190, which is the 25 millirem/year standard that is applicable to facilities of the nuclear fuel cycle,

including reprocessing but not including disposal or transportation. The high-level waste standard we are working on will cover the operational part of high-level waste disposal. For the purpose of our public process, then, we have chosen a numerical value that is not set in concrete. It must be subject to the rigors of a public review. We hope that during that public review we will get sufficient technical input either to ratify that number, lower that number, or raise that number. Our position is that it is not yet a settled matter. One of the things I remember from discussions over 10 years ago with regard to the 10 nCi/g limit was that it really wasn't based on highly technical analysis. It was based on a rationale. Similary, that's where the EPA is right now. We have a rationale.

I think the best thing that could come out of this conference would be a commitment to a highly coherent technical rationale and document that could be useful and could be provided to the EPA during the public review process. This rationale would form or could form part of the basis for setting our standard in this area. So I would invite the Department of Energy (DOE), in its response to the EPA Public Notice and in response to the standard, to endeavor to place all of its collective wisdom into a single document and send it to the EPA. I think that the 10 nCi/g value has served us well as a holding action. We need something now that will be good for many decades.

One further matter with regard to our low-level waste standard process: the definition of TRU waste at some number simply raises the issue of what one should do if that number is greater than 10 nCi/g. In the last decade, the material that is less than 10 nCi/g has been allowed to be disposed by simple low-level land burial. A valid question is, what should properly be the method of disposal of material between 10 and 100 nCi/g if 100 nCi/g is the ultimate choice? I think that when we get to working on the low-level standard, we would similarly appreciate DOE's thinking about what should be done with material that is greater than 10 nCi/g but less than 100 nCi/g. I understand that DOE is already thinking about this. We would hope that this could be of benefit to DOE and EPA.

That is all I had to say about the subject of TRU and high-level waste unless there are questions. I have with me today Dan Eagan, who has been in charge of this project for the EPA for many years now and who is much more conversant in the detailed numerical rationale than I am. Feel free to ask any questions. I think I can recognize which ones I can answer and which ones I cannot answer.

Alex Perge, DOE: Will you be soliciting comments from people from other countries? We have at least three countries represented here that are involved in such activities, and we've had comments from one of them in the past that were useful. If you hadn't considered it, I think you should.

Sjoblom: We are very much interested in what is being done in this area internationally. We try to keep abreast of the things that are going on, and it is quite extensive around the world. We hope to, in announcing and providing this to the public, take comments from anyone who is willing to provide them and to take the time to provide meaningful comment. Certainly people in other countries are thinking about these same problems, and we would be pleased to take their suggestions.

Jerry Cohen, Science Applications, Inc.: You mentioned EPA had a period of concern of about 10,000 years for high-level waste. Where did the 10,000 years come from, and how long does EPA worry about stable toxic waste (lead, cadmium, mercury)?

Sjoblom: The rationale for choosing 10,000 years was that we had to choose a time over which to base the analysis of dose to man. We chose the time so that it would be long enough to require a consideration of groundwater motion and short enough to be short in geologic time. We wanted to allow a sufficient time so that groundwater would be a significant or relevant factor in setting the standard.

Cohen: So health detriment was not a consideration?

Sjoblom: The period of time was chosen to get a proper analysis. Of course, the primary concern is health. That is the outcome of the calculation. I think Dan will be able to speak for the impacts beyond 10,000 years relevant to what they are in shorter times.

Dan Eagan, EPA, Office of Radiation Programs: Glen's answer is right on target as to why we picked 10,000 years. It was picked with an understanding that these standards will be implemented through design projections. You are not talking about monitoring a repository for 10,000 years. It turns out that, when you go through the analysis, 10,000 years is an appropriate figure to force consideration of reasonably good geologic sites without requiring projections beyond that. Some people have projected these things for millions of years, and we think that this makes the problem much harder. A lot of the time you have looked at the consistency of EPA's approach toward nuclear and non-nuclear waste. In fact, I've done a little bit of that recently. I would argue that the non-nuclear approach is very confused right now. In (RCRA) regulations, there are some things that seem to imply you only have a 30-year time horizon of concern. There are other provisions that imply that you have to maintain institutional controls and protection forever. They've had a great deal of difficulty in trying to sort that problem in the RCRA regulations. In fact, there is a project in the EPA right now to address (and it is not coming out of the radiation programs part of the agency) what the proper time horizon is, or should be, for all the various waste disposal programs and to see if there is some way that some consistent rationale can be applied across program areas.

But that project is still in its infancy right now. In fact, it just started a few months ago.

Sjoblom: The 10,000-year period was picked for an analytical reason specific to these types of wastes. As I'm sure you know, we talked about 1000 years on the mill tailings standard. Again, that refers to analytical specifics to that type of waste. So far, the numbers have been picked on the specific waste category involved, not the same value across the board. Dan Eagan does have a number of slides. If you like, we could run through some slides and perhaps get into a little bit more of the technical aspects.

Eagan: I think it was said earlier that in this business we are used to decades of worrying about what we do with radioactive waste and the fact that certain categories of waste need to be taken care of for a long time. That realization is relatively new to a lot of the chemical waste people. In fact, the thought and policy process behind that is, for government policies, still very much in its infancy. I've spent some time looking at the RCRA regulations for hazardous waste disposal that are now evolving, and you get contradictory signals from those. You get answers that waste generators only need to provide financial resources to protect the environment for 30 years after a waste disposal site is closed, but at the same time, our EPA regional administrators have the authority to extend that indefinitely, as long as they find the waste too dangerous. They recognize that there may essentially be a hazard there forever, and they recognize that fact quite explicitly in their Federal Register preamble. Yet they haven't dealt with that problem other than to assume that the regional administrator will be there forever too. I think we've evolved a different philosophy in the nuclear waste business, which states that you put the waste away so that you don't have to have people watching it continuously. That is a philosophy that has not come through yet in the hazardous waste area. If you put the chemical wastes and the radioactive wastes side by side and look at the policies, you do get things that don't match up very well.

Let me start off with an analogy to the notice you get on cigarette packages. Anything you hear today may change soon. The standards I'm going to talk to you about (40 CFR 191) have been in draft form for a long time. I suspect several of you have copies of them; they are becoming something like Russian underground literature. However, they have not yet been released publicly for comment and have not yet been approved by the administrator for proposal. Therefore, anything I say here may be subject to change. With all those caveats, most of what I'll discuss has remained constant since about 1980.

The standards, as Glen walked through them, have three basic parts. First, there is what we call subpart A, which will be standards to be applied to waste-management operations. This subpart would essentially just extend the existing 25 millirem dose limit and its comparable organ dose limits, which are now in 10 CFR 190, to all

waste-management operations except transportation. In other words, everything up to disposal and final sealing of a repository would be governed by Subpart A. Subpart B applies to disposal once you have backfilled and sealed the repository. It applies to how you are designing a facility to contain those wastes when you are ready to walk away from them and not deal with them in an operational sense anymore. Subpart B sets limits on projected releases over a long period of time. These limits will be implemented in the design phase for the engineers and all of us to design against. Finally, the Appendix to the package will contain some qualitative guidance on how disposal systems should be designed.

Subpart B basically says two things. One, it says we have to plan for releases that are unexpected; in fact the waste disposal system should not have planned releases. For what we call reasonably foreseeable releases (those that have a chance of greater than 1 in 100 over this 10,000 year period of occurring), we've set a table of release limits. For a lower probability category of releases, we then multiply that release limit times 10--allowing for more severe accidents to occur at lower probabilities. Below the lowest probability, we set no regulation at all, saying that there are some accidents that are so incredible that they should not be the subject of regulatory concern. To give you an idea of what the release limits look like, and this is only part of a complete table that is almost 2 years old now, we set radionuclide-specific release limits per an amount of waste. The high-level waste unit we chose was equivalent to the metric tons of heavy metal used to charge the reactor, and we set numbers specific for each radionuclide.

I'm going to show you how those numbers would be used for a particular repository, and I'll also make a couple of comments about how they would be applied to a TRU waste repository. Taking those limits, you would then figure a release limit multiplier that is based on the amount of waste in a particular facility. We saw no reason to set a limit that was per facility because we didn't know what the size of the facility should be. You estimate how much high-level waste and how many curies of TRU waste and divide by roughly equivalent denominators in terms of protection. In the case of high-level waste, the unit was the high-level waste in the 1000 metric tons heavy metal. In the case of TRU waste, we were talking about a unit of 3 million Ci of TRU waste. We're looking at this number to decide whether we've got enough precision to keep that 3 million Ci. We may in fact decide it makes more sense to change that to 1 million Ci. Figuring out your repository inventory, you would then come up with this multiplier. You would then determine the specific release limits by taking that Table 1 and multiplying each one of those radionuclide limits by the multiplier. In the design studies, you would compare projected releases from a repository against the release limits in the sum of the ratio form ulq. Any of you who know 10 CFR 20 will be quite familiar and comfortable with that formula.

To return to the question that was asked before about the 10,000-year period, we chose it for two reasons. I'm not trying to defend a choice between 9,000 and 11,000, but we are looking for something that was long enough to require assessment of groundwater pathways. We found that when we set numbers at 1000 years, the geologic characteristics of the site did not enter significantly into the performance assessment calculations. On the other hand, we wanted to set a number that was short enough, relative to the geologic timeframe, to be at least somewhat predictable. If you took a number like this to 100,000 years, you would have to contend with potential glaciation and several other geologic phenomena. Things are going to be a lot less predictable over 100,000 years than they would be over 10,000.

Let me return to this walk through of how we picked the numbers. I don't want to go through this entire slide except to say that we did assess the risks from geologic repositories and walked through what amounted to an achievability study. We found that risks could be held very low and below a level of risk that would correspond to only 1000 premature deaths over 10,000 years for a repository size quite typical of that now looked at in design studies. That size repository would hold all the waste we now have plus all the waste from existing commercial nuclear reactors. We then picked the level of risk that Table 1 is based on. We then argue (I think fairly forcefully) that, compared to other sources of radiation exposure, that level of risk is indeed very small. Using comparable environmental models, we looked at uranium ore bodies containing enough ore to create the waste that was in that repository. Because of the uncertainties in those calculations, we get a rather wide range of results. But if you look at 1000 health effects sitting in that range, the point we make is that the risks from high-level waste and TRU waste, when disposed of in accordance with these regulations, are either equivalent to or much less than the risks that would occur to society if the waste hadn't been generated to begin with. It is not a zero-risk approach, but you can argue that you incur no extra risk to future generations based on that comparison. Of course, 1000 deaths is considerably less than the risk from variations in natural background, and it is also less than our projections of health effects from the operation of uranium fuel cycle facilities over the first 100 years after operation.

The other point I will touch on is Appendix A. These criteria are qualitative steps that we think you should take in addition to meeting the quantitative goals we've set in our regulation. The first step says that you should dispose of wastes promptly once you have a disposal facility available. Don't store them indefinitely and, therefore, take away the incentive to find disposal facilities. The second step is a familiar ALARA concept. The third is that you should use multiple barriers in the design of the disposal system. Our objective is that, even though we may be able to project numbers over a long period of time, projections over those periods of time are going to be uncertain. You can't know something for sure over

10,000 years. One way to minimize the effects of that uncertainty is to not put all your eggs in one basket in a design sense. Again, this concept is similar to reactor safety concepts of defense-in-depth.

Our fourth step is that you should not rely on active institutional controls (guards, fences, etc.) to guarantee environmental protection for more than 100 years after disposal. It is possible to conceive of disposal sites that are absolutely perfect as long as nobody ever puts a drill hole in. These conceptual sites fall apart the first time somebody sinks a bore hole through them. That is something you should look at and avoid. We're not saying that you shouldn't worry about protecting the individual who may intrude into a repository, but you need to be sensitive to possible failures of institutional controls after 100 years.

The fifth step is to identify repositories as permanently as possible, and the sixth says you should not put a repository where you expect future mining for resources.

Step 7 says you should design a repository to allow for the possibility of waste recovery if all of the foregoing turned out to be wrong. That doesn't give any mined geologic repository a problem. Obviously it is easy enough, although it's not necessarily safe, to go back and dig up the material. However, there are disposal concepts, like the rock-melting capsule concept, that are irreversible once you do them. I would argue that it is not a good idea to use this type of disposal method because you may have done something wrong and cannot reverse it even very shortly thereafter.

In broad brush, that is what our package says. I'd like to use that as a basis for any further questions you might have.

Bill Lennemann: You talk about 10,000 years. Does this mean that you don't carry out your integrated dose commitments any further than 10,000 years, and then this is based on a dose limitation rather than on confinement?

Eagan: Our standards require that you integrate projected releases of radioactivity over 10,000 years. We picked the curies as a unit for our standards as opposed to man-rem because we felt that it was far easier to implement. In deriving those numbers, we did long-term dose commitments for those various curie release limits entered in the table to correspond with the level of risk we talked about. When the standards are implemented, NRC or DOE (as the case may be) only has to integrate the curie release up to 10,000 years. They don't get involved in dose calculations at all in Subpart B.

Lennemann: So in effect then, you say that after 10,000 years, dose commitments (although you have to calculate back) really make no difference. Once something has been released, it may not get very far in 10,000 years, but it may go into a fast moving water course,

and from then on it might be a hazard. I'm not disagreeing with what you've done. As a matter of fact, it's much better than these commitments I see carried out to 10^{17} million years.

Eagan: We've gotten some informal comments that accuse us of being insensitive to the people who live 11,000 years from now. I think we'd argue that the steps you take in designing a repository that will make it good for 10,000 years will make it good for longer than that. In fact, calculating dose commitments beyond the lifetime of the earth doesn't make a lot of sense.

Denis Thackrah, Nuclear Installation Inspectorate, Great Britain: I went along with your recommendations except for the last one. It seems to me that you are trying to have your cake and eat it too. If you design a repository so that it's easy to recover material if you have to, then I would argue that you've not designed a very good repository.

Eagan: The operative word there, and I may have used it incorrectly, is "easy." Let's take the Waste Isolation Pilot Plant (WIPP) as an example because it's a repository that clearly would meet this criterion. It's not going to be easy to get waste out of WIPP once you've sealed it. However, it will be possible. I don't think there would be much disagreement with that. What we're arguing is that it should be possible to do that. Indeed, we are hedging our bets that something that we can't foresee now might in fact have been wrong. There are disposal methods (admittedly not very seriously pursued right now) about which you cannot make that statement. For example, the idea of the rock melting capsule (where you had a capsule of high-level waste you put on the ground that melted its way into the earth to seek whatever equilibrium level it would) would be difficult to keep the string on when it goes down. You can't get it back once you've done it. That's the type of thing we were concerned about. We are not arguing that a repository should have perforations so we may dig here to get it back out. That's not the intent. Our intent was that it doesn't have to be easy to get out, but it should be possible to get the material back out.

Question: You mentioned as one of your seven criteria the use of several different effective barriers. Do you consider the geology with good absorption properties as an effective barrier?

Eagan: Do I consider that as an effective barrier? Yes I would.

Question: As opposed to hard engineered barriers involving exotic alloys and so forth?

Eagan: In the full wording of that, we say one should use several types of barriers, both engineered and natural. When we've been pushed, we've allowed that we think that means at least one of each. We certainly argue, and to some extent we find we have occasionally

looked a little different than NRC has, that the geology and its absorption is not only an important barrier but perhaps the most important barrier in a typical disposal system.

Question: Have you defined a zone over which one can take credit for the geology?

Eagan: As a matter of fact we have, in our definition of what we call "accessible environment," implicitly defined a 10-km radius around a repository where that would take place.

Bill Kennedy, Battelle-Pacific Northwest Laboratory: I wonder if the intent of your regulation is to cover defense wastes as well as commercial wastes and if the unit of 1000 metric tons of heavy metal becomes difficult to extrapolate to defense waste where such a unit is difficult to arrive at? Because so many of the results in this proposed regulation are based on the results of modeling and are dependent on the assumptions and the parameters used in that modeling process (especially over the 10,000 year period), I'm wondering if those models have been documented and reviewed and in what form?

Eagan: We do intend for our regulations to apply to defense as well as commercial waste. The choice of the unit of 1000 metric tons of heavy metal does give you some problems with respect to defense waste. In fact, Goetz Oertel and I have discussed that a little bit. He had some suggestions that I expect we'll take up when we get a chance to review the package during the public-comment period. There may be a better way to do it. I'm personally not convinced that this is totally unworkable, but Goetz is trying hard to convince me of that. In respect to the third question, indeed, it is very model-specific. Our standards depend very much on models as will the agencies that implement them. We have essentially three major technical reports, two of which are in draft, that will be released for public review and comment at the same time the standards are reviewed. In response to a request made some time ago, we have already set up an independent peer review panel (modeled after the Lewis Committee that reviewed the Reactor Safety Study) to look at our work to ensure that our analyses make sense. We intend to have a thorough technical peer review during the public comment period and also a policy review. I think that simultaneous review is very important, because it is very often important to know to what use the analyses were put when you are doing the technical review. We're not at all trying to present the "right" answer, as the Reactor Safety Study was sometimes accused of doing. We're trying to present an analysis that gives a reasonable upper limit to what the risks could be, and that's the context in which our analyses were done.

Larry Eisenstatt, West Valley Nuclear Services: You talk about premature deaths in your regulation. What is a definition of a premature death?

Eagan: It's a cancer.

Eisenstatt: Any cancer?

Eagan: Any cancer in the data base that the National Academy of Science has developed for us over the years.

Eisenstatt: So it would have nothing to do with the average life span?

Eagan: Not that we've defined so far. In fact, there are some more sophisticated health risk models that consider average life span. We have not incorporated them into these standards, though.

Eisenstatt: My second question goes back to your definitions of TRU waste. At what point in your waste management plan would you measure your activity concentration?

Goetz Oertel, DOE Headquarters: We measure the activity concentration at the source and again when you're tying to package it. In fact, there will be a presentation today by John Umbarger about how that is going to be done.

Charles King, Savannah River Laboratory: In light of your recommendation discussing the ALARA principal, how do your justify 25 millirem as the standard for any organ (75 millirem for the thyroid) versus your own EPA drinking water standard of 4 millirem? Who did the modeling?

Eagan: That ALARA recommendation applies only to disposal, and it is not in the same part of the regulation as the 25 millirem number. You are asking why 25 millirem as opposed to a lower number for waste management operations? When we looked at that number in developing this regulation, we knew that 25 millirem/year had been set for the rest of the commercial fuel cycle, other than the solidification processes and other waste-management processes. We didn't see a particularly useful rationale to crank that down lower, although indeed our feasibility studies say that much lower dose limits could be met by many of the solidification processes. Certainly, emplacement processes at the disposal site should not reach anywhere near 25 millirem. However, implementing different dose limits for different phases of the operation becomes administratively difficult. We thought it was simpler and a reasonable protection of public health just to extend that same 25 millirem number. We did not go ALARA by each step of the commercial fuel cycle.

The 25 millirem was in fact picked under 10 CFR 190 as being a reasonable approach to ALARA for the fuel cycle in toto, which is based primarily on reprocessing plants or on reactors, not anything we're covering here. We thought it was administratively the best way to approach this. So that's not an ALARA limit.

Pete Lakey, Battelle-Pacific Northwest Laboratory: I understand the International Atomic Energy Agency (IAEA) limit on sea dumping is somewhat higher, around 1000 nCi/g. Does EPA still consider sea dumping as a possible disposal route?

Sjoblom: The Protection, Research, and Sanctuaries Act makes high-level waste disposal in the ocean against U.S. law. The definition in the U.S. law is a qualitative definition. Then in the international scene, the definition of high-level waste (namely, that which is prohibited from being disposed of) is a quantitative definition and there are three numbers basically. The definitions include the concentration of alpha waste, of beta-gamma waste with a half-life greater than 0.5 years, and a concentration limit on tritium. The relationship between what we normally think of as high-level waste in this country and the definition of high-level waste with regard to ocean disposal is numerically several orders of magnitude. I think if you just run the numbers out, you'll see that. A typical spent-fuel or waste from a reprocessing facility is several orders of magnitude higher than the international definition of high-level waste that is prohibited from ocean disposal. Nevertheless, both internationally and in the United States, we feel that ocean dumping of high-level waste is clearly not within the current statutes.

Joe Lieberman, Nuclear Safety Associates: As I recall, in the models that you used to develop your health effects from which you got your release limits, about 85 to 95% of health effects are associated with intruder scenarios. At the same time, the latest version of the NRC Part 60 seems to (correctly in my view) put it in proper perspective. Could you comment on what is an apparent disconnect in the basic philosophic approach to regulation by the two federal agencies?

Eagan: First of all, we consider credible types of intrusion as something that should be looked at in judging compliance with our standards. Your comment is quite right for the repository geologies that perform the best in our modeling. In fact, about 80% of the remaining risk resulted from intrusion. It is true, however, that in geologies that did not perform particularly well, it was not the intrusion that changed but the other parts of the problem. In our poorly performing media, about 30 or 40% resulted from intrusion. To put that in perspective, we feel it is appropriate to set the numbers where we did in part to encourage good siting and in part to encourage at least reasonable design against intrusion scenarios. The preamble that was published for the version of 10 CFR 60 that NRC sought public comment on last July did come close to dismissing intrusion. In the final version they have come somewhat closer philosphically to where we are. They now identify intrusion as something that you specifically design against and consider in your licensing process. I would agree that between the drafts of our standard and the published proposed 10 CFR 60, there was a significant gap in philosophy. In fact, I think that the gap has closed quite dramatically since last summer. I think we both agree that intrusion is something you need

to consider. It doesn't assume that society loses all knowledge and walks around like idiots, but it assumes that it is something that can possibly occur and something you need to design against. I think the two agencies have come pretty close to general philosophical agreement on that, based on what I see in NRC's current drafts.

Don Oakley, Los Alamos National Laboratory: Do the three technical documents you referred to contain the models for groundwater movement from a repository; if so, are the models compatible with the SWIFT code that has recently been documented and published by NRC?

Eagan: The answer to the first question is yes they do. The groundwater models we use are very simple models, which is consistent with our whole approach to our analysis: to try and do as simple an analysis as made sense. We have benchmarked our computer programs against NRC's SWIFT program and the group of codes they developed down at Sandia, and when they simplify their code enough so that they can compare it with ours, they match. Their code, which has to deal with site-specific geology, had a much more sophisticated capability than ours does. They can do more complicated modeling. When they get down to our relative level of simplicity, the things do check out.

Lennemann: Does EPA consider that the United States is a party to the London dumping convention, which among other toxic materials also includes radioactive waste following certain IAEA definitions and recommendations? Now following the IAEA definition recommendations, which defines waste that is permissible to dump, does the EPA consider this the viable option for disposal of radioactive wastes in the United States?

Sjoblom: The EPA has had the responsibility since 1972 of regulating any proposed disposal of radioactive waste in the ocean. Since that time, there have been regulations put into EPA's 40 CFR series that deal with this subject to some extent. EPA's policy on radioactive waste disposal in the ocean is not mature at this time. The policy of Congress, when it wrote the law, was that high-level waste is prohibited and low-level waste may be permitted if a permit is obtained from EPA. EPA, in reviewing any permit application, must decide whether or not there is an unacceptable adverse impact on the ocean and on man as a result of such disposal. There have been no applications since that time. We will have to see what happens in the future.

INTRODUCTION TO SESSION I

Joe Lieberman, Nuclear Safety Associates

As you can see from the program, Allen Croff and I are to handle this session. It seems to me that much of the work done in the past in the nuclear waste business is now coming to the point where we're able to make some real headway both in the administrative base from which we have to operate, whether it is legislation or regulations, and in the organization of our resources to get on with the job. The presentations in Session I will be giving us some base information regarding alpha-contaminated waste; how we detect it and determine how much of it we have; what its potential associated biological or radiological hazards are and how we arrive at what they might be; and, following that, some estimates of quantities of such waste that might be expected from a fuel reprocessing plant that is, unfortunately, not operating.

PHYSICAL DESCRIPTION AND QUANTITIES OF ALPHA-CONTAMINATED WASTE FROM DEFENSE SOURCES

Richard Jensen, Rockwell International/Rocky Flats Plant-TWSO

This morning Alex Perge gave us a short history of transuranic (TRU) waste management and how it came about. My paper today summarizes the inventories and characteristics that have resulted from these practices (Slide 1). For the past year and a half, I've been doing systems analysis for the Transuranic Waste Systems office at Rocky Flats, the lead contractor to the Department of Energy (DOE), Albuquerque, which is the lead office in TRU defense waste planning. I will discuss three divisions of TRU waste: (1) newly, or currently, generated waste, which deals in projections or forecasts; (2) stored waste, retrievable waste that was put in storage in the early 1970s when the policies came into effect; and (3) buried waste, which is waste buried before the early 1970s.

Slide 2 is a map of the United States showing the storage and generating locations. The six storage sites are Hanford, the Idaho National Engineering Laboratory, Nevada Test Site, Los Alamos, Oak Ridge, and Savannah River. The arrows show generating locations and the storage sites where the waste is shipped. All of the storage sites except the Nevada Test Site are also generating sites.

The first major category is the newly generated waste (Slide 3). Under this division there are two subcategories, remote-handled (RH) waste and contact-handled (CH) waste. RH waste, as the name implies, is that waste that must be handled with equipment or with special shielding to protect the individuals who are handling it. Traditionally, CH waste is less than 200 millirems/h at the surface of the container.

I'd like to make two comments on the forecasts that I'll be discussing. First, I'll review the process that I went through to obtain these data. The first step was to contact the sites by telephone and ask for the data we wanted. Then, we made visits to the various storage sites and generators to discuss exactly what we were after and to allow staff there to ask questions. After I tabulated the data, they were sent back to the sites for review. Therefore, the data have gone through a question and answer process, and we feel that our numbers are reliable. The source of the data is the sites themselves, not estimates by the Transuranic Waste Systems office. Second, these forecasts are done only for 10 years. Although we are often interested in forecasts to the year 2000 and beyond, generator forecasts produce good detail for about 5 years and sometimes 10; then at the end of that tenth year, they produce a reoccurring number for however many years it is we ask the projection for. Therefore, we are only showing a 10-year projection here.

Slide 1

INVENTORIES & CHARACTERISTICS OF TRU WASTE

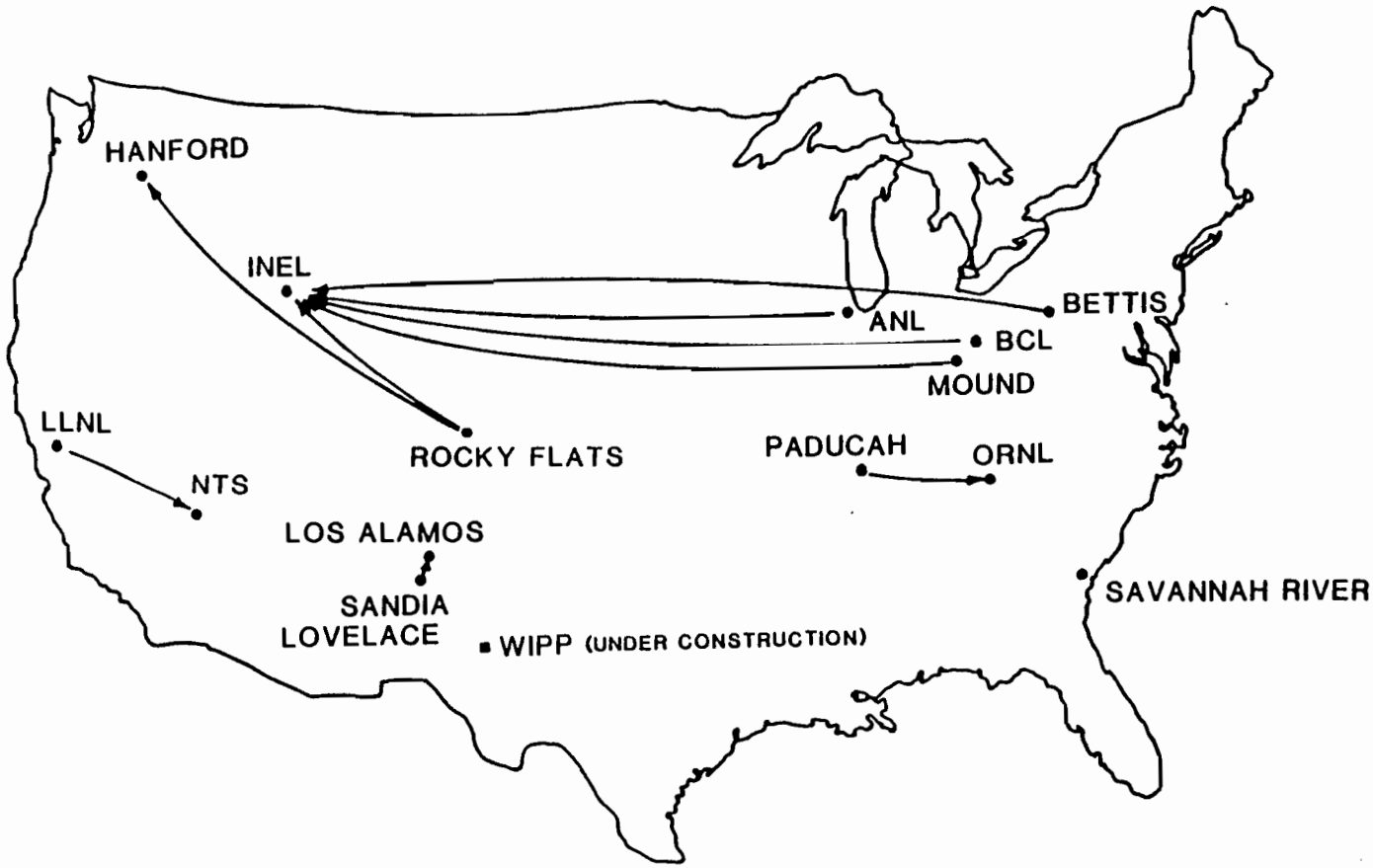
R. T. JENSEN

CHEMICAL SYSTEMS ENGINEERING

AUGUST 10, 1982

Rockwell International

Slide 2



LOCATIONS OF DOE FACILITIES THAT GENERATE AND/OR STORE DEFENSE TRU WASTES

Slide 3

MAJOR CLASSIFICATIONS of TRU WASTE

Newly Generated TRU Waste	Ave. Generation per Year (1982–1991)
Contact Handled	3684 cu.m.
Remote Handled	118 cu.m.
TOTAL	3802 cu.m.

Slide 3 shows the average generation per year for 10 years. For 10 years, most sites provided detailed projections. The 3802 m^3/year figure represents the total for all the sites. The projection doses incorporate volume reduction methods, which are currently in the planning stages. Slide 4 shows that the stored inventory in CH waste is 65,075 m^3. RH waste is 1757 m^3. These numbers are as of December 31, 1981.

The buried category (Slide 5) also has two divisions. The first is the actual buried waste, and the second is contaminated soil that resulted when the waste was buried underground then the container breached or, in some cases, was just put in the ground without any containment at all. The numbers for contaminated soil have a large spread, from 131,520 to 2.5 million, because several different assumptions can be used to calculate the amount of soil that has been contaminated by buried waste.

Slide 6 shows the buried waste in more detail, giving you an idea of the curies of TRU activity in the buried waste. On this slide, that number is 412,816 Ci. The key thing to notice is that the Hanford site has more than half of the total inventory of solid buried waste. The major effort, if any retrieval operations are undertaken, will have to be at Hanford. Also, as the footnote shows, there is an estimated 2 to 7 million m^3 of contaminated soil resulting from early liquid waste disposal practices, and this soil often does not show up in inventories, but certainly has to be considered.

Slide 7 summarizes the inventories to the year 2020. The bar on the bottom shows the known contaminated soil at about 130,000 m^3. The white bar represents the possible contaminated soil. (Of course, if it were extended to the 8 million m^3 that we have here, the bar would extend far beyond the end of the slide.) The second bar shows the buried waste. Again, more than half of the buried waste inventory is at Hanford. The stored waste inventory begins in about 1970 and goes through 1980. The graph shows how the current inventory compares to the volumes of contaminated soil and buried waste. The next portion of the bar is the estimated additions over the next 10 years, and the final part of the bar is the estimated amount to the year 2020. I should point out that these forecasts do not include waste from any possible major decontamination and decommissioning operations because we don't have projections on those inventories or that waste. The surplus facilities program now estimates only about 2000 or 3000 m^3 of waste; the rest of that program's sites are in a "to be determined" category. I've been told that the program expects to have very little TRU waste, if any at all, if the 100 nCi/g limit is applied.

Slide 8 shows the forecast waste forms in more detail. Most of the waste over the next 5 years will be combustibles or metal. (Glass is only about 1% of the 31% in the metal and glass category.) These waste forms are expected to change drastically, which is one reason we do not want to forecast much beyond 1985. As volume reduction methods

Slide 4

CLASSIFICATIONS of TRU WASTE (con't)

Stored TRU Waste	Total in Storage to Dec. 31,1981
Contact Handled	65,075 cu.m.
Remote Handled	1,757 cu.m.
TOTAL	66,832 cu.m.

Slide 5

CLASSIFICATIONS of TRU WASTE (con't)

Buried TRU Waste	Total Buried to Dec. 31,1982
Buried Waste	298, 920 cu.m.
Contaminated Soil	131,520–2,595,000 cu.m.
TOTAL	430, 440–2, 893, 920 cu.m.

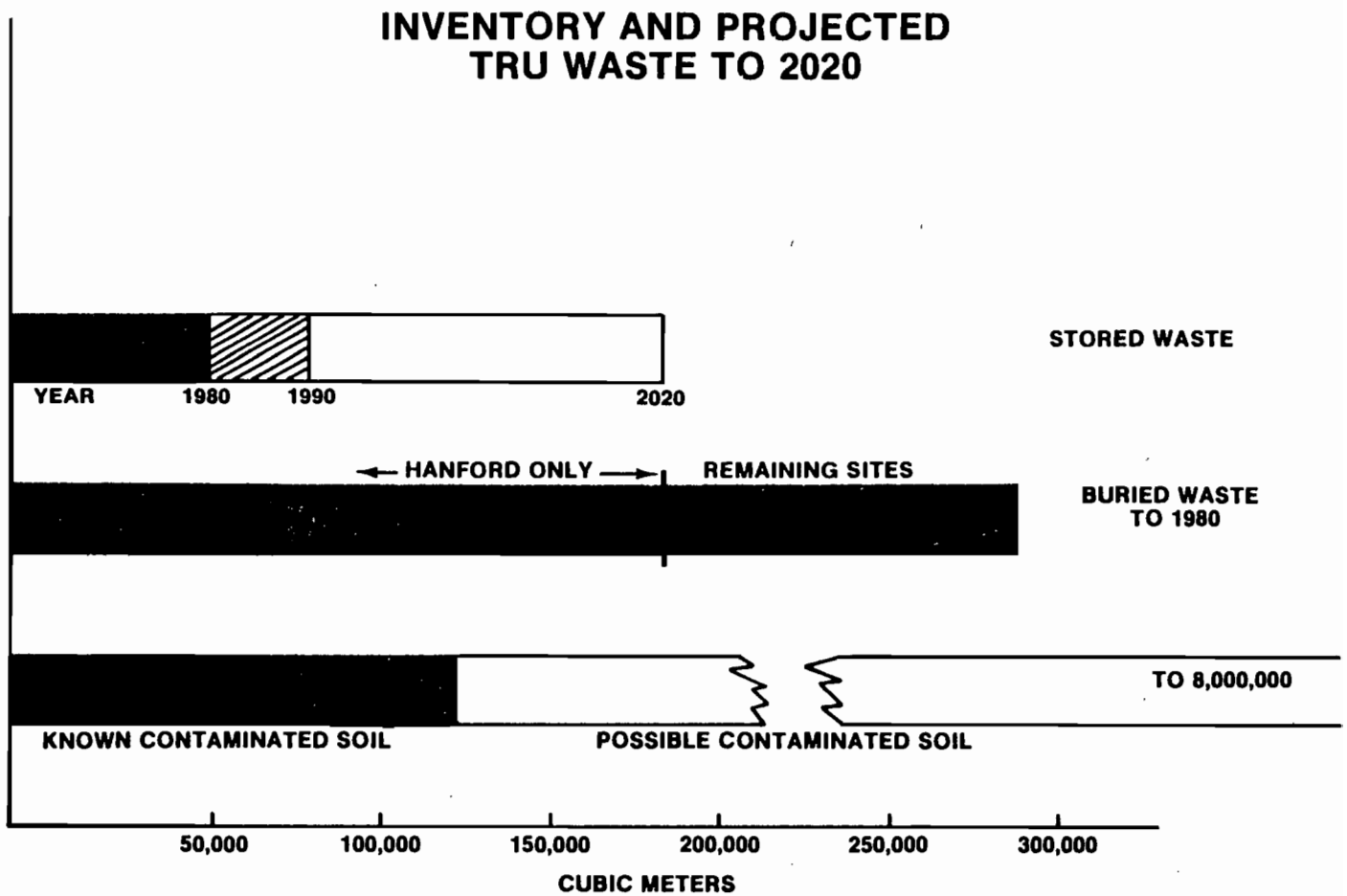
Slide 6

ESTIMATED AMOUNTS OF BURIED TRU WASTE

BURIAL SITE	SOLID WASTE EMPLACED (m^3)	CONTAMINATED SOIL* FROM WASTE BURIAL (m^3)	MASS OF TRU ELEMENTS (kg)	RADIOACTIVITY (Ci)
HANFORD	193,120	57,200-500,000	605	160,000
INEL	57,100	56,640-156,000	357	178,000
LANL	11,500	5,910-301,000	14	49,200
ORNL	6,200	11,770-1,600,000	5	2,100
SRP	31,000	UP TO 38,000	9	23,516
TOTAL	298,920	131,520-2,595,000	990	412,816

*IN ADDITION, THERE IS AN ESTIMATED 2 TO 7 MILLION m^3 OF CONTAMINATED SOIL RESULTING FROM EARLY LIQUID WASTE DISPOSAL PRACTICES.

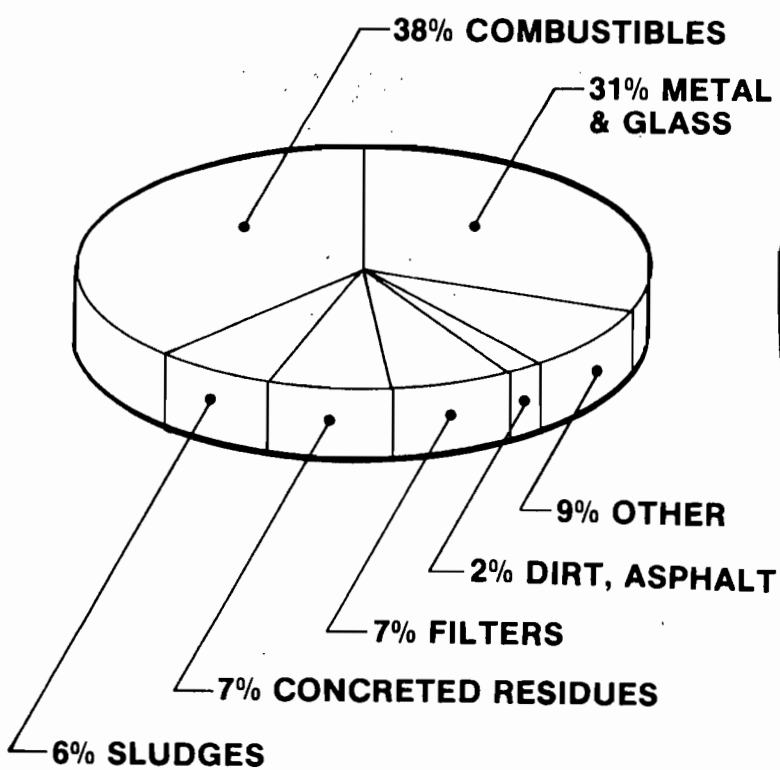
Slide 7


INVENTORY AND PROJECTED
TRU WASTE TO 2020
STORED WASTE
YEAR
1980
1990
2020
HANFORD ONLY
REMAINING SITES
BURIED WASTE
TO 1980
TO 8,000,000
KNOWN CONTAMINATED SOIL
POSSIBLE CONTAMINATED SOIL
50,000
100,000
150,000
200,000
250,000
300,000
CUBIC METERS

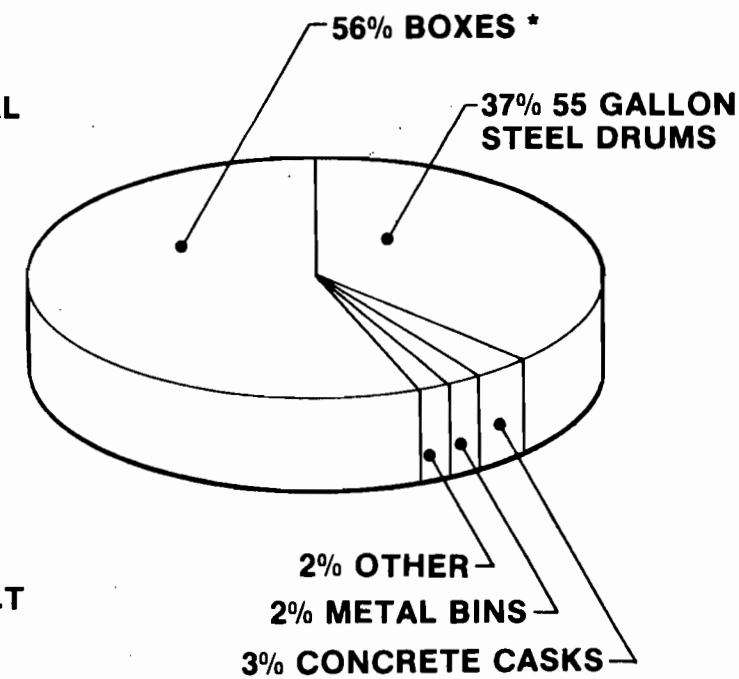
Slide 8

FORECAST OF CONTACT HANDLED WASTE FORMS AND CONTAINERS (1981-1985)

FORECAST - 1980 TO 1985 VOLUME %



FORECAST - 1980 TO 1990 VOLUME %



* PLYWOOD UNTIL 1983 - METAL THEREAFTER

come on line, incineration, for example, will decrease the combustible amount a great deal. On the other hand, the concreted residues that are now at 7% will increase significantly. The pie chart forecasting the types of containers to be used indicates that the majority of the waste will be packed in large boxes. Right now the 4 x 4 x 7 Rocky Flats boxes are most commonly used. In the next 5 years, they will be replaced by the TRUPACT.

The RH waste forecast (Slide 9) shows that most RH waste is combustible, and we have been able to break that waste into subcategories of plastic, paper, rubber, and cloth. Most of the RH waste will be contained in concrete cylinders and steel capsules.

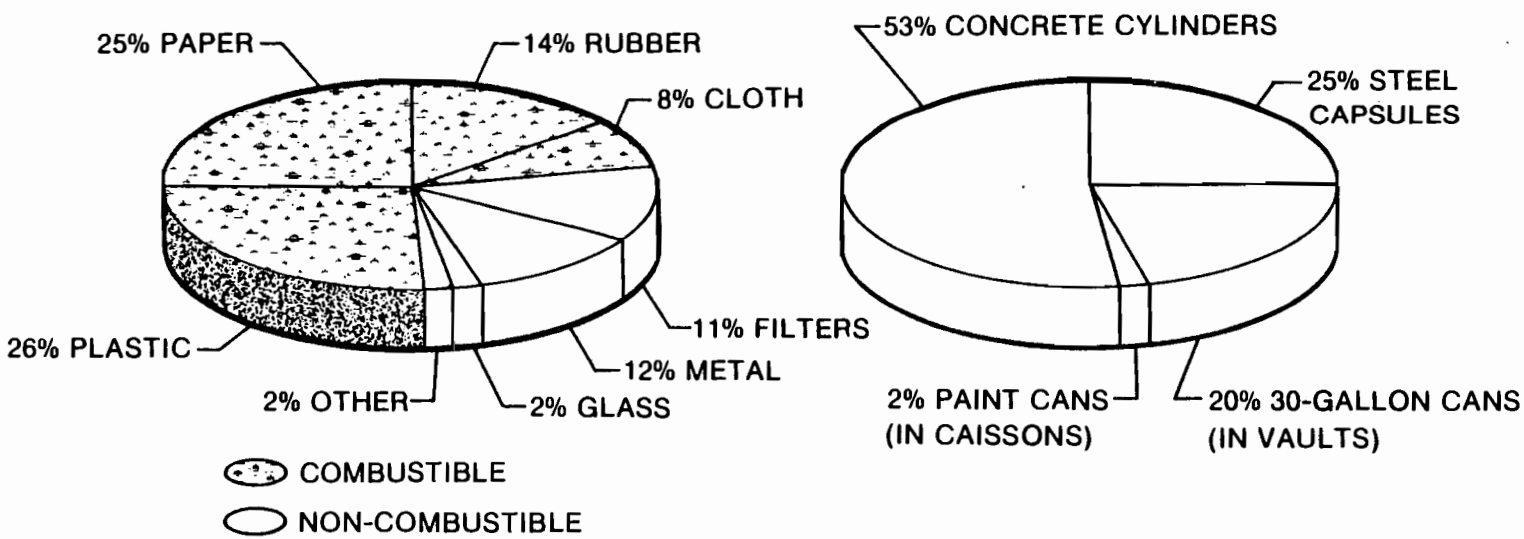
The current and projected inventories of stored TRU waste at DOE sites (Slide 10) shows that the Idaho National Engineering Laboratory has by far the largest inventory of stored wastes. The bar is broken in two places, indicating the large amount of waste stored at the Idaho facility. Most of the sites expect to about double their waste over the next 10 years, except for the Savannah River Plant. That plant's inventory is now 2608 to 8195 m^3, which is a much larger rate than in the past, and the staff expects the inventory to rise.

The mix of the containers and the waste forms of the stored waste (Slide 11) is similar to the forecast: largely combustibles, metal, and glass in the waste forms. The sludges category, 6.5% sludges, is the Rocky Flats term for inorganic salts that result from the recovery processes there. The graph on containers shows 44% plywood boxes and 41% steel or iron drums. In the forecast we specified 55-gal drums. The difference is that in the past the steel or iron drums have not been uniform. There are 30-gal, 55-gal, 85-gal, and other sizes of drums, and also various sizes of plywood boxes. There are also many shapes and configurations of concrete casks and metal bins. However, this slide shows that the total volume in storage, contents and containers included, is 60,683 m^3.

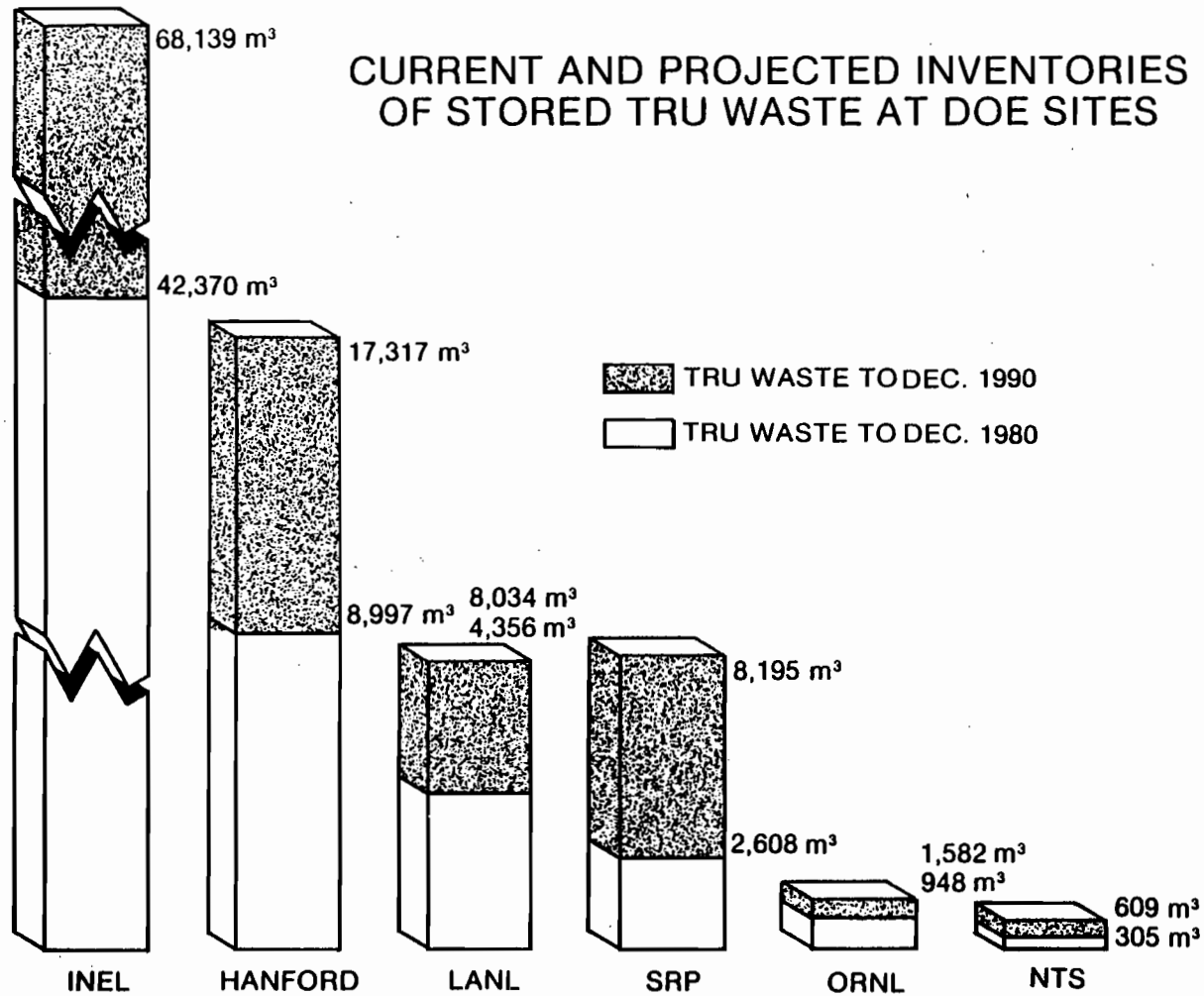
The RH waste inventory is significantly smaller than the CH inventory is (Slide 12). Much of the RH inventory, about 1100 m^3 or 63%, is process equipment that has been taken out of the Purex reprocessing facility at Hanford and has a small amount of TRU nuclides associated with it. It has not been possible to make accurate measurements; therefore, the equipment is assumed to be TRU waste. If in fact it is not TRU waste, then we would have a different picture of RH waste forms. Most of the waste would be combustible. A high percentage of the containers, mostly the process equipment stored at Hanford, is on flat-bed rail cars that are located in tunnels that isolate it from the environment. Most of the rest of the RH waste is in concrete cylinders and steel casks or capsules. The paint cans and steel drums, each 1%, also have secondary containment. They are placed either in large underground caissons or in steel inserts in the ground.

Slide 9

FORECAST OF REMOTE-HANDLED WASTE FORMS AND WASTE CONTAINERS (1981-1985)



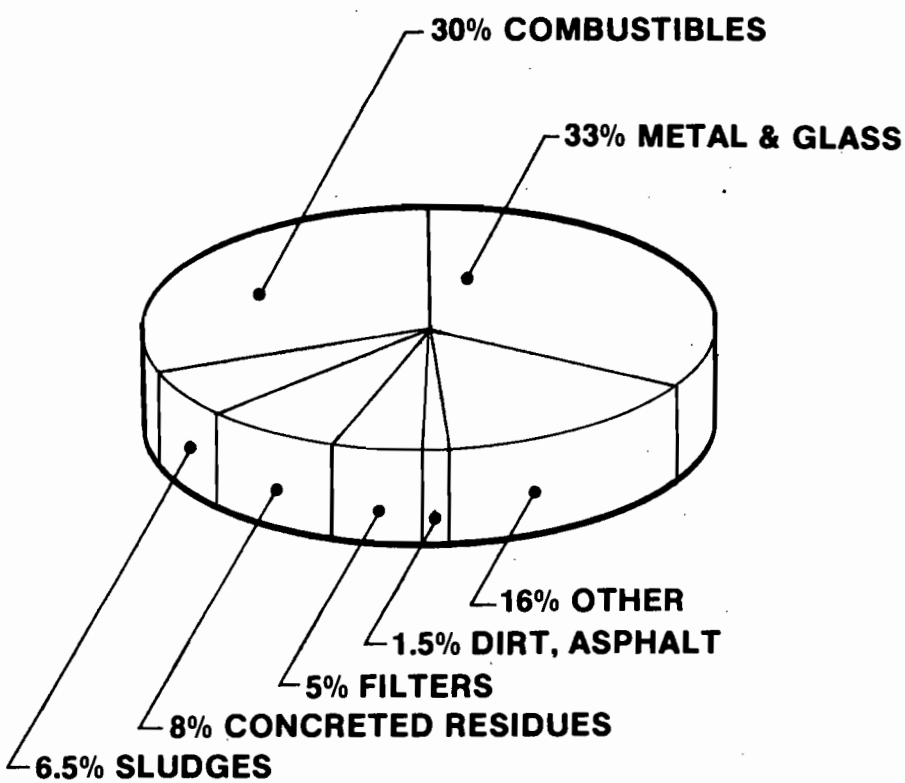
Slide 10


CURRENT AND PROJECTED INVENTORIES
OF STORED TRU WASTE AT DOE SITES
TRU WASTE TO DEC. 1990
TRU WASTE TO DEC. 1980
68,139 m³
42,370 m³
17,317 m³
8,997 m³
8,034 m³
4,356 m³
8,195 m³
2,608 m³
1,582 m³
948 m³
609 m³
305 m³
INEL
HANFORD
LANL
SRP
ORNL
NTS

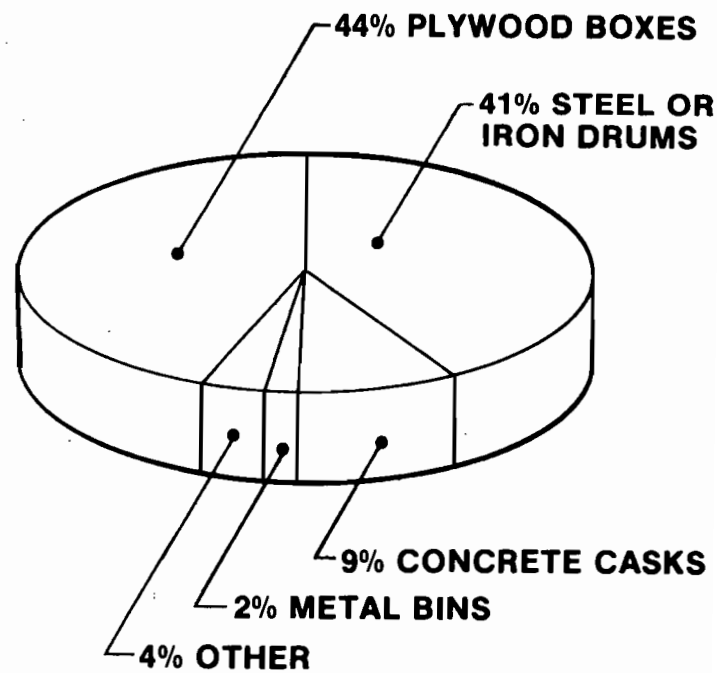
Slide 11

CONTACT HANDLED WASTE FORMS AND WASTE CONTAINERS IN STORAGE TO DECEMBER 31, 1980

INVENTORY TO DECEMBER 31, 1980 VOLUME %



INVENTORY TO DECEMBER 31, 1980 VOLUME %

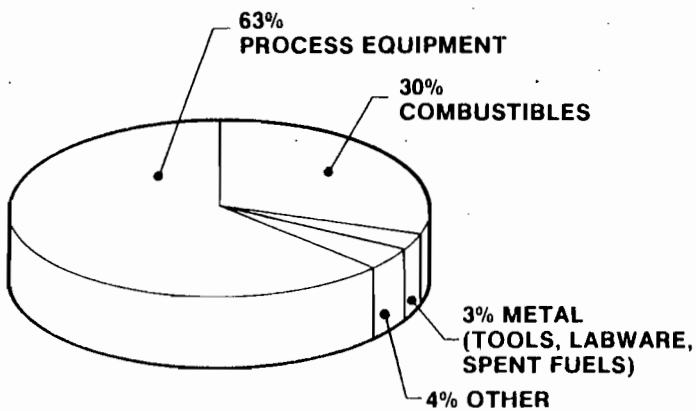


(TOTAL VOLUME = 60,683 m^3)

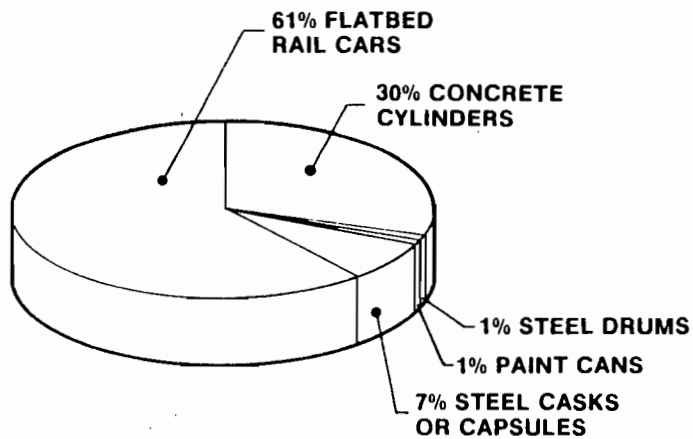
Slide 12

REMOTE HANDLED WASTE FORMS AND WASTE CONTAINERS IN STORAGE

INVENTORY TO DECEMBER 31, 1980
VOLUME %



INVENTORY TO DECEMBER 31, 1980
VOLUME %



(TOTAL VOLUME = 1712 m^3)

Next, I'd like to look at the TRU radionuclide content of the waste (Slide 13). So many numbers make up the details of the amount each nuclide contains that I didn't feel it would be worthwhile to put these numbers in front of everyone. The slide would be busy. But the estimates for newly generated waste are available for three isotopes: plutonium-238, plutonium-239, and americium-241. In stored waste, we have the total gram and curie amounts for eight major TRU isotopes, and these numbers will be included in the publication.

One of the key points I would like to make about the TRU radionuclide data is that, even though we do have the gram and curie totals of the TRU nuclides, these are not particularly helpful in determining how much waste is between 10 and 100 nCi/g. The nuclides are not uniformly distributed. However, we did look at the amount of curies or grams in specific containers of waste. To read the graph in Slide 14, begin at the bottom. The ten major categories of waste at Rocky Flats are listed. These categories comprise around 90% of the waste at Idaho Falls. The black part of the bar represents waste that is greater than 100 nCi/g. The lined portion represents waste about which we are uncertain, and the white portion represents waste that we believe is less than 100 nCi/g, based on numbers in the data bank. It should be pointed out that this is the percentage of containers on the Y-axis, not the percentage of volume, and this graph can't be directly related to volume because most waste forms, combustibles and metals for instance, are contained in both drums and boxes. The main point we are trying to make is that combustibles and metals, the largest portions of the waste, could largely be less than 100 nCi/g. Sludge and solid waste, however, is mostly greater than 100 nCi/g. It is now known that the evaporator salts, salts that were sent to Idaho in the early 1970s, are less than 100 nCi/g. In fact, for the most part, they are less than 10 nCi/g.

In summary, I'll go back to Slide 7, which summarizes the inventory and the projected inventory. The decisions today, of course, will have the biggest effect on the volumes of contaminated soil and the buried waste, although a decision to redefine TRU waste at 100 nCi/g is also going to decrease future projections significantly. These projections are based on a 10 nCi/g limit.

Craig Smith, Science Applications, Inc.: Do you have any idea what the concentration levels are for contaminated soil?

Jensen: They are very small, but I can't give you a number. I'm sure there are others here who could answer that a lot better than I could, as a matter of fact.

Answer from audience: In the case of contaminated soil associated with our buried waste at Rockwell Hanford, that portion of the soil immediately adjacent to breached containers may have contamination levels up in the thousands of nanocuries per gram. Farther from the

Slide 13

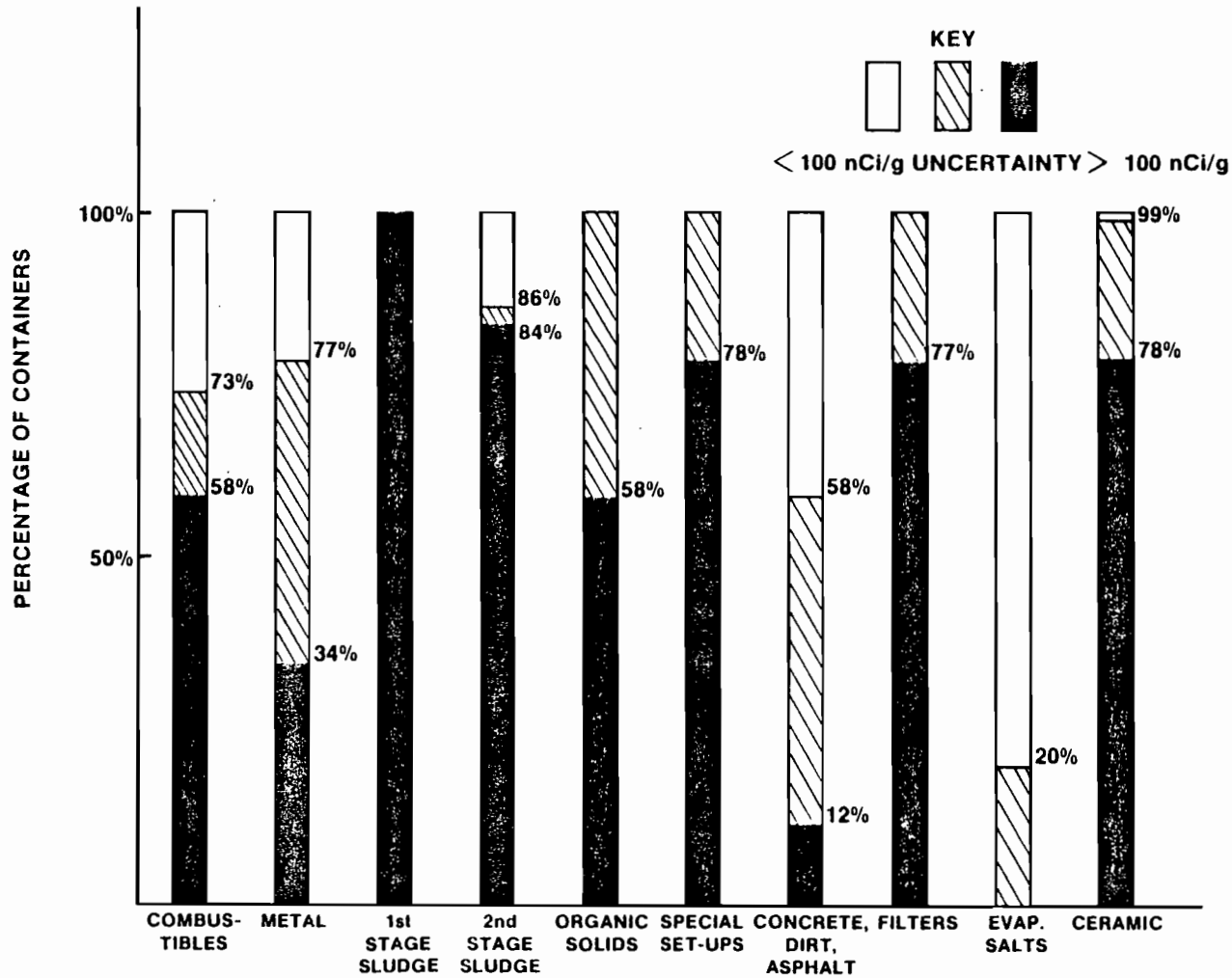
TRU RADIONUCLIDE CONTENT

NEWLY GENERATED - Estimates are available for three isotopes: PU-238, PU-239, and AM-241

STORED WASTE - Total gram and Curie amounts are available for eight major TRU isotopes

Slide 14

SPECIFIC ACTIVITY OF TEN MAJOR CONTENT CODES FROM WASTE GENERATED AT ROCKY FLATS PLANT



container, the contamination tails on down to zero. Most of it, I would estimate, is quite low.

Jensen: For the large volumes (3 to 8 million m^3) that we have here, surely most of the waste is somewhere in the range of 0 to 1000 nCi/g.

Bill Ellis, DOE/Savannah River: Are all these projections for 10 nCi/g?

Jensen: Yes, they are.

Ellis: Will you, or anybody else, be doing a quantitative analysis of the different volumes projected for 10 and 100 nCi/g?

Jensen: Yes. In fact analyses of that type have been going on for some time now. I don't have any of the numbers with me today, but this work is definitely being done.

Ellis: Will we have an approximate idea this week of what those numbers are?

Jensen: No, we won't.

Tom Smith, EG&G Idaho, Inc.: I will be presenting some of those data later this week. I have one diagram that shows some of those numbers, but with a great deal of uncertainty. My numbers are for the stored waste at Idaho. They do not cover other DOE sites--only those wastes that are shipped to Idaho. And again, the figures are uncertain.

Bill Kennedy, Battelle-Pacific Northwest Laboratory: On Thursday, I will be giving some calculations and support of work we have done at Hanford and trying to relate those calculations to a specific site that was used for liquid waste disposal. We were attempting to develop disposal criteria for that site, and I have a well profile of the extent of TRU contamination beneath a reference site that we use as an example in the analysis. However, I think the volumes of soil listed in this presentation as possible contaminated soil areas are adjacent to known contaminated sites and are soils that would probably have to be removed. Total volume would dilute the total concentration to levels probably below the 100 nCi/g limit. But you have to deal with isolated areas that are known spots of much greater contamination also.

Jensen: Thank you. I didn't mean to answer for everyone else. The TRU Waste System Office presentations won't give additional data, but others may.

Bill Lennemann: Do your contaminated soils include the Hanford cribs?

Jensen: Yes.

Lennemann: You also noted that Hanford has a larger amount of plutonium buried then Savannah River or any other of the sites. Did your calculations include the plutonium in the waste tanks?

Jensen: No, they do not.

Lennemann: At Hanford, do you consider the plutonium in the cribs as buried waste or as stored waste in your calculations? Is that why Hanford shows up so high?

Jensen: The plutonium in the cribs that has gone into the soils, yes, is considered in the contaminated soil inventory.

Lennemann: That is included in the Hanford calculations?

Jensen: Yes it is, and that is precisely the reason that they are so high.

Lennemann: When the soil from the cribs is removed, won't this source be removed? Have abnormalities of migration or isotopes beneath these cribs been observed? What has happened? Or is it just a matter of being in agreement with the law or with the bill that is going to come?

Jensen: That probably isn't a question for me; I don't know that they will be removed.

Kennedy: I believe this paper is perhaps a good introduction to the information I'll present in more detail later. It shows, in keeping with the common-sense approach we heard this morning, the alternatives that can be used for these areas.

Vern Rogers, RAE Corporation: What kind of information is available on the isotopic makeup of the wastes? For the newly generated wastes, you mentioned isotopics on plutonium-238 and -239 and americium-241. Do we have any extensive lists of what the isotopes are for the other wastes?

Jensen: Yes. We have the total gram and curie amounts of uranium-233, neptunium-237, plutonium-238, -239, -240, and -241, americium-241, and curium-244 for each storage site. There are also gram and curie amounts on a variety of other isotopes at some sites.

Rogers: The question was, are isotopic concentrations available for categories other than stored?

Jensen: All we have is a general percentage estimate of some isotopes. There are no accurate numbers. For a given amount of TRU elements, such as those seen in Slide 6, we have the estimated percentage of plutonium, americium-241, and curium-244. Two other recent reports have tried to categorize the breakdown on TRU waste.

One is the Oak Ridge report (DOE-NE0017), which you are probably familiar with; the other is the Shefelbein report from Sandia. My data are fairly consistent with these other reports (especially with the 0017 document because I am the source of that data). But, I should say that the 0017 for last year has been significantly revised. The latest one is in preparation now (DOE/NE0017/R1), and I would advise you to get the new one instead of the 0017. I used Mr. Shefelbein's work as a guideline for my report and tried to use some of his techniques for assembling tables. His work is very good, although it is now somewhat outdated. He does have an interesting table in his work on radionuclide content. His work has histograms that show the numbers of drums in Idaho and Savannah River that contain a given amount of plutonium. For instance, there is a histogram that shows how many drums have 1 g/drum, how many had 20 g/drum, and so forth, which is useful.

Bill Tedder, Georgia Institute of Technology: For some of your earlier numbers, you gave six significant figures. It is hard for me to believe those kinds of numbers. When you were giving the curies, you also had quite a few significant figures. Can you justify that? It seems to me that you have points-on distribution in those. Do you have any estimates of confidence intervals? You gave some numbers that were very large for small waste quantities. How can you justify that many significant figures?

Jensen: I can't justify those significant figures. Although the accuracy has definitely improved in recent years, the number of significant figures is generally greater than justified in a true scientific sense. They are nonetheless useful for accounting purposes. We generally use the numbers as reported by the sites. But I can't justify them and, in fact, I don't. I know they are not correct to that many significant figures.

DETECTION AND DETERMINATION OF ALPHA CONTENT OF WASTE

John Umbarger, Los Alamos National Laboratory

The collaborative program I will discuss involves our laboratory at Los Alamos National Laboratory and EG&G, Santa Barbara; it also extends to some of the sites we are working with now. Oak Ridge is our major contact, but we are also designing and building systems in collaboration with Idaho, Rocky Flats, and Richland. The program involves a lot of people and DOE facilities.

Why do we assay in the first place? We may do it because someone tells us to do it to satisfy a regulation. But aside from the regulation, we really want to do it for health and safety reasons. Worker and public exposure is the concern; we are interested in criticality measurements, dose measurements, or contamination measurements. Effective waste management is important.

A few years ago, everyone handled waste conservatively. If we didn't know what was in the waste, we handled it administratively as if it had higher levels than it probably had. This ties up a lot of resources and dollars.

Waste was also assayed because we didn't want any surprises. I was in the safeguard program for 4 years, and if you examine the safeguard program's records, you find that there were a few surprises. Some containers that people thought contained very little material were shipped around the country. But when they opened some of these crates, they found much more material. We don't want that to happen; that's another reason for assay. Assay, then, basically assures quality and that there are no surprises in a waste management program.

Economics is also involved. Volume can be reduced by assaying waste, to reduce packaging, transportation, and Waste Isolation Pilot Plant (WIPP) cost.

The basic goal of the assay program is to monitor transuranic (TRU) materials qualitatively and quantitatively. We apply that to defense waste and to commercial waste. Also, the techniques that we have developed in the program are generic. They can be applied to other types of radioactive materials such as those from the radiopharmaceutical industry. The main objective of the project is one of deliverable systems.

In collaboration with our sister laboratories, we are building systems and installing them in waste generators in an operational environment. The systems are integral to the operational waste management programs and, in that way, we provide technology transfer from the laboratory into the "real world," if you will, and to the commercial sector. The commercial sector is important because ultimately it will be doing the instrument manufacturing and, perhaps, the actual assay in the plants.

The approach of the program is demonstration and application. We are applying a technology base that already exists in the Department of Energy (DOE) laboratories:

- Nondestructive examination [NDE (which has been going on for about 35 years)]
- Radiation monitoring and dosimetry
- Nuclear safeguards
- Nuclear weapons testing

The bottom line is that much of the technology is available right now. You need to tap it and bring it to bear on some of your waste management problems.

WIPP and its waste acceptance criteria is another reason you're interested in assay, or certainly in verification. A number of items in the WIPP waste acceptance criteria require assay and verification. Determining fissile content, where you are interested in finding less than 200 g in a drum, is easy. Also verifiable is thermal power, where you're interested in ascertaining that no container has more than 500 W (by the way, 500 W is equivalent to 1000 g of plutonium-238; that is a lot of material and consequently is easy to monitor). Surface dose, surface contamination, and NDE are also all possible through the methods we have been developing. In NDE, you can pick up various things (e.g., free liquids). I will show some viewgraphs later of some of the things that you can identify inside casks or drums with this technique.

For TRU assay, the level is 10 nCi/g. This figure of 10 nCi/g means that about 370 disintegrations, or alpha particles, are emitted per second per gram of waste. For those of you who like English units, that is about 10^9 alphas per fortnight per gram of waste. Let me give you an example: for a 100 kg (10^5 g) drum (this size is typical in the waste industry) and for an allowable activity of 10 nCi/g, you multiply the size by 10^5 g, ending up with 1 mCi in the drum.

Therefore, for plutonium-239, you have to measure 16 mg. That is not much material when you convert it into a mass concentration level, which works out to 160 parts/billion. For chemists and atomic spectroscopists, that is a small amount, and when you get down to the curium or the californium isotopes, you are trying to measure parts per trillion.

Our assay development program consists of five areas: the site survey that we did at five DOE sites, the deliverable systems that we are now working on, our accelerator-based research, the economics of assay (which is important), and assay developments.

The five sites that we considered were Richland, Rocky Flats, Los Alamos, Oak Ridge, and EG&G, Idaho. At Richland, we found about a

20,000 drum inventory, with 3000 drums produced every year and about 35 crates. We would have to assay about 6000 drums every year. About 50% of these drums are expected to be less than 10 nCi/g, which would result in considerable cost savings.

Rocky Flats, like the other sites, has good administrative controls. The assay equipment could also assist with existing equipment and quality assurance for their overall program of the waste going to EG&G, Idaho, and eventually on to WIPP.

In addition to its administrative controls, Los Alamos has extensive experience with the MEGAS systems for assaying combustible waste. Consequently, we have had significant cost savings.

We term Oak Ridge the "gourmet center" of the nuclear industry. It has a little bit of everything. We are used to the weapons-grade plutonium and a few other isotopes, but at Oak Ridge you really get it all. We hope the experience we are gaining in Oak Ridge will allow us to make waste management easier when matrix and isotopics are better defined. At Oak Ridge, there is a wide spectrum of isotopics. Oak Ridge has 3000 drums in storage. Our assay test and evaluation program began in March and is well under way.

Idaho, as you all know, is an interim storage site, and waste packages are best assayed at the generator. However, Idaho does need safety instruments for criticality, dose measurements, and contamination. Idaho has a potential problem with exhumed waste.

We are now working on a number of deliverable systems. I mentioned that we had already installed the Oak Ridge system. The Richland system, which we are planning now for installation in 1985, is an 83-gal drum counter. Rocky Flats will receive a crate counter with installation next year. Idaho will have a 55-gal drum counter with installation in FY 84 and a crate counter in FY 86. The crate counters will take the 4 x 4 x 7 ft crates. These will also hold a six-pack of drums.

Our accelerator-based research program is a large effort. To simplify, we are looking at both proton and neutron interrogation. We add to those interrogations passive interrogation for neutrons and passive gamma ray interrogation, studying gamma rays that are produced passively by the materials. These systems are generic; they can be applied to a wide variety of isotopes and matrixes. We are applying these systems to drums and crates with detection levels less than 10 nCi/g in most cases, particularly for drums. This works out to be less than a milligram of fissile material.

For assay capability, our accuracy is not very good (if you are a chemist), but we are generally delighted if we can get 30 to 50%. Our detection limit for drums (and packages that are smaller than drums) will be less than or equal to 10 nCi/g. For crates, however, we claim

only about 100 nCi/g. Problem wastes are those with (1) unspecified matrix, (2) matrix that is going to have a neutron poison in it, and (3) a wide variety of isotopes that we were not expecting. In these cases, our detection limits could enlarge (get poorer) by a factor of 10 and our errors could widen by a factor of 2.

These assay techniques can be applied to high-level wastes from the commercial sector. We have assayed drums with content radiation levels over 1000 rem/h. We have no problem with them, and we think we can go much higher than that, probably by a factor of 2 to 5, and still do the assay at less than 100 nCi/g. However, the neutron system we use is insensitive to fission product backgrounds (common in high-level wastes).

We have studied matrices like sludge, steel, wet and dry rags, sand, polyethylene, and graphite. We looked at bitumen (which the French use) and found that the bitumen gives us problems. It looks just like a barrel of wax or water. The neutrons cannot get in, and if a few do, they create TRU fissions; the neutrons cannot get back out to be counted. That has been our biggest problem. Concrete, on the other hand, is easy for us to deal with. We feel that we can do less than 10 nCi/g for a drum full of concrete that may weigh 1000 lb.

One element of the economics of assay is instrument cost. The costs that I will discuss are basically for installing the instrument, including a large inventory of spare parts and including a year of follow-up when the instrument is actually warrantied. You cannot install an instrument and cut the umbilical cord immediately. The follow-up year is critical to ensure that the program really works. For a 55-gal drum system, cost is about $0.75 million; for the crate counter, a little bit over $1 million; and for the 2-ft combustible package counter, anywhere from $80,000 to $120,000.

Richland provides an example of economics of assay. Consider instrument cost and the operational costs of drum storage and handling after the assay. You have two routes: shallow land burial and TRU storage. Once WIPP is finished, the waste must be transported. We are assuming that the throughput is 2500 drums/year up to 1990 and 5500 drums after then. This also assumes that Richland will continue to use underground storage. Given all these assumptions, Richland ends up with a curve that shows that, if 19% of the drums are diverted (via assay) to shallow land burial (because they have been proven less than 10 nCi/g), Richland will break even paying for all operational costs. Richland expects its percentage diverted to shallow land burial to be much higher (45%). At 45%, the 20-year cost recovery is about $13 million.

Los Alamos has the MEGAS Box Counter, which will handle nearly all of the combustible flow, fission product context TRU waste produced by the defense industry. The system is rather inexpensive to operate and also to purchase. It requires combustible wastes to be put in

a small package, about a foot square by a couple of feet high (about 60 L). Los Alamos has been using small packages all along, so assay was easy to begin. We have been using the MEGAS system at Los Alamos since about 1975, and the data I am showing here represent all the combustible waste coming out of TA-55, the main plutonium facility at Los Alamos. TA-55 is the new structure that started operation in 1978. All combustible wastes coming out of the room areas go through this system. We have found that over 98% of all the TRU wastes are less than 10 nCi/g; less than 1% is between 10 and 100 nCi/g; and less than 1% is over 100 nCi/g.

In 1981, Los Alamos ran about 4600 boxes through the system (over 9000 cu ft^3). Only 66 ft^3 was found to be TRU waste. Before assay, Los Alamos had to assume that all waste, because it was potentially contaminated, was considered contaminated above 10 nCi/g. If you assume that disposal costs, without assay, are \$50/ft^3 and disposal cost for waste going to shallow land burial is \$7/ft^3, assay saves about \$400,000 each year. Operational costs are about \$100,000 a year with one person doing the assay on a routine basis, making the savings about \$300,000.

This picture shows the MEGAS system built in collaboration with Pacific Northwest Laboratories (PNL) for Richard Allen and Bud Arrowsmith's program. The systems at Los Alamos and Richland (which was installed by a commercial company) are similar. The technology for the MEGAS was transferred to the commercial sector. There is a company in Los Alamos, and there are others around the United States, that can build these systems, install them, and show your people how to run them.

If you consider the economics of assay, as I mentioned earlier, Idaho has the problem of exhumation of waste. Idaho estimates that it has about 5.5 million ft^3 of soil compacted in and around the drums in the storage area. About 3 million ft^3 are probably less than 10 nCi/g, but this cannot be proven. Sampling the field is impossible. Assume a \$200/ft^3 differential expense for TRU materials. This yields about \$600 million in savings by using an assay facility that would cost less than 2% of that.

What happens to economics when you go from 10 to 100 nCi/g? It is really a function of the volumes diverted from WIPP, naturally, and it will vary by site. At Los Alamos, going to 100 nCi/g will probably not help. As we saw, the MEGAS system proved that over 98% of their combustible waste was already less than 10 nCi/g; going up to 100 nCi/g would not matter. But at other sites, the savings of going to 100 nCi/g could be large, perhaps over several billion dollars. These data were provided by our colleagues at Richland, Idaho, and other sites.

Let's look now at the assay systems themselves. The first is a differential dieaway technique for barrel counting. (We gave it

that name because we monitor the time decay history of the neutrons produced by the fissioning material after it has been pulsed by an external source.) We use a small DT-generator as an external source. The generator is about 1 ft long and 4 in. in diameter, almost the size of a light bulb. When is burns out, it can be replaced in about 30 min. The barrel sits inside a detector cavity. We apply the same principles to the crate counter system. The DT-generator gives off a burst of neutrons; these are 14 MeV neutrons. They flood the entire cavity, slow down in the matrix material inside the drum, bounce around from the polyethylene and the graphite inside the cavity, and finally slow and are captured by the fissile material inside the drum. Then a whole new generation of fissioning neutrons, separated in time from the original pulse from the neutron generator, has been produced. These neutrons have a different energy. We were doing a thermal interrogation before (until the neutrons have slowed down); the new generation of neutrons is being emitted with a much higher energy. You have a classic fission energy spectrum. You can detect the neutrons with energy differentiating detectors, and you can also separate them in time. This method has been developed in the last 2 years. Previous techniques did not allow prompt neutron detection; this one does, and that's why sensitivities have improved 100-fold. In the past we could only look at delayed neutrons, which are a small percentage of the overall neutrons given off in any fissioning event.

Now I will briefly discuss some of the work we've been doing at Oak Ridge. This slide shows the Oak Ridge site with the assay building and TRU storage pads. When you do test and evaluation programs, often, after installing the equipment, you find it isn't quite what you thought it was going to be. For those of you who are building plants with an assay system, please take account of what your TRU traffic is, how materials will move up and down the corridors, and where you're going to store your materials. At Oak Ridge, the storage pads were all underground, we thought; only the top layer of barrels was above ground. But we got a significant neutron shine coming from the pads into the assay area, which tended to raise our background and limit our sensitivity.

The Oak Ridge National Laboratory (ORNL) program is truly a collaboration between our two laboratories. A program like this could not be performed without the complete support of the host facility. If the host did not come forward and open all the necessary doors, helping whenever you have a problem and providing technical people, it would be impossible. Working with ORNL on the program has been great.

This slide shows the drum counter with the door closed and the draw bridge up. To do the system as quickly and as cheaply as possible, we chose the draw bridge idea. This slide shows the ramp down and a barrel in place, with more barrels ready to go. A fork lift places the barrels on the pad. The contact-handled (CH) barrels sit on little skids that have ball bearings that allow them to roll freely. Some of the barrels from ORNL, by the way, have 10^6 neutrons/s coming

out of them, so we found significant neutron backgrounds, in this case coming from inside the drum. This slide shows the door open. The neutron generator is in the back and at the top is a normalization flux monitor that allows us to monitor the output of the neutron generator. It also senses the matrix effects. Although the matrix can change by a great amount, we find that we're usually plus or minus 30% using the flux monitor. The same assay techniques apply to crates or six-packs of drums. A passive and an active assay are used. This slide shows the crate counter, set up at Pantex, where we have had a lot of operational experience. This slide shows the crate counter that we're building for Rocky Flats, and Walt Kuntz, one of the developers of the system, is holding the little neutron generator. Usually, when you think of accelerators, which the generator is, you think of a great big device, but accelerators are getting smaller. The accelerator in this slide is a little bit bigger. It is a standard commercial electron accelerator (linac), which we're using at Pantex to do not only the assay of the TRU materials using photon interrogation, but also to do a nondestructive examination of the package by putting up film so you can tell what "shapes" are inside. To start to look at free liquids, you can start to look at some of the undesirable things that might be inside that drum. Before you open it, you can make sure you do not have any surprises. Let me give you an example of some of the pictures you can take. This slide is a radiograph of a crate that was 4 x 4 x 2 ft tall. Inside were several drums and some debris, including a 50-caliber bullet and a parachute clip. This slide is a radiograph of a different package. This one had six drums inside the package. It's nice to know, before you break into that big plywood carton, that you will not get material all over the floor or have stuff that will fly around. A picture like that is, as they say, worth a thousand words at least.

My final thought concerns how best to use the assay dollars that we have within the whole TRU complex. They are limited; we have a lot of constraints on our money, and there's just not enough of it to go around to do the kind of job that you, as waste managers, would like to do. We think there are really two ways of solving assay problems. First, you have dedicated systems at the large generators like Rocky Flats, Idaho, and Richland. But we think that smaller generators ought to be serviced by a mobile system. We did some work at Los Alamos in the late 1960s and early 1970s on a mobile van that we called the Mobile Nondestructive Assay Laboratory (MONAL). With a complete assay laboratory built into it, MONAL traveled all over the country for a number of years. I served on it in Oak Ridge. It was also at Rocky Flats and other places. It was phased out because of economic, not technical, reasons. In fact, I think it was a bit before its time. It even had a complete active interrogation system in the rear end with a barrel handling system underneath that could load the barrels, pop them up inside the van, do the assay, and bring them back out.

Sharing assay costs, as is done with a mobile system, is crucial. Many facilities share the cost, because the system can go to one site for 1 month and another for 2 or 3 weeks. You can do both the assay and the examination of the package. Eventually, this concept should be transferred to the commercial sector.

MONAL was a 50-ft trailer; this slide shows the floor plan. In this slide, one of the drums is being loaded. The drum carrier moves around and, as I said, it pops it up into the interrogation cavity. This slide shows the shield door for the accelerator room in the rear end. Filled with oil and water, the door is neutron shielding. This slide shows the control room and a couple of old friends of mine. But this slide is only about 1 week old. It shows a linac system for doing both TRU assay and nondestructive examination of the package. This slide shows one byproduct of another program at Los Alamos, a portable accelerator that you can put into a van and move around the country, then take it out and set it up within a couple of hours and start doing the analysis. This system will be finished by next summer. I think we ought to take advantage of technology that is already being developed under other DOE programs.

In conclusion, let me give you our idea of where we are in waste management and assay. Our position is like Matthew 25:31, which is the parable of the sheep and the goats. Our job is to try to separate out the sheep--less than 10 nCi/g--and the goats--greater than 10 nCi/g. Unfortunately, we end up with the turkeys! The turkeys are sitting in the middle, making our job a whole lot harder. We can usually identify the sheep and the goats, but there are a few turkeys, no matter how hard we try. We still can't give you a definitive answer on which side of the fence they should sit on. For those of you who are going to run back to your room and dig out your Gideon, be sure that it's verse 31 and not verse 1; that's another problem in the industry. Matthew 25:1 is the parable of the five foolish and the five wise virgins.

Joe Lieberman, Nuclear Safety Associates: John, are the cost numbers you gave purchase costs or installed costs?

Umbarger: Those are fully installed costs with a warranty and spare parts inventory.

Lieberman: I was interested in the scaling of the instrument cost as a function of its sensitivity. As an example, your drum counting instrument, sensitive to 10 nCi/g, costs about $750,000. What would its cost be if it only had to be sensitive to 100 nCi/g or 1000 nCi/g?

Umbarger: In one slide I showed, we were trying to measure 16 mg of plutonium-239 at 10 nCi/g. If you go to 100 nCi/g, then that will be 160 mg, which is still below the threshold of the typical safeguards instrumentation that can measure, say, 0.5 g of fissile material by a factor of at least 3 or 4. So, unfortunately, by going from 10 to 100 you don't save very much; you've still got the basic computer system, a lot of polyethylene, moderated helium 3 tubes (and the helium 3 tubes are very expensive), and all the work to put it together. If you should, however, go to 1000 nCi/g then I'd say you'd probably cut your costs by 30 or 40%. You might save 15% by going to 100 nCi/g, maybe 25% on some applications, but you'd have to select your application.

Steve Adams, EG&G, Idaho: You mentioned that some matrices and collections of isotopes make it difficult to determine 10 nCi/g. At this time, is it possible to know which barrels those will be before you measure them?

Umbarger: No. But we can tell after measuring the barrel that we have problems with it. For example, the flux monitors that we use tell us that we have a lot of hydrogenous material or that we have some neutron absorbers. We can "flag" the barrel and say that it is suspect. That's one of the "turkeys." Most of our systems have a gamma-ray assay system on the front end. We do at Oak Ridge, and we recommend that you have gamma-ray detecting devices as part of any system. With the gamma-ray device, you begin to pick up all the various isotopes and, even though you can't always be quantitative (because of matrix absorption), you can be qualitative. The device is specific to most of the isotopes. You can tell with the neutron assay that you've got significant problems with that barrel just because, for example, of the wide range of isotopics. We have ways of flagging it, but we don't have ways to unravel that particular barrel. Some drums will have to be pushed aside unless you want to turn them into a complete research program. Yes, I think we can probably flag 95% of the "turkey" barrels, but that other 5% will still slip through.

Tom Tracalla, Battelle-Pacific Northwest Laboratory: If you take 16 mg of plutonium, representing 10 nCi/g, and you homogeneously distribute that, as opposed to a case where it's located in one location, what kinds of sensitivity problems do you have?

Umbarger: None. In fact, if you lump it together, you run into matrix problems from self attenuation. You have some self-shielding going on in the plutonium itself. Our systems are both active and passive, and this is a thermal interrogation system, which is very good for small amounts of plutonium. But when you get up into the gram-like quantities, if it's all lumped together, you have a problem because the neutrons will not get into the center of that little plutonium ball.

But now you've got a passive system. By looking at the spontaneous fissioning isotopes such as plutonium-240, you can say, "Hey, I've got a lump of stuff here." That is generally not a problem. By the way, the assay times, I never mentioned before, are short. We are running at Oak Ridge, for example, on the active portion, at 167 clock seconds of assay time, 10,000 pulses of the accelerator.

Larry Eisenstatt, West Valley Nuclear Service: Can your system determine how homogeneous the TRUs inside a barrel are?

Umbarger: We can to a degree. Let me show you how we do that. This slide shows the crate counter. Inside each one of the side panels on the door and the walls are two banks of detectors (16 banks total). Each one is run independently into a computer system, which takes all the data. With the computer system, we can compare how many counts per second we are getting in one bank versus the other 15. So you can start to identify hot spots, and, in a six-pack of drums, we think we can pick out a hotter than average drum. We purposely made our drum counter have a flat response across the cavity so that it does not matter where the plutonium is.

Wally Sumner, Allied General Nuclear Services: Are you talking primarily about demonstrating handling CH waste?

Umbarger: That's right.

Sumner: Do you have any plans to demonstrate with RH waste, and what impact would that have on your $750,000 cost?

Umbarger: That would probably affect the facility's costs more than ours. In fact, the crate-counting system that we're building with Idaho is for crates that are going to be loaded by forklifts. Everything could be done remotely if you have well-shielded forklifts, and remote handling doesn't bother our system much until you get over 1000 rem/h. At that point we just start stacking lead inside, which doesn't hurt the neutron assay but cuts down the gamma rays. I don't think remote handling will raise our cost significantly, but it will probably change the operation cost.

Charles King, Savannah River Laboratory: Your detection system is based on neutron absorption by fissile material. What about the nonfissile material detection limits?

Umbarger: As an example, let's take uranium-238, americium-241, and some of the others. We can detect those by several means. In proton interrogation, we will pick up the "heavies." And you also have a gamma-ray system. All of these isotopes give off some radiation or they wouldn't be of concern to us. So we can detect for any isotope; I've got a long list here and I'll be happy to tell how we're going to do any particular isotope, except, of course, for the turkeys, which fall in the middle again, and them I'll have to throw away.

Ray Lambert, Electric Power Research Institute: What margin do you give yourself to ensure meeting limits, and what kind of calibration systems do you get locked into? Do you have to have drums of different matrices and an elaborate calibration to be sure your system is, in fact, geared appropriately?

Umbarger: Our algorithms calculate and determine whatever the measured activity level was. At some point, the numbers mean less because the measurement went below our detection limits. But we feel that for most drums we can see a fraction of a milligram, which means a fraction of a nanocurie per gram. That is why we feel confident that we can go after 10, because we are measuring below 1. Your second question related to the calibration procedure. At Oak Ridge, and then as a follow-up on the work at Rocky Flats, we're putting all kinds of matrices in the counters to make sure that we understand what the matrix effect is. We have calibration drums that are basically drums filled with various matrix materials with tubes down them. One tube is in the center, one halfway out to the wall, and one at the wall. We can locate all kinds of isotopes as a function of radius on the drum and at various heights within the drum cavity itself, if that answers your question. The calibration procedure that we have to go through to understand what is going on is extensive. That finally gets boiled down to an algorithm that the computer just crunches.

Mike Barainca, DOE, Idaho: I want to follow up on a previous question. Are your instruments calibrated? One of your slides, I believe, said the accuracy was 30 to 50%. Are your instruments calibrated so that when you are getting a readout you are being conservative within that error band?

Umbarger: We work with each plant and tell each one what the instrument will do, but a plant may want to set the instrument so that the error is stacked. Some plants may want to cut off at 6 nCi/g, knowing they have a possible 50% error. Anything over 6 they might assume as 10. But that is an operational matter. We give plants our best estimate of what the errors are and what the content is. And then they tell us how they want the algorithm to read so that the plant can divert it to one stream or another.

Bill Ellis, Savannah River Laboratory: The 30 to 50% error bar was based on 10 nCi/g when in fact you have gone up to 100.

Umbarger: Certainly at 100 your statistical errors are reduced by the square root of 10. But our biggest errors tend to be biases from the matrix effects and the isotopics. I don't think errors improve much by going to 100. If you tell me that you want just fissile content, for example, then we can do that accurately. But if you say, on the other hand, that you want some isotopic specific values, then I think the errors will remain. For total fissile, we could probably do 10%. At the higher quantities we do 3 or 2%. The system becomes a standard safeguard measurement technique.

RADIOLOGICAL HAZARDS FROM ALPHA-CONTAMINATED WASTE

John Rodgers, Los Alamos National Laboratory

The topic of this paper is the radiological hazards of alpha-contaminated wastes (Slide 1). Because I will talk about hazard, I thought it would be helpful to make the distinction between risk and hazard explicit. The term "hazard" implies the existence of some threat and the potential for its occurrence. A threat or hazard, in other words, may exist without risk. For there to be a risk and for the threat to become meaningful, potential pathways for exposure to man must exist. Failure to make this distinction has added much heat and little light to the nuclear debate. How often have we been bombarded with the anti-nuke sloganeering, "How many lethal doses are there in a pound of plutonium?" We are all familiar with press portrayals of plutonium as fiendishly toxic. And radioactive waste is said to be the ultimate form of pollution. Many of you remember the studies of Slovic and his colleagues about the public's perception of risks; the qualitative aspects of dread and catastrophic potential were found to strongly influence lay people's risk perceptions. One must be aware that discussing the hazard of a toxic substance has the potential to fan flames of dread and fear of catastrophe, resulting in a misapprehension of the risks associated with technologies using that substance. I hope my discussion of several components of radiologic hazard of alpha waste will not be construed as an enumeration of risks.

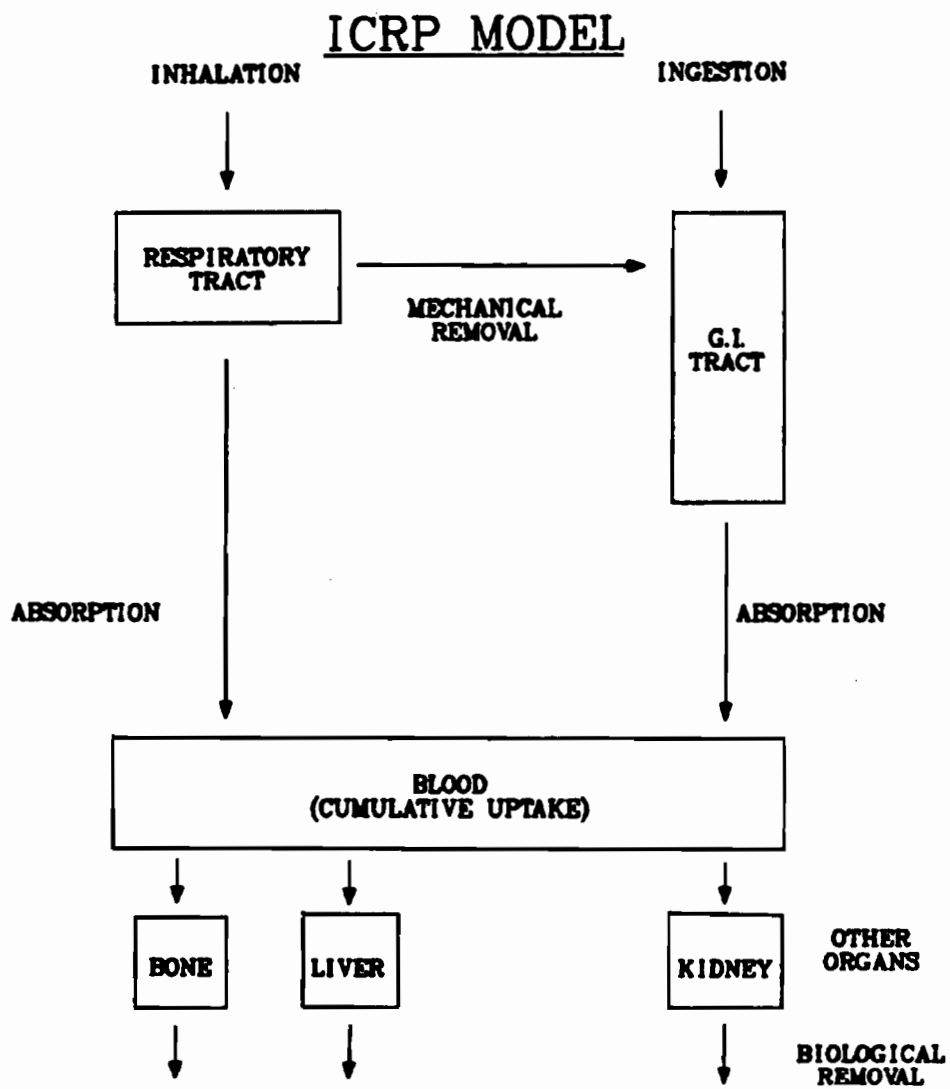
Let's turn to the main elements of this discussion and review some of what is known about radiobiological hazards associated with transuranic (TRU) elements taken into the body. We will also review what is known about radioecological hazards associated with various transport pathways of TRUs in the environment. Both of these are part of the overall radiologic hazard of alpha-contaminated waste disposed of by earth burial. I want to begin with radiobiological hazards of alpha emitters. The two routes of human exposure that are most significant in a discussion of hazards from TRUs released in the environment from buried waste are inhalation and ingestion. Let's first consider inhalation. Slide 2 shows the International Commission on Radiological Protection (ICRP) model. This is really the Task Group lung model and an ingestion model shown schematically. First, inhalation with deposition in the respiratory tract is followed by mechanical removal by mucocilliary processes to the gastrointestinal tract. There is also absorption into the blood directly from deposition in the lung and absorption from the gastrointestinal tract. Ultimately, there could be biological removal but also deposition in bone, liver, kidney, and other critical organs.

Plutonium and thorium compounds are often tenaciously retained in the lung. These compounds have clearance times on the order of 500 days, and uranium, americium, and curium are often more rapidly cleared with 50-day half-times. Plutonium and other TRUs absorbed into the

Slide 1

THE RADIOLOGICAL HAZARDS OF ALPHA - CONTAMINATED WASTE

Slide 2


ICRP MODEL
INHALATION
INGESTION
RESPIRATORY TRACT
MECHANICAL REMOVAL
G.I. TRACT
ABSORPTION
ABSORPTION
BLOOD (CUMULATIVE UPTAKE)
BONE
LIVER
KIDNEY
OTHER ORGANS
BIOLOGICAL REMOVAL

bloodstream are deposited principally in the liver and skeleton. Human and animal data show great variability in relative absorption and deposition in these organs. ICRP has recommended values of 0.45 for the fraction deposited from blood to both bone and liver. The human biological half-times in these organs are presumed to be 100 years for retention in bone and 40 years in the liver, extremely long biological half-times.

How have the Task Group lung model predictions matched observed data (Slide 3)? McInroy's data on plutonium from fallout sources in the general population have been compared with Task Group lung model predictions. Slide 3 shows some of the data, indicating that the burden in the lung is well predicted, but representation of deposition in other organs is not. The lung number is 0.14; prediction is 0.12. The autopsy figure for liver is 0.73, and the Task Group lung model prediction is 0.54. Measured liver deposition is about 35% greater. In bone, the autopsy figure is about 0.09, compared with the predicted 0.2. (However, McInroy tells me that his figure may be low because the bone samples he analyzed were not fully representative of the total skeleton, and the predictions are based on total skeleton.) Notice the enormous discrepancy in the lymph node data, which have an autopsy value of about 2, and the Task Group lung model, which has a value of 26.5. This discrepancy reflects the assumption in the model of 10% retention with no clearance. I would say that agreement within a factor of 2 in the case of bone, which is critical for hazard assessment, confirms the strategy and also that modeling kinetics of inhalation does not introduce a large uncertainty in the hazard estimation.

Next, let's consider ingestion intake (Slide 4). Compared to inhalation, ingestion is usually a minor route of entry into the body for TRUs. The variation in the reported mammalian gut uptake fractions is quite large, spanning at least 2 orders of magnitude. The variation comes from several sources, the most important probably being age (just 2 orders of magnitude here), actinide species, and chemical form of the ingested contaminant. The age factor resulted from studies of uptake in very young animals. In young rats, for example, the assimilation is about 2 orders of magnitude greater than in adults. On a comparative basis, plutonium is assimilated less readily than americium, and americium is assimilated less readily than curium. We are talking about factors of 2 to 10 over plutonium. This fractionation is also seen in the translocation behavior following inhalation. If plutonium and americium were inhaled, the americium component would be cleared from the lungs and deposited in the critical organs much more rapidly than the plutonium component.

From assimilation alone, 2 to 10 larger body burdens can result per unit intake of other actinides. The effect of the chemical form of the ingested actinide on uptake is highly significant. Uranium, perhaps, best illustrates the point. Estimates of assimilation of uranium from food, not chemical forms in water, range from 0.6% in

Slide 3

CONCENTRATION OF FALLOUT Pu IN MAN 1974

(McINROY 1981)

ORGAN	Pu CONC. (pCi/kg) AUTOPSY	TGLM
BONE	0.09	0.20
LIVER	0.73	0.54
LUNG	0.14	0.12
LYMPH NODE	2.0	26.5
KIDNEY	0.01	0.02

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Slide 4

FACTORS AFFECTING ASSIMILATION FOLLOWING INGESTION AND THEIR UNCERTAINTIES

AGE FACTOR	ORDER OF MAGNITUDE OF UNCERTAINTY
AGE	2
ACTINIDE SPECIES	1
CHEMICAL FORM (FOOD)	3

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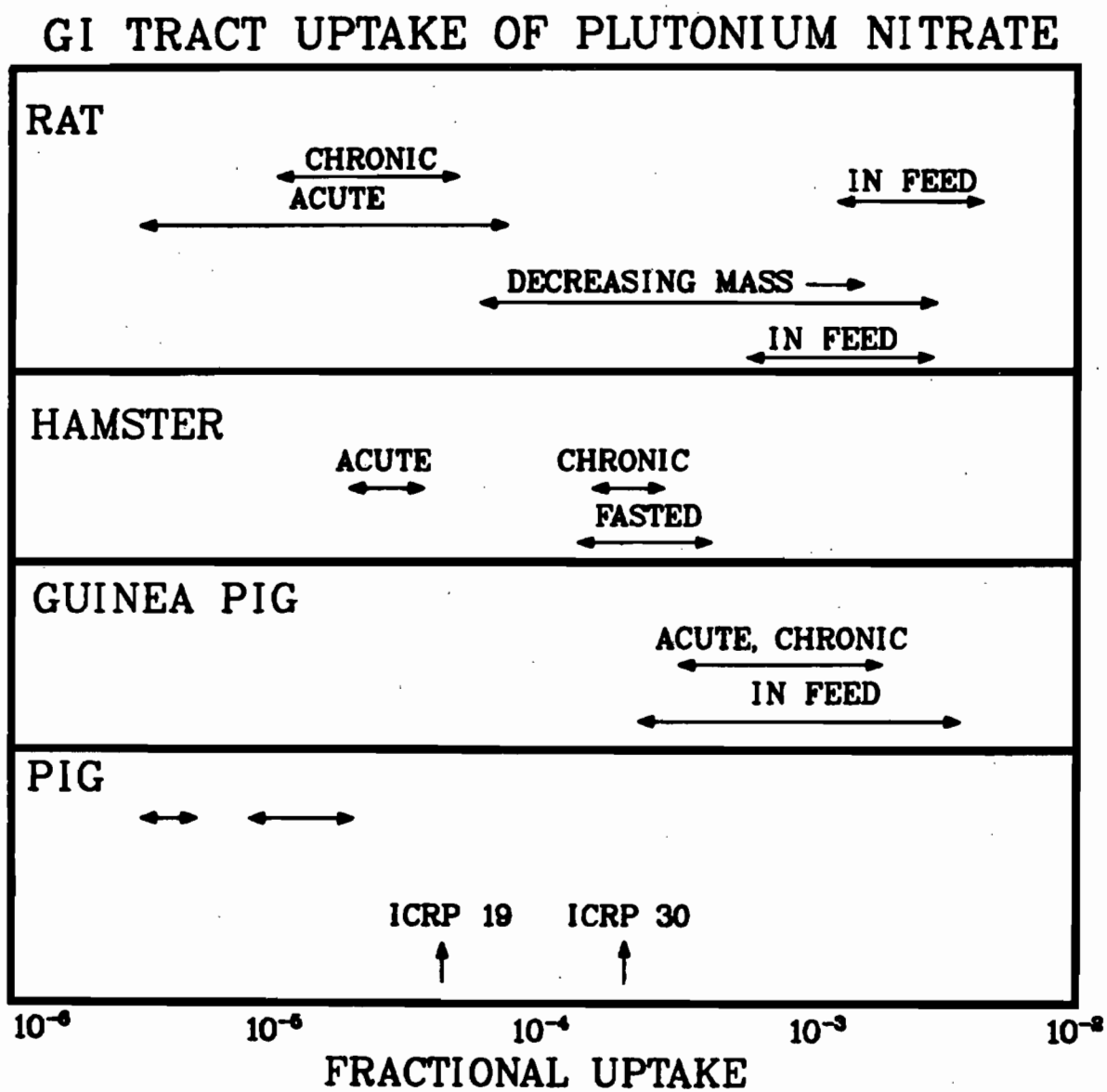
cattle to 2% in swine. Dietary studies indicate that human uptake of uranium in food ranges from 2 to 32%. These estimates are 1 or 2 orders of magnitude greater than measured assimilation from nitrate forms administered to human subjects.

Even the data on uptake of plutonium in nitrate form in the mammalian gut show considerable variation (Slide 5). The highest range of uptake fractions shown on this graph are associated with chronic feeding and with incorporation in feed. The scale is 10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}, and 10^{-2}. I think it is interesting that in the rate, this particular set of data shows that decreasing mass in the feeding regimen leads to greater uptake. I think this has important implications for environmental sources, which tend toward the low end of that range. Baxter and Sullivan's data show that in the citrate form, plutonium uptake from the gut in the rat is 2 orders of magnitude greater than in the nitrate form. That's like 10^{-3} versus 10^{-5}. Ballou and others have found that plant-incorporated plutonium exhibits an additional order of magnitude greater uptake. I think in this study the rats were fed tumbleweed that had been contaminated with plutonium. Similar results in other species reinforce the expectation that incorporation in food is a significant factor in determining gut uptake fractions. On this presumption, ICRP recommended that uptake fractions at 3×10^{-5} (ICRP-19) and at 1×10^{-4} (ICRP-30) may underestimate the worst-case environmental context.

Fractional uptake from the gut, fractional deposition in various organs of the body, and retention times are all critical factors that combine in the estimation of dose. The table in Slide 6 shows rem per microcurie values in critical organs from inhalation (on the left) and ingestion (on the right). These data are taken from Oak Ridge modeling with the INREM II code. If we consider just the portion of relative hazard proportional to dose per unit intake, we see that inhalation is a more hazardous mode of intake than ingestion is. Because the highest inhalation doses are up to 3 orders of magnitude greater than ingestion doses, for plutonium-239, the dose in the bone works out to about 360 rem/mCi for inhalation versus 0.2 rem/mCi for ingestion. Also on this basis, certain actinides are more hazardous than plutonium, particularly in ingestion. For example, the bone dose from americium intake by ingestion is 3 times the plutonium dose rate, and the liver dose is 38 times the corresponding plutonium dose. If we remember the expected higher gut uptake fractions, which were not assumed here (I think 10^{-4} was used for all of the actinides), then the relative hazards for neptunium, americium, and curium are correspondingly higher.

To conclude this brief overview of radiobiological hazards, inhalation presents the greatest hazard for entry and leads to the greatest doses. Also, there are many sources of uncertainty in our estimation of this hazard. The most significant, apparently, is associated with fractional gut uptake and gaps in our understanding of the metabolism

Slide 5


GI TRACT UPTAKE OF PLUTONIUM NITRATE
RAT
CHRONIC
ACUTE
IN FEED
DECREASING MASS
IN FEED
HAMSTER
ACUTE
CHRONIC
FASTED
GUINEA PIG
ACUTE, CHRONIC
IN FEED
PIG
ICRP 19
ICRP 30
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
FRACTIONAL UPTAKE

Slide 6

ACTINIDE DOSE PER UNIT INTAKE

(REM/ MICROCURIE)

	INTAKE MODE•			
	INHALATION		INGESTION	
NUCLIDE	BONE	LUNG	BONE	LIVER
Th-232	4530.	454	18.	0.02
U-238	2.9	480	11.	0.05
Np-237	4240.	59	87.	16.0
Pu-238	3270.	608	2.1	0.44
Pu-239	4160.	580	2.6	0.49
Am-241	9730.	64	80.	17.0
Cm-244	4560.	67	38.	0.44

- THE UPTAKE FRACTION FOR Np, Pu, Am, AND Cm WERE ASSUMED TO BE EQUAL 10^{-3}

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of some of the actinides besides plutonium. Finally, much of the metabolic data that have been incorporated in these models are derived from animal studies; very little human data exist.

We have been talking about hazard when actinides gain entry by way of inhalation or ingestion, but the inherent radiobiological hazard of actinides will be offset if disposal processes effectively isolate wastes from the biosphere and if transport through various pathways in the ecosystem is highly inefficient. Consequently, we must examine the effectiveness of the major pathways for translocation of radionuclides from waste to man. I have called the measure of this effectiveness radioecological hazard. I have not done a full-blown pathways analysis that would include a scenario, a source term, site conditions, and so on. Rather, the context relates to release efficiencies, membrane discrimination, adsorption, and so on. You might call it the phenomenology of the pathways. To discuss this hazard, we will consider, in sequence, release pathways or release processes, transport mechanisms, and finally human exposure in each of the major pathways.

Let's consider first the aquatic pathway, which starts with a release by erosion followed by sediment transport to surface water and then exposure by surface water uses. Erosion rates are highly variable across the continent, depending on climate, soils, and man's activities. The maximum erosion rate is reached, interestingly enough, in regions of somewhat limited rainfall; erosion rates both in more arid climates and in more humid climates are smaller. The difference reflects the effects of vegetative cover, rain frequency, and that kind of thing. The erosion hazard would appear to range over almost an order of magnitude depending on location. TRUs released by erosion would be expected to become rapidly attached to small particles either by hydrolysis and precipitation or by cation exchange reactions with particles and surfaces; these reactions are vital determinants of the ultimate fate of plutonium in the environment. Some nuclides may enter the environment as stable organic complexes and be transported in soluble form in surface waters. Initial chemical reactions and tendencies to remain soluble depend on the initial chemical form of the TRU element. However, the original source characteristics become less important as time goes on and weathering and aging proceed. To reiterate, under aerobic conditions (that is, in the surface environment), the ultimate behavior of TRUs--regardless of chemical form--will be determined by processes involving hydrolysis and sorption on particulates or surfaces, and the formation of soluble complexes with organic and inorganic ligands. In some cases, this inherent tendency acts to reduce hazard by tying up TRUs in the soil compartment, but in other cases that tendency might amplify hazard because preferential adsorption, for instance on very small particles, would increase the inhalation hazard.

The groundwater pathway release phenomenon occurs when precipitation infiltrates burial pits, wastes are leached, and hydraulic transport

to an aquifer takes place. In some soils, very little percolation occurs even with 20 or 30 in. of rain. In others, there is almost as much percolation, or more potential percolation, than there is precipitation.

A schematic of shallow earth burial would illustrate the physical and hydrologic conditions of soil disturbed by waste burial. Wastes are emplaced in a host soil and covered with a trench cap. When precipitation occurs, there is competition between infiltration, runoff, deep seepage, evaporation, and evapotranspiration by plants that might be on the surface. If infiltration is large and is not compensated by evaporation and evapotranspiration, one of two problems can result. First is the bathtub effect: high precipitation and low host soil permeability can lead to saturating the trench contents with leachate, and that leachate can be at the ground surface. Where water saturates the wastes, you can have a release of leachate at the site or perhaps at a spring downgrade from the trench. The second problem related to conditions of high precipitation and high host soil permeability can lead to leachate release to the groundwater.

At the Department of Energy (DOE) and commercial sites, a full range of soil conditions (low to high permeability) and climate conditions (arid to humid) has been encountered. Los Alamos and INEL are low permeability, arid climate, and Barnwell and Savannah River are high permeability, high humidity. The low permeable, high humid range has more surface and subsurface water problems. At Los Alamos, for example, evapotranspiration dominates over infiltration and, hence, Los Alamos is more susceptible to erosion processes than subsurface percolation. At Savannah River, however, subsurface effects predominate. In addition to site hydrology, the processes that affect leaching of the waste materials are prime factors in the groundwater pathway. Among the factors accelerating leaching are the presence of chelating materials in the waste and the corrosive products of decomposition of organic waste. On the other hand, solidified waste encapsulated in concrete or polyester-styrene, for example, will exhibit releases that are essentially diffusion limited. In this case, waste form stability may be the primary determinant of uncertainty in cumulative fraction of release over long time frames. What Nielson and Colombo call "effective diffusivity" is the proportion of surface to volume. When solids crumble, the diffusion-limited process still can lead to a large cumulative fraction release.

Once TRUs are released to groundwater, transport is subject to convective-diffusive and sorption-desorption processes of the host rock or soil. For example, the uncertainty of the migration hazard depends on (1) the ionic species of the radionuclide (plutonium-4 versus plutonium-5, or plutonium dioxide oxy-cation, which affects geochemical retardation); (2) the influences of time (whether the parent is reduced or daughter activity is introduced by radioactive decay or whether chemical equilibrium, which also affects retardation, is achieved); (3) the nature of sorptive surfaces, which may be

more or less effective in retarding movement in the transport paths; (4) groundwater factors, such as chemical composition, that influence sorption-desorption; and (5) groundwater velocity, which influences the convective transport rate.

Soil sorptive properties are measured by the distribution coefficient of the radionuclide being transported. This coefficient, K_d, is the ratio of the nuclide concentration in the solid phase to its concentration in the liquid phase. As such, it is a lumped parameter roughly reflecting the combined equilibrium effects of geochemical and physical processes such as ion exchange. Generalizing groundwater transport hazard across the great variety of rock and soil types encountered is difficult. Site selection provides an initial boundary condition on the hazard, but other factors cause uncertainties because transport may occur over great distances and long times. That is, if a site is selected, the geochemistry is determined for that site, yet often there may be variations in the geochemistry some distance from the site that have a strong influence on the final effect of the groundwater pathway. These variations may be unknown or hard to incorporate in the analysis. Slide 7, for instance, indicates that, in a comparison of actinides, uranium and neptunium tend to exhibit low K_d in a variety of settings and are also susceptible to changes in mobility with changes in geochemistry. Consequently, they are perhaps most hazardous in groundwater transport. Although plutonium often has a higher K_d, perhaps 1 or 2 orders of magnitude, it has the potential for switching to forms having very different K_d, so it belongs with uranium and neptunium in hazard potential, as suggested at the bottom of the slide. This slide is a rough grouping of actinides sensitive to changes in redox potential, water chemistry, rock type, and so on (e.g., plutonium, neptunium, and uranium). In contrast, thorium, americium, and curium not only tend to have a high K_d, but are relatively stable under changing conditions of groundwater chemistry and rock type. Bondietti, who suggested this grouping, has a third category for technitium and other particularly pesky types.

The third category of release phenomena can be called biological intrusion. The pathway is terrestrial release and transport. Release processes can involve erosion of the cover or direct intrusion through it. Native plant and animal intrusion at undisturbed sites may be all that is involved, or the more serious case--human habitation of a burial site after control is lost and the trench cap has eroded or has been partially removed as a result of human activities--can occur. If it is released to the surface terrestrial environment by any of these mechanisms, TRU is subject to transport, mainly by the forces of wind and water, but also by biotic activity and mechanical disturbances of man. Contaminants will be entrained in the hydrologic and mineral cycles of the ecosystem. Slide 8 illustrates how activity in the soil compartment cycles into the atmosphere, being deposited on plants and, in some cases, directly back onto the soil. Activity can be introduced to the soil indirectly through plant mortality and the formation of litter-humus.

Slide 7

COMPARISONS OF ACTINIDE SORPTION ON ROCK

K_d, ml/g

SOLID	U(VI)	Np(V)	Pu(IV)	Am(III)
QUARTZ	0.3	0.5	225	1323
BASALT	2.8	0.5	60	1033
SHALE	6.7	49	145	962
GRANITE	6.3	63	320	$3X10^5$
BENTONITE/QUARTZ	16	13	160	500

ACTINIDES RELATIVELY STABLE TO CHANGES IN GEOCHEMISTRY: Th, Am Cm

ACTINIDES SENSITIVE TO CHANGES IN REDOX, WATER CHEMISTRY, ROCKTYPE: Pu, Np, U

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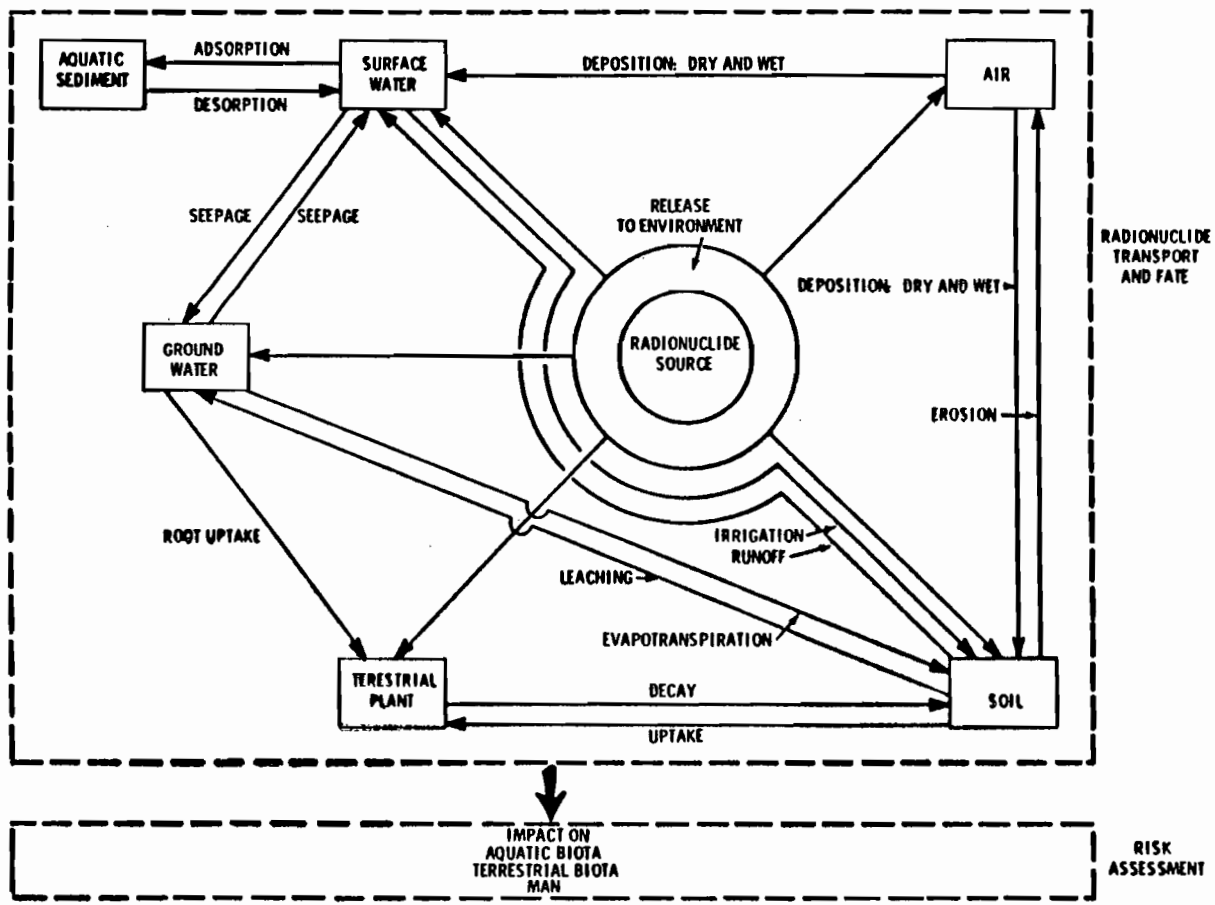
Slide 8

RADIONUCLIDE SOURCE AND MAJOR EXPOSURE PATHWAYS



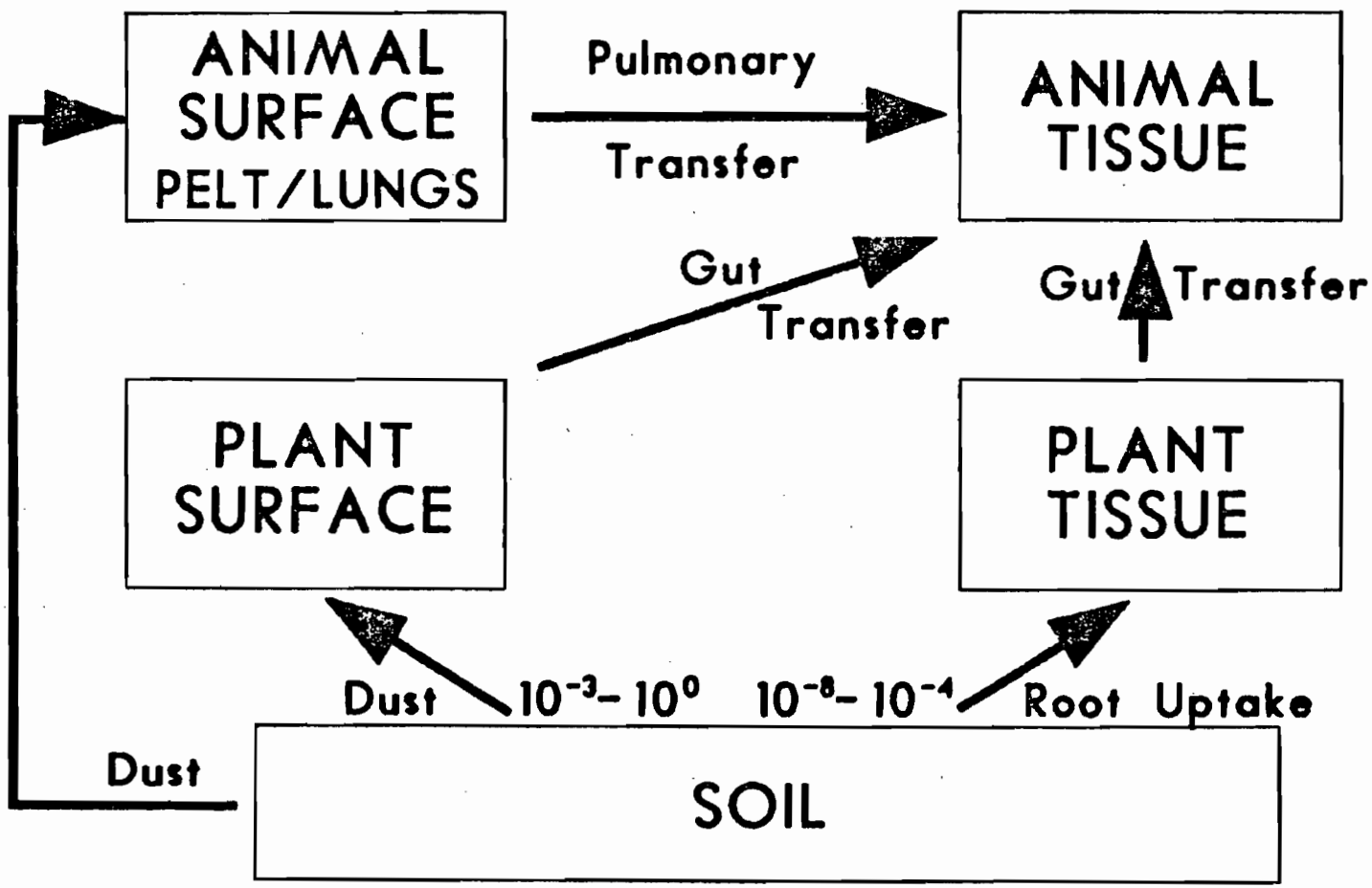
It is instructive to examine the inventory of an actinide like plutonium after sufficient time has passed to allow for quasi-equilibrium in the system. Data for fallout plutonium in an ecosystem show that by far the largest fraction of inventory is retained in soils, followed by vegetation litter and animals. Inventory ratio is the ratio of the activity in a given compartment to the total activity in the system. In part, a large soil inventory ratio reflects a relatively large mass in the soil compartment; obviously, discrimination processes are at work at each stage in the food chain (also, plutonium exists in a strongly bound absorbed state in soils). The range of orders of magnitude in inventory ratios is great. For vegetation, for instance, it might be 5 orders of magnitude. This range reflects the effects of ecosystem diversity.

Of the processes affecting transfer from soils to plants and from plants to animals, physical transport of contaminated dust dominates over root uptake in plants and over uptake from the gut in animals. A comparison of plutonium concentration ratios for field- and glass-house conditions at NTS shows this. Concentration ratio is the concentration in the plant over the concentration in the soil in which the plant is growing. At NTS, concentration ratios of field plants were 2 or 3 orders of magnitude larger than those of plants grown indoors. Data from small mammal tissues taken at Los Alamos in Mortandad Canyon show a similar effect. Inventory ratio, for instance, shows the importance of pelt and other exposed surfaces compared with internal organs.

Concentration ratios integrate many of the physical and biological processes of contamination in the environment, and I will return to the use of those ratios in a minute. Once again, as shown in this figure of plutonium transport pathways, the direct contamination of plant surfaces by dust produces much higher concentration ratios than root uptake does (Slide 9), but the root is the major ion-absorbing organ of the plant. Ion uptake is metabolically mediated across cell membranes. Because of the relatively low uptake of plutonium from soil, it has been assumed that active discrimination is the effect of soil sorption reducing the quantity of soluble actinide available to the plant. Once in the root, actinides are translocated in the xylum stream. In general, concentrations are greater in leaves than in stems, and the lowest concentrations are found in seeds. Therefore, the dietary hazard from vegetables depends on whether the edible portion is a protected seed or a leaf, which is exposed to dust and receives a larger portion of the root uptake. However, harvesting can increase contamination in protected parts of plants, such as wheat grain, so the distinction has to be used with care in assessing hazard. To assess this hazard, the types of food in the diet must be known. Based on limited data on root uptake processes, neptunium is likely to rank higher in bioaccumulation than curium, curium higher than americium, and americium higher than plutonium. Again, actinide species have to be taken into account.

Slide 9

PLUTONIUM TRANSPORT PATHWAYS



Discrimination by the mammalian gut is also suggested. The ingestion hazard from meat and milk are doubly reduced: once when the domestic animal ingests forage and again in the human gut. So for actinides, meat and milk don't contribute much to hazard in the dietary pathway.

Exposure conditions are the third component of hazard equations. Different scenarios dictate different conditions of exposure, and we will probably be hearing about these later in the workshop. Based on human diet patterns, dust loading conditions, a variety of land uses, and other factors, it appears that there is about an order of magnitude in uncertainty in the most critical ingestion and inhalation parameters affecting dose, such as dust loading or variation in diet components. Without a doubt, the most difficult pathway hazard to evaluate is the controversial matter of human intrusion. Human land use considerations enter into all the major pathway chains of events. A host of considerations--institutional controls, siting requirements, waste treatment, waste form modification, burial technology, etc.--all affect the hazards that various pathways will have in a given disposal setting.

It is difficult to put all these hazard estimates together, especially because much of the evaluation has been relative. I've been speaking of americium relative to plutonium, and so on, out of necessity. How do several components of radiologic hazard combine? One can't just simply add hazards. One approach is suggested by Jack Healy, who has combined the radiobiological hazard of plutonium doses to critical organs with plutonium's general radioecological hazard through various pathways, to find limiting concentrations in surface soils anywhere such that no more than 500 millirem/year will be delivered to the critical organ of an exposed individual under normal land use conditions. This approach produces general soil concentration numbers. Mechanical resuspension dominates. The figure for wind suspension is 960 to 4700 pCi/g. The figure for limited areas is 7600 pCi/g. For mechanical resuspension, the figure is 140 to 680 pCi/g, which is far more limiting. The ingestion numbers range from 260 to 2400 pCi/g, depending on the amount of contaminated material (e.g., vegetation or animal products grown on the contaminated soil). Mechanical resuspension of dust and growing of food crops are exposure modes defining limiting pathways, and this will be true whether the surface soils are contaminated by erosion, irrigation with contaminated water, or direct intrusion in the wastes. (However, no process considerations were included in the numbers I just gave you.) If we include the relative hazards of dose potential of the other actinides, we expect the corresponding limits to be reduced by factors of 2.5 for intake by inhalation or 3.5 for intake by ingestion relative to plutonium. Similarly, when the effects of ecosystem transport potential are considered, corresponding limits for other actinides might be pushed down by factors of 2 to 5. The reasoning is the concentration ratio approach: assume intake by all pathways from the source and surface soil. You can look at the expected concentration ratios (Slide 10). This was done by Bondietti

Slide 10

ESTIMATED LIFE TIME ACTINIDE ACCMULATION IN HUMAN BONE (BONDIETTI 1979)

NUCLIDE	CR = CONC. BONE/CONC. SOIL
Th, Pu	0.002
Am, Cm	0.005
U	0.01

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of Oak Ridge. We are looking at concentrations of actinides in bone (all pathways). He has estimated the lifetime accumulation in bone and derived concentration ratios of bone to soil on the order of 0.002 for thorium and plutonium, 0.005 for americium and curium, and 0.01 for uranium, which is to say that if all physical and chemical factors are constant, about 2.5 times more americium and curium may accumulate in bone than plutonium or thorium. Uranium may show a 5-fold greater accumulation. (This is the range 2 to 5 that I mentioned.) Again, if long-term site control, deep burial, and modified waste are considered, hazard is reduced by processes like radioactive decay, sorption, and dilution, and the limits go up.

Let me give you some examples of concentration limits derived for shallow land burial for randomly contaminated materials and explain how they might be affected by some of these considerations. Curium-244 has a half-life of only 18 years, and hence its concentration limit in wastes may be influenced mainly by the ingrowth of its daughter plutonium-240. Americium may be limited by its greater ingestion hazard. In our final document, I think this number was about 5 nCi/g.

Finally, when a full-blown risk assessment leading to recommendations for limits in wastes is done, the final value will reflect judgments on these conflicting tendencies with respect to hazard. The aim will be to ensure that the manifestation of any of them is not likely to be realized.

Alan Moghissi, Environmental Protection Agency (EPA): John, your paper is certainly one of the key papers in assessing the main point of this workshop. Many years back, I was personally involved in studies of TRU elements at the Nevada test site. You made, for example, the statement that in those days we were not smart enough to know that the plant absorption of plutonium was about the same for deposition on the plants and root uptake. Activity that has gone through the root is taken up by the gut much better than activity that is deposited on the leaves, so that the multiplication factors actually remain the same. Activity taken up by the root is taken into the gut 100 times better, but you have 100 times as much material on the leaf.

Rodgers: I see what you are saying.

Moghissi: We no longer have the problem with plutonium that we had during the early 1970s when we could not figure out why plutonium was sometimes solubilized and sometimes was not. Studies done in Las Vegas by the EPA or the Public Health Service showed that the solubilization was largely a result of the microorganisms that excreted oxi-acids and therefore solubilized plutonium. Taking the easy scenarios, if you had stayed away from the form of the waste from the point source in the soil where the various isotopes of various elements are released, what would have been the dose to man? More

and more we are using the ICRP-26 approach in which you take the organ doses and multiply them by appropriate correction factors to come up with the whole-body equivalent dose. Most of us have done that. Have you done such a thing?

Rodgers: No, we haven't. I had some reservations about using that approach partly because of its relationship to the occupational case. In the occupational case, maybe it makes some sense to worry about being able to add internal doses to whole-body external doses, but I'm not sure if that makes a whole lot of sense in the environmental case.

Moghissi: Let me assure you that that approach is in there. If I had to predict, I would predict that that approach is making its way into the regulatory process and will soon also become a part of the regulations for environment. Every time you make a risk analysis you are making simplifying assumptions. Everybody agrees with that.

Rodgers: That's correct.

Moghissi: However, when you do these simplifying assumptions and come up with a number, as your last table showed, you sometimes come up with a number that is too perfect.

Bill Lennemann: Concentrations have always bothered me, particularly with waste, because your point sources are not average concentrations; they are generally high concentrations. You can call a gram of plutonium in waste an average concentration over, maybe, a couple of hundred cubic feet of waste, but that gram of plutonium is a very high concentration point source. This has always bothered me in figuring out concentration limits because I don't know what the answer is. You could have a high concentration of plutonium with one particular plant or with dusty soil. Although you may have given an average concentration of 10 nCi/g, that particular point source may have a concentration of 100 nCi/g.

Rodgers: Remember that in my talk I tried to address not the risk but the hazard. The concerns that you express are, I believe, part of the risk assessment, the pathway analysis in the limit derivation where uncertainties like that of dilution with uncontaminated waste are folded into the analysis. The last numbers I discussed were somewhat misleading because that kind of compensation presumably was done, and I hadn't really talked about it all that much. I really only wanted to suggest how some of the relative hazards might push limits up and down if you fold in different concerns about hazard. However, a full-blown risk assessment considering the probability of a plant hitting a particular piece of contaminant has to be part of that analysis.

Preston Hunter, Ford, Bacon, and Davis: John, I am impressed with the amount of data you have on various factors relating to resuspension and uptake and so forth. I think the data represent a good effort to summarize what is going on. It seems to me that these data would have a tremendous impact on some of the dose assumptions and numbers that we have been traditionally using in risk assessment, ICRP-26, for instance, or ICRP-30. With the range of data that you have there, which is sometimes quite sufficient for as many as 2 to 4 or 5 orders of magnitude or more, I would be interested in hearing you comment on the impact on our currently perceived understanding of doses received by the traditional ICRP-26 numbers. If you don't have a comment or aren't in a position to make one, I would like to comment that I think we need to go ahead and start factoring in some of these numbers and do a study to find out what those impacts are going to be. Just one more comment. I think your last slide would probably be better if it were put in the form of a range of concentration limits reflecting the range of input numbers that you had.

Rodgers: Yes, it probably would be better to have a range. In fact, in the study that Healy and I did, we suggested a range of numbers depending on a lot of conditions and assumptions. To respond to your first remark, I think that indeed we do need to consider the impact of some of the more extreme ranges of uptake fractions, from the gut for example, in assessing doses if the fractions are relevant to the environmental case in assessing the limits that we are talking about.

Hunter: John, what would some bounding calculations indicate? It looks like you have such wide range in data values that you can hardly come up with an answer that you can put any handles on.

Rodgers: I think part of the problem is resolved if you are careful about selecting a scenario, and I didn't indicate the scenario in the study that Jack Healy and I did. Maybe he'll address that. If you pick a climate and a soil type, and so on, that will narrow this enormous range. Then within a particular set of conditions, a level of uncertainty still exists, but it is not anything like 5 orders of magnitude.

ALPHA-CONTAMINATED WASTE FROM REPROCESSING OF NUCLEAR FUEL

Wally Sumner, Allied General Nuclear Services

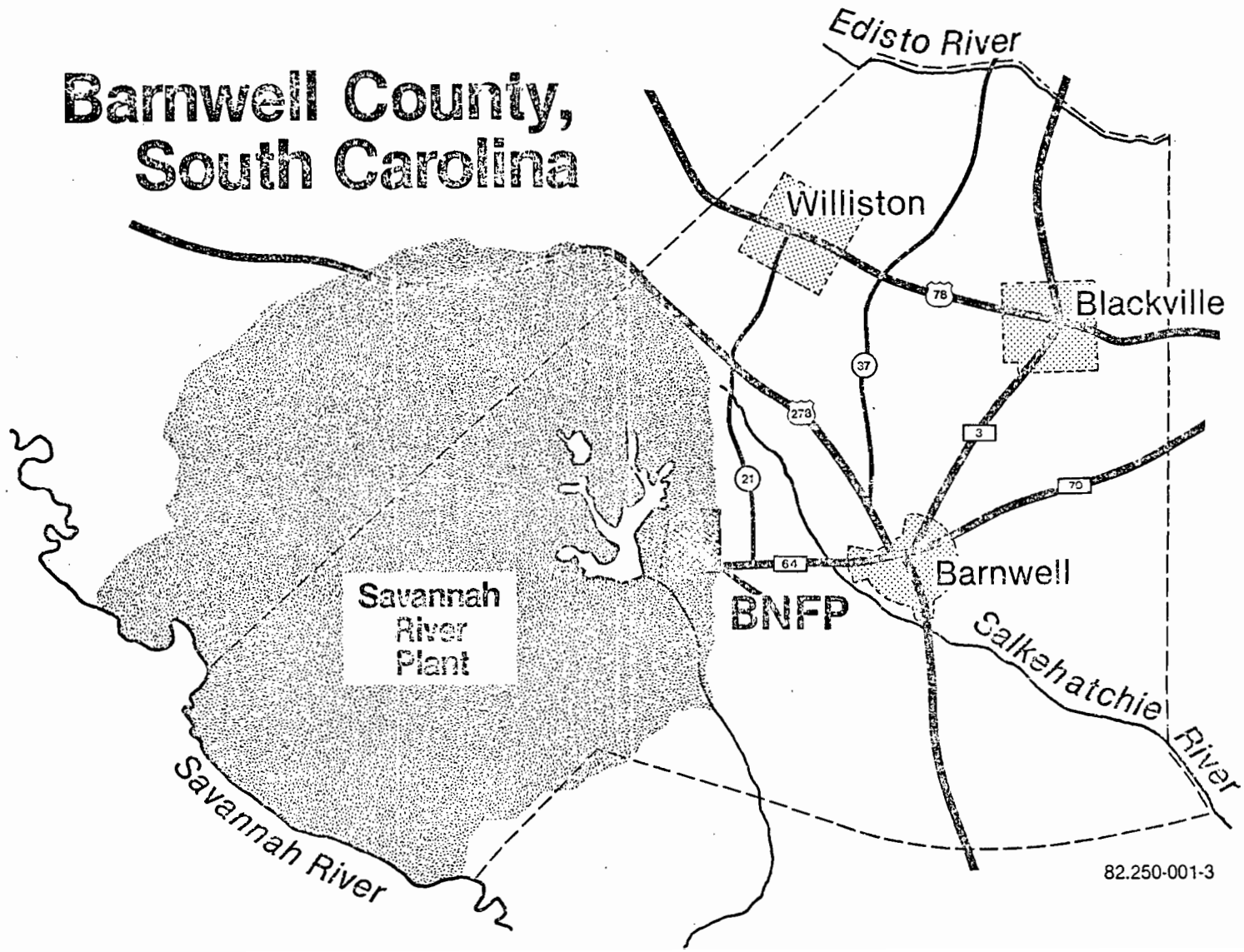
Those who have had their second cup of coffee probably figured out that the Barnwell Nuclear Fuel Plant is located in Barnwell, South Carolina. If you haven't had your second cup of coffee, I have provided this map (Slide 1). We have about 1700 acres of land located contiguous to the Savannah River Plant; we are also contiguous to the Chem-Nuclear low-level burial ground. We are not related to the low-level burial ground at all, other than being a small customer now, and hopefully a large customer in the future. Sometimes people get us confused because they think we operate that burial ground, but we don't. Our plant was specifically designed to process light-water reactor fuel at a rate of 1500 metric tons of uranium a year. According to the original intent, it was to be a commercial facility operating on a commercial basis. We have not processed any actual spent nuclear fuel at this time; we have [through our testing and checkout, conducted research and development (R&D) programs that have been going on for the last 5 years] processed about 500 metric tons of natural uranium through the plant. Along with that and with our original plans to complete the facility and to provide waste management facilities, we have made estimates on what we think the wastes generated at the plant are going to be.

What I am providing you with this morning unfortunately is not based on actual operating data, but it is our best guess at this time as to what those wastes might be. We recently completed the latest evaluation of those wastes under contract to the Office of Nuclear Waste Isolation (ONWI), and these are the data that I will present to you this morning.

The Barnwell Nuclear Fuel Plant (Slide 2) includes the separation facility (where we will receive fuel into the facility). We plan to use the classical chop-leach process (the fuel is chopped up and dissolved in nitric acid and then passed into a Purex process where uranium, plutonium, and fission products are separated). From that point, a uranyl nitrate product will come out of the separation facility and go into storage. Then these products will go into a uranium hexafluoride facility where they are converted to UF_6 for shipment to an enrichment plant. I might point out that the facilities you see in solid blocks have been completed; whereas, the ones in the broken blocks have not been constructed, but are planned to complete the facility.

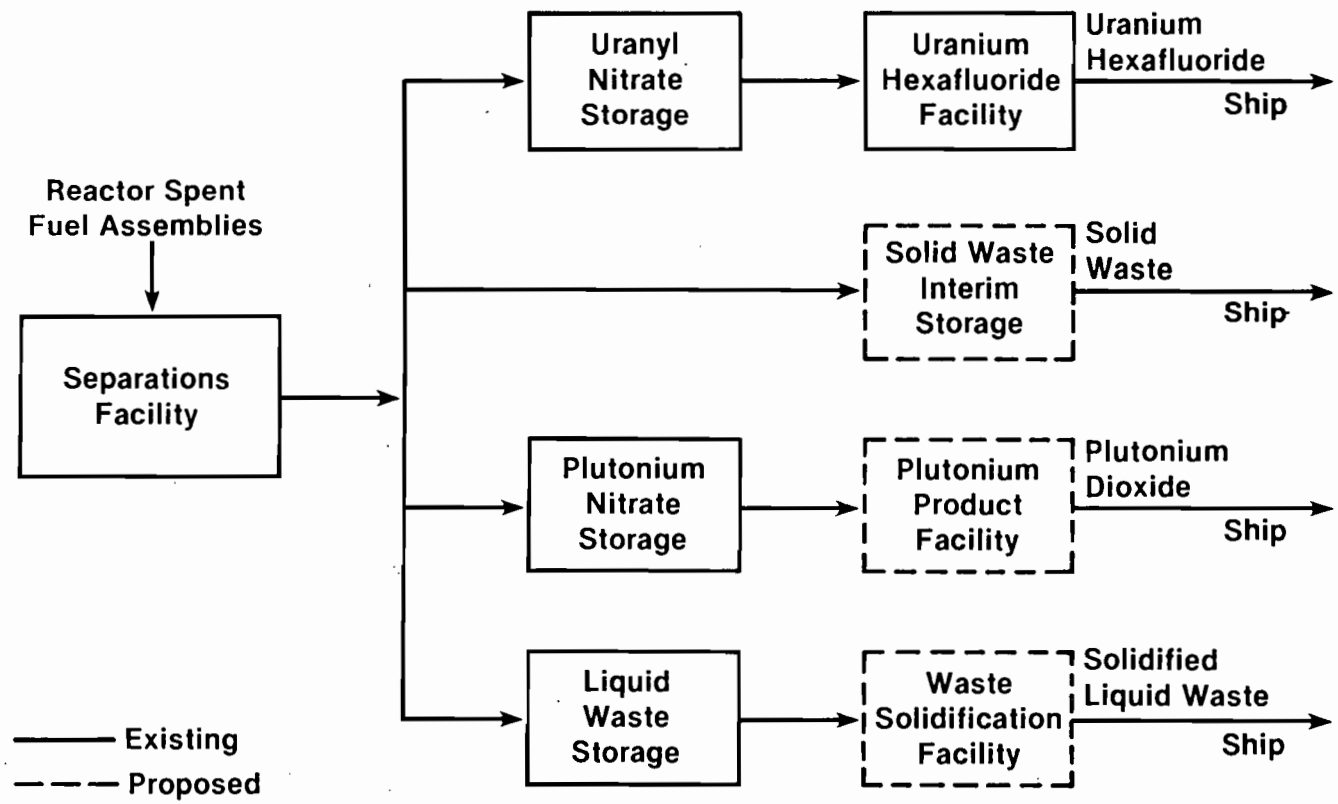
Besides the uranium, we separate out the plutonium, and the product coming from the separations facilities is in the form of plutonium nitrate. The intention would be to take that plutonium nitrate and convert it to plutonium oxide, which would then be shipped off site or to a future fuel-fabrication facility adjacent to the plant for fabrication of MOX fuel. The other stream coming from the

Slide 1


Barnwell County,
South Carolina
Edisto River
Williston
Blackville
Barnwell
BNFP
Savannah
River
Plant
Savannah River
Salkehatchie River
78
37
278
3
70
21
64
82.250-001-3

Slide 2

Barnwell Nuclear Fuel Plant Reprocessing Flow Chart



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separation facility is a liquid waste, which is also in a nitrate solution. The intention would be to design and construct a liquid waste solidification facility and prepare that waste for disposal at the federal repository.

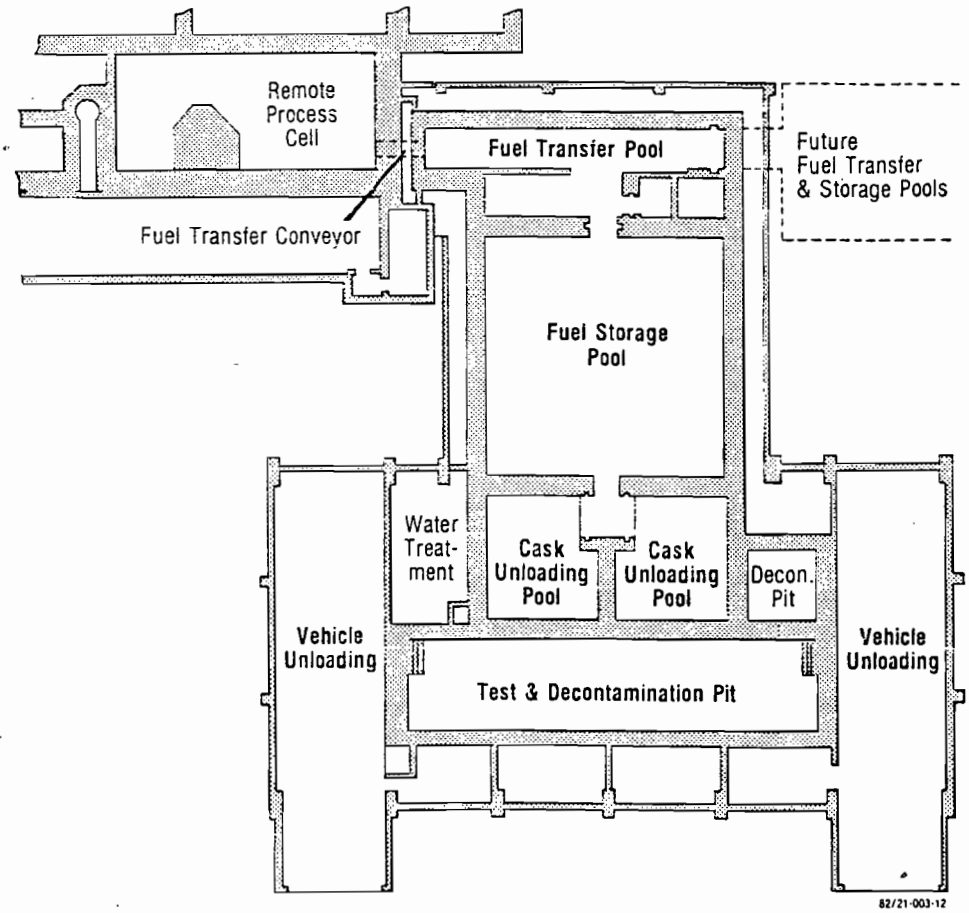
From an aerial view of the entry point of the plant, you can see the fuel receiving and storage facility, the point at which we actually receive the fuel and store it before reprocessing. This gives you a layout of the spent-fuel storage pools (Slide 3). We have two cask unloading pools and a spent-fuel storage pool, which were originally designed to store only 360 metric tons. That is a marshalling or staging area for the process. We also have a spent-fuel transfer pool that is used to introduce the spent fuel into the process where the chopping and the leaching begin. The wastes coming from this area are essentially comprised of failed equipment, filters, general trash, and ion exchange beds, which are used to clean up the water. The wastes from the fuel receiving and storage station are classified as non-TRU. In other words, we don't expect to have any TRU waste coming from that part of the process.

I might say that, in making our classification between TRU and non-TRU, we assumed that the level or the break point was 10 nCi/g because that is what people were considering. There is no means provided for actually detecting waste at that level, not withstanding what we heard yesterday from Los Alamos. It looks like we are getting to the point where we can now actually detect waste at that level, but at the time we were making these studies, our assumption was that you cannot actually detect that level of waste. Therefore, our judgment establishing TRU versus non-TRU is based strictly on the point of origin. In other words, it is a matter of judgment that the origin of the waste in the facility determines whether or not we classify it as TRU or non-TRU waste.

Slide 4 gives an aerial view of the main separations facility and of what we call the hot and cold laboratory area, which is located adjacent to the separations facility. This is the facility that houses most of the chemical processing and separations facilities.

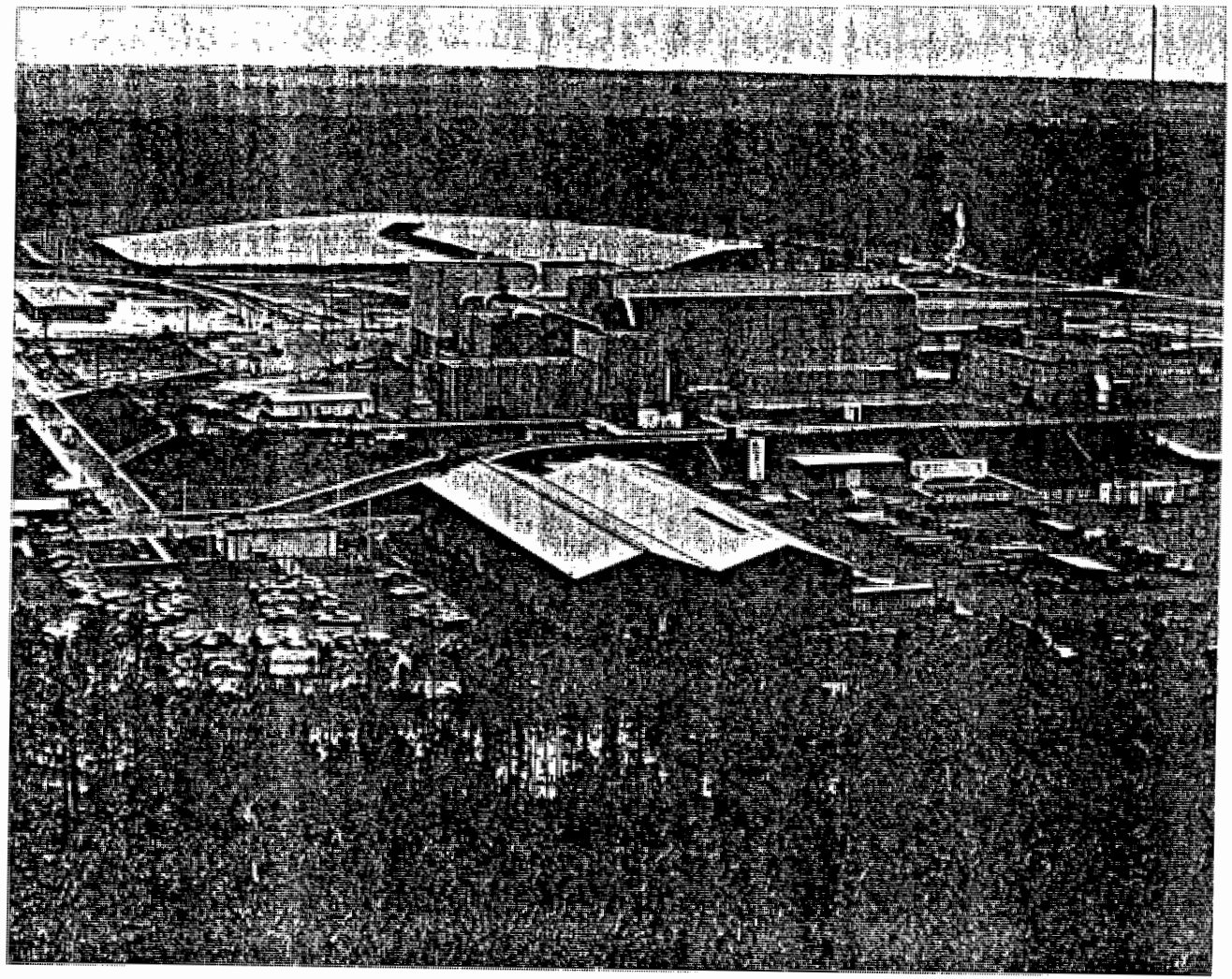
Slide 5 gives you an overview of the flow sheet that is used in the facility for separations. We have a cask receiving and the fuel storage pool. From here, it goes into the shear where the fuel is chopped. In the dissolver, the uranium, plutonium, and fission products go into solution. The solution goes into the first stage of solvent extraction of the Purex process. At this point, most of the fission products are removed and stored as high-level waste, which we will eventually solidify and prepare for shipment to a federal repository. The uranium and plutonium continue in the solvent extraction process and are separated or partitioned using an electrolytic in-line process that we have developed. The uranium and plutonium are split at this point. The uranium goes into one additional cycle of solvent extraction for purification. Then we

Slide 3



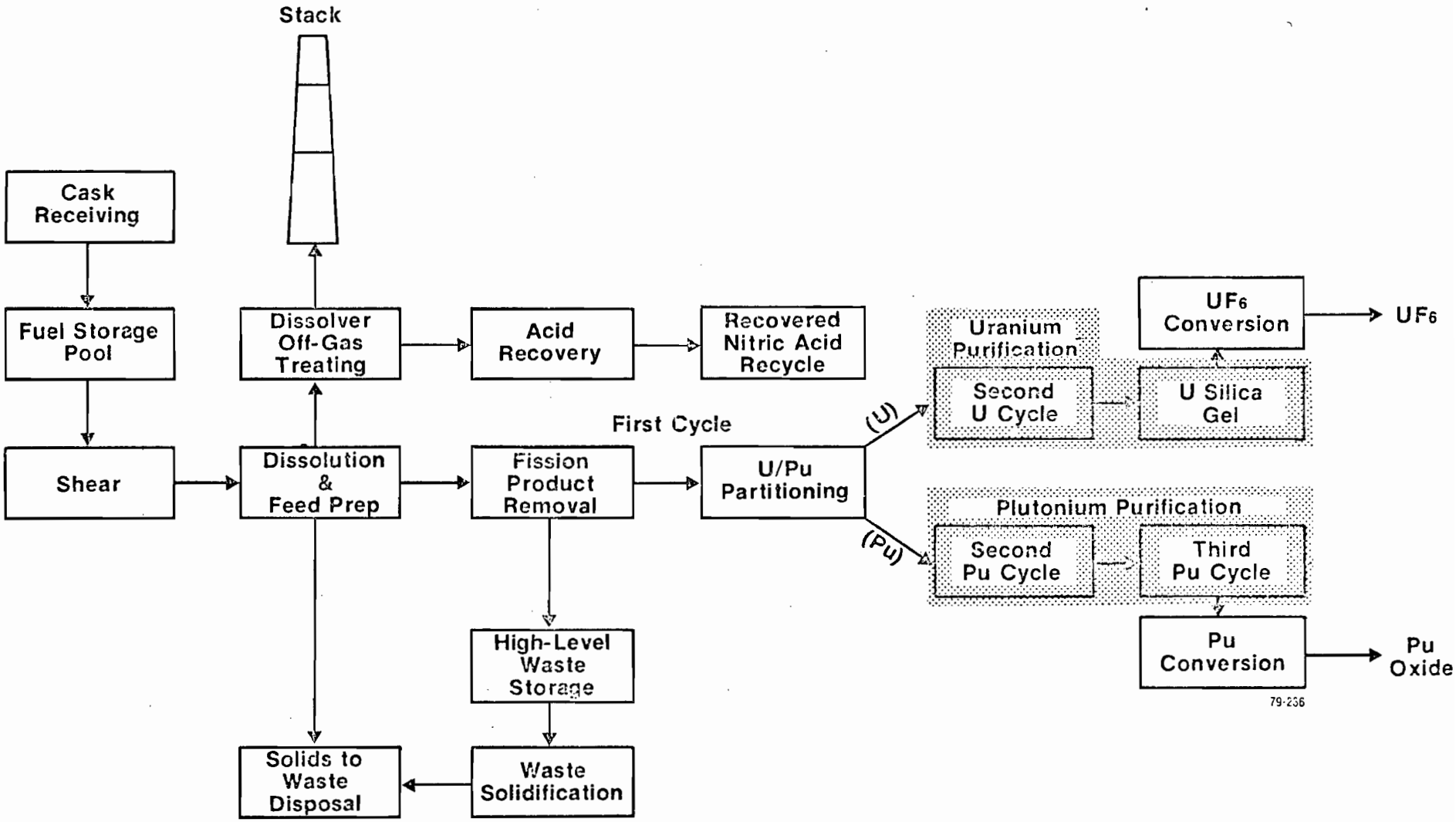
FUEL RECEIVING AND STORAGE STATION (FRSS)

Slide 4



Slide 5

Classical Purex Process at the BNFP



polish the uranium by passing it through a silica gel bed to remove the final traces of fission products, convert it to UF_6, and ship it off site. The plutonium enters two more cycles of solvent extraction; it is concentrated, stored, and converted to the oxide shipped off site.

Slide 6 presents an overview of the separations facility, and hopefully, it will give you some idea of the operations that result in the production of our TRU waste. The fuel-receiving station is located here, and the fuel is introduced into this remote process cell for shearing and to initiate the processing of the fuel. We provided a remote process cell to enclose and handle the equipment that we feel requires routine maintenance and replacement, and this cell provides for routine, remote operation and maintenance. Adjacent to the process cell, we have a remote maintenance and scrap cell, which services that remote operating cell and allows us to remove equipment, to dispose of it, or to prepare it for disposal by remote means. Adjacent to that, we have five process cells that handle primarily the solvent extraction equipment and process. These cells are designed essentially for no maintenance. The equipment placed in these cells have no moving parts. All of the piping and process equipment is welded. There are no pumps, valves, or other parts that are subject to failure. So we have placed them in these cells where there is no provision for remote handling.

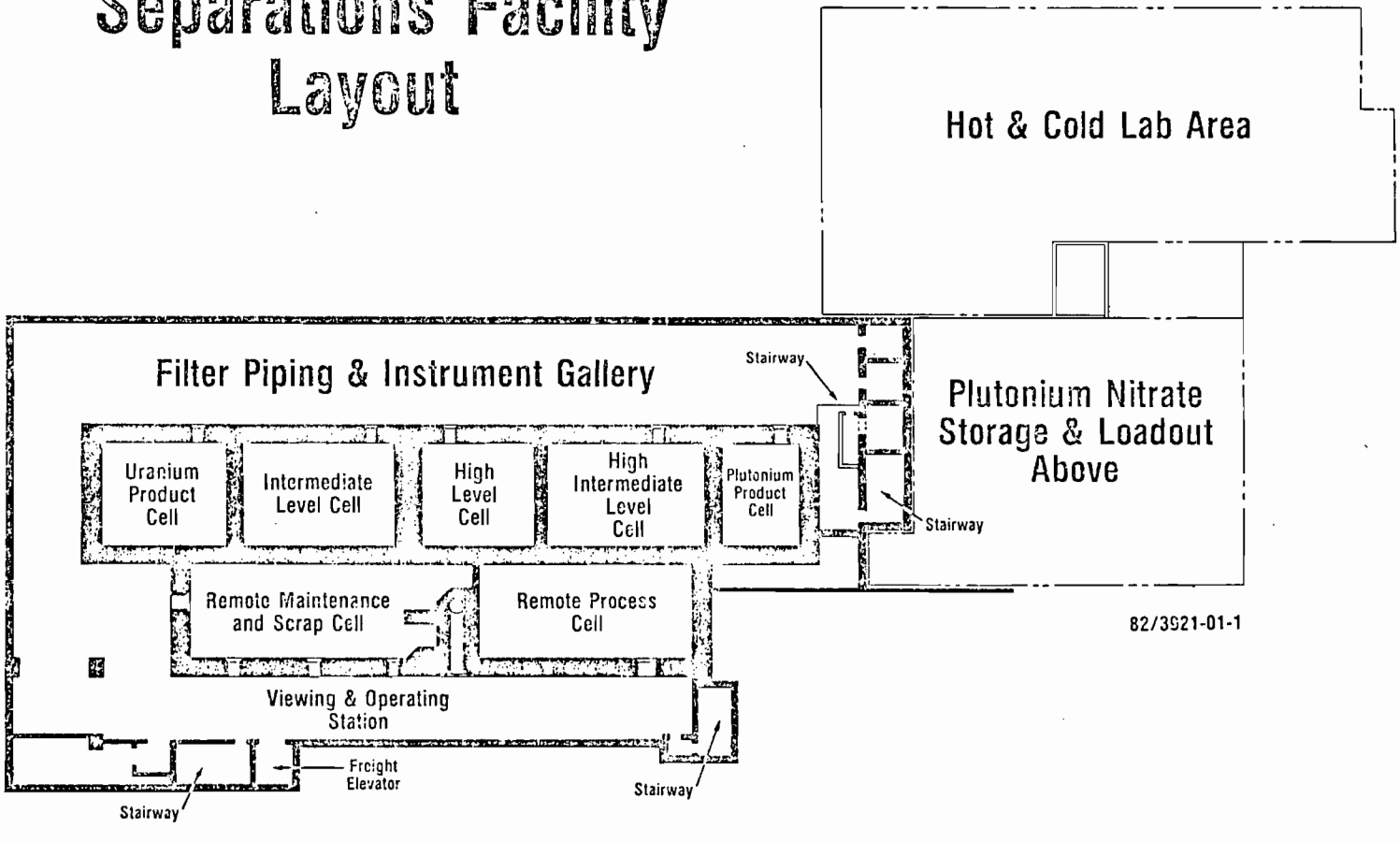
In the event that we do have to make a modification, for decommissioning, or in the event that we have an unexpected failure, we have provisions for remotely decontaminating the equipment, both internally and externally, enough that people can actually enter the cell and have hands-on contact maintenance. Surrounding these operating cells are galleries to which the operators do have access. In the case of the remote cell, we have viewing windows in this area for handling the remote equipment. In the galleries indicated here, we have lots of piping and instruments that service the process cells. Adjacent to this, we have a plutonium-nitrate storage area and our hot and cold lab area, which is primarily used for analysis.

The TRU waste coming from this part of the process is listed here, and I guess I need to make a few definitions (Slide 7). We talked a little bit yesterday about having trouble with definitions and about the confusion being encountered because of those definitions. I would just like to add to the confusion this morning a little bit. Alpha-contaminated waste, in this case, is the waste that we classify as potentially having greater than 10 nCi/g of TRU waste. I am only showing the TRU waste, or alpha-contaminated waste. I am not including other waste, which would be classified as non-TRU.

Under filters and general trash, you will notice the waste I listed as high-level or low-level. This is a little different from the normal definitions that you might have, particularly for low-level because what I am talking about here is the level of beta-gamma

Slide 6

Separations Facility Layout



Slide 7

SEPARATIONS FACILITY

Alpha Contaminated Solid Waste Estimate

	cubic feet/year
Hulls	22,500
Lab Hot Cell	730
Filters	
high level	1,440
low level	16
General Trash	
high level	9,000
low level	27,000
Failed Equipment	1,000

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radiation coming from the trash or the waste. It would probably be consistent with yesterday's terminology, when we were talking about remote-handled (RH) waste versus contact-handled (CH) waste. Instead of RH waste, I refer to it as high-level waste; and instead of CH waste, I refer to it as low-level waste. The other thing is the break point; our break point between RH and CH waste, rather than being the 200 man-rem/h at surface that we talked about yesterday, is 50 man-rem/h. This is because, in going through the analysis of time and motion studies for handling the waste and in an attempt to keep occupational exposure to a minimum, we felt like we needed to break at 50 rather than the 200 man-rem/h.

As you can see, one of the primary waste sources is the cladding hulls, which are left over after the dissolution (because the zircalloy does not dissolve in our process). This leaves a large amount of solid waste that has to be handled, stored, and eventually disposed of at a federal repository. We have waste coming from hot cells that are used for taking samples and for doing some analytical work in this area. This also provides us with about 700 ft^3/year. The high-level and low-level filters are primarily the HEPA filters that we have to use in our ventilation systems to filter the air before release to the environment. These filters also result in quite a bit of high-level waste.

General trash includes clean-up materials, gloves, shoe covers, and highly contaminated laundry. We do plan to have a laundry on site to take care of low-contaminated and usual/normal laundry, but many times, you may have some clothing (anti-C clothing) that might get too contaminated for the laundry to handle. Then it would have to be discarded.

Failed equipment would include small failed equipment like tubing. The composition of this material is essentially a very wide spectrum. We have cellulosic materials (e.g., wood, paper, cloth), plastics (e.g., polyvinylchloride and polyethylene), rubber, metal, and glass.

When we talk about general process trash, that is exactly what we mean--general process trash. I guess the numbers are self-explanatory. Failed equipment includes the things coming out that are too big to actually be placed into a 55-gal drum; this equipment must be chopped up and repackaged in something like the 4 x 4 x 8 container we were talking about yesterday. This container would be handled separately until time for disposal at the federal repository.

This photograph is an aerial view of where the uranyl nitrate would be converted to UF_6. As you can see, it is essentially a standard construction facility, not a hardened facility. It was designed and built under part 70 of the codes rather than part 50 because most of the fission products and TRU have been removed from the uranium and deal only with trace quantities so that, in general, we do not

have to worry too much about shielding and contamination. There is an exception to that, and I will show that in Slide 8.

We use this process to convert the uranyl nitrate to UF_6: the uranyl nitrate is received from the separation facility, it is concentrated, calcined down to UO_3 in a fluidized bed, and after some feed preparation steps, reduced by contact with hydrogen gas in a fluidized bed. It is reduced to UO_2; the UO_2 is then contacted with hydrogen fluoride gas in another fluidized bed where it is converted to UF_4. The UF_4 is fluorinated with fluorine gas in a fluidized bed, and at this point, the UF_4 is converted to gaseous UF_6; the UF_6 comes off in a volatile form, which is then recondensed and packaged for shipment to an enrichment plant.

The reason we do have some concern in the plant about TRUs, although as I mentioned, we only have trace quantities coming in the front end, is that when we get to this fluorination step the TRU and fission products that are in there tend to accumulate because most of them do not volatalize with the UF_6. In this step, we would tend to have an accumulation of transuranics, and because of that, we are planning to have wastes that are classified as TRU, again assuming the 10-nCi/g limit. If the limit goes up to 100 nCi/g or certainly if it goes up to 1000, it will probably make a significant difference; we may not have to worry about TRUs. When the fluorinated bed is dumped, we do expect that bed residue to be classified as TRU.

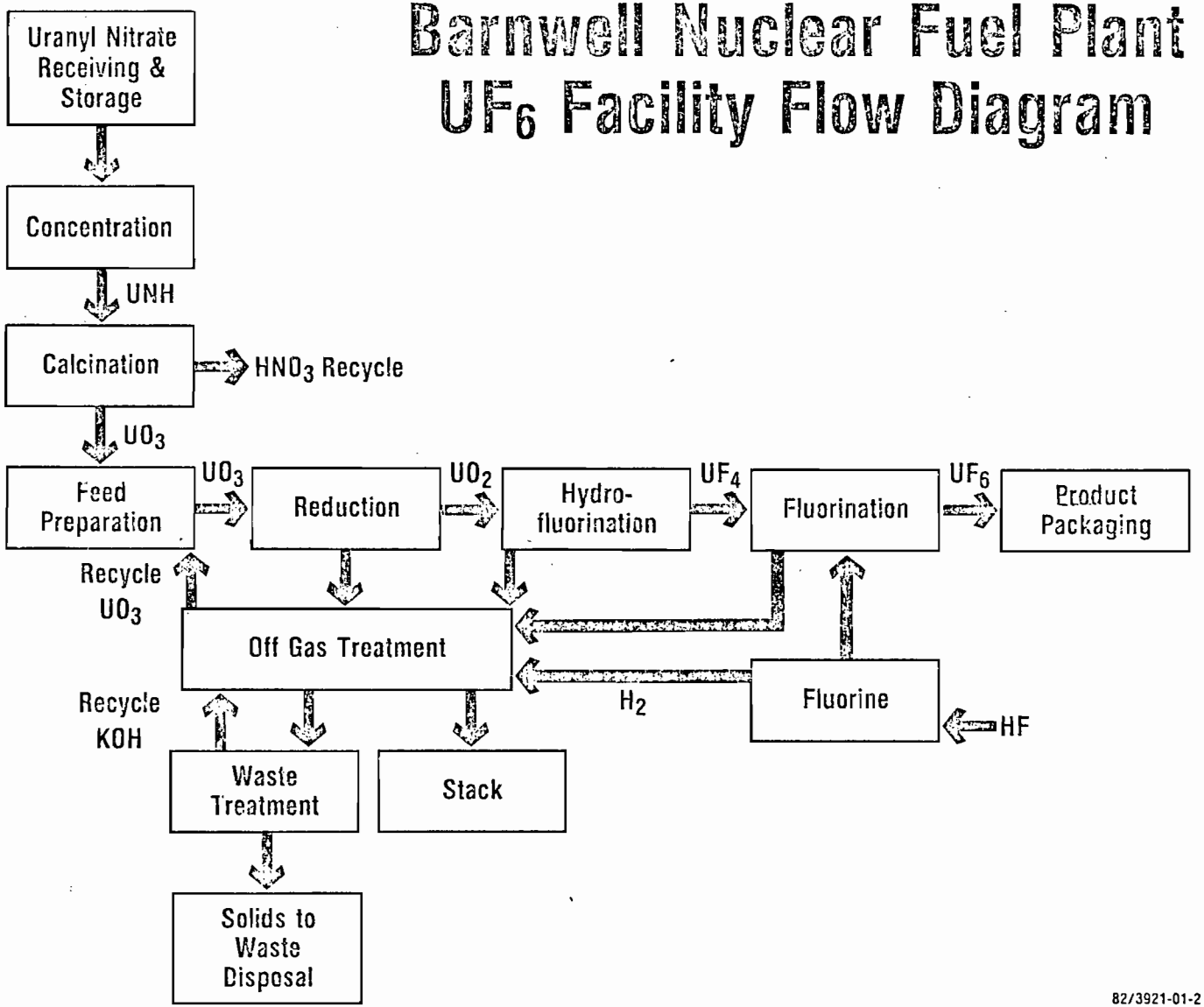
The largest waste coming from this facility actually occurs in the off-gas treatment where all of the off-gases from the various fluidized beds are scrubbed with potassium hydroxide to remove the fluorides from the off-gas. That scrubber solution is contacted with lime to precipitate calcium fluoride. We do have a large amount of calcium fluoride resulting from this off-gas; however, we do not expect that to be TRU. Instead, it will have only trace quantities.

To summarize the waste coming from the UF_6 facility (Slide 9), and remember our waste is affected by that fluorinator, which might tend to accumulate enough TRU that the waste will be classified as TRU or alpha-contaminated waste, we estimate that we would wind up with these numbers: 2500 ft^3/year from the fluorinator itself and about 1500 ft^3/year from filters in the fluorinator off-gas system and some of the general trash that might accumulate or result from operating around that fluorinator.

That takes care of the existing facilities at Barnwell, but we have begun to consider providing facilities for handling plutonium and liquid waste. The process that we selected for plutonium conversion about 5 to 6 years ago when we were first considering designing a facility (in fact, we did design the facility to about 35% completion) used the plutonium IV oxalate precipitation method. In this method, the plutonium nitrate would be contacted with oxalic acid and the plutonium oxalate would be precipitated, filtered using a vacuum drum

Slide 8

Barnwell Nuclear Fuel Plant
UF_6 Facility Flow Diagram



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Slide 9

UF_6 FACILITY

Alpha Contaminated Solid Waste Estimate

	cubic feet/year
Fluorinator Bed Material	2525
Filters	
high level	100
low level	100
General Trash	
low level	1250

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filter, and then be dried, calcined, and screened with a hammer mill provided to take care of our particle size specification (Slide 10). It would be blended, sampled, then packaged in canisters with some amount of storage on site, with eventual shipment to an MOX fuel fabricator. Because we will deal with plutonium in this planned facility, we expect that all of the solid waste coming from this facility will be classified as TRU. We have attempted to minimize the wastes that we would expect to come from this facility, however, by recycling most of our liquid waste back to the separations facility so that most of the waste generated would be from operation of the processes in the glove boxes--general process trash.

Slide 11 shows our estimate of solid waste coming from this facility. We planned to remote-operate but contact-maintain this facility, and that would mean that equipment in glove-box situations would either be maintained directly in the operating glove box or be moved to another glove box facility where it would be contact-maintained. This facility would have a lot of glove-box type maintenance. When all the plutonium is there, you have a lot of radiation coming from it; therefore, we would be using remote operation.

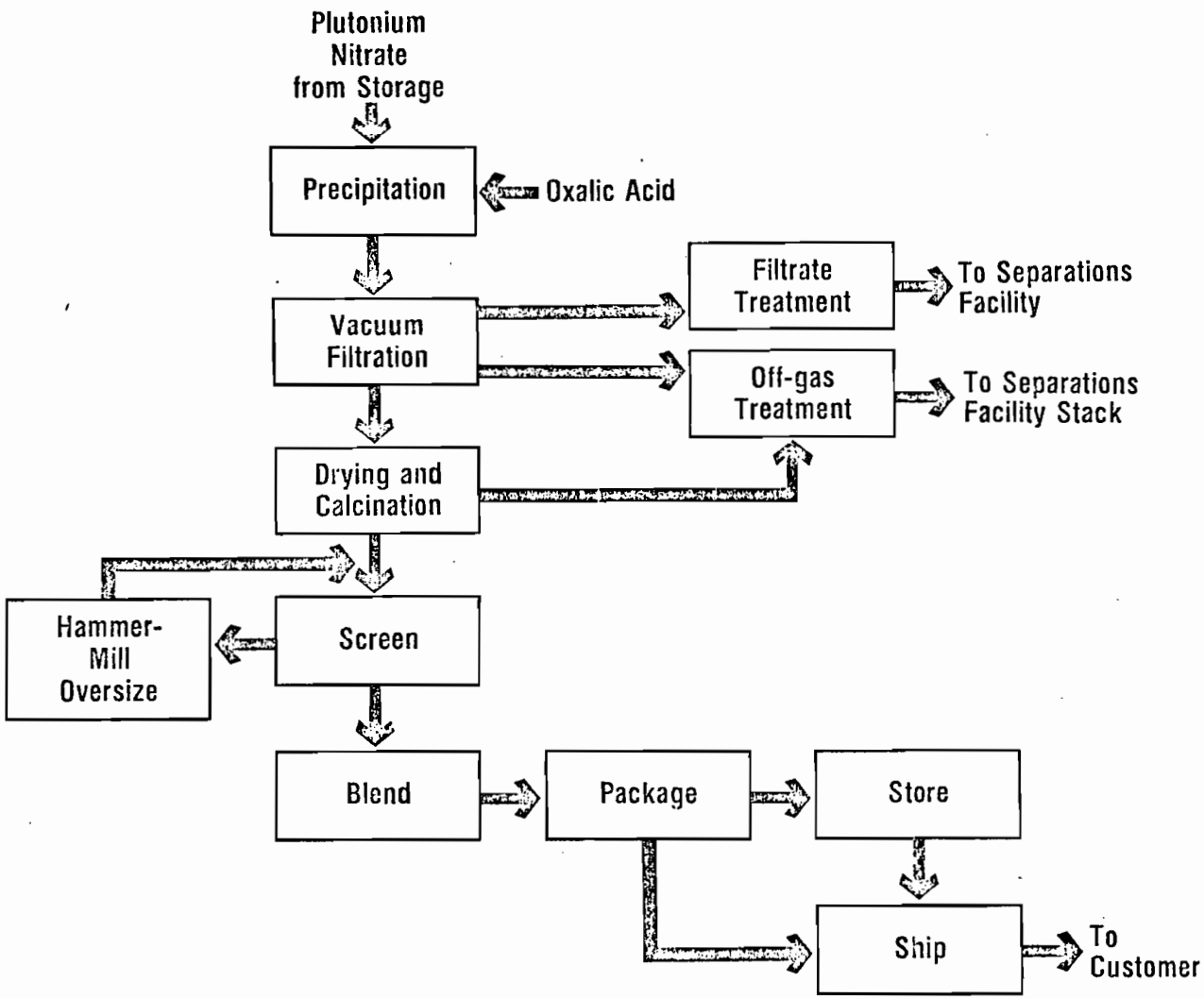
We have also looked at conceptual designs for liquid waste solidification, and we are now using the liquid-fed melter as our base reference case. For our plans, it is a relatively straightforward process. We would combine our high-level liquid waste and our intermediate-level liquid waste and feed them to a liquid-fed ceramic melter along with some frit glass maker. Borosilicate glass would be formed in canisters, which would be decontaminated, placed in overpacks, probably placed in some onsite storage, possibly as much as 5 years' worth, and eventually transferred to the repository (Slide 12).

Slide 13 shows the TRU waste that we would expect to come from this facility. The solidified high-level liquid waste, besides being defined as high-level waste, is also TRU waste. The failed equipment would be about 700 ft^3/year, and the filters and the general trash would combine to about 6800.

The solid waste coming from the facility (cladding hulls, general process trash, and the solid waste other than solidified high-level waste) would have to have something done to it. At this point, we are just going to assume that it is held on site until we decide to process it, to treat it further, or to ship it to a federal repository. Slide 14 shows some of the concepts we have for onsite storage. For low-level or CH TRU waste, our intention is to place it into cargo containers, which when filled would be covered over by a berm or earth cover. It would be placed on an asphalt pad for collection of any seepage or rainwater, which would be monitored before disposal or discharge to the environment, and the top would also be covered for protection from rain.

Slide 10

Barnwell Nuclear Fuel Plant
Plutonium Product Facility Flow Diagram



Slide 11

PLUTONIUM CONVERSION FACILITY

Alpha Contaminated Solid Waste Estimate

	cubic feet/year
Failed Equipment	700
Filters	3060
General Trash low level	2500

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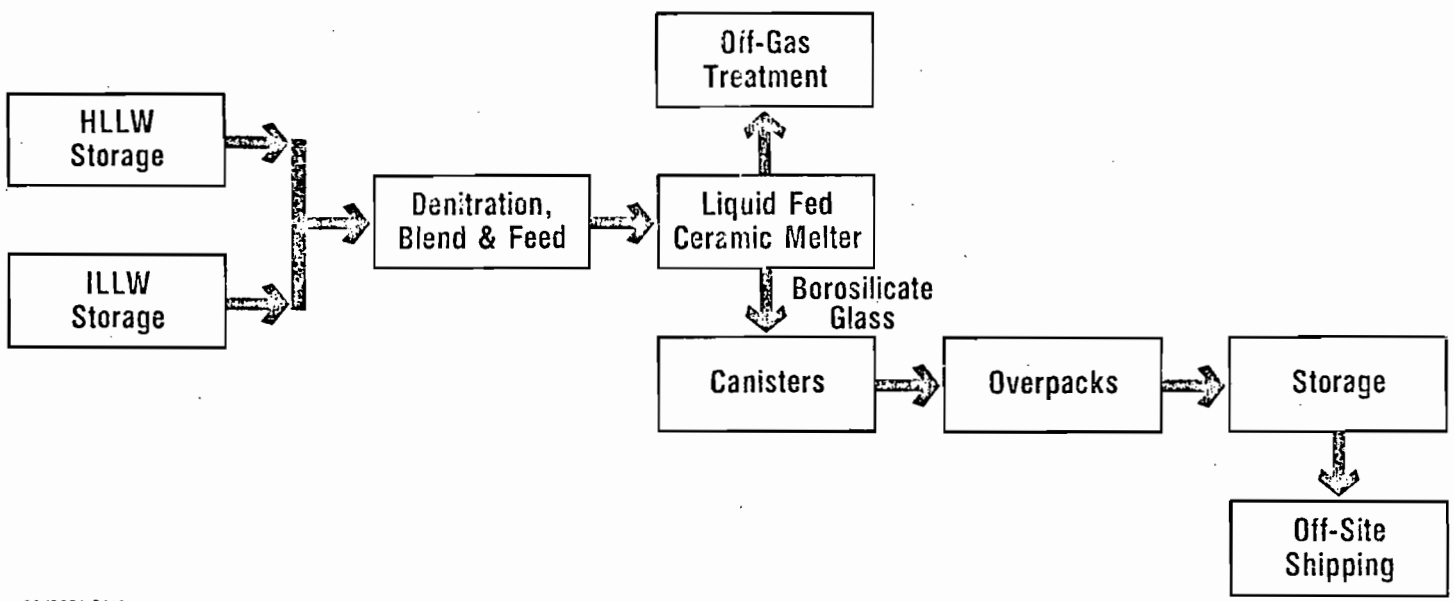
Slide 12

Liquid Waste Solidification Block Flow Diagram



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Slide 13

LIQUID WASTE SOLIDIFICATION FACILITY

Alpha Contaminated Solid Waste Estimate

	cubic feet/year
Solidified HLW	4900
Failed Equipment	700
Filters	
high level	800
General Trash	
high level	6000
Lab Hot Cell	365

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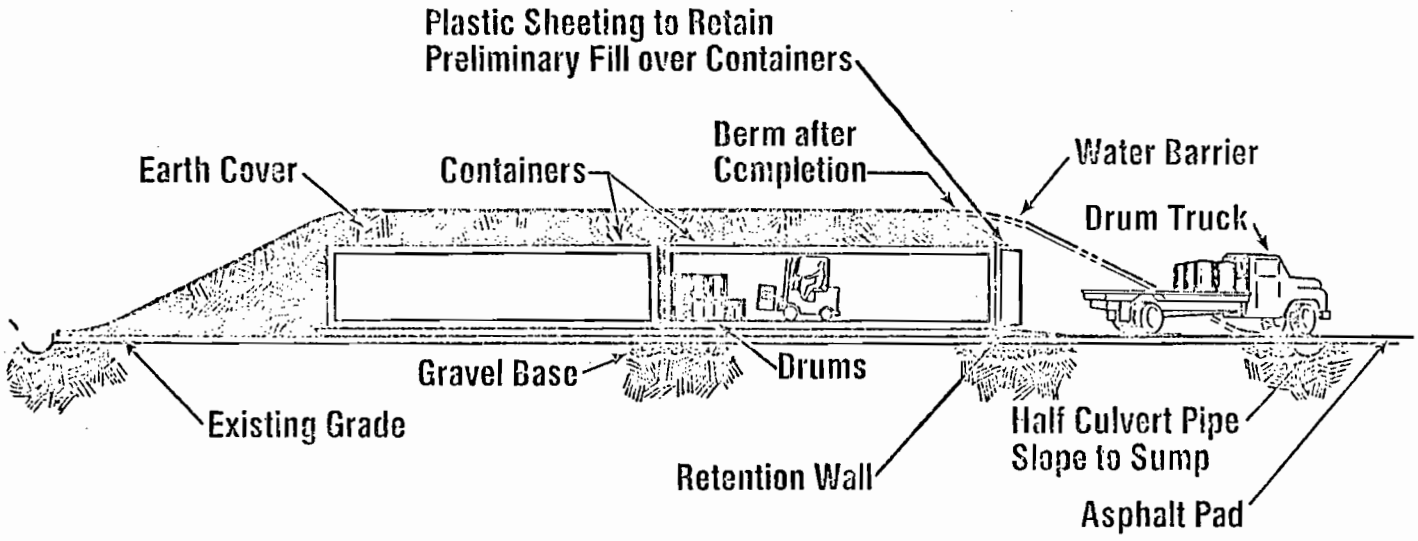
Slide 14

Low Level Storage Handling Operation



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For RH waste, we would also use an engineered berm that would have water barriers on top and bottom, the bottom water barrier being a double layer of clay soil, which would essentially separate the berm from the ground (Slide 15). In this case, we would provide caissons, drilled into the berm, that would be designed to hold five 55-gal drums of RH waste. In the case of the hulls, we would use a similar system of berms and caissons, with each caisson designed to hold one of our hull containers (Slide 16). The hull containers are roughly 3 ft in diameter and 8 ft tall, much larger than the 55-gal drum. For emplacement, these would be remote-handled by cranes and shielded as required.

To summarize, the alpha-contaminated waste from all these sources comes to a total of about 85,000 ft^3/year. This is the raw volume; it does not include the displacement volume of the container. If you wanted to consider that, you would probably have to add about 20% to take into account that not all of the container's volume is used to hold waste. In addition to the 85,000 ft^3 of TRU waste, we estimate about 69,000 ft^3/year of non-TRU waste, which could go to a burial ground like Chem-Nuclear. The grand total for the waste generated in these facilities is about 154,000 ft^3/year.

Our estimate, looking at the impact of volume reduction on the alpha-contaminated waste, is that about 45% of that waste would be combustible. The volume could be reduced by incineration. We estimate that about 70% of the alpha-contaminated waste is compactible so that we could actually reduce the volume by compacting.

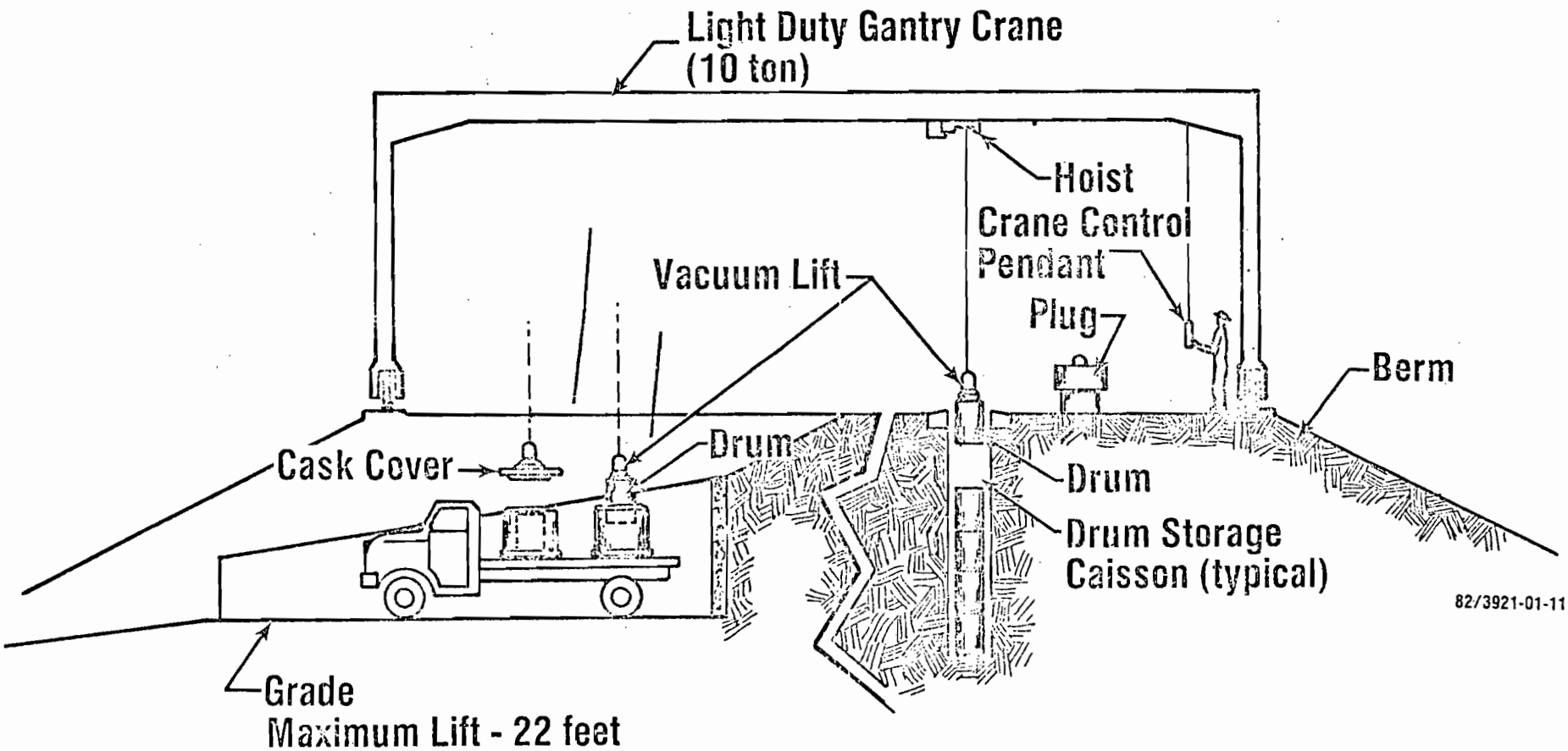
We were asked to take a look at what we think the effect would be on these volumes if we increased the limit from 10 to 100 nCi/g. We made a stab at it, and we figured that we could probably reduce our volume of TRU waste by 20%. Remember, however, that we are not operating the plant; we are using our best judgment and that is the number we came up with. It could be higher or it could be lower.

In conclusion, a reprocessor, particularly a commercial reprocessor, is always concerned with safety. We want to meet the safety requirements, to make sure we store and handle the waste safely, and to prevent it from entering the environment. At the same time, we are concerned with cost. I believe Governor Ray mentioned yesterday that the disposal cost for non-TRU waste may be about \$460/m^3 as compared to \$20,000/m^3 for TRU waste. Operating cost does, after all, wind up going back to the consumer like the cost of electricity and light bills. We are looking for a TRU waste limit that is as high as possible yet safe and acceptable.

<u>Joe Lieberman, Nuclear Safety Associates</u>: Is the information you presented in published form other than your paper?

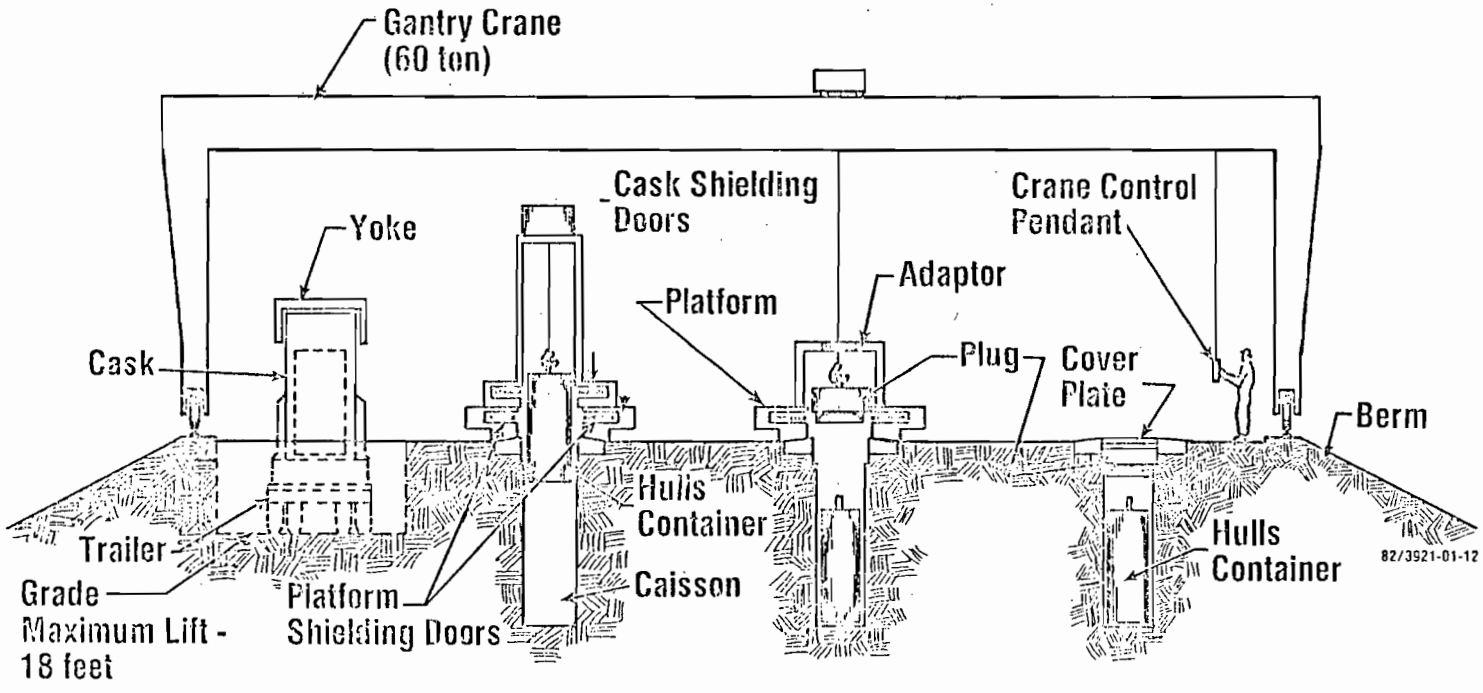
<u>Sumner</u>: As I mentioned, we did issue a report to ONWI, and I

Slide 15



High Level Storage Operation

Slide 16



Hulls Container Storage Handling Operation

believe it is available as an ONWI report. The report number is ONWI/3092/TOP01.

Paul Dejonghe, CEN/SCK Boeretang 200: Have you estimated the quantity of plutonium that would end up in the wastes? Is it possible to make a distinction between the high-level wastes and all the rest?

Sumner: I didn't quite get your question.

Dejonghe: You gave volumes of wastes, but you didn't say anything about the content of plutonium; what percentage of the waste will be plutonium? Is it something like 1, 2, or 3%? If possible, make a distinction between what will be found in the conditioned high-level wastes and what will be found in the other wastes.

Sumner: For the separations facility, I believe we estimated, or at least made a judgment because we have not operated it, a total loss of about 1%. I would expect the bulk of that to be in the hulls and the solidified high-level waste, maybe 99% of that 1%. The rest of it would be in the general process trash, filters, and this sort of thing. This estimate excludes the handling of plutonium oxide. I think when we made our estimate, we were looking at about an additional 0.5% loss for handling the plutonium oxide.

Pete Lakey, Battelle-Pacific Northwest Laboratory: You showed no wet waste such as dissolver solids or ion exchange resins. I assume that is because everything is going back into the high-level waste.

Sumner: Yes.

Lakey: That concept, as I see it, is probably not demonstrated. There seems to be an area of high interest in treating and immobilizing dissolver solution sludges.

Sumner: We have been looking at special handling of dissolver solids, undissolved solids, for several reasons. We do have a centrifuge that clarifies our feed solution in the front end--we would possibly have some solids coming out of that. We have a basket that collects large particles coming directly out of the dissolver. We are considering installing an additional solid separator downstream of the dissolver to collect those insolubles coming out of the dissolver for a couple of reasons. First, some of those solids or particles (some of the noble metals) are radioactive and high thermal generators, and we didn't want those in the waste tanks because they might settle out and increase corrosion at those hot spots. Also, interest is growing in the possibility of separating out and recovering the noble metals. Because as much as 50% of them would be included in these dissolver solids, the solid separator would be an easy way of catching them and doing something else with them, purifying them to separate them out. We have been looking at a means of collecting those solids. If we didn't want to recover them and we just wanted to dispose of them,

we might just take them, when they are separated out, directly to the waste solidification facility and incorporate them in the glass.

Bill Tedder, Georgia Institute of Technology: I have two questions about waste definitions. The first one has to do with yesterday's presentation on the possibility of defining all the waste coming from the reprocessing site as being high-level. Would you be willing to comment on that? Second, it seems to me that you have worked up some basic operational definitions of waste categories, and I was wondering if you would like to see any features included in the other government definitions of waste categories. What features, based on your technical expertise, might be helpful in reducing confusion and reducing the amount of paper work?

Sumner: In response to both your questions, I think that the TRU waste we've listed up here, with the exception of high-level waste, should be looked at as a separate category. We talked about those two costs Governor Ray mentioned ($20,000 m^3 for repository waste and $460 for low-level burial ground waste). We have always believed that most of these TRU wastes do not need to be handled like high-level waste because most of them do not have high heat generators. There is no reason to put them in a 17 in. x 10 ft canister and bury them with the same method and the same criteria that you bury high-level waste. TRU wastes could be sent to the federal repository--maybe a separate facility could be designed for handling them so that the space in the facilities at the repository could be used better and so that costs would be much lower. Some people have suggested another alternative for TRU wastes: use them as backfill into the mine area as you seal off the storage area for the high-level waste. I think it is important to distinguish and categorize the difference between high-level waste and some of the TRU wastes that may have to go to a federal repository, but should be handled differently and more efficiently at less cost than high-level waste.

Preston Hunter, Ford, Bacon, and Davis, Utah: Because the cost of waste disposal depends on the disposal method used, obviously you are considering disposing of some of your low-level products at the Chem-Nuclear facility and the rest of it, I presume, at the federal repository. Other disposal methods might be available for confinement. For example, do you have numbers on the actual inventories of some of these alpha-contaminated wastes in conjunction with the volumes that you presented?

Sumner: The inventories?

Hunter: In curies, for example, per cubic foot or meter or whatever unit of measure you want to use.

Sumner: Again, we were pretty much limited to guessing whether it is was greater or less than the 10-nCi/g limit. Until we have some operating data and some wastes that we can actually analyze to

determine the curie content, the curie content in our waste will be just a best guess.

Hunter: Can you give us a ball-park guess about the alpha-contaminated waste, in curies, of your hulls?

Sumner: I did estimate that, and I guess that is the one waste we can at least make a decent guess on. We have always assumed that about 0.1% of our undissolved fuel would be remaining with the hulls, and several years ago when Oak Ridge was dissolving some of the Robinson fuel, I think the actual analysis was about 0.12%. Based on that Oak Ridge analysis, we estimated a curie content for the alpha in the range of 10 to 100,000 nCi/g. I was hoping we might get a limit that might allow us to classify those as non-TRU, but it turned out to be a little higher than we had hoped. Unless we show, by a long processing experience, that the content would be less than 0.1%, and maybe something a lot lower, it looks like those wastes will have to be classified as TRU.

Howard Kittel, Argonne National Laboratory: Is is practical to convert your process to produce a mixed oxide? If it is, what influence will it have on your waste streams?

Sumner: During our research and development in the old days of nonproliferation process evaluations, back when we were supporting the National Aeronautic and Space Administration Program, we did examine the possibility of running a mixed co-conversion process and producing mixed oxide. We showed that we could probably handle the throughput of co-processing in the separation facilities, probably with some minor modifications, without too big an impact on the plant. We looked at a MOX fuel conversion facility. We did not make a detailed analysis, but I would say that co-conversion with the MOX would probably produce larger volumes, maybe double what we had up here for plutonium.

Charles King, Savannah River Laboratory: Why do you plan to do onsite UF_6 generation instead of shipping the uranyl nitrate to the gaseous plant? Isn't the final destination of UF_6 and uranyl nitrate the same location?

Sumner: That decision was made a long time ago, and at that time, our customers (the utilities essentially) requested it. I guess the other big incentive was that the original owner, Allied Chemical, knew a lot about uranium conversion and wanted to be in that business.

NEAR-SURFACE DISPOSAL OF ALPHA-CONTAMINATED WASTE

George Levin, EG & G Idaho, Inc.

I am here to talk to you about near-surface disposal. As I hope most of you know, prior to 1970 or 1971, alpha-emitting nuclides were buried in near-surface Department of Energy (DOE) and commercial disposal sites throughout the country. I will attempt to give you a perspective on what a near-surface disposal is, what is practiced today, and what it might mean if the transuranic (TRU) low-level waste boundary was shifted.

Near-surface disposal is the current euphemism for shallow land burial. Near-surface disposal is basically disposal of waste in the top 50 ft of the earth's crust. East of the Mississippi River, 25 or 35 ft is about the deepest working depth that one might use. Disposal sites for low-level waste are simply collections of trenches, which are as long as 300 ft, as wide as 50 ft, and as deep as 50 ft. The waste is normally stacked in the trenches and covered with dirt backfill; then a trenchcap is put on and the cover is seeded, vegetated, and returned to a natural state. On some of the DOE sites, the waste is not packaged, but dumped into the trench in a solid stable form and covered in the same manner.

The trench cap is particularly vital. Its purpose is to keep the water out, and it functions in that manner by being more impermeable than the soil around it. Therefore, the water will preferentially go around the trench cap and not go through the waste. The kind of systems being examined today for trench caps include wick systems and other devices to direct the water around the waste. The disposal site's purpose is to contain the waste to a sufficient degree and for a sufficient length of time so that, during that time, the exposure to the public meets performance objectives. At the end of the control period, the waste is no longer radioactively hazardous. Until the Environmental Protection Agency (EPA) establishes other levels, DOE and the Nuclear Regulatory Commission (NRC) are using 25 millirem/year as the performance objective for all pathways at a disposal site.

How does waste get out of a disposal site, or more important, how does the radioactivity contact people? There are two ways for the waste to move. Either the water or the air can move the wastes. Those are the media for transport. For alpha-emitting nuclides, the air movement is a more important pathway. The air gets to the waste when the waste is exposed by some kind of erosion, whether it be wind erosion in the West or water erosion in the East. Water reaches the waste when it rains, when the trench cap does not function as well as it should, or when alternations in the water table raise the water table, allowing water to seep in from the bottom. In a few select places, you get side-wall penetration through flow in the groundwater system. Any of these ways can function, at least theoretically, to bring the waste to the biosphere. The other alternative is for a human to intrude

on the waste. The postulated scenarios for those kinds of intrusion involve some institutional loss in memory. After about 100 years, our society forgets where a disposal site is located. At that point, a farmer may start farming the land, and in his zeal to improve the productivity, he may strip off the top 5 ft of soil and put some new soil down, thereby exposing the waste. If the waste is near enough to the surface, burrowing animals or the plants can reach down to the waste. Other scenarios that are sometimes involved include the attractive-nuisance argument. This argument states that the old disposal site is an attractive nuisance to archaeologists or treasure hunters who might go into the disposal area to recover the wrenches, heavy equipment, and other valuable items. When I was at Los Alamos, they were covering a road grader. I imagine some construction company might be interested in the Los Alamos road grader. These scenarios (water, subsurface migration, surface pathways, airborne pathways, and intruder) are all examined when determining whether a site is acceptable or when determining the performance of the site. All these scenarios are modeled and described on computers, and one attempts to predict the future performance of the site with these kinds of pathways. It is important to remember that these scenarios are not reality, but rather mathematical predictions of what we think the future might be. The computer only calculates with the schemes that we put into it, and because these schemes are our assessments of what the future might be, the assessments necessarily involve simplification and conservative assumptions. Otherwise, the problem is not tractable. So that we all understand rules of the game today, the current limit for alpha-emitting nuclides is 10 nCi/g for DOE and its sites. Anything more than 10 nCi/g is stored at Idaho, Savannah River, Oak Ridge, Los Alamos, or Richland. Everybody stores TRU waste except for Rocky Flats; they ship it to us.

Where do you get alpha-emitting nuclides contaminating the waste? In the commercial sector, the only day-to-day source is power plants. Surveys have shown that power plants have anywhere from 0.1 to 5 nCi/g and sometimes more in their waste stream (e.g., from the reactor water cleanup system powder on a boiling water reactor or the letdown system runs on a pressurized water reactor).

Theoretically, if one were to take some of this ion exchange material and incinerate it and achieve an overall volume reduction factor of 10 to 20 or as much as 100, one could cross the 10 nCi/g threshold with unsolidified waste. If you solidified the waste you might be back down around that threshold. Other wastes result from decommissioning old fuel-fabrication plants and old laboratories. You get steel and other items contaminated with alpha-emitting nuclides, and some of these items meet today's requirements for TRU wastes. There are commercial companies that are asking what to do with the waste. There are no commercial facilities that will accept it and DOE will not accept it, so they are stuck with it today. There is not a lot of that kind of waste; probably less than 1000 ft^3 of such waste is generated annually. Mainly, this waste consists of metal; there are

many glove box sites. DOE generates more TRU waste than everybody else, some of which is generated through the weapons production efforts. Candidly, all I know is that waste is transuranic. I do not know how it is made and I do not know its characteristics.

The other place this waste will come from is facility decommissioning. All of the DOE sites have old reactors and other facilities that will be dismantled and decommissioned. Some of these facilities will contain levels of alpha-emitting nuclides that may make them TRU wastes. These are the primary sources I know about.

What does it mean to those of us in the low-level waste business if the rule changes, if the boundary between the low-level and TRU waste becomes 100, 1000, or 1,000,000 nCi/g or anything other than 10 nCi/g? I think it affects us directly in three ways. First, we will have more waste. If we increase the limit, we are going to have more waste than we had before. Second, there will be an increased exposure to the public and to the people around the site. The increase will be small, and although I'd guess it is immeasurable, it is certainly capable of being calculated to the accuracy that one can run a computer program. If you have a cyber machine and you run double precision, you can evaluate about 20 significant figures. So you can certainly calculate the increase. Third, it is going to permit some increased use of volume reduction equipment because you will not be turning low-level waste into TRU waste. I think that is also a very small reduction; the reduction figure may run to 20 places, but at least it is theoretically possible.

For those people in the commercial business, the amount of annual waste increase is relatively small. About 3,100,000 ft^3/year now goes to the commercial disposal sites. This waste is probably divided 50/50 between Barnwell and Hanford; Beatty gets the slop and the static in the figures. Nobody wants to send waste to Beatty these days because it is too expensive and too much trouble. Another 1000 ft^3 a year is not going to matter. When decommissioning of power plants and other facilities becomes a reality, another 1000 or 2000 ft^3 may be produced. It does not look as though significant quantities would be involved because that would perturb the already precarious commercial system. If the commercial system (in the next 3 to 4 years) carries through with some of the initiatives of today and if there are 2 or 3 new disposal sites, it will be well within the capability of this system to handle the additional waste.

DOE represents another situation. I think the amount of stored waste today that might be affected is not very large, maybe 20% of the volume. With the exception of possibly Idaho and Oak Ridge (where the disposal sites have limited capacity left) the stored waste will not be a problem for the low-level waste disposal sites to absorb over the next few years. I think the problem down the line is, again, decommissioning. If the rules change, some of the old Hanford reactors, the old Hanford tanks, the Savannah River Roll tanks, could

present a problem. The amount of waste would probably dwarf anything that we have to deal with today, and I think the nature of the waste would really put a lot of pressure on the sites and the lead office to come up with some innovative and cost-effective ways of dealing with the waste. What does one do with an old million-gallon tank with some salt cake at the bottom that was going to be high-level retrieval waste? Does one cut it up? Does one blast it to the moon? Send it to the ocean? All sorts of lovely things. It is just so easy to handle; you put it in your pocket or you dig a little hole and you throw it in. I think it really is going to be incumbent on the various sites that house this type of equipment to devise a safe and cost-effective way of disposing of the waste. I think it is going to be a real challenge to our ingenuity. I think that will be the biggest volumetric effect caused by any change in the limit.

In terms of dose to the public, certainly at DOE sites, a change in the limit is not going to have any effect. Every DOE site has a buffer zone. I think we in Idaho had the smallest buffer zone; (it's 8 miles to a rest stop on Highway 20, and the waste would not get off boundary for 8 miles). Idaho's buffer zone happens to be in the up-stream direction for the groundwater flow. Therefore, it is not even a good case.

Most or all of the commercial sites are located (I expect they will continue to be) where the soil contains significant quantities of shales, clays, and organic material. These soil types have an affinity for some of the radionuclides. This is just straight chemistry; it has nothing to do with their radioactivity characteristics. In fact, the TRU nuclides are contained the best in the groundwater floating system by the soil because TRU nuclides have slower mobilities. All the analyses today have never shown that groundwater movement of TRU nuclides would impose any realistic limit on the TRU content of waste or on the alpha-emitting nuclide content of waste.

The only limits that I have ever seen calculated occur for the airborne exposure pathways, and they primarily occur through the inadvertent intruder scenario (farming, treasure hunting, or attractive-nuisance scenarios). This seems to be the limiting scenario for airborne exposure. For TRU nuclides, the alphas have to get into the body to do real damage; they enter when you breathe them. Most of the analyses I have seen would support raising the TRU content to the 100 to 500 nCi/g range depending on how conservative the analysis is and how much one would like to build on top of that conservative analysis. There are people in the audience who have done the analysis and who are far more knowledgeable than I am about the details of the analysis. The only other way I could think of that increased public exposure could result is if there were a transportation accident associated with a major fire. The fire might volatilize enough waste to release it, and anybody close enough to the accident might breathe the waste. Again, I have trouble visualizing

that as a major concern. The accident frequency for transporting radioactive waste is very low. I'm sure Ron Pope will tell you about the transportation aspects after lunch, and all you have to do is examine the data base that the transportation center has put together to see that accidents just do not happen. The safety record for radioactive waste is better than that for vehicular accidents. The packages and the fixation agents are designed to withstand 20 or 30 min. of fire, and are so tested. Again, I have difficulty figuring out how there is a major increased exposure problem for the public if the TRU nuclide limit was adjusted. Certainly, when a truck drives by a person, the person will not see an increase. The alphas will not get out of the packages, let alone out of the sides of the truck.

Another, perhaps minor, effect is that an increase in the limit may allow some increased use of volume reduction. There are cases where some material could be made into TRU waste. That is not cost effective. There may even be cases where people dilute their waste to make it low-level waste because there is no way to dispose of TRU material today. That is self-defeating. It is not hard to visualize a company with 50 ft^3 of TRU waste that may be contaminated to a 50 nCi/g limit turning the waste into 500 ft^3 of 5 nCi/g waste by throwing saw dust or paper in the box, then disposing of it as low-level waste. This type of disposal is probably cost effective today. I suspect this limit is ill-serving the regulators and everybody else who has tried to create these limits as well as ill-serving those of us who really do not want to get any more exposure than necessary.

I guess there is one way that TRU nuclides could get out of a disposal site, which DOE has demonstrated at Richland and Oak Ridge. If you dump large quantities of EDTA or a similar chelating agent into the ground in solution form, the waste can migrate. We can move it, and we have done that. However, it takes a lot of volume--thousands of gallons. Besides plant and animal intrusion and normal events, there is no other pathway for which adjusting the limit will make a major difference. Adjusting the limit may have minor good side effects.

I would like to close with one of my favorite topics. As I have gone through this presentation, I have tried to isolate the areas of major contention, the points of discussion, or the controlling factors for adjusting the TRU limit or waste boundary that refers to man going to the waste. All the other pathways do not represent a real problem; man going to the waste is the problem. I cannot say that this will not occur. No one can guarantee that it will not occur. I think the appropriate question is a matter of regulatory philosophy, "Should those kinds of scenarios be part of the numbers game?" We are setting the limits for how we regulate ourselves as a country. I think it is a very real question and I think it is the very first question that needs to be addressed. Should six farmers, two archaeologists, or three treasure hunters determine how 220 million of us are regulated? I know that I have given you extremes, but I think that is really the question. I do not advocate ignoring those

kinds of scenarios. I think the important question is to determine the numbers, the boundaries, between TRU, low-level waste, and in the case of the NRC regulations and waste classification systems, which waste goes where. Should those kinds of scenarios be limit setting? I happen to believe that, as a matter of regulatory philosophy, these scenarios ought not to be used. They ought not to be used because I do not think that it makes sense for six people to determine what 100 million people live by. However, I also think that one ought to consider those scenarios. I do not think it is far fetched to create a situation in which someone accidentally can get enough exposure to die; but I think it is inappropriate to use that situation to set a limit. There is a reasonable compromise. It is appropriate, as in the latest versions of 10 CFR 61, to put up monuments, to put up impediments to penetration and whatever other creative solutions people can create. It is also appropriate, as part of the license application in the case of a commercial site, to perform the same kind of analysis done for the DOE sites. Analyze these scenarios and determine the dose that an intruder might receive. For example, if the dose is 25 rem once in a lifetime, okay. However, if it is 500 rem, or whatever the lethal dose is, that is a different situation. I believe that is the appropriate way to deal with the intruder scenarios. We should not put these so deeply within the standard-setting process and the regulatory process that they become the primary concern for a disposal site. For example, in the eastern United States, if you bury waste deeper, you are, in fact, moving the waste closer to the water table. You are presumably reducing the time that it takes for the waste to get into the water table and into the groundwater flow path. Depending on the nature of the groundwater flow path, that may or may not be significant. If there is a gross flow path, you may be decreasing the time it takes the waste to get to drinking water even though you are better protecting the site from the intruder. Is that a trade off that we ought to make? Personally I think not.

In summary, I have no problem with raising the alpha-containing nuclide limits to a reasonable level. I would advocate first that, as I understand the scheme of things, the EPA should adopt a regulatory philosophy, set the rules of the game, and then leave it to NRC and DOE to follow those rules and to calculate appropriate limits in a sound, scientific, and sensible way.

John Healy, Los Alamos National Laboratory: When you raised the question on the intruder pathway, I tend to agree with you; however, I would point out that this question has been brought up at headquarters and to the lawyers in DOE. The lawyers have said that it must be included. So I think before we start making our own decisions, we have to worry about decisions that have been made in the past. You referred to a 25 millirem/year limit. Where is this written down, and how is it to be applied? Is this to be applied to the people who work in the place? Is it to be applied to our scenarios?

Levin: It is a performance objective.

Healy: I see no way in which you can go to 100 nCi/g if you are going to set a limit like that.

Levin: I'm referring to offsite people, John. Anybody off this site. It does not affect occupational exposure. It is off site for all pathways. Total integrated dose to offsite; something like the nearest individual in a year.

Healy: I think you may have trouble justifying 100 nCi/g if you're going to limit it to 25 millirem/year.

Levin: The other thing I'd point out is that whether to include the intruders needs to be settled by EPA, not by the DOE lawyers. I think that in setting their standards and their criteria they should define the rules of the game for the federal government and determine how one analyzes so that one analyzes consistently. I'm not advocating that we change the limit today.

Healy: I have no objection to that if that is what the EPA does, but as of now, the only official pronouncement we have is from the DOE lawyers.

Don Wood, Rockwell Hanford Operations: It was my understanding that the limits set in 10 CFR 61 were actually based on 500 millirem rather than on 25 millirem/year. Is my understanding correct or could you or someone from NRC comment on that?

Levin: The performance objective for the intruder scenario was 500 millirem/year. The performance objective for everything else was 25 millirem/year. Now 500 millirem/year has been removed as a performance objective, but it is still considered in the calculations as I understand it. Correct me if I am wrong. The fact that the objective is still 500 does set some of the limits in Table 2, or Table 1.

Paul Lohaus, Nuclear Regulatory Commission: The 25 millirem/year limit is applied to environmental releases from the site and would be applied to an individual at the site boundary. As such, that limit was not really applied directly in the calculation of the concentration limits. What we did, primarily as a matter of convenience, was to apply the intruder type of analysis, using a 500 millirem exposure to the individual, as a basis for calculating the limits. Other factors were also considered in the analysis in addition to intrusion, primarily the need for long-term stability at the site. For example, if you look at the existing requirements in effect at the existing commercial sites, there are limits at least for reactor filter sludge waste and resins that would require solidification of the waste. So, in addition to looking at the intruder, we did apply other considerations that ensure stability. The stability is going to help reduce the long-term maintenance, long-

term care, and the potential for trench cap subsidence and water infiltration, which in turn would increase the potential for migration from the site. In terms of the limits themselves, they were primarily set as a matter of convenience and were calculated based on looking at intruder pathways. As part of my talk today, I planned to present the limits that we have calculated based on our analyses, talk about the public comments that were received on the part 61 rule that was proposed last July, and then present what we have recommended to NRC as final limits in the recommended final rule dealing with TRU nuclides.

Ed Watson, Battelle Pacific Northwest Laboratories: Did I understand you to say that it would make little difference whether you had 10 or 100 nCi/g?

Levin: In terms of what?

Watson: In terms of waste disposal.

Levin: Commercially it will make little difference. For DOE, it may potentially make a large difference. It depends on how some of the facilities sort out when they are decommissioned. I think that is especially true for existing waste sites. It is going to make a great deal of difference. I think the tanks are the rich ones. They become low-level waste, so the difference dwarfs anything we have now. The DOE sites have the problem, not the commercial sites.

Stephen Woolfolk, Westinghouse Corporation/WIPP: You mentioned the commercial sites. I spent a year in Texas working indirectly with the state on its low-level waste disposal site, and one of the things I found is that Texas is heavy-metal paranoid. If you increase the limit to 100 nCi/g I think you are going to find a lot of the low-level waste disposal sites will have much more difficulty getting licenses or getting authorized by the states to operate. We had a big fight about getting Texas to accept 10 nCi/g. The state was very concerned about anything dealing with plutonium or any heavy metal. I would like you to comment.

Levin: I believe you are talking about TODD shipyards because Texas does not have a disposal site.

Woolfolk: No, but legislators are trying to alter the law to authorize the state to create one.

Levin: I am aware of that. Texas has enacted two laws actually, including an authorization bill for about $3 million. I do not believe the laws have been published yet.

Woolfolk: During the hearings about the law, they were very concerned about the 10 nCi/g limit. They were concerned about any heavy metal.

Levin: People are concerned about heavy metals; heavy metals are toxic and people are scared to death about plutonium. I do not know that my mother knows the difference between 10 and 100 nCi/g. If that's what you are saying, I agree with the people who are scared. I just don't know when one tells someone that a nanocurie is 10^{-9} Ci and displays it with all the zeros and the 1. I'm not sure that going to the 8th versus the 9th place is going to be significant to my mother or somebody like that. Excuse me, but I use my mother as a surrogate citizen.

Hans Christensen, Stockholm, Sweden: Can you say something about the leach rate of the solidified alpha waste that you mentioned in your talk?

Levin: I could say a lot of things about it. What we do in this country is to solidify waste in concrete, and the leach rates run all over the place. They run from maybe 10% in a year initially to low numbers that are almost immeasurable. This is one of the problems that we are dealing with in the program. The high-level waste people are dealing with it too. Let me go back a little bit. If you look at the NRC regulations and some of the things DOE is talking about, there are wastes that, whatever the final numbers are, have greater concentrations of certain nuclides than is permitted for near-surface disposal. One of the ways to deal with that is to put it in a waste form that contains it better than you would today. The ultimate challenge is to get predictable leach rates so that you can get credit for the waste and for the extra containment. I don't know anybody who has really solved that problem today. If someone has got a solution, come talk to me. We could use it in the program. We do not have a solution to that problem. There are some good waste forms that provide good containment. They are pretty stable, and they solidify a lot of things. DOW Chemical has a new product out that seems to be able to contain things. People are looking at epoxy resins, a very fine product. I can give you laboratory measured leach rates, but God only knows how they relate to what is in the ground. I certainly don't. There are some special waste forms in the ground at Savannah River, where we have put real waste from power plants that was solidified in concrete using the Stock system. We have DOW Chemical stuff in there from a boiling water reactor, and we are going to study it over the next 10 to 20 years. Then we will measure leaching migration and controlled environment in the ground. We are going to start it up in Richland in the dry site, although we probably will not see anything. Those are the first realistic measurements of leach rates that I know have been done. We are going to try, with these data and some Brookhaven data that include laboratory measurements, to see if we can relate the two. If this is successful the laboratory, tests can be meaningful in predicting what would happen in the ground.

I can give you laboratory numbers, but they do not tell you what is going to happen in the ground. Most of the commercial waste is

solidified in concrete. There is only one plant using DOW Chemical, and there are a few plants using ureaformaldehyde. Most plants use concrete. I guess the other option now is to put waste in a high-integrity container, which is basically a high-impact, high crosslink polyethylene. This container allegedly has a 300-year life in the ground. That is all I can tell you.

Charles King, Savannah River Laboratory: What is the current thinking on the standards for the protection of the groundwater? The 10 CFR 61 regulation refers to the EPA drinking water standard.

Levin: Not any more.

King: So there's an update on 10 CFR 61?

Levin: The philosophy in 10 CFR 61 is something that I support. I think it is right. It accepts that a certain amount of radioactivity will be released from a disposal site. The problem with that is assuring people that you are still protecting the groundwater. That is like the problem of heavy metals in Texas. It is a problem, but it is a human problem, not a technical problem. It has to be dealt with at that level. I happen to believe one can do it successfully, but I think that has yet to be proven. Why don't you wait until this afternoon, and Paul Lohaus will tell you all about what is in 10 CFR 61.

Lohaus: I would like to mention that the proposed rule really contains two limits. One was the 25 millirem/year limit to the whole body, 75 millirem/year for thyroid, and 25 to other organs that would be applied at the site boundary. We said you should not exceed the EPA drinking water standard at the nearest public drinking water supply. Based on public comments (principally on comments from EPA), that was an inappropriate use of the EPA drinking water standard. In our final recommended part 10 CFR 61 rule, we have removed specific reference to the EPA drinking water standard and retained the 25 millirem/year limit at the site boundary. As part of the analysis of a specific site, we would look at meeting the 25 millirem/year limit, but at the same time we will consider what, if any, potential effects there might be on drinking water supplies in that area, which do not necessarily apply to that limit.

DEEP GEOLOGIC DISPOSAL OF ALPHA-CONTAMINATED WASTE IN WIPP

John Sadler, Westinghouse/WIPP

I would like to discuss the Waste Isolation Pilot Plant (WIPP) and in doing so briefly provide you with some background information and a brief facility description. I will close with a discussion of some typical waste characteristics, including a description of the waste certification activities, and the current status of WIPP.

In 1955 the National Academy of Science recommended bedded salt as the best geological formation for waste disposal (Slide 1). This recommendation was followed in the mid-1960s by Project Salt Vault. In 1971 extensive studies were begun on salt, with particular emphasis directed toward the New Mexico area (Slide 2). In 1974, the WIPP program was established. The WIPP site, shown in Slide 3, is located about 26 miles from Carlsbad, New Mexico. In 1977, the WIPP Project Office was established; Slide 4 shows the current organization. The primary participants are Sandia National Laboratories (scientific advisor); Westinghouse (technical support contractor; also Westinghouse has two subcontractors, Dravo and D'Appolonia); Bechtel National (architect-engineer); the Corps of Engineers, which joined the project this year (construction manager); and finally Fenix and Scisson [site and preliminary design validation (SPDV) shaft drilling contractor].

WIPP is located at the Los Medanos site in southeast New Mexico. Slide 5 shows the basic stratigraphy of the area. The bedded salt layer, which is the interface between the Rustler and the Salado, starts at about 850 ft. The storage horizon selected is about 2150 ft in the salt of the Salado formation.

In 1977 a public law was passed that redefined the WIPP mission (Slide 6). This law specifically identified WIPP as a defense facility, which is exempted from regulation by the Nuclear Regulatory Commission (NRC). Slide 7 restates the mission and indicates that the mission will be accomplished in phases. The first phase will be the SPDV program. During the second phase, the facility will serve as a demonstration facility for the storage of transuranic (TRU) waste; after a 5-year retrievability decision, the facility will become a permanent TRU repository. Finally, one of WIPP's most important functions is to be a research and development facility where experiments in situ can be carried out in salt for high-level defense and experimental waste. All high-level waste experiments will be retrieved before decommissioning.

In 1981, the Department of Energy (DOE) issued the Final Environmental Impact Statement Record of Decision, which allowed us to begin work at the site. In Slide 8, the shaded area shows the SPDV portion of the schedule; also shown is the full WIPP construction schedule. The key dates on this schedule are September 1983, the final validation

Slide 1

WHY BEDDED SALT?

- STABLE GEOLOGICAL FORMATION
- GOOD RADIATION SHIELDING
- TENDS TO "HEAL" CRACKS OR FRACTURES (plastic under pressure)
- GOOD THERMAL CHARACTERISTICS
- PRESENCE OF SALT INDICATES ABSENCE OF SIGNIFICANT UNDERGROUND WATER

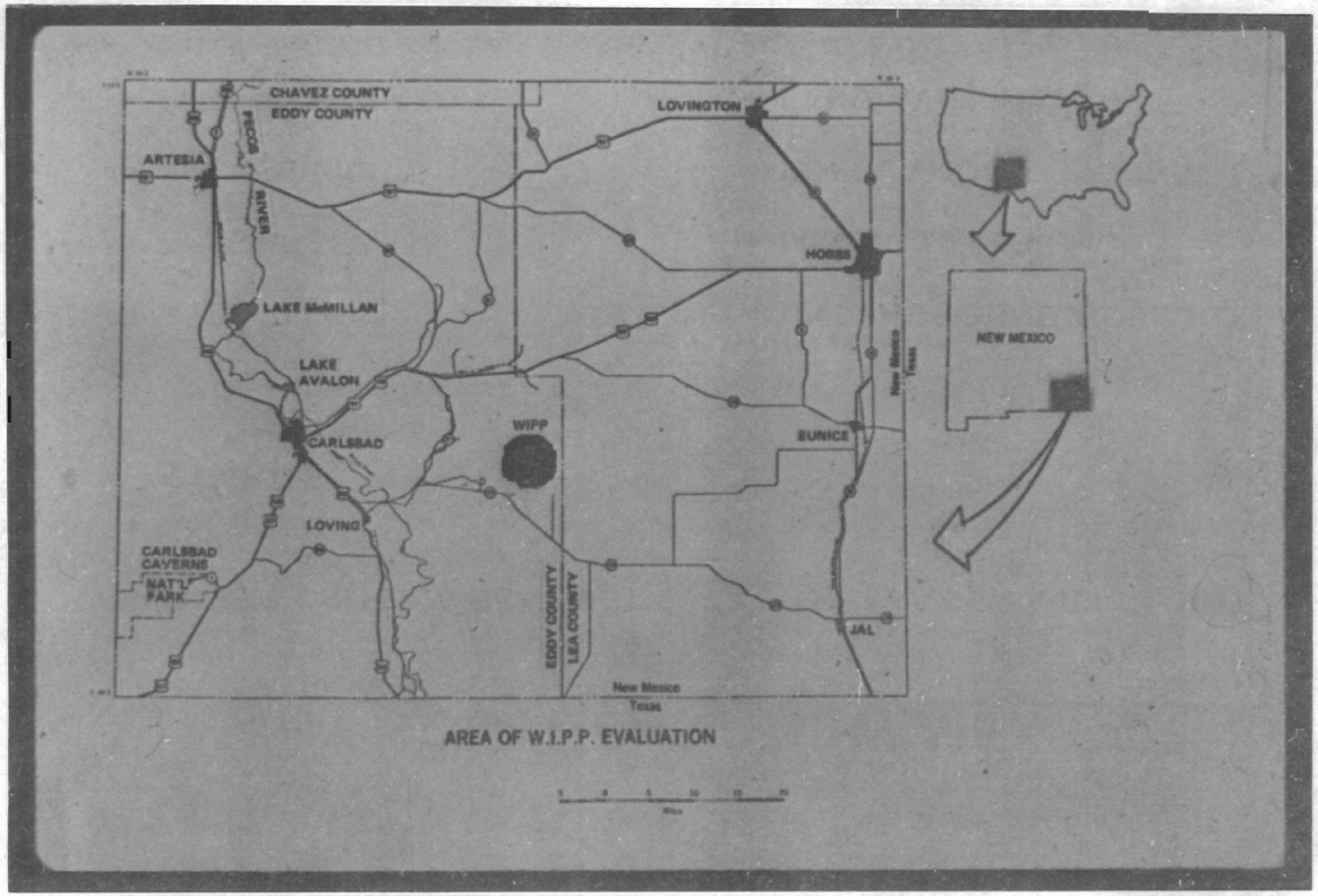
ISOLATES RADIOACTIVE WASTE FROM BIOSPHERE

Slide 2

WHY SOUTHEAST NEW MEXICO?

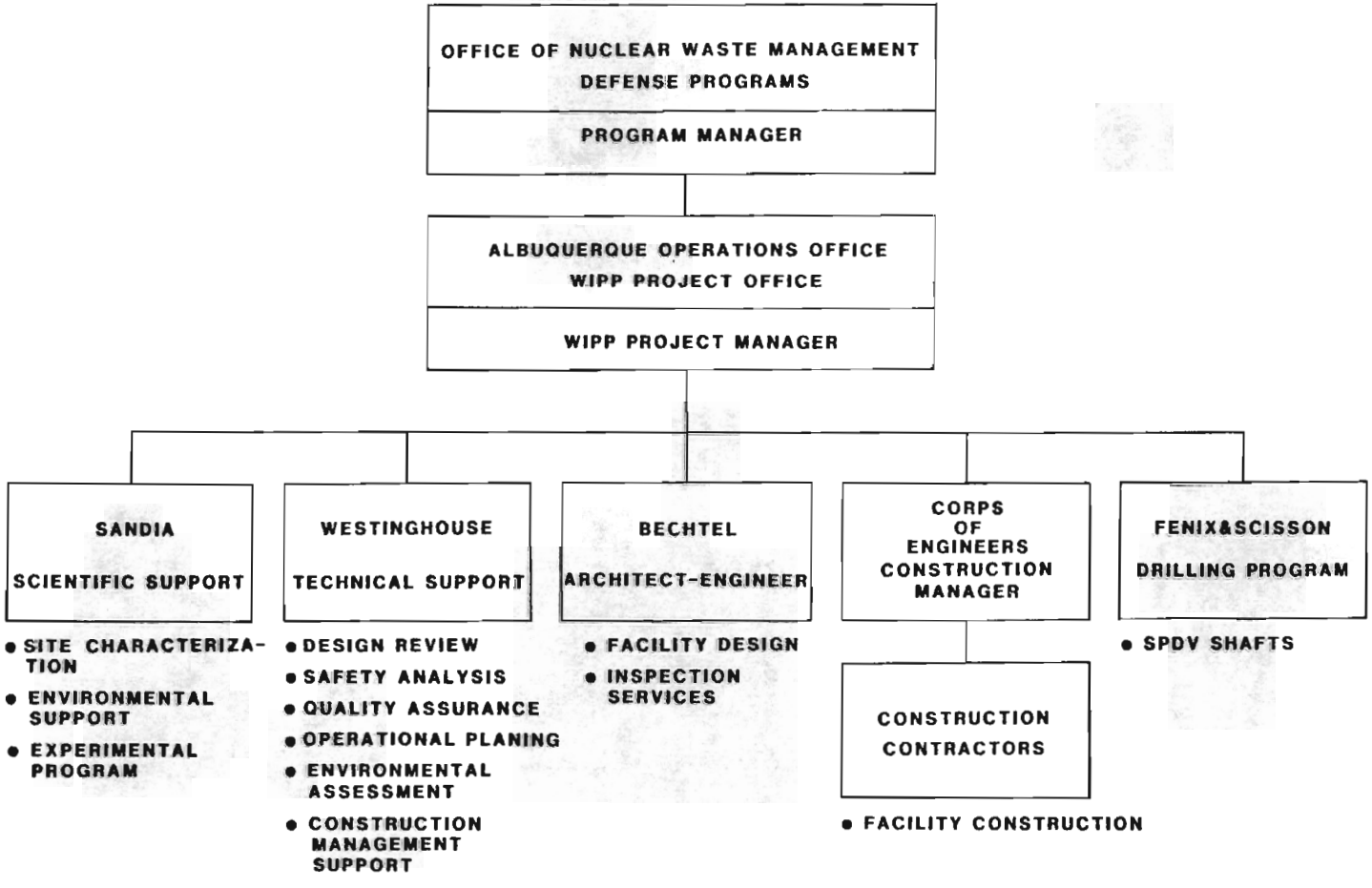
- MAJOR CRITERIA BEST MET BY SOUTHEAST NEW MEXICO SITE
- SALT BED
  - DEPTH
    - THICKNESS
      - LATERAL EXTENT
- HYDROLOGY
- RESOURCES
- ACCESSIBILITY
- SITE INTEGRITY
- UNDERGROUND GEOLOGY
- MINING EXPERIENCE
- POPULATION DENSITY
- LAND AVAILABILITY

Slide 3

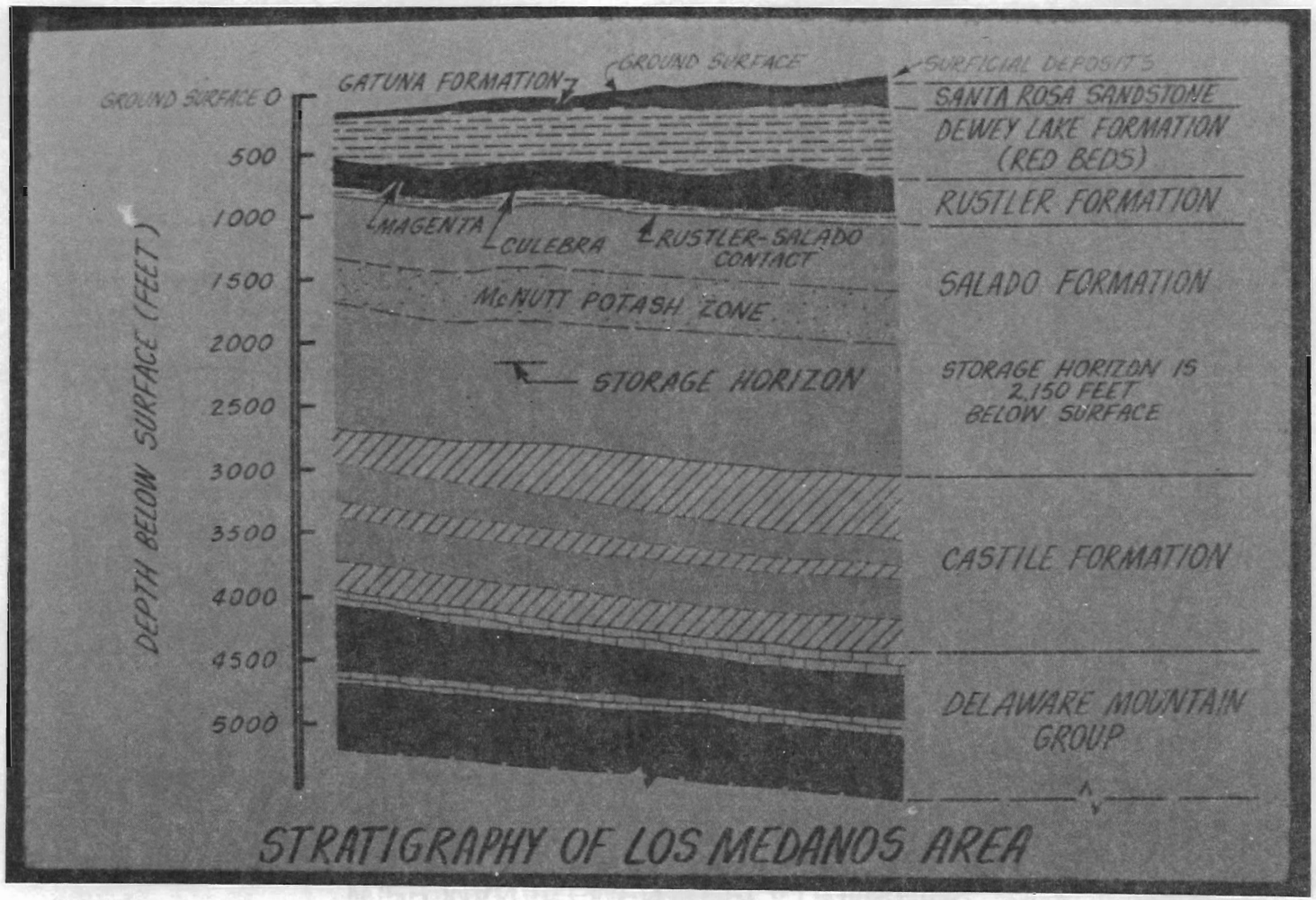

CHAVEZ COUNTY
EDDY COUNTY
PECOS
RIVER
ARTESIA
LOVINGTON
HOBBS
LAKE McMILLAN
LAKE AVALON
CARLSBAD
WIPP
EUNICE
LOVING
CARLSBAD CAVERNS NAT'L PARK
EDDY COUNTY
LEA COUNTY
JAL
New Mexico
Texas
NEW MEXICO
AREA OF W.I.P.P. EVALUATION

Slide 4

WIPP MANAGEMENT RELATIONSHIPS



Slide 5


GROUND SURFACE 0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
DEPTH BELOW SURFACE (FEET)
GATUNA FORMATION
GROUND SURFACE
SURFICIAL DEPOSITS
MAGENTA
CULEBRA
RUSTLER-SALADO CONTACT
McNUTT POTASH ZONE
STORAGE HORIZON
SANTA ROSA SANDSTONE
DEWEY LAKE FORMATION (RED BEDS)
RUSTLER FORMATION
SALADO FORMATION
STORAGE HORIZON IS 2,150 FEET BELOW SURFACE
CASTILE FORMATION
DELAWARE MOUNTAIN GROUP
STRATIGRAPHY OF LOS MEDANOS AREA

Slide 6

WIPP MISSION

"The WIPP is authorized as a defense activity of the DOE . . . for the express purpose of providing a research and development facility to demonstrate the safe disposal of radioactive wastes resulting from the defense activities and programs of the United States exempted from regulation by the Nuclear Regulatory Commission."

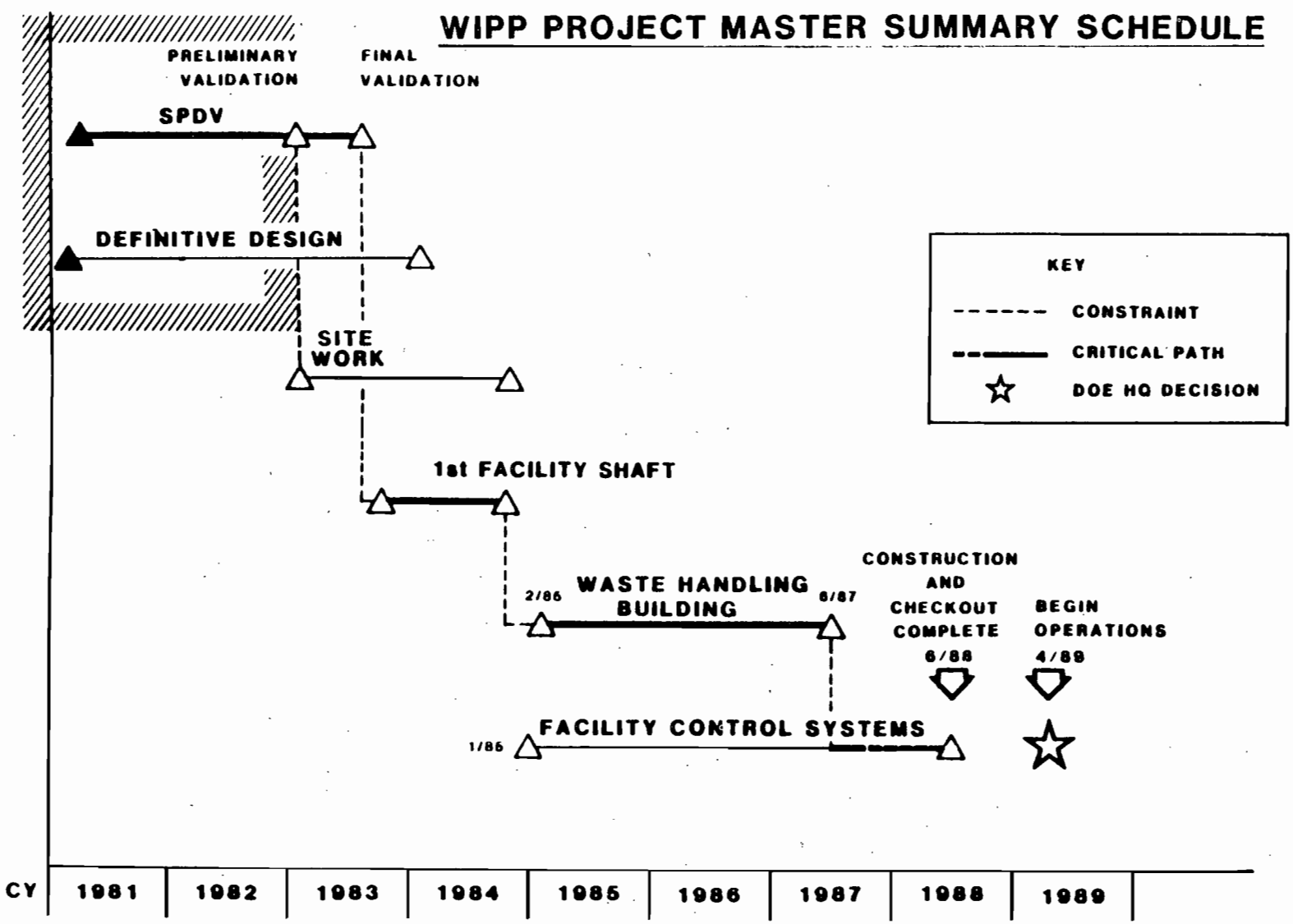
--P.L. 96-164

Slide 7

AUTHORIZED WIPP MISSION

- PROVIDE SITE AND PRELIMINARY DESIGN VALIDATION (SPDV Phase).
- PROVIDE FACILITY FOR GEOLOGIC DISPOSAL OF DEFENSE RELATED TRU WASTE ON A RETRIEVABLE BASIS.
- PROVIDE CAPABILITY FOR EXPERIMENTATION WITH DEFENSE HIGH LEVEL WASTE.

Slide 8


WIPP PROJECT MASTER SUMMARY SCHEDULE
PRELIMINARY VALIDATION
FINAL VALIDATION
SPDV
DEFINITIVE DESIGN
SITE WORK
1st FACILITY SHAFT
2/86
WASTE HANDLING BUILDING
6/87
CONSTRUCTION AND CHECKOUT COMPLETE 6/88
BEGIN OPERATIONS 4/89
1/86
FACILITY CONTROL SYSTEMS
KEY
CONSTRAINT
CRITICAL PATH
DOE HQ DECISION
CY
1981
1982
1983
1984
1985
1986
1987
1988
1989

date for both the site and the preliminary design, and April 1989, the key milestone to begin operation. In April 1989, the first waste will be received at WIPP.

The SPDV is shown schematically in Slide 9. It provides for two shafts and limited underground development with minimal surface facilities. The objectives of the SPDV are (1) to provide in-situ, at-depth investigations of the site geology and thereby augment the previous site characterization work and (2) to support the preliminary design validation by looking at the short-term response of the three elements (shafts, drifts, and rooms) that characterize the WIPP facility.

Slide 10 shows the full WIPP, again in a perspective view, and the shaded portion represents the SPDV that is now under way. The full WIPP includes the full surface facilities and three shafts instead of the two that we now have. The storage area (to the left on the slide) consists of eight panels for storage in individual rooms. A second area is devoted to both radioactive and nonradioactive experiments that are planned for WIPP. I should point out that I am describing the cost-reduced design for WIPP. For 6 to 9 months we have been trying to reduce costs at WIPP, mainly by simplifying or deleting some of the surface facilities and by eliminating one shaft. WIPP previously had been designed as a four-shaft facility.

Slide 11 compares excavation, cost, construction time, number of shafts, and schedule completion of SPDV versus full WIPP. The dollar values indicated represent capital dollars. The percentages listed under SPDV are the percentage that SPDV is of the total WIPP cost.

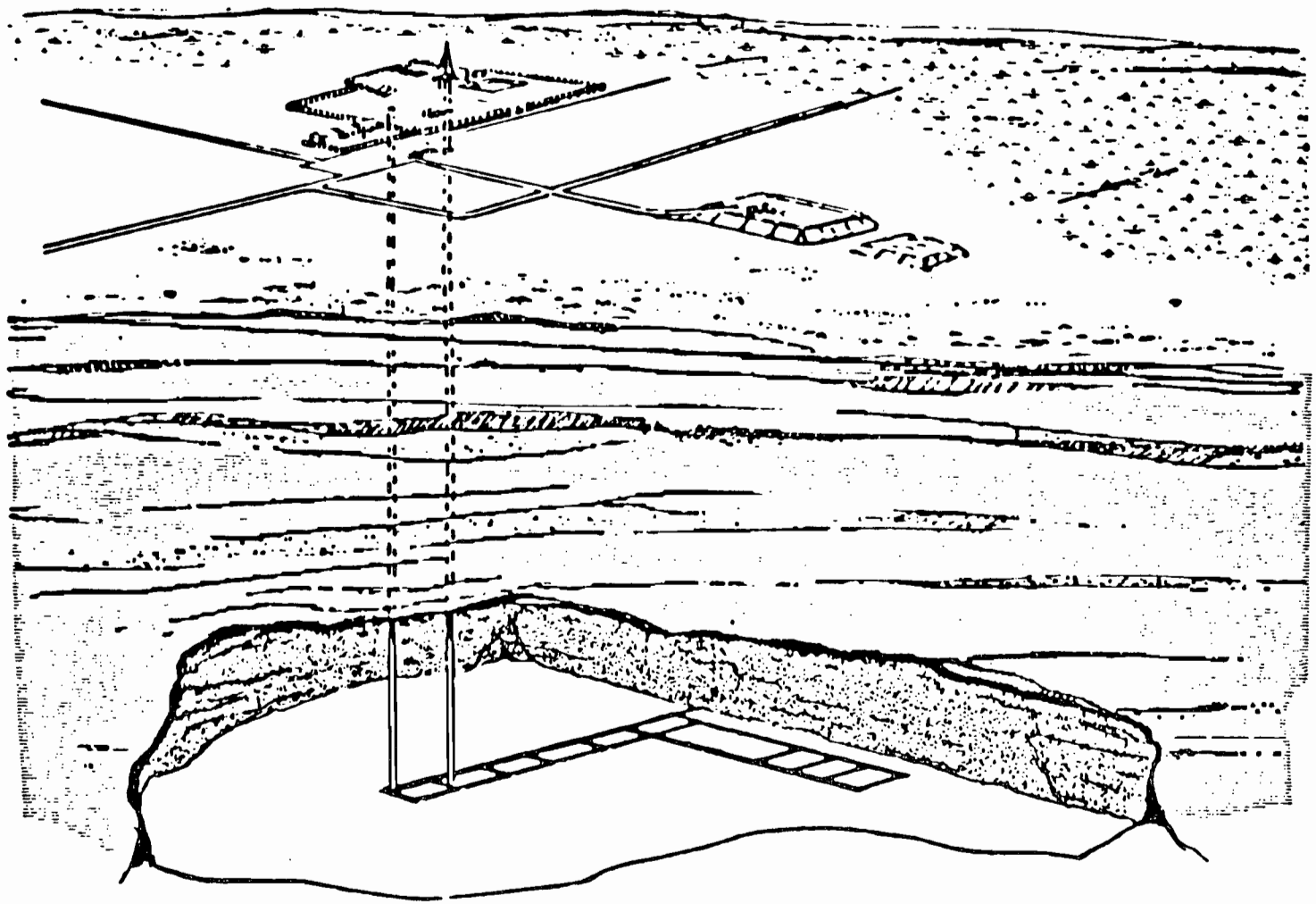
The WIPP site includes three zones, although Slide 12 shows four. There has recently been a change in zone 4. Zone 1 is the 160 acres where the surface facilities are located. Zone 2, about 2000 acres, basically overlies the area having potential for underground development. Zone 3 provides a 1-mile buffer between zones 2 and 4.

Slide 13 is a plot plan of the site, showing the fenced area, which encompasses about 35 acres. The key facilities are the waste handling building, which is located over the waste shaft, the construction and salt handling shaft, the exhaust shaft, and the exhaust filter building. The site is served by both rail and truck. I would like to point out that the salt pile is rather large; it is 0.2 miles long by 0.125 miles wide by 60 ft high.

Slide 14 shows the basic trimetric of the WIPP facility. Also, this slide indicates the underground ventilation flow. In the cost-reduced mode, we plan to operate WIPP on a split-shift basis, which means that one shift will continue construction of the underground while the second shift performs actual storage operations. Air is brought in through the construction and salt handling shaft, directed to either the construction area or to the waste storage area, and brought out

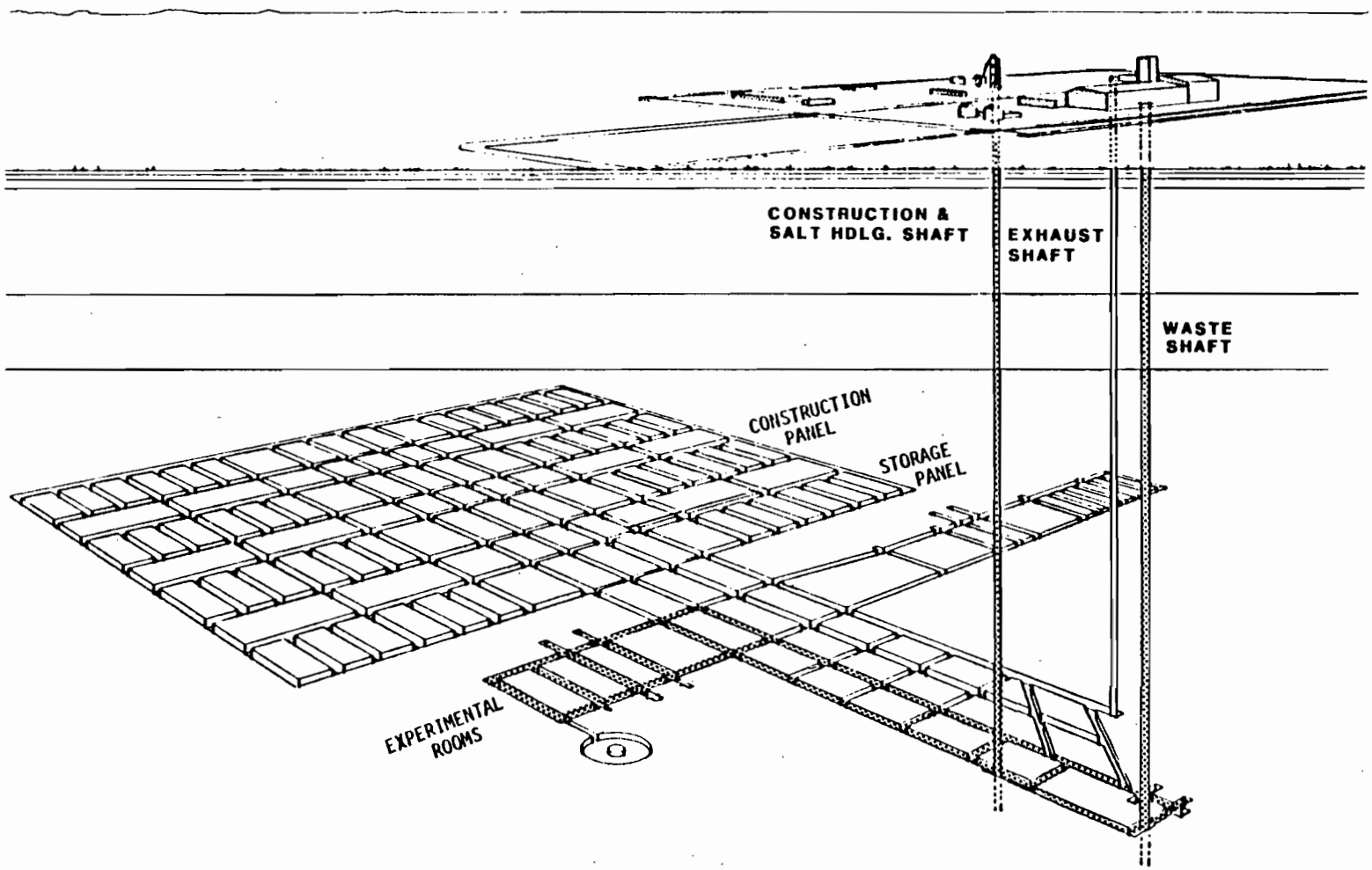
Slide 9

SITE PRELIMINARY DESIGN VALIDATION FACILITY



Slide 10

FULL WIPP FACILITY



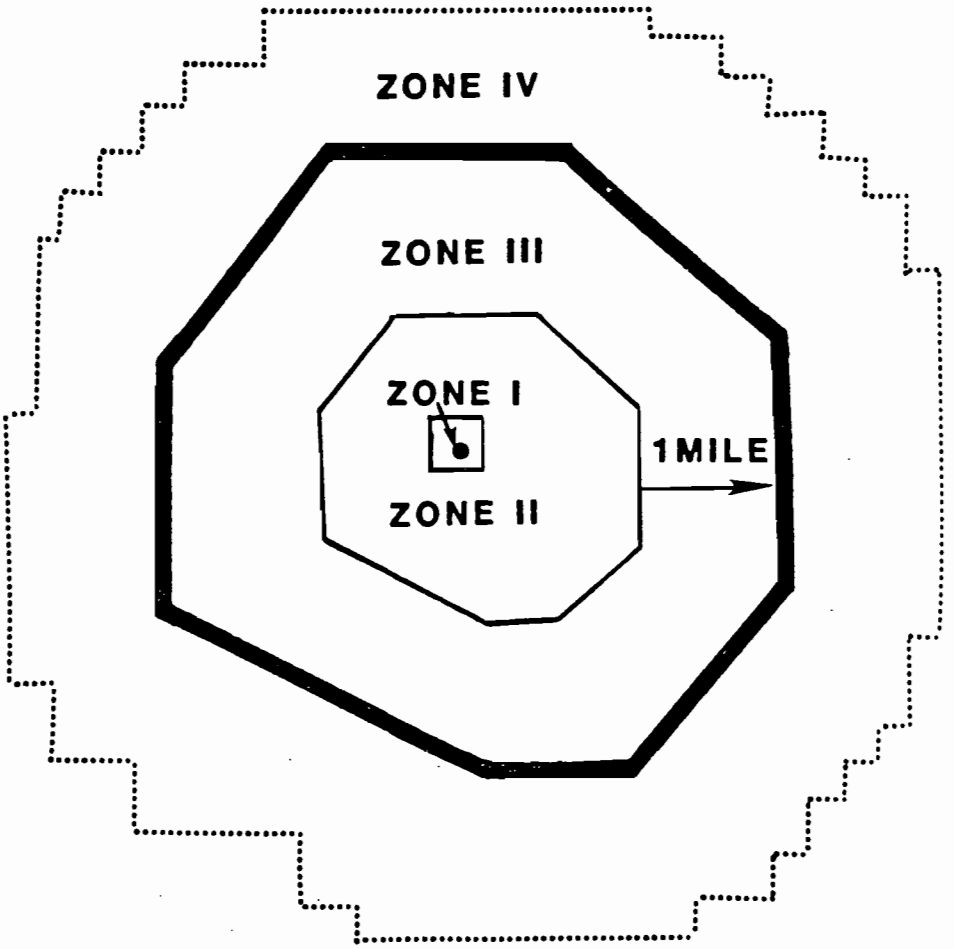
Slide 11

SPDV vs Full WIPP

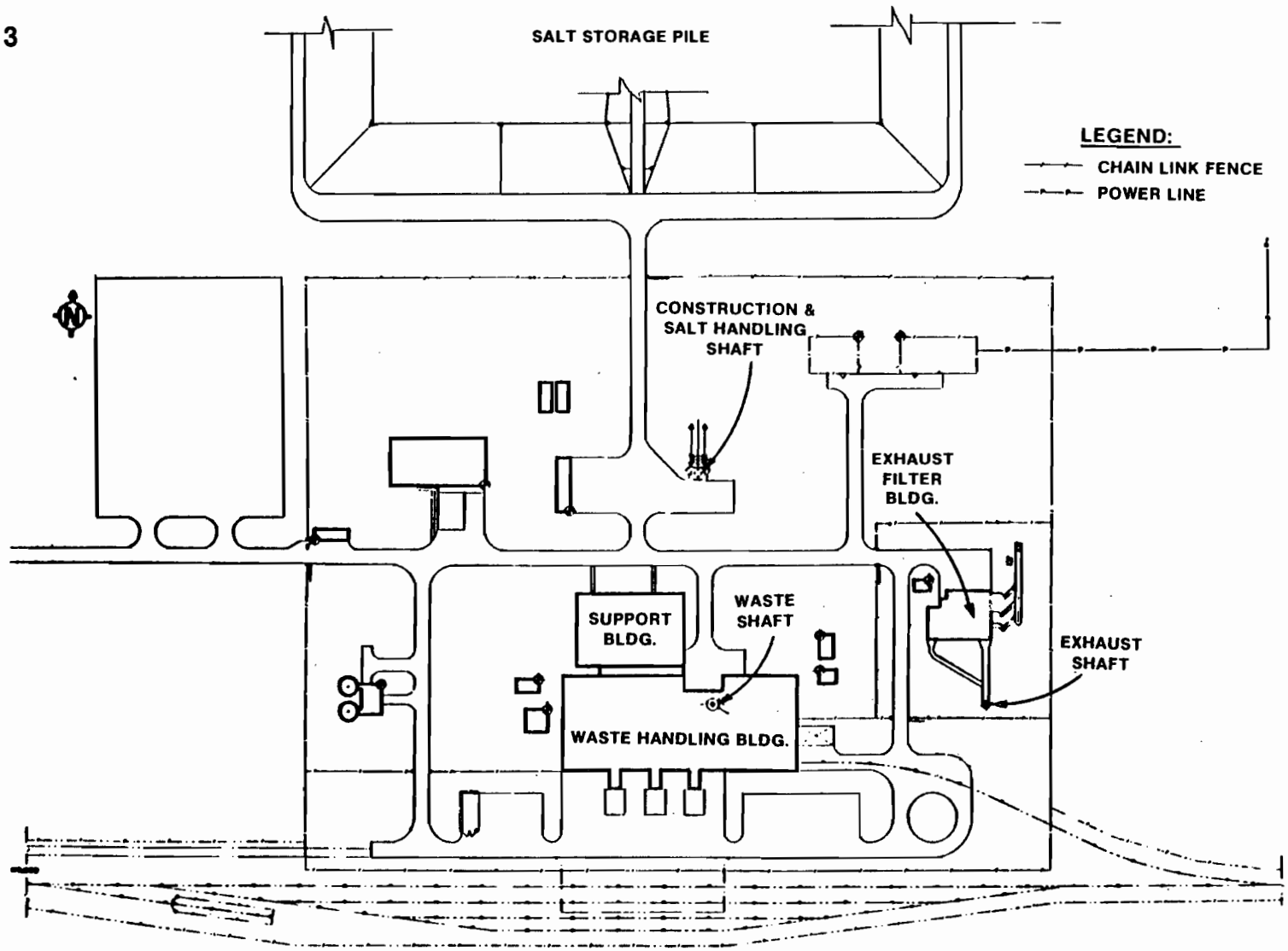
	SPDV	Full WIPP
TOTAL TONNAGE EXCAVATED	100,000 (5.5%)	1,800,000
TOTAL ESTIMATED COST	$41.5.0M (8.2%)	$504.0M
CONSTRUCTION TIME	2 Years	4-5 Years
SHAFTS	2 (10′ & 6′)	3 (10′, 19′ & 10′)
CONSTRUCTION COMPLETION	1983	1988

Slide 12

WIPP CONTROL ZONES



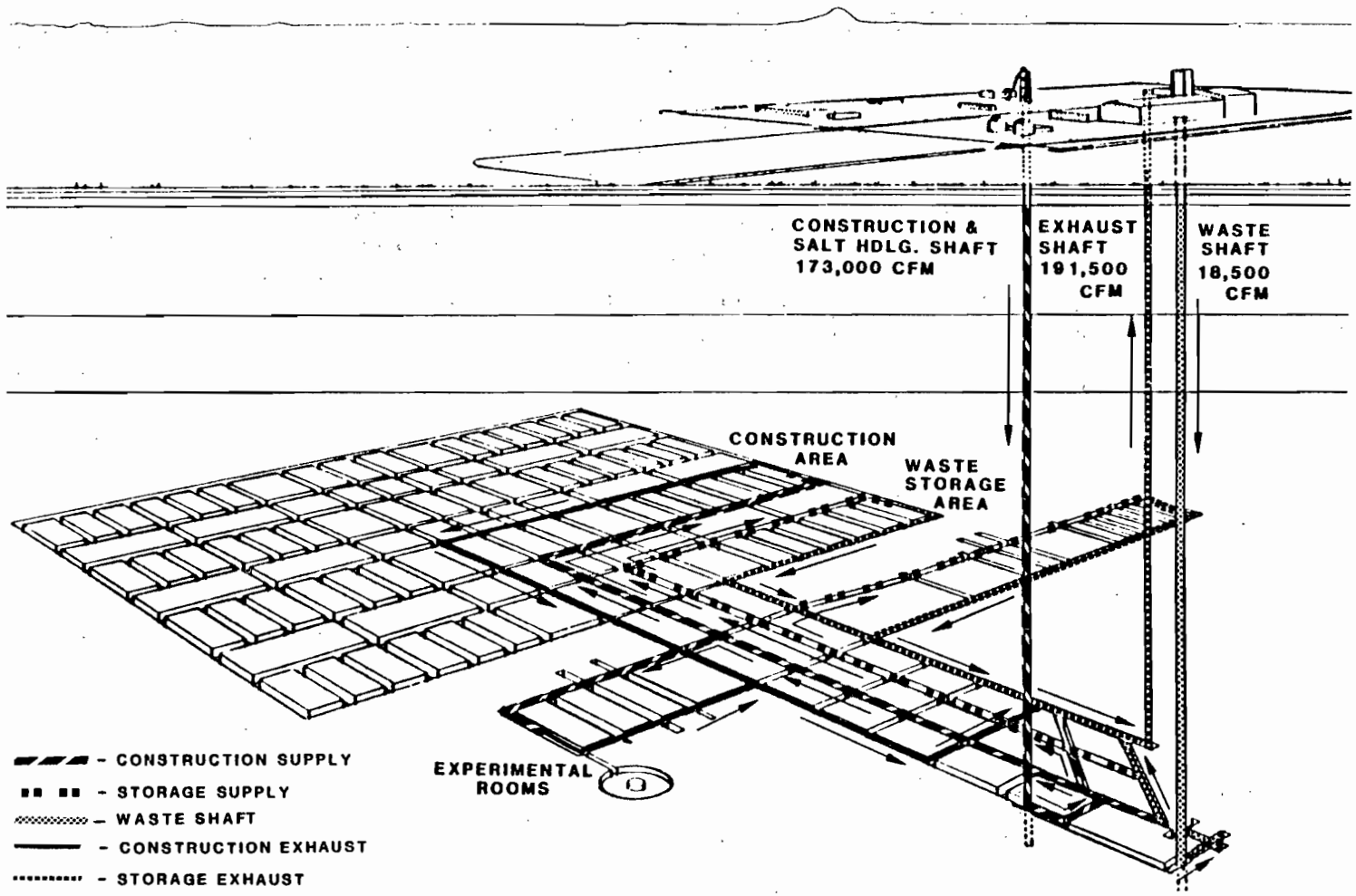
Slide 13



WIPP Site Facilities Plot Plan

Slide 14

U/G VENTILATION



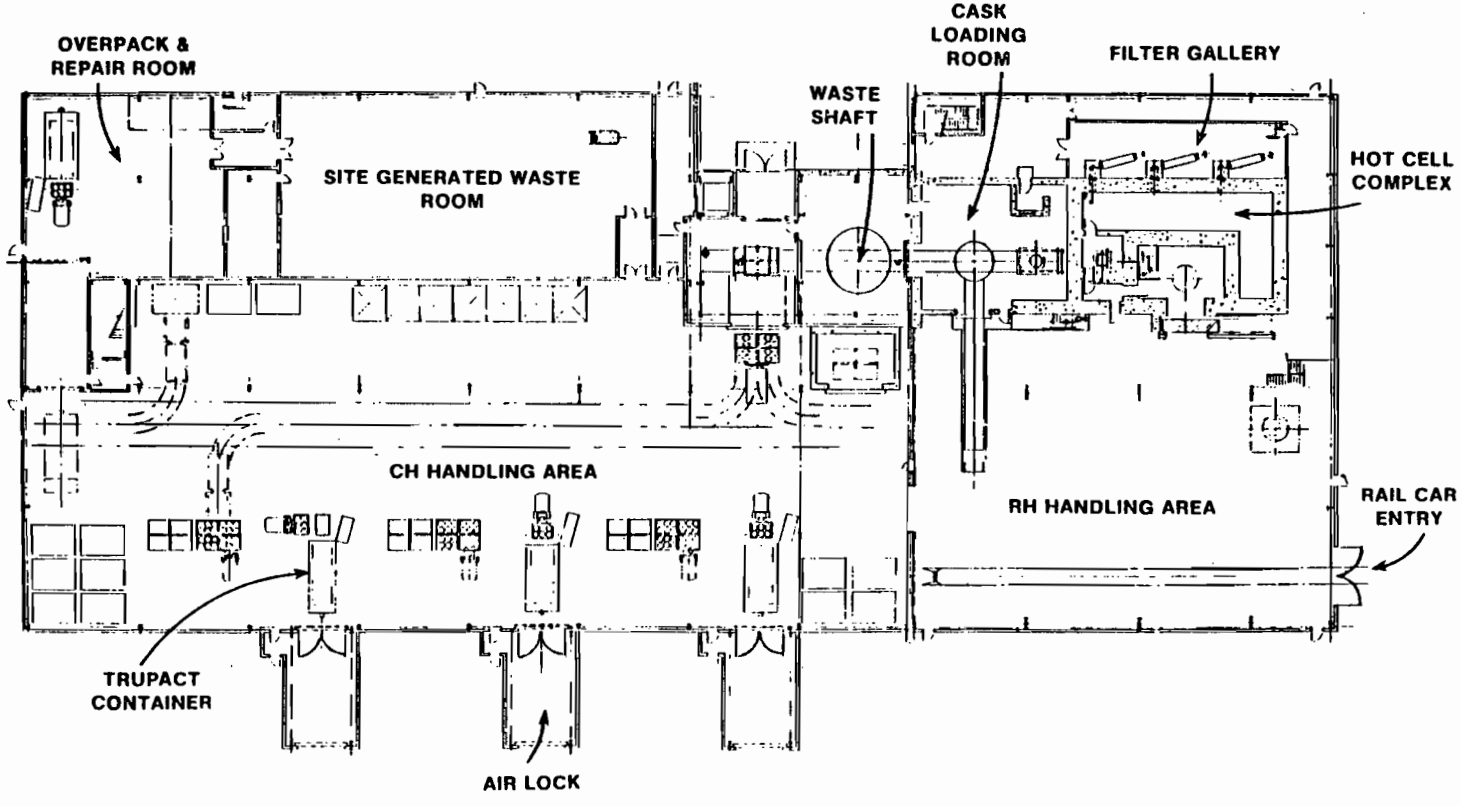
through the exhaust shaft. During storage operations, air flow is such that operating personnel are always upwind of the stored waste or the experimental areas where radioactive materials are undergoing tests.

One important aspect of WIPP is that, although surface facilities provide for continuous HEPA filtration of exhaust or ventilation air in areas where radioactive materials are handled, in the underground HEPA filtration is not done. Salt dust loading in the air makes it impractical for HEPA filters to be on line continuously. Therefore, the underground filtration system is one in which the exhaust is monitored and normally exhausted without passing through the HEPA filters. However, in the event of an increase in radiation levels, the exhaust would be diverted through HEPA filters, which are located in the exhaust filter building.

Slide 15 is a plan view of the waste handling building, which is a primary surface facility on the WIPP site. It includes three primary areas: to the bottom left is the contact-handled (CH) waste handling area, where CH waste is received and processed; the waste shaft where CH waste is taken using the hoist, which is located in the second area; and, to the right, the remote-handled (RH) waste handling area, which is used to handle both RH TRU and experimental and defense high-level waste. Material for the CH area, packaged in TRUPACTS, is received either by truck or rail. These TRUPACTS are offloaded; then the TRUPACT itself is brought into the building. The TRUPACT is then unloaded, and the waste is palletized, taken to the hoist, and taken underground for storage. The RH area also receives from either truck or rail. The casks from rail shipments are brought into the receiving area, offloaded from the rail car, and processed through a cask unloading station into the hot cell. The waste then goes to a cask loading room and the canister is loaded into a facility cask. The facility cask is then loaded on the waste shaft hoist and taken underground for ultimate storage or for the experiment, as the case may be. The waste hoist is limited to a 40-ton payload.

Three numbers now quantify CH waste at WIPP: 6.3 million ft^3 of total storage capacity at a rate of 500,000 ft^3/year with an anticipated storage within the first 5 years of 1.4 million ft^3 (Slide 16). For RH waste we talk in terms of 1000 canisters. Our design is such that we can handle much more than that, but we now anticipate receiving only 1000 canisters of RH waste. The experimental defense high-level waste is now projected at 40 equivalent canisters, which is a small number, compared to full operation of the facility. The schedule projects that waste will be received in FY 1989 and FY 1990; the retrievability decision, therefore, must be made in FY 1994 for CH TRU waste and in FY 1995 for RH TRU waste. One key point to be made is that WIPP does plan to retrieve all experimental and all defense high-level waste.

Slide 15



Waste Handling Bldg.

Slide 16

WIPP OPERATIONS

- WASTE QUANTITIES:

— CH	6.3×10^6 FT^3, TOTAL 0.5×10^6 FT^3/YR, PEAK 1.4×10^6 FT^3, INITIAL 5 YEARS
— RH	1,000 CANISTERS TOTAL
— EXP./DHLW	40 EQUIVALENT CANISTERS, TOTAL

- RECEIVE INITIAL WASTE:

— CH	3QFY89
— RH	FY90
— EXP./DHLW	3QFY89

- RETRIEVABILITY DECISION:

— CH	FY94
— RH	FY95
— EXP./DHLW	TO BE RETRIEVED

Slide 17 characterizes the plutonium-239 content, the heat generation, and the surface dose rate of the CH and RH waste.

The Rocky Flats slide (Slide 18) shows waste data from FY 1981 and presents the various content codes, on the bottom, and the quantity of waste. According to these data, in 1981 Rocky Flats generated about 1900 m^3 of waste. The three largest content codes accounted for about 75% of the waste, and the eight largest content codes accounted for essentially 95% of the waste. Slide 19 shows a typical plan for the receipt of CH waste at WIPP.

Waste certification is an issue that is important to the WIPP project. Certification (Slide 20) is based on the Waste Acceptance Criteria (WAC), a document that identifies about 19 areas that waste generators must address and that sets specific criteria for acceptance to WIPP. This document was originally generated by a steering committee represented by WIPP, DOE headquarters, and a number of the generating sites. A number of documents that support the WIPP WAC have been issued or will be issued soon. The criteria require each site to prepare specific certification quality assurance plans and detailed procedures and to submit those plans and procedures for review/approval by the WIPP Certification Committee. The DOE and the Certification Committee have audit authority to implement the procedures.

In Slide 21 and Slide 22, I have tried to show some of the key WAC for CH waste. An equivalent set of data is applicable to RH waste and the sets have few differences. It is important to recognize that the WIPP WAC address waste form characteristics, packaging, and handling. At the WIPP facility, no credit has been taken for performance assessment of packaging except for short-term handling and retrieval considerations.

I do not intend to discuss Slide 23 in detail other than to say it is a Rocky Flats slide showing an early assessment of Rocky Flats' ability to meet the WIPP WAC for newly generated waste. "Early" means the latter part of 1981. The slide shows the Rocky Flats waste content codes and some of the more important WAC. To put the slide into perspective, Rocky Flats believes that the boxes that are not shaded are capable of meeting the WAC. Some of the shaded boxes require further study to determine if the waste meets the WAC. For other shaded boxes, Rocky Flats has identified some further action that must be implemented. The boxed waste categories at the top of the figure are those that Rocky Flats considers will meet the WAC by early 1982. This table is a Rocky Flats assessment. We have not yet gone through Rocky Flats' implementation procedures to approve the certification process.

A milestone of our waste certification projections is that Rocky Flats will ship the first of the certified waste to INEL this year (Slide 24). All other sites will begin generating certifiable waste

Slide 17

WASTE CHARACTERISTICS

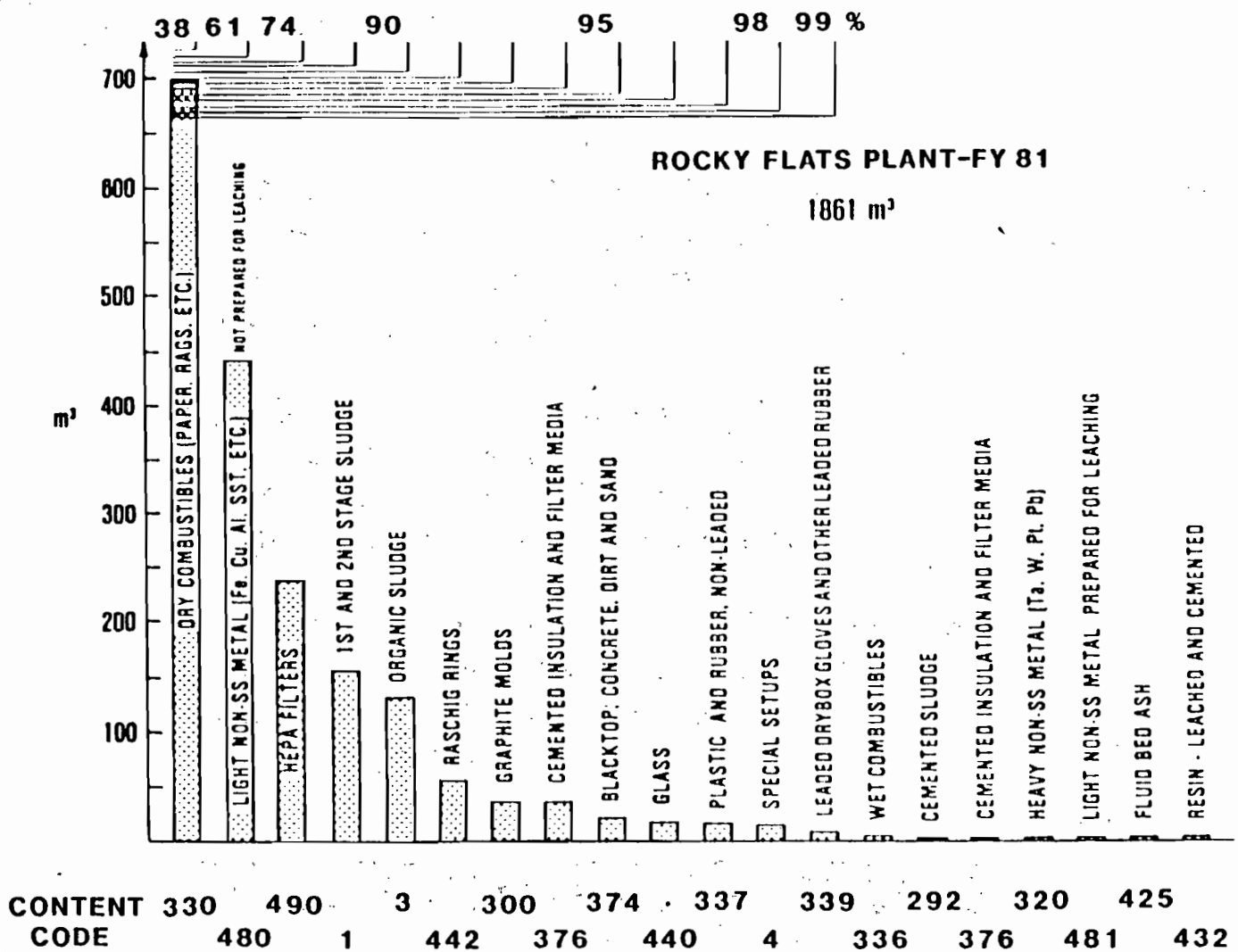
- CH TRU (210 l Drum):
  - Pu—≦200 gm MAX; 13 gm AVG.
  - HEAT—10 watts MAX; 0.04 watts AVG.
  - SDR—≦200 mrem/hr MAX; 2 mrem/hr AVG.

- RH TRU (2 ft. dia. x 10 ft. long canister):
  - Pu—125 gm MAX; 7 gm AVG.
  - HEAT—60 watts MAX; 4 watts AVG.
  - SDR—100 rem/hr MAX; 1.6 rem/hr AVG.

- EXPERIMENTAL/DHLW:
  - HEAT—1.5 kw MAX*, 200 watts AVG.
  - SDR—4.5×10^5 rem/hr MAX*, 2.5×10^4 rem/hr AVG.
  - SIZE—2 ft dia. x 10 ft long MAX, 1 ft dia. x 6 ft long canister

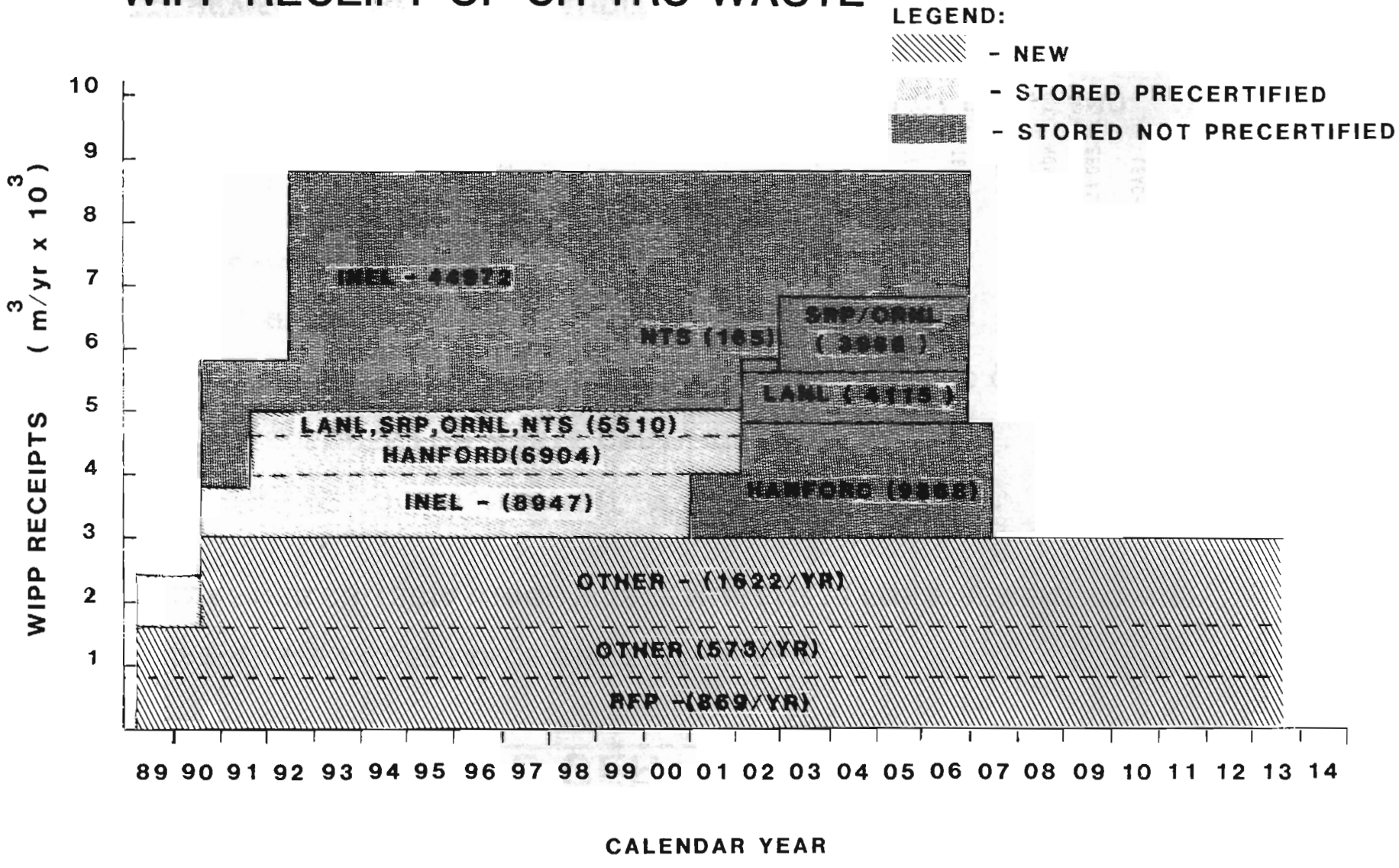
*Experimental Waste

Slide 18


38 61 74 90 95 98 99 %
ROCKY FLATS PLANT-FY 81
1861 m³
m³
700
600
500
400
300
200
100
DRY COMBUSTIBLES (PAPER, RAGS, ETC.)
NOT PREPARED FOR LEACHING
LIGHT NON-SS METAL (Fe, Cu, Al, SST, ETC.)
HEPA FILTERS
1ST AND 2ND STAGE SLUDGE
ORGANIC SLUDGE
RASCHIG RINGS
GRAPHITE MOLDS
CEMENTED INSULATION AND FILTER MEDIA
BLACKTOP, CONCRETE, DIRT AND SAND
GLASS
PLASTIC AND RUBBER, NON-LEADED
SPECIAL SETUPS
LEADED DRYBOX GLOVES AND OTHER LEADED RUBBER
WET COMBUSTIBLES
CEMENTED SLUDGE
CEMENTED INSULATION AND FILTER MEDIA
HEAVY NON-SS METAL (Ta, W, Pt, Pb)
LIGHT NON-SS METAL PREPARED FOR LEACHING
FLUID BED ASH
RESIN - LEACHED AND CEMENTED
CONTENT 330 490 3 300 374 337 339 292 320 425
CODE 480 1 442 376 440 4 336 376 481 432

Slide 19

WIPP RECEIPT OF CH TRU WASTE



Slide 20

WASTE CERTIFICATION

- WIPP WASTE ACCEPTANCE CRITERIA (WIPP WAC):
  - DEFINES CRITERIA WHICH WASTE MUST MEET FOR SHIPMENT TO WIPP
- SUPPORTING DOCUMENTATION:
  - QA MEASURES FOR WASTE CERTIFICATION
  - CERTIFICATION REQUIREMENTS, NEWLY GENERATED CH WASTE
  - CERTIFICATION REQUIREMENTS, STORED CH WASTE
  - CERTIFICATION REQUIREMENTS, RH WASTE
- IMPLEMENTATION:
  - PREPARATION OF SITE SPECIFIC CERTIFICATION/QA PLANS AND PROCEDURES
  - REVIEW, APPROVAL AND AUDIT BY WIPP CERTIFICATION COMMITTEE

Slide 21

WIPP TRU WASTE ACCEPTANCE CRITERIA

Contact Handled

GAS GENERATION	≤ 10 moles per cubic meter of storage room volume
COMBUSTIBLE MATERIAL	Acceptable in approved containers
IMMOBILIZATION	Particulates must be: ≤ 1 w/o, ≤ 10 micron dia. ≤ 15 w/o, ≤ 200 micron dia.
SLUDGES	Container must have corrosion protection
FREE LIQUIDS	NOT ACCEPTABLE
EXPLOSIVES COMPRESSED GASES	NOT ACCEPTABLE (Defined by 49 CFT 173 Subparts C & G)
PYROPHORIC MATERIALS	Must be made non-pyrophric— 1% by weight of radionuclide metals acceptable if dispersed in waste
TOXIC MATERIALS	(Poison A or B per 49 CFR 173) Only if TRU contaminated

Slide 22

WIPP TRU WASTE ACCEPTANCE CRITERIA

Contact Handled

CORROSIVE MATERIAL	Only if Neutralized or otherwise rendered non-corrosive
WASTE CONTAINERS	DOT Type A Design Life of 15 years after emplacement Non combustible
SURFACE CONTAMINATION	$\leq$ 50 picocuries/100cm^2 alpha $\leq$ 450 picocuries/100 cm^2 beta-gamma
FISSILE MATERIAL LIMIT	200 g. per 55 gal drum 100 g. per 30 gal drum 500 g. per DOT 6m container 350 g. per DOT 7A box 5 g. in any ft.^{3} for all others
COLOR CODING	For greater than10 mr/hr For greater than 0.1 watt/ft^3 For any special hazard/toxic material For combustibles over 25 volume %
DATA PACKAGE	Keyed to Package Identification No. Contains all appropriate Data Certification Statement that package meets criteria

Slide 23

	001	002	003	004	007	292	300	301	302	310	311	320	330	334	335	336	337	338	339	371	372	373	374	375	376	393	410	411	420	421	422	432	440	441	442	480	481	490
EXPLOSIVES/ COMPRESSED GASES (EXP)	001/EXP/1	002/EXP/1	003/EXP/1	004/EXP/1	007/EXP/1	292/EXP/1	300/EXP/1	301/EXP/1	302/EXP/1	310/EXP/1	311/EXP/1	320/EXP/1	330/EXP/1	334/EXP/1	335/EXP/1	336/EXP/1	337/EXP/1	338/EXP/1	339/EXP/1	371/EXP/1	372/EXP/1	373/EXP/1	374/EXP/1	375/EXP/1	376/EXP/1	393/EXP/1	410/EXP/1	411/EXP/1	420/EXP/1	421/EXP/1	422/EXP/1	432/EXP/1	440/EXP/1	441/EXP/1	442/EXP/1	480/EXP/1	481/EXP/1	490/EXP/1
FREE LIQUIDS (LIQ)	001/LIQ/1	002/LIQ/1	003/LIQ/2	004/LIQ/1	007/LIQ/1	292/LIQ/1	300/LIQ/1	301/LIQ/1	302/LIQ/1	310/LIQ/1	311/LIQ/1	320/LIQ/1	330/LIQ/1	334/LIQ/2	335/LIQ/1	336/LIQ/2	337/LIQ/1	338/LIQ/1	339/LIQ/1	371/LIQ/1	372/LIQ/1	373/LIQ/1	374/LIQ/1	375/LIQ/1	376/LIQ/1	393/LIQ/1	410/LIQ/1	411/LIQ/1	420/LIQ/1	421/LIQ/1	422/LIQ/1	432/LIQ/1	440/LIQ/1	441/LIQ/1	442/LIQ/1	480/LIQ/1	481/LIQ/1	490/LIQ/1
GAS GENERATION/ ORGANIC CONTENT (GAS)	001/GAS/5	002/GAS/5	003/GAS/4	004/GAS/5	007/GAS/1	292/GAS/1	300/GAS/1	301/GAS/1	302/GAS/1	310/GAS/1	311/GAS/1	320/GAS/1	330/GAS/5	334/GAS/1	335/GAS/1	336/GAS/5	337/GAS/1	338/GAS/1	339/GAS/5	371/GAS/1	372/GAS/1	373/GAS/1	374/GAS/1	375/GAS/1	376/GAS/1	393/GAS/1	410/GAS/5	411/GAS/1	420/GAS/1	421/GAS/1	422/GAS/1	432/GAS/1	440/GAS/5	441/GAS/5	442/GAS/5	480/GAS/5	481/GAS/5	490/GAS/1
IMMOBILIZATION/ PARTICULATES (IMM)	001/IMM/2	002/IMM/2	003/IMM/1	004/IMM/1	007/IMM/2	292/IMM/1	300/IMM/1	301/IMM/2	302/IMM/1	310/IMM/2	311/IMM/1	320/IMM/1	330/IMM/1	334/IMM/1	335/IMM/4	336/IMM/1	337/IMM/1	338/IMM/4	339/IMM/1	371/IMM/2	372/IMM/4	373/IMM/2	374/IMM/2	375/IMM/4	376/IMM/2	393/IMM/2	410/IMM/2	411/IMM/2	420/IMM/2	421/IMM/2	422/IMM/2	432/IMM/1	440/IMM/1	441/IMM/1	442/IMM/1	480/IMM/1	481/IMM/2	490/IMM/2
PYROPHORICS (PYR)	001/PYR/1	002/PYR/1	003/PYR/1	004/PYR/1	007/PYR/1	292/PYR/1	300/PYR/1	301/PYR/1	302/PYR/1	310/PYR/1	311/PYR/1	320/PYR/1	330/PYR/1	334/PYR/1	335/PYR/4	336/PYR/1	337/PYR/1	338/PYR/4	339/PYR/1	371/PYR/1	372/PYR/1	373/PYR/1	374/PYR/1	375/PYR/1	376/PYR/1	393/PYR/1	410/PYR/4	411/PYR/1	420/PYR/1	421/PYR/1	422/PYR/1	432/PYR/1	440/PYR/1	441/PYR/1	442/PYR/1	480/PYR/2	481/PYR/2	490/PYR/2
SLUDGES (SLU)	001/SLU/1	002/SLU/1	003/SLU/1	004/SLU/1	007/SLU/1	292/SLU/1	300/SLU/1	301/SLU/1	302/SLU/1	310/SLU/1	311/SLU/1	320/SLU/1	330/SLU/1	334/SLU/1	335/SLU/1	336/SLU/1	337/SLU/1	338/SLU/1	339/SLU/1	371/SLU/1	372/SLU/1	373/SLU/1	374/SLU/1	375/SLU/1	376/SLU/1	393/SLU/1	410/SLU/1	411/SLU/1	420/SLU/1	421/SLU/1	422/SLU/1	432/SLU/1	440/SLU/1	441/SLU/1	442/SLU/1	480/SLU/1	481/SLU/1	490/SLU/1
TOXIC/ CORROSIVE (TOX)	001/TOX/2	002/TOX/2	003/TOX/4	004/TOX/4	007/TOX/2	292/TOX/4	300/TOX/1	301/TOX/1	302/TOX/1	310/TOX/1	311/TOX/1	320/TOX/1	330/TOX/1	334/TOX/1	335/TOX/1	336/TOX/1	337/TOX/1	338/TOX/1	339/TOX/3	371/TOX/1	372/TOX/1	373/TOX/1	374/TOX/1	375/TOX/1	376/TOX/1	393/TOX/1	410/TOX/1	411/TOX/1	420/TOX/1	421/TOX/1	422/TOX/1	432/TOX/1	440/TOX/1	441/TOX/1	442/TOX/1	480/TOX/1	481/TOX/1	490/TOX/1

1 MEETS REQUIREMENTS/NO ACTION REQUIRED.
MEETS REQUIREMENTS UNDER ASSUMPTIONS NOTED/NO ACTION REQUIRED.
DOES NOT MEET REQUIREMENTS/ACTION REQUIRED.
COMPLIANCE WITH REQUIREMENTS UNKNOWN/FURTHER STUDY REQUIRED.
MEETS REQUIREMENTS/HOWEVER, INTERNAL ACTION PURSUED.
CERTIFIED WASTE FORM
CERTIFIABLE WASTE FORM

Slide 24

WASTE CERTIFICATION PROJECTIONS

- RFP SHIPS INITIAL CERTIFIED WASTE TO INEL—4QFY82
- INEL DEVELOPING PROGRAM TO CERTIFY STORED WASTE
  - — SWEPP OPERATIONAL FY85
  - — PREPP OPERATIONAL FY86
- OTHER SITES START CERTIFYING WASTE—FY 83
- ALL NEWLY GENERATED WASTE CERTIFIED—FY 84

next year; that generation will be completed by the following year. Idaho will start to do the same thing when the SWEPP and PREPP are operational in 1985 and 1986.

On Slide 25 I have tried to indicate some of the unique characteristics of WIPP. Once again, I think that it is important to recognize that WIPP is exempted from regulation by NRC. Also, no long-term credit has been taken for packaging. It is also important to recognize that WIPP does receive the waste in a prepackaged form, specifically in type A containers, primarily for onsite handling and retrieval, if necessary. The impact of the change in the TRU nanocuries per gram is not projected to be significant, but a change probably would reduce the amount of waste that will be available for use in WIPP. Finally, it is important to recognize that WIPP is an R&D facility.

I would like to switch now to some photographs that indicate the progress at the site. Clearing of the site was started on April 20, 1981. Slide 26, taken in early June, shows an augering rig located over the SPDV exploratory hole. This auger went down to 100 ft, allowing a casing to be put in for drilling. The hole was 12 ft in diameter; its finished size will be 10 ft in diameter. Slide 27, taken in mid-June, shows the drill rig in place over the exploratory hole. The drilling started on July 4, 1981, and was completed on October 24, 1981. The drilling ran 112 days, 3 shifts per day, which corresponds to a rate of about 20 ft/day. At the end of about 2200 ft of drilling, the shaft was out of plumb by a little over 2 ft.

If you want to see what a 12-ft drill bit looks like, Slide 28 has a view of one. Slide 29 shows the liner, which was installed inside the casing that had been installed in the exploratory shaft. It is 10 ft in diameter, and I think you can see the pick-up truck inside. The shaft went down to a depth of 850 ft. The 20-ft long sections were welded on the surface to 40-ft long and then placed in the hole. Slide 30 shows the placement of the last section of the liner, which was a little bit longer. The liner was cemented in place on December 4, 1981. For the 6-ft diameter ventilation shaft, drilling started December 24 and was completed February 21; it covered 59 days, and the drilling rate was 37 ft/day.

Slide 31 shows the hoist, which is now installed at the exploratory shaft. The hoist will be used for salt removal during the balance of the SPDV construction and for the shaft outfitting, which is now under way. Slide 32 shows the Westinghouse drive motor originally built for the hoist in 1926.

Slide 33 was taken 2150 ft underground and shows people developing the shaft station at the bottom of the exploratory shaft. Slide 34 shows the drift that runs from the exploratory shaft to the ventilation shaft. The drift runs for about 400 ft and is rough in its present configuration. Breakthrough to the exploratory shaft was achieved on June 13, 1982. Finally, Slide 35 shows a more recent aerial view of

Slide 25

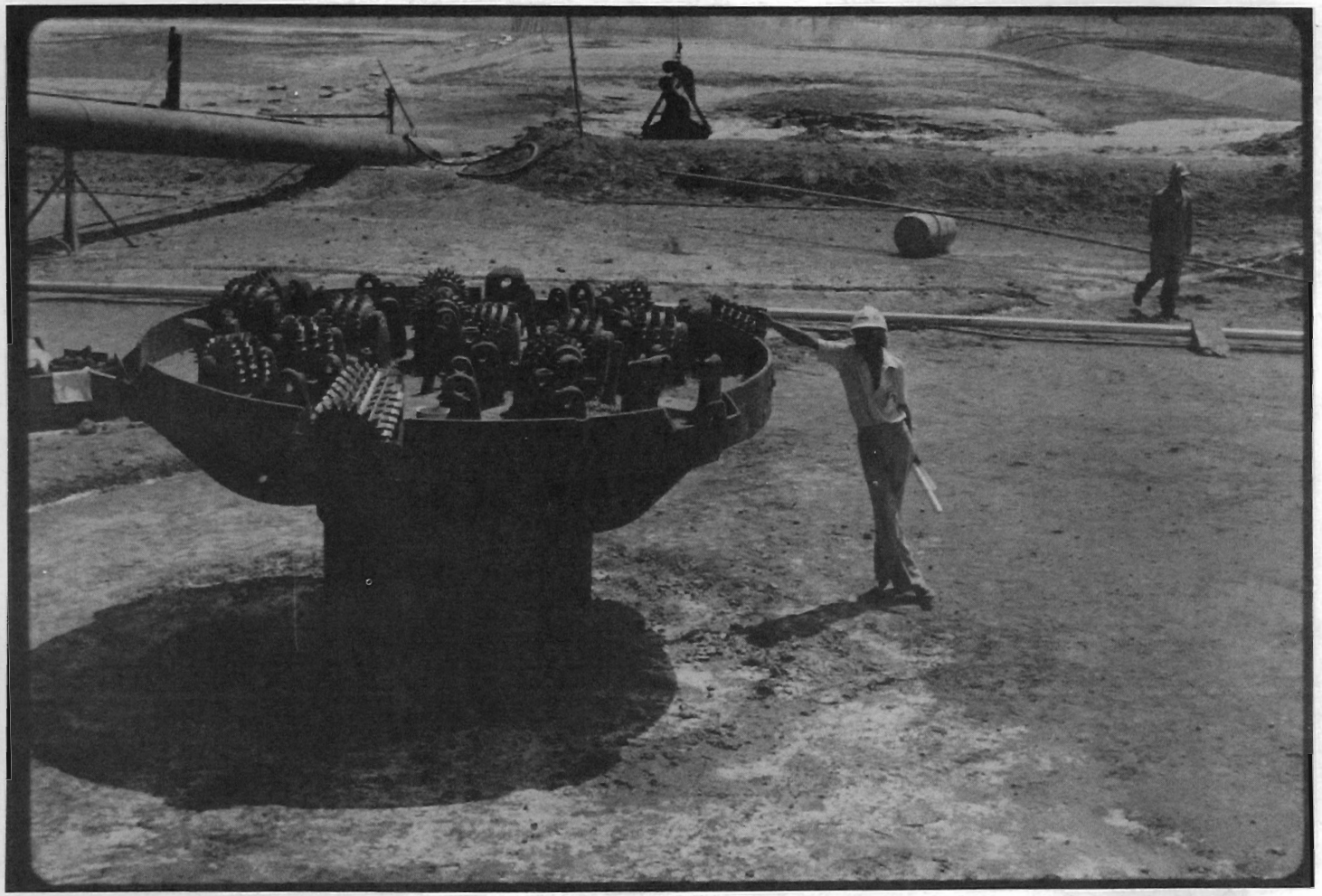
UNIQUE CHARACTERISTICS OF THE WIPP DESIGN

- WIPP EXEMPTED FROM REGULATION BY NRC
- ALL WASTE IS RECEIVED PACKAGED
- NO CREDIT TAKEN FOR LONG TERM PACKAGE PERFORMANCE
- TYPE A PACKAGE REQUIRED ONLY FOR ON-SITE HANDLING-EMPLACEMENT AND RETRIEVAL, IF NECESSARY
- A CONSCIOUS DECISION WAS MADE TO OPERATE WIPP CLEAN
- A CHANGE FROM 10 NCi/GM WOULD IMPACT AVAILABLE QUANTITY OF TRU WASTE ONLY
- SURFACE TRU WASTE HANDLING FACILITIES INCORPORATE HEPA FILTERS ON A FULL TIME BASIS
- DUE TO SALT DUST ENVIRONMENT EXHAUST AIR FROM U/G STORAGE AREAS IS HEPA FILTERED IF STORAGE EXHAUST EXCEEDS 4 MPC HOURS —ALPHA AND BETA
- DESIGN PROVIDES FOR WASTE STORAGE AND CONTINUING U/G CONSTRUCTION
- U/G VENTILATION PRECLUDES PERSONNEL FROM BEING DOWNSTREAM OF STORED WASTE
- WIPP IS A RESEARCH AND DEVELOPMENT FACILITY

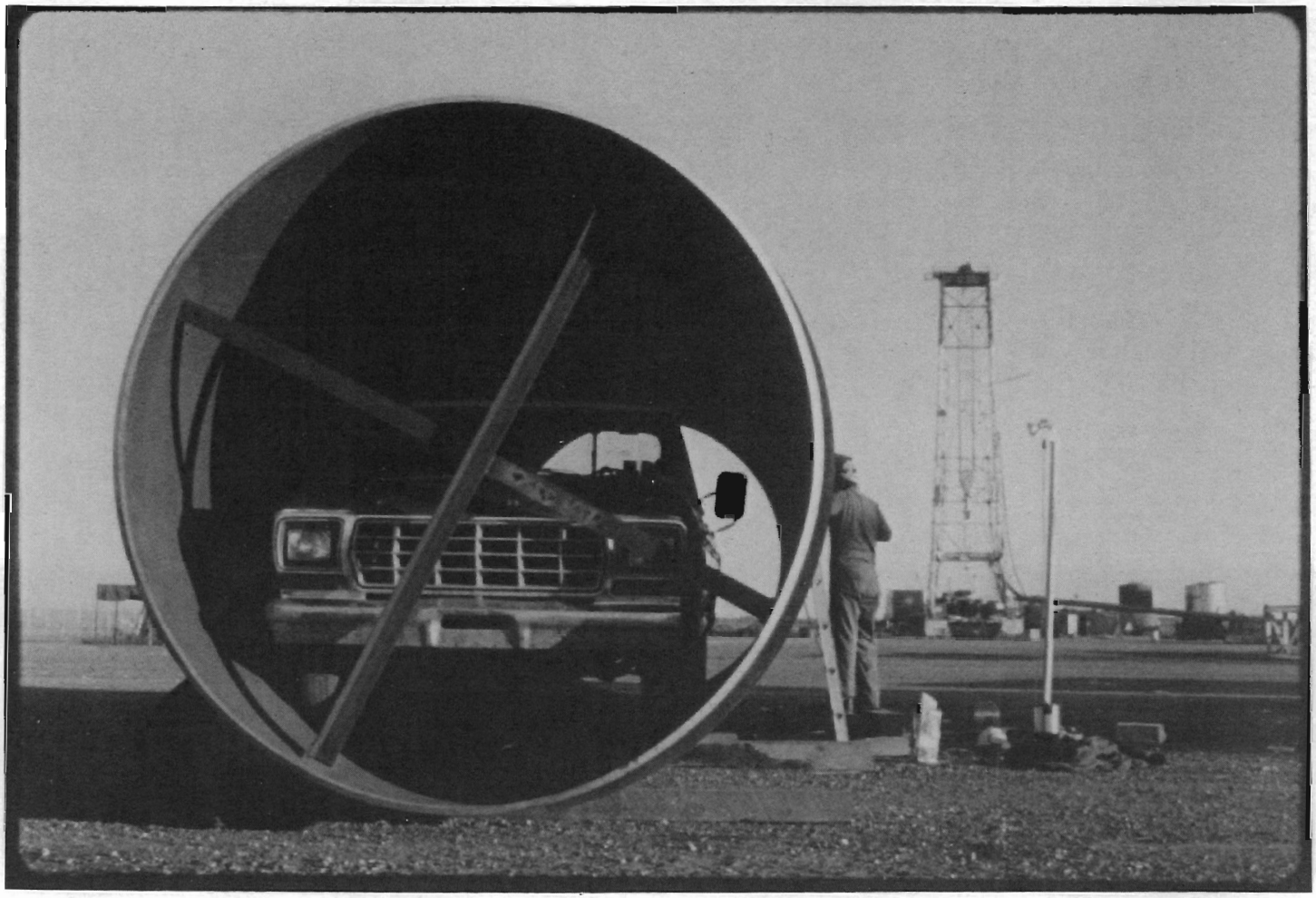
Slide 26

Slide 27

Slide 28

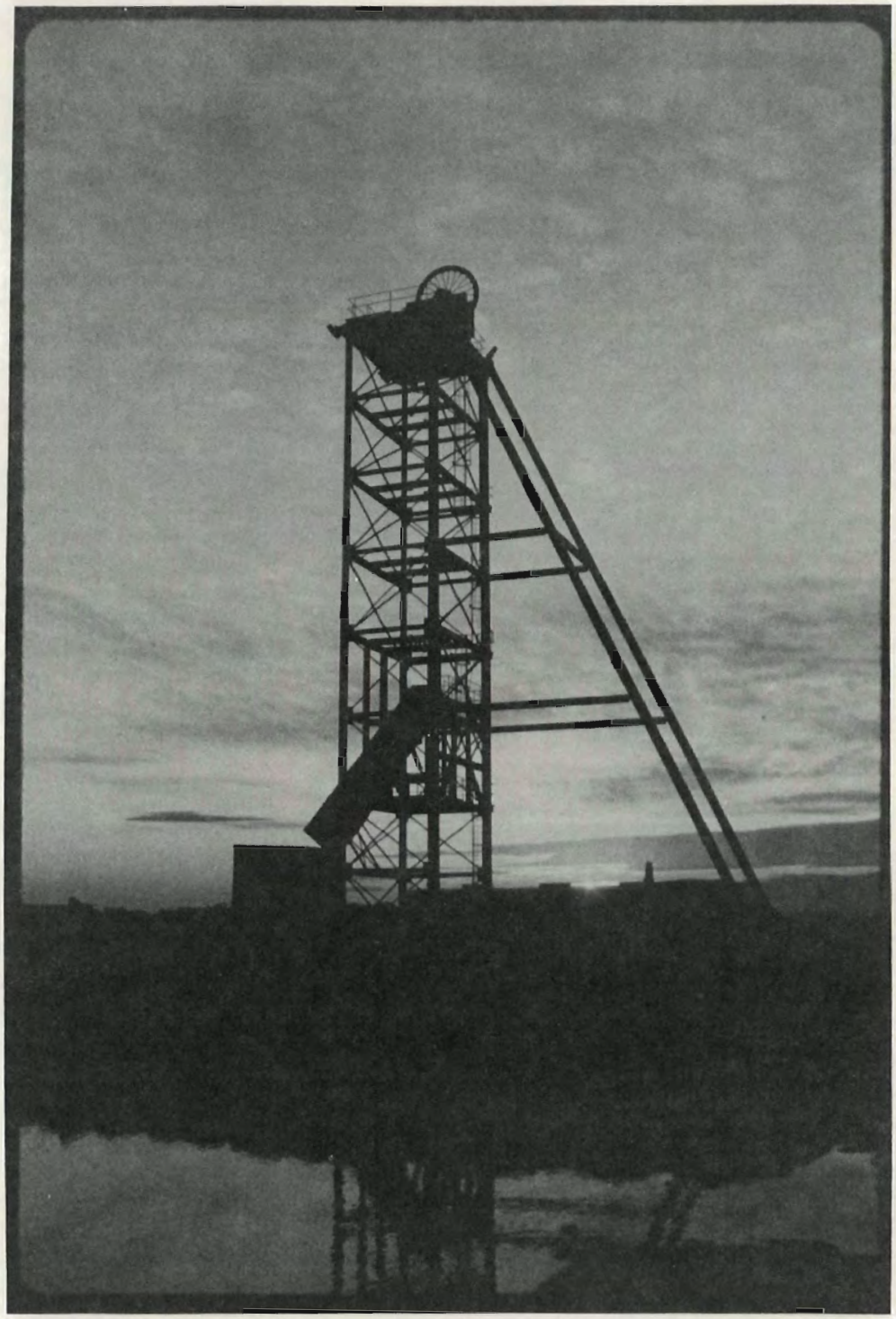


Slide 29

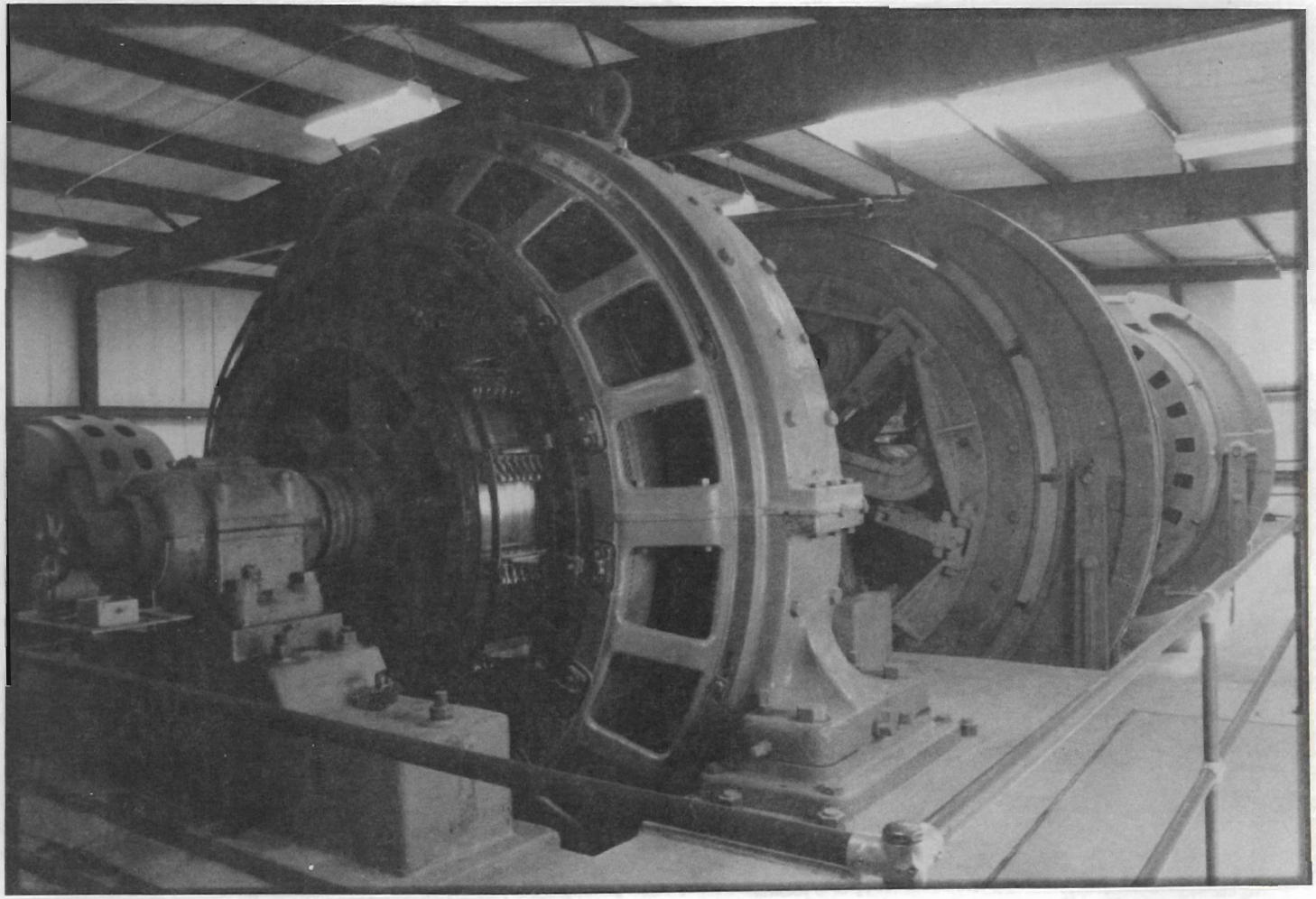


Slide 30

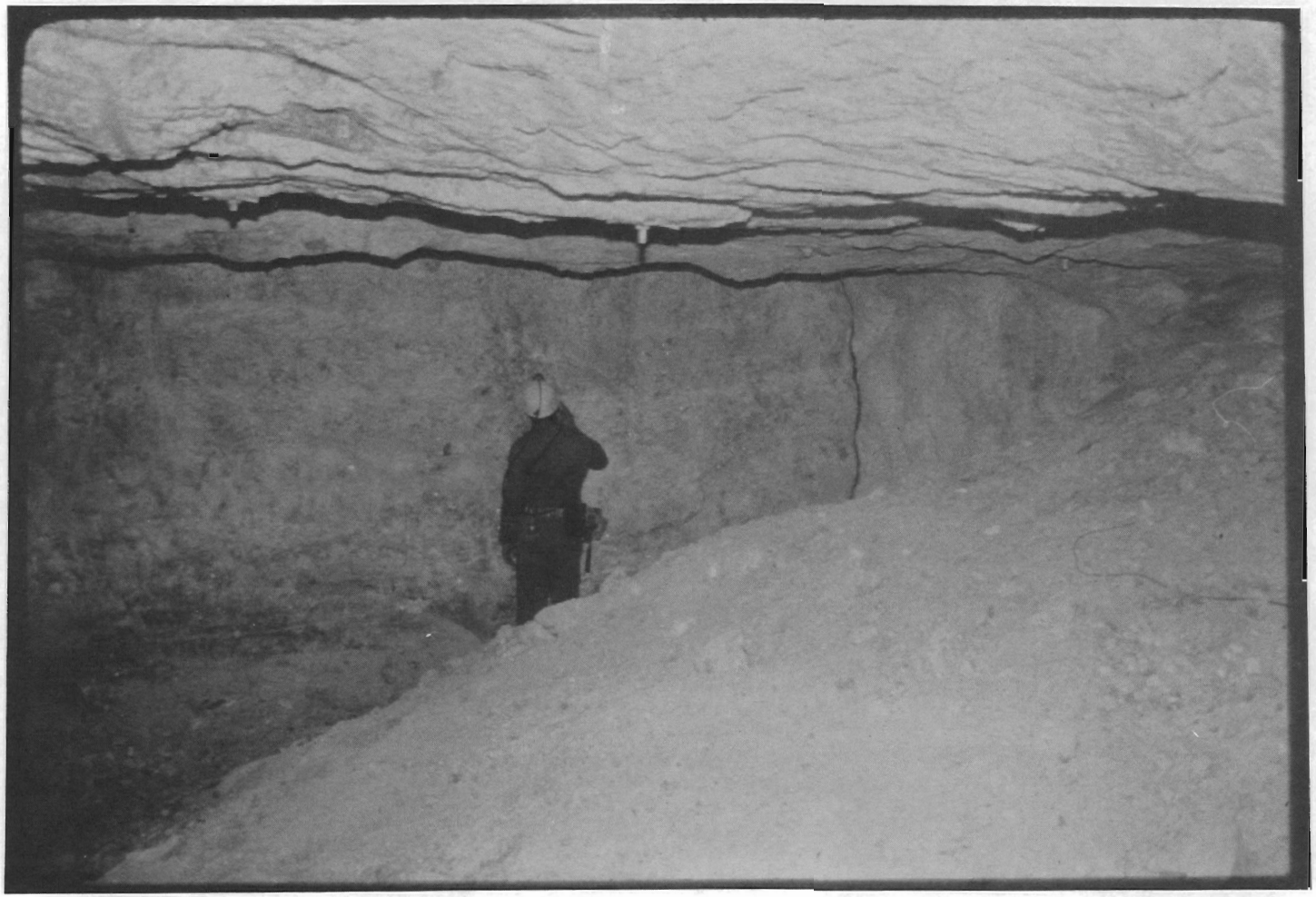
Slide 31



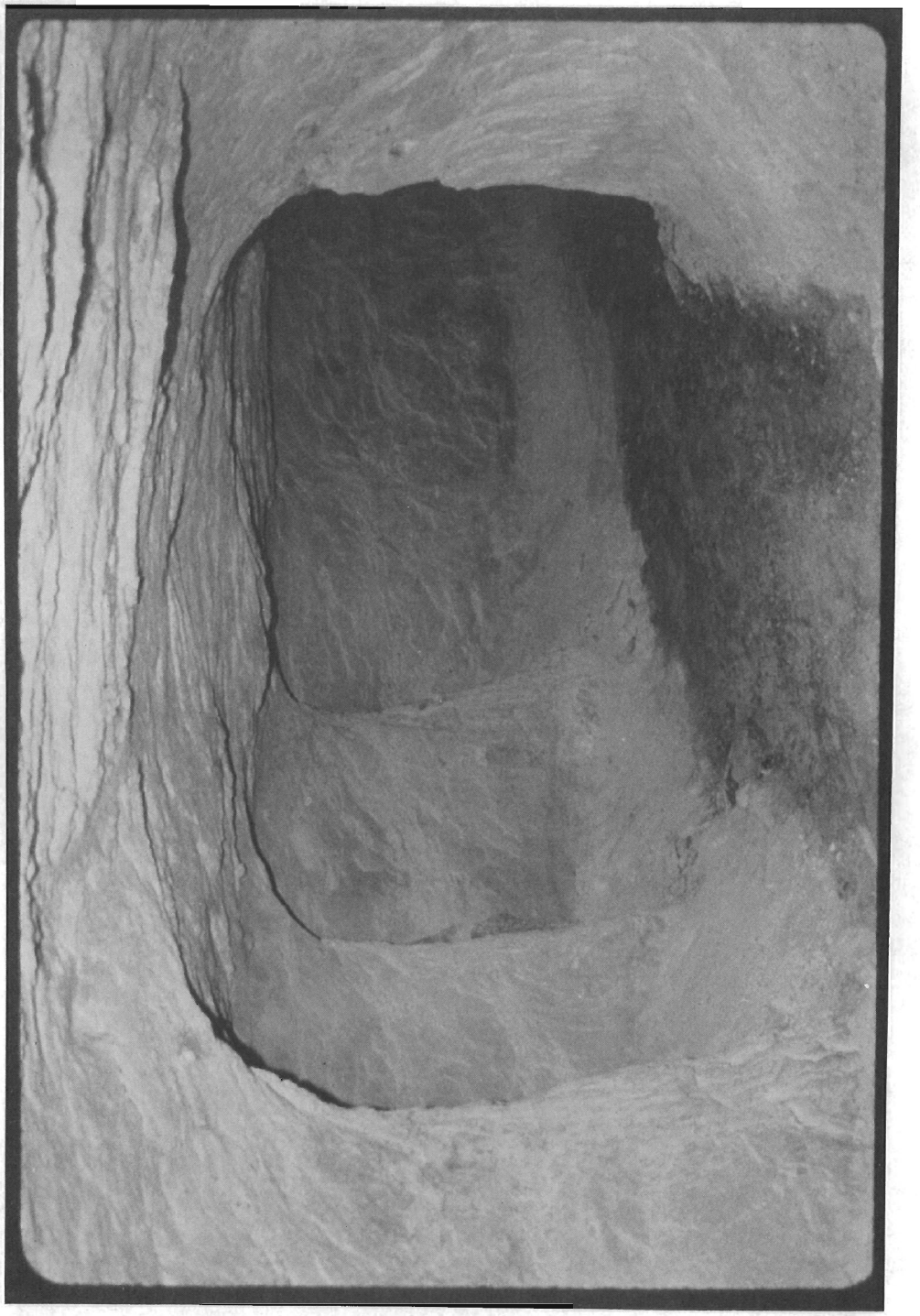
Slide 32



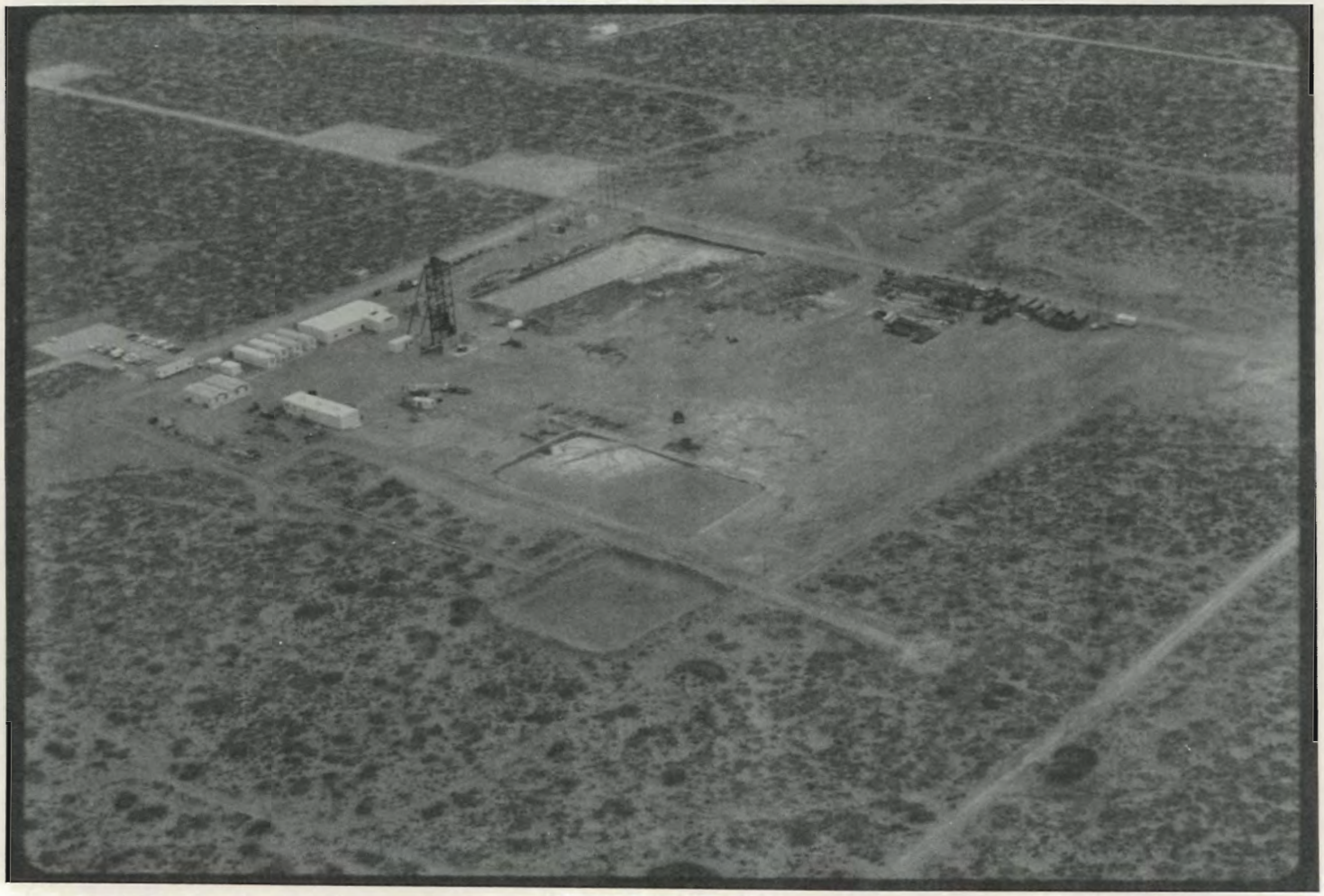
Slide 33



Slide 34



Slide 35



the site. As you will notice, the drill rigs are gone. We are in the process here of outfitting the site.

Slide 36 summarizes our current project status. We are more than halfway through the SPDV portion of the program. The dates shown here are the current official dates. We are hoping to advance the validation date, which is September 1983, by about 3 months to correspond to the start of full WIPP construction. We also hope to advance the date for receiving waste from April 1989 to about October 1988.

In conclusion, Slide 37 shows what we believe WIPP to be.

Question: Could you give us more information on the location, the extent, and the significance of the brine that has recently been identified?

Sadler: One thing Ed didn't mention when I started is that I'm a marine engineer by training. People have accused me of coming to the site when I heard there was brine down there, but that is not really the case. Brine was originally encountered a little more than 1 mile from the center of the site in the deepening of the WIPP-12 bore hole, and that occurred about 2 years ago. We have since drilled another bore hole called DOE-1, which is located about 1 mile south of the center of the site. We went to a depth of 4000 ft into the Castile formation below the Salado formation and into the area where you would expect brine to be found. At the location where it should be, we did not find any brine at all. This was a follow-up to finding brine at WIPP-12. I think people will say we did not fully expect to find brine at WIPP-12, but WIPP-12 was drilled because the potential for brine existed. There was a similar potential at DOE-1, but no brine was found there.

Tom Chikalla, Battelle-Pacific Northwest Laboratories: Could you comment on the nature of the experimental program involving the emplacement of the defense high-level waste canisters?

Sadler: A number of elements are involved. For defense waste, you have to look at the impact of temperature on the response of the geology. A number of tests (initially nonradioactive) look for thermal structural interactions in situ in salt. These tests will be followed up by actual demonstrations using the defense high-level waste, examining handling operation, brine migration, impacts, materials, chemistry, and those kinds of things. Some limited tests are planned in which there will be some defective canisters. Earlier, waste experiments were considered where bare waste would be put in WIPP. That is no longer the case. The defective canisters will be used to see what the close-in impacts are.

Joe Lieberman, Nuclear Safety Associates: I have two questions about the question that was asked about the brine. First, has any

Slide 36

WIPP PROJECT CHARTER MILESTONES

Description	Original Date	Status
BEGIN SITE PREPARATION FOR SPDV	4/81	Complete
BEGIN DRILLING 12' SHAFT	6/81	Complete
COMPLETE DRILLING 12' SHAFT	11/81	Complete
COMPLETE SPDV UNDERGROUND DEVELOPMENT	9/83	
BEGIN FACILITY SITE DEVELOPMENT	2/83	
BEGIN FACILITY CONSTRUCTION (Third Shaft)	9/83	
COMPLETE TITLE II DESIGN	2/84	
COMPLETE FACILITY CONSTRUCTION	6/88	
RECEIVE FIRST WASTE	4/89	

Slide 37

"The WIPP is the cornerstone of all terminal waste storage research in the United States, since there is no comparable project underway in the commercial sector".

...Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1983

reorientation of the underground facility been precipitated by finding the brine?

Sadler: Not at this point. The brine is under active study, and a final conclusion has not yet been reached.

Lieberman: Second, all through your talk, you used the word storage instead of disposal. Is there any particular reason for that?

Sadler: Yes. I think we are a storage facility until we decide that we will no longer retrieve TRU waste. Then, we will become a repository. We have been allowed to use the term repository only in this manner; we are particularly careful to avoid the use of repository for the short term. (That relates to TRUs.)

Denis Thackrah, Nuclear Installation Inspectorate, England: Could you elaborate on the decision to exempt this site from regulation by the NRC? I would have thought one of your problems would be public acceptance of the project. Wouldn't the public be more likely to accept the project if it is being regulated by the NRC?

Sadler: Let me answer this briefly then let someone from DOE provide a broader answer. From the WIPP point of view, the public law specifically exempts us from NRC; my understanding is that this exception is basically for national security--the defense activities of the United States shall not be subject to the purview of NRC. Someone else may expand on that if necessary.

Roger Dintaman, DOE, WIPP Project Office: That is essentially the right answer. Our authorization committee, the Armed Services Committee, did not want a licensed facility. That is why the Authorization Act is specific.

GREATER CONFINEMENT DISPOSAL METHODS AND CONCEPTS

Paul Dickman, Reynolds Electrical and Engineering Co., Inc.

I'm Paul Dickman from the Nevada Test Site, and contrary to popular belief, 10 nCi/g is our background level.

When Keith Gilbert called me about 2 weeks ago and asked me to give this paper on greater confinement, I, like many of you, foolishly volunteered. I asked him, "What do you want me to talk about?" He read a list starting with greater confinement techniques including deeper burial, engineered barriers, trench grouting, hydrofracture, improved containers, waste forms, etc. "We want to have costs for each alternative as well as appropriate isotope concentration limits, dose risks, and cost-benefit analyses. And you have an hour to talk." Well, I won't exactly tell you what I said to him in response, but I intimated that Rocky Mountain High was supposedly a euphemism and that he was a little bit mistaken.

Today, I am going to talk about confinement, greater confinement concepts, and, particularly cost estimates for greater confinement. Now, when we talk about confinement, we are talking about a system (Slide 1). The purpose of this system is to reduce the rate at which waste can migrate into a biopathway. Zero confinement is basically just introducing the materials directly into the biopathway, and 100% confinement is isolation. For example, these are confinement factors. The waste chemistry is one factor. (That is, the KD's, solubility, waste form, leachability, etc.) Waste containers, disposal methods (shallow-land burial or geological repository), and of course disposal location all contribute to reducing the amount of material that can migrate, or the potential for its migration, and therefore contribute to confining it.

Slide 2 is just a hypothetical confinement chart in which you have the location providing 50% of the confinement, the method providing 15%, the container and form adding a few more percentages, the total of which is 90%. The question that always comes up is, "When is good good enough?" When is 90% as good as 100% or isolation, or when is 30% as good as 90%? And that is really where the purpose of cost-benefit studies come in. What you are asking is, "Does the potential dose reduction, by increasing confinement, justify the cost of the greater confinement methods?"

What I'm going to talk about are the greater confinement costs. My cost estimates are based on the Nuclear Regulatory Commission's (NRC's) 10 CFR 61 draft environmental impact statement's (DEIS's) economic analyses. The costs are broken out by various phases of operation of a burial facility. In this case, the capital costs are the siting design and the construction. Then you have operational costs, including receipt and disposal of wastes and actual

Slide 1

CONFINEMENT FACTORS

WASTE CHEMISTRY X

WASTE FORM X

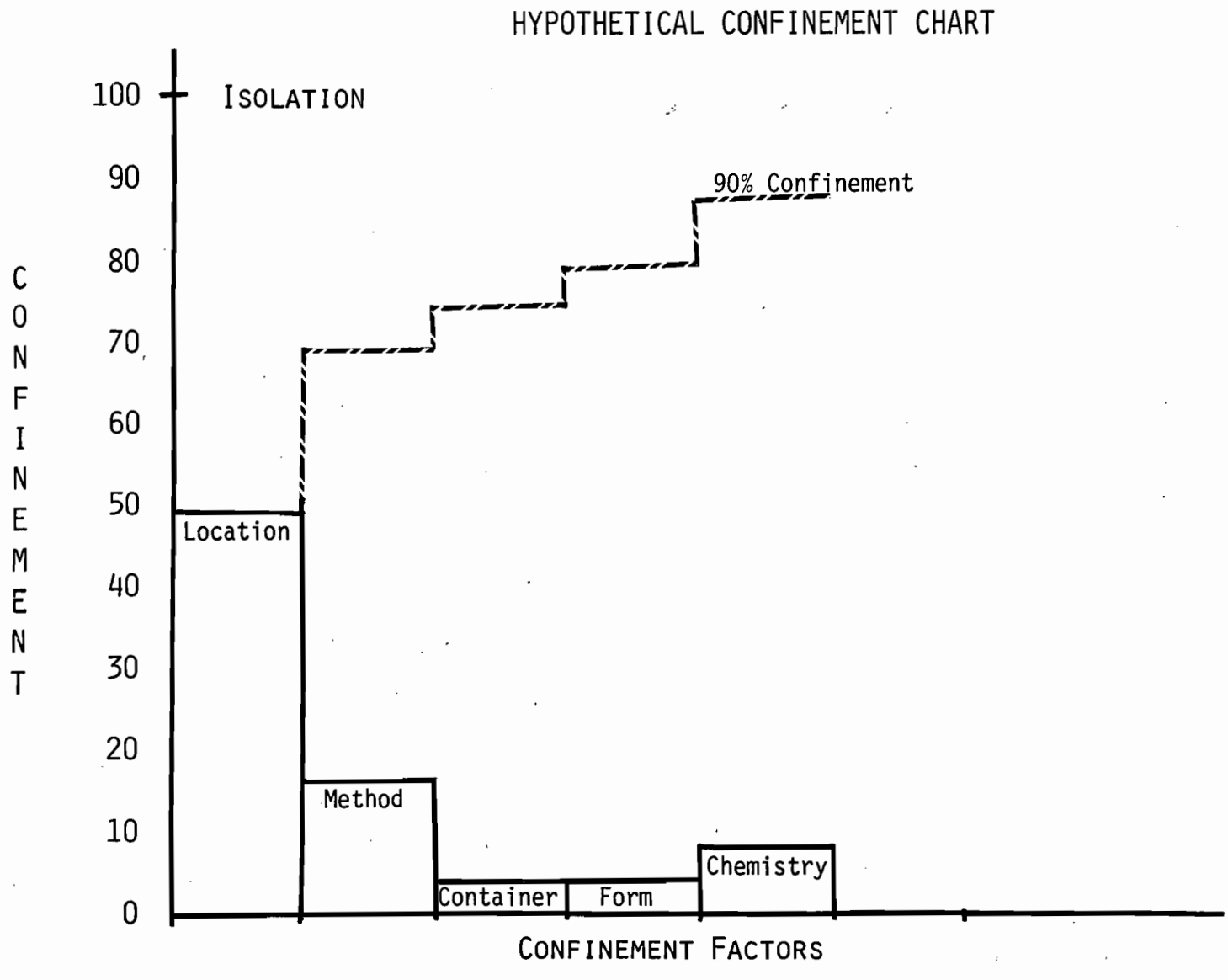
WASTE CONTAINER X

DISPOSAL METHOD X

DISPOSAL LOCATION =

C O N F I N E M E N T

Slide 2


HYPOTHETICAL CONFINEMENT CHART
ISOLATION
90% Confinement
CONFINEMENT
100
90
80
70
60
50
40
30
20
10
0
Location
Method
Container
Form
Chemistry
CONFINEMENT FACTORS

construction of the disposal facility, or trenches. You also have closure and institutional control costs.

The assumptions are that you have a 20-year facility handling about 50,000 m^3/year and disposing of 1,000,000 m^3 over the lifetime of the facility (Slide 3). All costs are based on 1980 dollars. I consider many of the estimate factors used by NRC to be fairly low. For example, they use $21,000/year as the annual salary for a heavy equipment operator. At the Nevada Test Site we pay $18/h for heavy equipment operators, and our iron workers make $21/h. That is at least a factor of 2 or 3 difference. I'm not taking applications. That is just one area, but I used their values to be consistent throughout all the analyses.

The important thing is to look at the incremental cost over the base-case shallow-land burial (Slide 4). This slide shows that NRC estimated their capital cost to $77 million and their operating cost to be about $107 million over the lifetime of the facility. The important thing to observe when you talk about greater confinement is the reduction in costs for care and maintenance that you have over a long period of time. Your institutional control costs go down substantially; that is one of the purposes behind greater confinement--to improve your shallow-land burial situation.

The overall cost per cubic foot for shallow-land burial is about $6.31. This is NRC's reference shallow-land burial case presented in the DEIS. I don't know how those estimates have changed between now and the final environmental impact statement. The first (GCD) alternative is the Deep Trench I (Slide 5). This alternative has basically the same number of trenches as shallow-land burial, except that we have a 10-m cap cover. Capital costs are about the same. Deep Trench I costs about $500,000 more than shallow-land burial. Most of the additional cost is for land acquisition. Your operating costs are about 17% more, and your closure costs are 34% less because you have less work to do. You don't have to stabilize trenches or bring in as much fill material. The institutional control costs are also 51% less. What you end up with is what NRC calls their moderate or intermediate closure case. Therefore, there is less than a 1% cost difference for this particular GCD alternative design and the shallow-land burial case. By the way, $6.30/$ft^3$ for low-level waste for a shallow-land burial facility is, I think, fairly low. I think it is at least double that figure in most locations. In fact, at the Nevada Test Site, we think our average is about $4 to $5/$ft^3$ and we are one of the cheapest, if not the cheapest, facilities within the DOE system.

Slide 6 shows the figures for Deep Trench II. Deep Trench II uses a 22-m cap cover. The first deep trench concept would be one where you would have a limiting case because of groundwater like that you would find in the humid parts of the country. Deep Trench II is what you would find more in the western parts of the country where you could

Slide 3

COST ESTIMATE FACTORS

- CAPITAL COSTS - SITING, DESIGN, AND INITIAL CONSTRUCTION
- OPERATIONAL COSTS - RECEIPT AND DISPOSAL OF WASTE AND CONSTRUCTION OF DISPOSAL TRENCHES/CELLS
- CLOSURE COSTS - DECOMMISSIONING AND STABILIZATION
- INSTITUTIONAL CONTROL COST - LONG TERM CARE AND MONITORING

Slide 4

SHALLOW LAND BURIAL

FIFTY EIGHT TRENCHES (180 X 30 X 8 M) WITH 1 M CAP COVER

	($ MILLIONS)
• CAPITAL COSTS	$ 77.3
• OPERATING COSTS	107.5
• CLOSURE COSTS	5.9
• INSTITUTIONAL CONTROL COSTS	34.6
TOTAL	$ 225.3

DISPOSAL COST - $225.3/M^3 OR $6.31 FT^3

Slide 5

DEEP TRENCH WITH THICK COVER - I

FIFTY EIGHT TRENCHES (180 X 30 X 18 M) WITH 10 M CAP COVER

	($ MILLIONS)
• CAPITAL COSTS	$ 77.8
• OPERATING COSTS	129.4
• CLOSURE COSTS	2.0
• INSTITUTIONAL CONTROL COSTS	17.7
TOTAL	$ 226.9

DISPOSAL COSTS - $226.9/M^3 OR $6.36 FT^3

Slide 6

DEEP TRENCH WITH THICK COVER - II

FIFTY EIGHT TRENCHES (180 X 30 X 30 M) WITH 22 M CAP COVER

	($ MILLIONS)
• CAPITAL COSTS	$ 77.8
• OPERATING COSTS	150.5
• CLOSURE COSTS	1.0
• INSTITUTIONAL CONTROL COSTS	8.5
TOTAL	$ 237.8

DISPOSAL COSTS - $237.8/M^3 OR $6.66 FT^3

dig deeper. In this case, your operating expenses go up 40%, and your overall costs go up only by about 5 or 6%. In this case, because of the deeper cap cover, your institutional control costs are based on what the NRC uses as their low institutional control case. Therefore, those costs go down by 75%. The overall cost is $6.66/ft^3.

Slide 7 shows the augered shaft alternative and should read 3 m in diameter instead of 4 m as shown. Basically, it's a shaft that is augered to a depth of about 40 m. You put your waste in and backfill up with a 20 m cap cover. In this case, the operational costs go up quite substantially; it is about 81% more expensive than shallow-land burial. However, your closure costs are quite a bit less. As in the Deep Trench II design, you don't really have that much to do after closure. This particular concept, the augered shaft, is very useful for remote-handled (RH) materials because you have a self-shielding design. The overall cost is $7.80/ft^3.

Slide 8 shows the deep-crater or quarry alternative. One thing everybody says when they find out you're from the Nevada Test Site is, "Why don't you guys use all those holes you've got out there in the desert and put waste in them?" It's a nice idea, but what you forget is that you may have a hole, but you don't have any dirt to put in the hole. What you have is to dig another hole to put dirt in the hole you already have. You really haven't saved any money. In this case (particularly where you are looking at one large crater or quarry with a 360-m diameter bottom, a 700-m diameter top, and a 20-m cap cover into which you put your waste), your operating costs are $140 million. That is about 31% more than the cost of shallow-land burial. The catch is this: all your closure costs occur in your year 21. Basically, you really haven't covered any waste until you complete the facility. You must consider the incremental cost of having a closure fund and storing that for 20 years. If you project it on a 10%/year inflation rate, it works out to about $600 million. That is what you need in year 21 to close out your facility.

Slide 9 shows the grouted trench concept. Basically, it is the same thing as a shallow-land burial trench into which you inject a grouting material like cement or a type of drilling mud. Costs are about 35% more than for shallow-land burial. You really don't gain much over the Deep Trench I design. It is about an 8% overall increase in cost or $6.80/ft^3.

Slide 10 shows engineered barriers, which have a 5.5-m cap of sand and clay, gravel, asphalted concrete, and topsoil, with a 1-m backfill and 1 m of soil on the cap. The operating costs are 52% more than for shallow-land burial. The total cost above shallow-land burial is about 12%, or about $7.18/ft^3.

Slide 11 gives you a little bit of a summary of the cost values. The mined cavity disposal (from the 10 CFR 61 DEIS) costs $23.80/ft^3, which is about 372% more than for shallow-land burial. I think that

Slide 7

AUGERED SHAFT

4 M DIAMETER, 40 M DEEP AUGERED SHAFT WITH 20 M CAP COVER

	($ MILLIONS)
• CAPITAL COSTS	$ 77.8
• OPERATING COSTS	189.1
• CLOSURE COSTS	1.0
• INSTITUTIONAL CONTROL COSTS	8.5
TOTAL	$ 276.4

DISPOSAL COST $276.4/M^3 OR $7.80 FT^3

Slide 8

DEEP CRATER OR QUARRY

CIRCULAR OPEN PIT 40 M DEEP, 360 M DIAMETER BOTTOM, AND 770 M DIAMETER TOP WITH 20 M CAP COVER

	($ MILLIONS)
• CAPITAL COSTS	$ 77.3
• OPERATING COSTS	140.5*
• CLOSURE COSTS	1.0
• INSTITUTIONAL CONTROL COSTS	8.5
TOTAL	$ 227.3

DISPOSAL COST - $227.3 M^3 OR $6.37 FT^3

*NOTE: ALL MAJOR BACKFILLING OPERATIONS OCCUR IN 21ST YEAR AND ESTIMATE IS BASED ON 1980 DOLLARS IF PROJECTED TO 20TH YEAR, BACKFILL COST FUND WOULD HAVE TO BE APPROXIMATELY $600 MILLION.

Slide 9

GROUTED TRENCH

CEMENT GROUT INJECTED INTO TRENCHES

	($ MILLIONS)
• CAPITAL COSTS	$ 77.8
• OPERATING COSTS	145.2
• CLOSURE COST	2.0
• INSTITUTIONAL CONTROL COSTS	17.7
TOTAL	$ 242.7

DISPOSAL COST $242.7/M^3 OR $6.88 FT^3

Slide 10

ENGINEERED BARRIERS

5.5 M THICK CAP COMPOSED OF LAYERS OF SAND CLAY GRAVEL, ASPHALTIC CONCRETE, AND TOPSOIL ON TOP OF 1 M OF BACK-FILL AND 1 M SOIL CAP

	($ MILLIONS)
• CAPITAL COSTS	$ 80.2
• OPERATING COSTS	163.6
• CLOSURE COSTS	1.0
• INSTITUTIONAL CONTROL COSTS	8.5
TOTAL	$ 253.3

DISPOSAL COST $253.3/M^3 OR $7.18 FT^3

Slide 11

DISPOSAL COST ESTIMATE SUMMARY

	$/M^3	$/FT^3
• SHALLOW LAND BURIAL	$ 225.3	$ 6.31
• DEEP TRENCH - I	226.9	6.36
• DEEP TRENCH - II	237.8	6.66
• AUGERED SHAFT	276.4	7.80
• DEEP CRATER*	227.3	6.37
• GROUTED TRENCH	247.7	6.88
• ENGINEERED BARRIERS	253.3	7.18
• MINED CAVITY DISPOSAL	839.0	23.80

*NOTE: MAJOR COSTS OCCUR DURING FINAL BACKFILLING WHICH ARE NOT INCLUDED IN ESTIMATE.

number is low. I guess we'll find out in the future. It doesn't cost you that much more to use a greater confinement concept than it does to use shallow-land burial. The difference is the operating cost. You are paying more now to save money in the future. That is one of the things that has to be considered. Costs ranged from about 1% up to 23% for the various alternatives. What we consider to be the most cost-effective alternative is a combined deep trench and augered shaft design. Basically, the augered shaft is what you use for things that are not contact handled (CH), and the deep trench is what you use for the CH materials. I didn't estimate that concept because it depends on the fraction of your waste streams. Hopefully, in the final paper, I'll get around to doing that estimate.

Cost estimates for solidification with bitumen (again these are from 10 CFR 61) are $\$600/m^3$; with cement, $\$650/m^3$; and with synthetic polymer, about $\$2500/m^3$ (Slide 12). If we add in the disposal cost of about $\$225/m^3$, you get total costs of between \$1000 and $\$3000/m^3$. If you incinerate material, the incineration costs are about $\$2000/m^3$. One valve is for fluidized bed; the other one is for a controlled-air incinerator. You have a volume reduction; therefore, you have less for disposal, and it comes out to be about $\$2000/m^3$.

People are going to argue with what I did in Slide 13. What are confinement factors? I don't really know how to estimate them. It's very site-specific, that's all you can really say. What a deep trench buys you in one location depends on the analysis that you want to do. For approximation purposes, if you assume that shallow-land burial is 1 and that an arid shallow-land burial site is 0.17 (which incidentally is what the NRC uses in their 10 CFR 61 analysis), the difference between an arid and a humid shallow-land burial site is a factor of 6. Assume that with a trench having 10 m of cover, you are buying about 100% more protection, or a factor of 100 more protection. So these are basically your confinement factors estimates.

If you apply the confinement factors to a unit concentration of curies per cubic meter, you get values of (if you use 1 Ci/m^3 for shallow-land burial) about 1000 nCi/g (Slide 14). I'm just using these estimates for a basis of comparison. In theory, you could get up to about 1000 Ci/m^3 in an augered shaft. Now, of course, in your mined cavity disposal you can have unlimited concentration amounts because you assume that is isolation.

Why greater confinement? Good question. Basically, it reduces potential for human and biological intrusion (Slide 15). Second, it buys you time for inventories to decay before environmental transport processes take over. Third, and perhaps most importantly, it saves you money in the long-term maintenance and post-operational stabilization of your facility.

I want to quickly show you some pictures of what we've been doing because a lot of things that I've talked about here are hard to

Slide 12

ESTIMATED WASTE PROCESSING AND DISPOSAL COSTS

SOLIDIFICATION	PROCESS COSTS ($/M^3)	AFTER PROCESS VOLUME (M^3)	DISPOSAL COST (225/M^3)	TOTAL ($/M^3)
• UREA FORMALDEHYDE	631	1.4	315	946
• CEMENT	650	1.65	372	1,022
• SYNTHETIC POLYMER	2,445	2.00	450	2,896
INCINERATION/SOLIDIFICATION				
• FLUIDIZED BED PLUS POLYMER ($1,938/M^3 UNTREATED WASTE WITH 40:1 REDUCTION FACTOR)	1,999	0.05	11	2,010
• CONTROLLED AIR PLUS POLYMER ($2,060/M^3 UNTREATED WITH 20:1 VOLUME REDUCTION)	2,182	0.1	23	2,205

*EXCLUDING TRANSPORT

Slide 13

ESTIMATED

CONFINEMENT FACTORS

METHOD	C_F HUMID	C_F ARID
SHALLOW LAND BURIAL	1.0	0.17
DEEP TRENCH WITH THICK COVER I	0.01	0.017
DEEP TRENCH WITH THICK COVER II	0.005	0.0085
AUGERED SHAFT	0.001	0.00017
DEEP CRATER OR QUARRY	0.001	0.00017
GROUTED TRENCH	0.1	0.017
ENGINEERED BARRIERS	0.01	0.017
MINED CAVITY DISPOSAL	0.0	0.0
SOLIDIFIED ASH IN SLB	0.016	0.0027

Slide 14

ESTIMATED PU-239
CONCENTRATION LIMITS FOR
EACH GCD ALTERNATIVE

METHOD	CI/M^3 HUMID	CI/M^3 ARID
SHALLOW LAND BURIAL	1	6
DEEP TRENCH WITH THICK COVER I	10	60
DEEP TRENCH WITH THICK COVER II	200	1,200
AUGERED SHAFT	1,000	6,000
DEEP CRATER OR QUARRY	1,000	6,000
GROUTED TRENCH	10	60
ENGINEERED BARRIERS	200	1,200
MINED CAVITY DISPOSAL	SPECIFIC ACTIVITY	SPECIFIC ACTIVITY
SOLIDIFIED ASH IN SLB	62.5	375

Slide 15

COST VS. CONCENTRATION FOR Pu-239

METHOD	HUMID ($/CI)	ARID ($/CI)
SHALLOW LAND BURIAL	225.3	38.3
DEEP TRENCH I	2.2	0.4
DEEP TRENCH II	1.2	0.2
AUGERED SHAFT	0.3	0.05
DEEP CRATER	0.2	0.04
GROUTED TRENCH	24.8	4.3
ENGINEERED BARRIERS	2.5	0.4

visualize. We basically are using an augered shaft design for a demonstration of greater confinement, which is being funded by the low-level waste program. Basically, the design is nothing more than a shaft 120-ft deep and 10 ft in diameter. We will have a waste zone here at about 75 ft, and we also have a casing that we have inserted here to help guide our waste in. We have instrumentation along the sides of the shaft, and we're going to be injecting tracers and watching migration patterns. This is what we just did recently; this shows you our auger rig and we have a concrete pad. This is a 10-ft diameter auger rig, which digs down and takes a chunk of soil, comes up, and backspins off the dirt. It can go down to a total depth of about 120 ft. This picture was taken after we had drilled the hole. This is the main borehole, 120-ft deep. Over here is a shallow test hole that we're using in conjunction with Los Alamos National Laboratories to test the same set of experiments that we are conducting in the main borehole. This picture was taken on the day we decided to instrument it, and these are instrumentation strings. These are 120-ft long and look kind of like a sick Chinese dragon, but basically, these are insulated lines. These green bundles here are horse-hair packing that we put around the sections where instrumentation come out of the insulation. We pulled all the lines up with a crane that reached up about 117 ft so we had about 3 ft of slack back on the bottom. We had to carry that over.

Here we are lowering the instrument strings down the hole. That's just another picture of us lowering them down the hole. You can see the instrumentation here sticking out from beneath the horse-hair packing. This particular portion of the insulation has a reflective foil on it because we expect to get temperatures in excess of 100°C down there. Some of the waste that we are going to be using generates about 1000 W thermal. The wastes are some cesium, strontium capsules. The reason I included this picture is that we put a little sign here. It says, "Greater Confinement Disposal Facility, June 22, 1982, the deepest drilled shaft for solid low-level waste." Actually it took us about 1.5 h to come up with that statement. We had to think of enough caveats to put in because it wasn't the biggest hole and it wasn't the deepest.

This picture shows what it looks like if you look down the top. This is looking down all 120 ft, and you can see the instrumentation lines streaking down. All this material is alluvium. It is a free-standing hole. This is a corrugated metal pipe that we used as a form and to hold the surface together. I think that's a pretty amazing shot myself. This is a tracer injection line that runs down all the way to the bottom. This is the casing that we inserted down the hole, which is 60 ft. Those heavy equipment operators will tell you why they earn all $18/h. They handled that thing like it was a carton of eggs. This kind of gives you an idea of the scale, when they are swinging it over down the hole.

Preston Hunter, Ford, Bacon and Davis: I missed what the horse hair was for.

Dickman: This is basically to protect the instrument. We're using thermocouple psychrometers, which have a ceramic head on them; they're very delicate. We didn't want those banging against the sides of the hole as they go down. Also, it's to protect rocks that may sluff from the surface from dropping down and knocking the instruments. This is just to deflect them a little bit; it provides a little bit more protection.

Hunter: Have you taken them off?

Dickman: No. We left them on, in place.

Hunter: When you showed those slides on those differential factors, what was the basis of those?

Dickman: You mean the differential factors.

Hunter: Not the cost, but the confinement factors.

Dickman: Basically, I just assumed that shallow-land burial was 1 and that there were some fudge factors. That's all I could really come up with in the time allotted. I just assumed that for Deep Trench I, it was a factor of 100 better; and for Deep Trench II, it's a factor of 500 better.

Hunter: Those are kind of arbitrary.

Dickman: Right.

Hunter: I wasn't questioning it. It's a useful guess.

Dickman: Yes, it's a guess. That's all you can really do. The one thing I will point out is that the fudge factor for the grouted trench (0.1) is the one that the NRC uses in the 10 CFR 61 EIS.

Hunter: We do have some analyses that would probably give you some better numbers than those fudge factors.

Dickman: Those fudge factors are site-specific, and they are really isotopic-specific too. It's very difficult to really talk about them. Primarily all I want to emphasize from this talk are the differential costs between the various alternatives. In this case it really isn't that much of a difference between greater confinement and shallow-land burial.

TRANSPORTATION OF ALPHA-CONTAMINATED WASTE

Ron Pope, Transportation Technology Center, Sandia National Laboratory

Today I'd like to try to cover a number of items relating to the transportation of transuranic (TRU) waste, specifically, contact-handled (CH) TRU waste. I will describe for you very briefly the development program of the Transuranic Package Transporter (TRUPACT) which we are developing. I will then try to provide you with a summary of cost estimates that we've made using TRUPACT for transporting CH TRU waste between various Department of Energy (DOE) sites. I will also try to give you a feel for what kind of cost savings might accrue if the definition of TRU waste were changed. In addition, I will try to give you a feeling for the cost savings that might result if we did nothing but provide detailed assaying of the waste form. That is, by identifying the curie content, there are some cost savings that could result.

Before I get into this, I think we all need a common basis for discussing the topic. Let me describe some of the regulatory definitions that we deal with in the transportation area. The first one is Type A packaging. Type A packaging is Type A quantity of radioactive material. That packaging is designed to survive the normal conditions of transport. A Type A quantity of material is that value of material that has been deemed safe, relative to human exposure, if the package were exposed to an accident and the package should leak.

In this slide, I have tried to give you a feel for what kind of Type A quantity material would be transported in Type A packaging. Existing regulations say that Type A quantity of plutonium is 1 mCi and is the same for americium. Revision of the regulations has been proposed, and it's my understanding that the revisions will be put into effect around the turn of the year. Here, Type A quantities are isotopic-specific. For example, plutonium-238 is 3 mCi and plutonium-239 is 2 mCi. As you see, they are generally in the single-digit millicurie range except for plutonium-241, which is 100 mCi.

The other type of packaging that we commonly deal with is a Type B packaging. This packaging has been designed for carrying quantities greater than Type A. Not only is it designed to provide containment and shielding during the normal conditions of transport, but this packaging is also designed to withstand the rigors of a severe transportation accident. We have specific design criteria that we must meet in terms of drop, puncture, thermal environment, and water immersion.

When we talk about alpha-contaminated, or TRU, wastes we also have another constraint, which is specific or unique to the U.S. regulations. If we have radioactive waste or radioactive material with greater than 20 Ci of plutonium, we must provide, within the

Type B packaging, two levels of containment for that material. The regulations specifically state that there must be an inner container placed within the Type B packaging and that both the inner container and the Type B packaging must retain their containment when the packaging is exposed to the normal and accidental conditions of transport that are specified in the regulations. Some materials are exempt to this regulation. Namely, plutonium alloys, plutonium metals, and reactor fuel.

Having given you a common basis so that we can discuss transportation, let met briefly outline the development of the TRUPACT program. This program was started in about 1978, and until about 8 months ago our goal was to have an operational waste transportation system on-line that would begin to serve the Waste Isolation Pilot Plant (WIPP) in 1988 or 1989. About 8 months ago, DOE put us on a fast track, and our goal now is to have a limited fleet TRUPACTS in service, certified for operation, by 1984. This system will be what we call a bi-modal, that is a truck, system that will be 8-ft wide and will also be capable of being carried by rail. We have denoted this as TRUPACT-1. This package will initially be DOE-certified. For those who are not aware of the details of the certification process, DOE has self-certification capability for the shipment of DOE materials. We do, however, design the packages and DOE certifies that they meet Department of Transportation (DOE) regulations. We meet the regulations that would be imposed on a Nuclear Regulatory Commission (NRC) certified package.

TRUPACT-I will provide one containment level. If we have contents that go into TRUPACT that are greater than 20 Ci, we must address the double-containment issue by either providing a second level of containment or seeking exemption from the regulations. We have not yet addressed this issue in detail. We could seek exemption from this requirement for double containment. We might also provide the double containment through a separate reusable inner container or a separate single-use container that would fit inside.

The plans are that the limited fleet that will go into service in 1984 will provide us with practical experience before we commit to building a large fleet. Any minor changes that might need to be made to improve the efficiency or the longevity of it will be identified in the near term. It is planned that at least two TRUPACTS will initially be built (possibly as many as 4) and put into service between Rocky Flats and Idaho. Another one may also be used for demonstration purposes at other sites or even used for accelerated lifetime testing. This decision depends on the cost of the TRUPACT and the amount of funding that is made available as time progresses.

Further program long-term objectives including designing not only the truck version, which is 8-ft wide, but also designing a larger 10-ft wide version, which would accommodate more efficiently the CH TRU wastes that need to be shipped. The wider version would also

accommodate large decontamination and decommissioning components. Our goal is to maximize the internal volume and the pay load, maximize the lifetime and the utility of the system, and to minimize costs and turn-around time.

This slide shows some of the waste containers that we started designing around. In the upper right corner you see the standard 17C or 17H type drum. This is a Type A package. On the left, you see a system that was developed by the Sandia/WIPP people about 3 years ago for modularizing these 55-gal drums into units of six. The entire purpose of the strapping system was to pull six of these drums together to speed up the handling at the shipping and the receiving site. In the lower left corner, you see what some people call the "Sand Box" (for Sandia), or, as we prefer to call it, the "modular box." This was designed by the Sandia WIPP people to facilitate handling of drums whose integrity might be in question. For example, if you had a combustible waste container it would be placed inside this metal box and would then meet the WIPP (WAC).

The picture on the right shows this modular box in its sealed configuration. This box, within the last year, has been tested by Rocky Flats and has been qualified as a Type A box. Our hope was that, in spite of the fact that the modular box had not been designed for double containment, through testing we would demonstrate that it provided double containment. Recent tests performed on this in the 30-ft configuration have shown that the box does not have sufficient strength to provide double containment.

This is a photograph of a small-scale model of the TRUPACT as we envision it. Let me just briefly explain how the system operates. The containment for the system is provided by an inner stainless steel box. In the model, we have cut away a portion of that so you can see the detail of the wall structure. That inner stainless steel box is supported on an inner tubular truss system. This wall, with the tubular truss system, is separated from the outer wall by roughly 6 to 8 in. of polyurethane foam, which provides impact, some puncture, and thermal protection for the fire environment. On the outer surface of the package, we have a second tubular truss system and an outer steel wall, which provides weather protection. Not shown in this model, but lying just in-board of the outer tubular truss system, is a puncture-plate system. The ends of the box have roughly 3 ft of foam and structure. The open end has a 3-ft door, mostly made up of foam, which provides the impact resistance that we need to be able to resist the end drop. The system is closed with an inner door, which is about 4 in. thick and made of honeycomb/plate structure. The door will have 3 elastomeric seals to provide containment. That seal system is testable when you close the door. Recent tests that we've performed on the seal show that it is capable of sealing down to about 10^{-7} atmosphere CC per second, so it is essentially leak-tight by regulations.

This slide shows the detail of the wall from the inner containment vessel through to the outer steel weather protection wall. As I indicated, we have tubular truss members supporting the inner and the outer wall structure, and towards the outer portion of the wall, attached to the frame members, we have the puncture-protection system. That now consists of about 0.25 in. of 301 stainless steel, and laying on top of that will be a 1-in. panel of Kevlar. Kevlar, for those who don't know, is a registered commercial fiber, which when woven into fabric material is used in bullet-proof vests. We have recently run tests that show that this composite puncture-protection system provides us with the protection we need to meet the regulations. With that system, we have a packaging that will handle a loaded legal weight of 50,000 lb, a payload weight of about 13,000 lb.

The TRUPACT will be carried either by truck or rail. Here is a depiction of what the TRUPACT would look like on a truck/trailer system. The trailer will be a step-deck design because to provide the height needed to accommodate most of the waste forms, we would not meet the requirements for legal transport if it was on a flat-bed trailer The package is then tied down to the trailer using standard (ISO) attachment points.

This is a artist's depiction of how the TRUPACT would be loaded when it's mounted on the trailer. You would open the outer and inner doors and roll-up a frame that has rollers on it. The floor of the TRUPACT will have a roller system. With a fork lift, or by whatever means you want, you would put your waste package on this platform and roll it in to the TRUPACT by hand.

This slide shows a similar system in which TRUPACT is off-loaded from the trailer and might be sitting on the floor of a warehouse or the WIPP facility. You would then use a similar platform that has rollers, put your waste on the rollers, and roll the waste in or out.

Finally, the TRUPACT is being designed so that it can also be carried on flat-bed rail cars. Here is a depiction of two TRUPACTS on a standard four-axle rail car.

To assess the cost of transporting these wastes, we have looked in detail at the types of wastes that exist at Idaho. The TWSO projections show that, for the type of material that was discussed yesterday, over the first 20 years of operation of WIPP, there will be about 146,000 m^3 of CH TRU, assuming the definition remains 10nCi/g, which is about 7300 m^3/year. All of our calculations have been based on 10,000 m^3/year. The numbers we just heard this morning show that WIPP was designed for about 13,500 m^3/year. We are in between what TWSO is predicting and what WIPP has been designed for.

We have looked at the inventory of waste that is stored at Idaho, and we find that about 33,000 drums and 4800 boxes are in the less than

20Ci range. Right now these numbers are fairly uncertain because of the type of inventory they have, but it appears that there are about 40,000 drums and maybe about 1200 boxes that are in the greater than 20 Ci range. These would have to be handled differently.

When we break this down to percentages, for the waste that exists at INEL, we would now have about 5200 shipments between the boxes and drums. Of these 5200, between 3300 and 3800 of these would not require double containment. That is, between 65 and 73% of the shipments could be made in TRUPACT as it is now being designed without any further consideration of double containment.

We have made two cost studies relative to TRUPACT. The first one was made about 2 years ago and was a detailed assessment of shipments from the various DOE sites to Idaho and then to WIPP. The second study did not model the logistics in detail, but considered such issues as double containment; the costs of loading, sealing, and unloading the TRUPACT; the actual costs of developing the hardware; and purchasing site equipment (e.g., the loading platforms and leak test devices). In the assessment that I've made in the last 2 weeks, I've used these two studies to consider the effects of changing the waste definition and also of detailed assaying of the waste.

The first study assumed that we had 25% of the shipments made in TRUPACT-I by truck and 75% made in a larger TRUPACT by rail. It only considered single containment of the waste. It did not consider any of the development of hardware costs. It assumed 10,000 m^3/year going to WIPP. As I pointed out, it considered detailed logistics modelling of the waste and their movement within the United States. It was for all 10 nCi/g or greater CH TRU wastes. That study showed that over the first 20 years of WIPP operation, the total transportation cost would be about $140 million.

That study also looked at different alternatives. For example, instead of the 25 and 75% split between truck and rail, if we were to ship 50 and 50, the cost would drop from $140 to $128 million. If it was all by truck it would be $98 million. However, if we were to develop only the smaller TRUPACT (TRUPACT-I) and we were to ship 75% of the waste using that smaller system by rail and only ship 25% by truck, the cost would be $12 million less than if we developed the two systems. It is apparent there are large trade-offs that can be made in terms of the mode of transport and the costs.

The second study is one that was completed about 2 months ago and has not yet been fully documented. The base case was the same as the previous one that I've just mentioned (25% by truck, 75% by rail) with no double containment. It did include the development of the system, the costs of loading, sealing, and unloading, and the site hardware. Instead of $140 million, the costs from the second study were $192 million. About $50 million are involved in the developing of the system and in the sealing, loading, and unloading

costs. If we consider double containment and make on estimate of how much of the waste will have to be double-contained and how much might be exempted from the double-containment requirement because of its immobile nature, we find that our best guess is that about 13% of the waste would have to be double-contained in single-use modular boxes similar to but stronger than the one I showed you earlier. The costs would go from $192 million to $211 million. Again, this is over the first 20 years of WIPP operation.

For the purposes of this meeting then, I first looked at the cost savings if we were to perform detailed assaying of the waste. Numbers that I obtained from Idaho indicated that about 23% of the drums and 12% of the boxes now at Idaho will be below the 100-nCi/g limit. If we assume that the population below 100 nCi/g is linear, we find that all of the boxes would have greater than Type A quantities within those boxes just because of the large volume contained therein. About 67% of the drums would have less than 100 nCi/g and could then be shipped as Type A. In other words, assuming that the drums still have their integrity, they could just be loaded on a truck and shipped as is without having to load in TRUPACT. Significant savings occur because payload weight goes up significantly; you are not using an expensive Type B packaging and you pay no return charges on the transport. Over a 20-year period, about 13,400 drums could be shipped as Type A. All of this is assuming that the definition of TRU waste stays the same and that all this waste must be moved from Idaho.

Thus, if we were to perform the detailed assaying, the cost savings by making these Type A shipments for the drums that are Type A quantities is about $15 million. You reduce your costs from the $211 million, where we assumed that we've had very minimal assaying, to $196 million.

If the definition of TRU waste has changed from 10 to 100 nCi/g, the maximum possible saving occurs if you don't transport the material at all. Let's assume that it's at Idaho and that Idaho can retain the material. In that case, we reduce the number of Type B shipments by about 18%, and the total cost savings over 20 years is about $38 million.

That is a summary of the cost savings that might result from changing the definition of TRU waste. The other issues that I was asked to address are listed on this slide and they're all what I call "will nots." Changing the definition of TRU waste from 10 to 100 nCi/g will not decrease or increase the number of types of packages that we have to design. It will not affect the transport mode by which TRU wastes are carried. We can carry it either by road or rail, and the definition of TRU waste has no impact on that. It will not affect the system performance criteria, except that some of the drums might be carried as Type A if a detailed assay is made. That is independent of whether the definition is changed or not. Finally, it will not

affect--and it will not be affected by--any regulatory constraints that I know of relative to the transport regulations.

I'd like to make a couple of comments in closing. The numbers that I've shown you can be summarized as follows: Type B shipments, for the average distances that we're looking at in the United States, would cost about $\$1000/m^3$. Last night, John Umbarger showed a number of $120/drum for the shipment of drums from Richland to WIPP. That number by our estimates is low by almost a factor of 2. The cost should be about $200/drum. If detailed assaying is performed (and as I pointed out, some of these drums could then be carried as Type A shipments), instead of being $\$1000/m^3$ the cost could be as low as $\$100/m^3$. Again, these are all average numbers and would be subject to variation depending on the shipping distance.

Mel Shupe, DOE Richland Operations Office: Do you have a rough estimate of the percent of waste that would be sent from the Hanford site? Relative to the total cost, you've given us about $198 million depending on the scenario.

Ronald Pope, Sandia National Laboratories: From the TWSO Master Plan, a minimum of about 12% of the CH TRU going to WIPP will come from the Hanford site.

Craig Smith, Science Applications, Inc.: You said that there would be about an 18% reduction in the number of shipments of Type B packages if the limit were raised to 100 nCi/g. What is the basis for that calculation?

Pope: That calculation is based on the numbers that I showed on one of the slides. Idaho estimated the number of drums and the number of boxes that would be below 100 nCi/g. That's the maximum savings that could result if that waste could stay at the site where it is. In other words, a co-located shallow land burial site would produce the maximum cost saving.

Charles King, Savannah River Laboratory: How are your transportation standards as a function of nuclide established? And, question two, you're using Kevlar in the TRUPACT wall, presumably for impact resistance. Have you done tests to confirm that stability?

Pope: Let me take the second question first. The Kevlar is used for puncture protection, not impact resistance. We have been trying to solve the puncture problem for quite awhile. Our design a year ago showed just a stainless steel puncture plate, but to get resistance to puncture with stainless steel we had no payload left. We then went through an exploratory program, examining about 15 alternative concepts. Kevlar offered the greatest advantage, but unfortunately it was quite expensive. It runs the cost of the TRUPACT up by about $10,000 per unit. We have done scale model testing on actual models of TRUPACT and also on simple puncture plates. Two weeks ago we ran a full-scale punch test. We dropped

a panel of each backed up with 44,000 lb of concrete, representing the entire package. The test showed that we have the ability to resist puncture and still have a payload of about 16,000 lb. Answering the first question, the regulations as a function of nuclide have been developed through international cooperation and promulgated in transportation regulations developed by the IAEA (Safety Series No. 6). The breakdown by nuclide is based on a detailed risk model.

Jerry Cohen, Science Applications, Inc.: I realize the stringency of the design objectives. I'm trying to ask how the potential hazard resulting from the rupture of a (TRU) waste container justifies that stringency of control?

Pope: Those are the regulations that we must meet to be able to ship these materials. If I understand what you are asking, you feel that these are too stringent?

Cohen: I don't know. I know a lot of study had gone into spent fuel and high-level waste transportation. One study considered the consequences of an accident. Was that kind of assessment performed specifically for TRU wastes?

Pope: Yes, it was. The study was reported in the Waste Isolation Pilot Plant (WIPP) environmental impact statement, and basically the analysts were required to compound worst-case upon worst-case, such as a train traveling 70 miles an hour through a large population center under worst weather conditions, impacting, and rupturing the package. That study estimated how much material would get out and looked at the consequences, and the resulting requirements are well within acceptable reason.

Bill Evans, Savannah River Laboratory: My question is on the 20 Ci per shipment limit. We understood in the past that an attempt was being made to get a waiver of that limit to make the shipment of plutonium-238 and other material a little easier. Is that not so now? Will the Type B package still be built?

Pope: The Type B packaging must be built no matter how the double containment issue is settled. Our initial application for certificate will only be for 20 Ci shipments or less. The decision has not been made whether we will attempt to doubly contain all of the waste or seek exemption for some of the waste. That study of that issue will continue. As I've indicated, we went on a fast-track schedule about 8 months ago, and we've devoted all of our time and effort recently to getting the basic TRUPACT structure designed. We are scheduled to have the first draft of the Safety Analysis Report written by October 1.

Howard Kittel, Argonne National Laboratory: From the drawings you showed of the TRUPACT loaded on the truck bed, for that matter on the flatcar, it looked like there was a lot of unused space on the bed

of the truck. Has any thought been given to sizing the TRUPACT so that it uses the full space on the truck bed?

Pope: With the dimensions we are showing for a 13,000 to 16,000 lb payload, we are at the 80,000 lb legal truck weight limit, and we cannot make the TRUPACT bigger without exceeding that limit. And we cannot shorten the truck bed without violating the bridge formulas in some states.

Bill Lennemann: How is the waste in the 55-gal drums now being transported between Rocky Flats and Idaho?

Pope: In ATMX cars.

Lennemann: Does this method seem suitable?

Pope: The ATMX car has proven satisfactory in the past. The problem is that those cars are rapidly approaching the end of their service life, and the fabricator that made the ATMX cars no longer exists. The ATMX car operates under a Department of Transportation exemption.

Ken Gablin, K.A. Gablin & Associates: Are your 20-year figures compensated for escalation or are they multiplied by 20 in 1982 dollars?

Pope: All of the numbers I've given you are in 1982 dollars.

Ray Lambert, EPRI: What did you assume about special trains when you did the rail cost analysis?

Pope: The costs assumed only normal train service.

King: How does the TRUPACT compare to an SST?

Pope: I'd prefer not to address that issue.

Don Box, Oak Ridge National Laboratory: You mentioned a 13,000 lb payload, yet when we conducted the test we were loaded to 30,000 lb for the first truck and 16,000 for the second. Aren't you designing a light payload?

Pope: For the rest of the participants, Oak Ridge has recently been performing the test that I referred to assessing the performance of the modular boxes. Our design goal, 8 months ago, was to have a 30,000 lb payload in the rail system and 18,000 lb payload in the truck system. As I've explained, because of the puncture problem our payload had dropped to only 13,000 lb in the truck design, and we don't know what it will be in the rail design. But to assess the performance of the modular boxes in a drop environment, the first drop was with a 30,000 lb payload corresponding to our projected rail payload. We ruptured all of the boxes in that test. To correct you,

Don, the second test was run with a payload of only 11,000 lb, and again all the boxes ruptured. So some work still needs to be done on the inner-containment system before we have a double containment capability.

FOREIGN EXPERIENCE IN ALPHA-CONTAMINATED WASTE DISPOSAL

Pete Lakey, Battelle-Pacific Northwest Laboratory

It is a pleasure to be here, not only from the standpoint of seeing many old friends and making new acquaintances, but fortunately this work fits well with my assignment at Battelle-Pacific Northwest Laboratory (PNL). My qualifications for giving a summary like this stem from a program I am involved with at Battelle. We have a three- to four-person effort called International Program Support, which is aimed at collecting information on foreign practices in waste management, collating it, and then disseminating the information. We issue the information as topical reports, available through your libraries and through NTIS. I'm sure most of you are aware of these reports, but if you aren't, the references to those reports will be in the published paper. Incidentally, the information we publish is strictly unclassified. There is one other restriction to publishing information obtained in our contacts with foreign representatives. Quite often we obtain access to proprietary information, and by agreement with these representatives, we do not publish anything of that nature. Most of our information comes from the proceedings of international meetings. These include symposiums, workshops, and seminars. Visitors, such as those we have here today, are a source. I would like to remind you that the trip reports that those making foreign trips prepare are a very valuable source of information for us. We try to get copies, and those reports have proven to be very valuable.

The purpose of our work is to provide a data base for the Department of Energy (DOE) in planning and evaluating their technology exchange with other countries. Our principal contacts in DOE are Mel Shupe at the DOE Richland Operations Office and Alex Perge at DOE headquarters.

Before I get into the summary, I would like to qualify the information I'll present. In looking over the literature, you soon realize that much of the published information has to do with R&D. Today, I am trying to emphasize what is really done in foreign countries. Sometimes it is difficult to differentiate between R&D and actual operating practices. Incidentally, when you are traveling to foreign countries, you might keep that difficulty in mind and try to learn more about operating practices in addition to the particular research you are interested in.

The differences in terminology also confuse an evaluation like this. In this country, alpha waste has been well defined. We know what it means; we have a distinct transuranic (TRU) waste category and program effort. The definition is not so clear in other countries, and you will find more use of the terms "intermediate-level waste" or "medium-level waste," which can be a combination of low-level and alpha wastes. In the literature discussing the different wastes, it seems to me that in other countries the discussions of treatments cover

both low-level and alpha-contaminated waste. However, in the disposal area, the alpha wastes are generally tied to the high-level wastes. Finally, I might emphasize that most of our information was obtained from the literature and is therefore subject to my interpretation, so I invite corrections. Please let me know where I may be in error on the slides I am showing today. I request particularly that visitors from other countries give me that input.

Just to narrow the discussion, I would like to start by looking at where you get alpha-contaminated radioactive waste. I've listed the major elements of the nuclear fuel cycle activities from mining through decommissioning, including weapons production (Slide 1). Actually, the term "weapons production" probably could be better referred to as "materials production." In the mining, milling, and enrichment (fuel fabrication operations that use virgin uranium), you do not get alpha-contaminated waste. Obviously, as George Levin pointed out earlier, we found that in reactor operation you do not get alpha-contaminated waste unless you have some unusual events such as were experienced at Three Mile Island.

The interim storage of spent fuel also produces no alpha-contaminated wastes; however, in reprocessing and in the waste treatment and fabrication of mixed-oxide fuels, direct handling of the alpha-nuclides is involved. Therefore, you get these alpha-contaminated wastes. During interim storage of wastes, transportation, and disposal operations, the waste is isolated by the packaging; therefore, you do not get any alpha-contaminated wastes. When you decommission facilities (such as reprocessing plants, mixed-oxide fabrication plants, and materials production plants), you will create alpha-contaminated wastes.

Slide 2 lists the countries that have reactors and indicates those plants producing alpha-contaminated wastes by the operations indicated on Slide 1. I have omitted decommissioning as a source because there is so little decommissioning occurring today. Reading down the list, you will note that Belgium has a reprocessing plant. This plant is really shut down and probably should have been listed in a decommissioning column. However, in decommissioning that plant, they have produced alpha-contaminated waste. They also have a mixed-oxide fabrication plant at Dessal. We know that China is a weapons-producing country and, therefore, does produce alpha wastes. They are reported to have a Purex-type reprocessing plant to obtain their weapons material.

France has two reprocessing plants; one at La Hague and one at Marcoule. They have a mixed-oxide fuel fabrication facility at Cadarache and also a weapons- or material-production capability. West Germany has a small reprocessing plant at Karlsruhe and a mixed-oxide fabrication plant near Hanau. India had three reprocessing facilities, a mixed-oxide fuel fabrication facility, and also a

Slide 1

SOURCES OF ALPHA-CONTAMINATED RADIOACTIVE WASTES

OPERATION	SOURCE
MINING AND MILLING	NO
ENRICHMENT	NO
FUEL FABRICATION FOR ONCE-THROUGH FUEL CYCLE	NO
REACTOR OPERATION	NO
INTERIM STORAGE OF SPENT FUEL	NO
FUEL REPROCESSING AND WASTE IMMOBILIZATION	YES
FUEL FABRICATION FOR RECYCLE OF PLUTONIUM	YES
INTERIM STORAGE OF WASTES	NO
TRANSPORTATION AND DISPOSAL OPERATIONS	NO
DECOMMISSIONING	YES
WEAPONS PRODUCTION	YES

Slide 2

COUNTRIES PRODUCING ALPHA-CONTAMINATED RADIOACTIVE WASTES

COUNTRY W/REACTOR	SPENT FUEL REPROCESSING	MIXED-OXIDE FUEL FABRICATION	WEAPONS PRODUCTION
ARGENTINA			
BELGIUM/EUROCHEMIC	X	X	
BRAZIL			
BULGARIA			
CANADA			
CHINA	X		X
CZECHOSLOVAKIA			
FINLAND			
FRANCE	X	X	X
GERMANY, EAST			
GERMANY, WEST	X	X	
HUNGARY			
INDIA	X	X	X
ITALY	X	X	
JAPAN	X	X	
KOREA (SOUTH)			
NETHERLANDS			
PAKISTAN			
SPAIN			
SWEDEN			
SWITZERLAND			
TAIWAN			
UNITED KINGDOM	X	X	X
UNITED STATES	X	X	X
USSR	X	X	X
YUGOSLAVIA			

weapons-material capability. Japan, at the Tokai site, has both a reprocessing facility and a mixed-oxide fuel fabrication facility.

Italy has two facilities that are fairly small, almost pilot-plant scale, reprocessing plants, and a mixed-oxide fuel fabrication facility. The big three producers are the United Kingdom, United States, and USSR. The United Kingdom is very large in reprocessing. They have four plants, two at Dounreay and two at Windscale. They also have a mixed-oxide fuel fabrication plant at Windscale. We are all familiar with the situation in the United States. I only have limited information on the USSR, but we are fairly sure, from the highly publicized contamination incident, that they have reprocessing capability. They are also active in the breeder program; therefore, they have plutonium fuel fabrication capability.

In summary, you can see that there are at least ten countries producing alpha-contaminated wastes. That list is growing, and the rate at which it grows depends on the growth of either materials production or power production. Argentina, Brazil, and Pakistan have shown interest in reprocessing. Another thing to keep in mind is that there are many countries with reactors that have their fuel reprocessed elsewhere. Sweden and Switzerland are two examples. Generally, the reprocessing agreements include return of high-level wastes to the source country and probably the alpha-contaminated wastes. Because of waste return, these countries will eventually have an interest in treatment and disposal of their alpha-contaminated wastes. As I understand it, the eastern-block countries (Czechoslovakia, Hungary, etc.) have agreements to ship their spent fuel back to the USSR. I'm not sure that the alpha-contaminated wastes are returned, but that is a possibility.

On Slide 3, I have described what we know about the definitions of alpha-contaminated radioactive waste in different countries. The countries listed on the slide are those that I have shown on the previous slide as producers of alpha-contaminated waste. Belgium has a limit of 15 g of plutonium per 200 L, which is roughly equivalent to the International Atomic Energy Agency (IAEA) limit on sea dumping. Incidentally, the numbers that you see on the slide have different units, so I have tried to provide some standardization in the parentheses by converting each of these to nanocuries per gram, based on a density of 1 g/cm^3. You have to realize that this assumption is open to challenge because the density of waste can vary between 0.1 for combustible waste to 3.0 for concrete. We have no information for China. For France, I show a limit of 0.1 Ci of alpha per cubic meter. However, Dr. Lavie from France has informed me that their current limit is 1 Ci/m^3.

West Germany has no formal definition although I have heard that they are coming up with some definition. I know that they are investigating an iron mine over there for use on non-alpha wastes. If they are separating alpha from non-alpha wastes, they will have

Slide 3

NATIONAL DEFINITIONS OF ALPHA-CONTAMINATED RADIOACTIVE WASTE

COUNTRY	DEFINITION
BELGIUM	>15 g Pu/200ℓ $>10^{-10}$ Ci α/cm^2 OF SURFACE
CHINA	?
FRANCE	>0.1 Ci α/m^3 (~100 nCi α/g)[a]
WEST GERMANY	NO DEFINITION
INDIA	>1 μCi α/FT^3 (0.035 nCi α/g)[a]
ITALY	?
JAPAN	NO DEFINITION
UNITED KINGDOM	>20 mCi α/m^3 (20 nCi α/g)[a] $>10^{-10}$ Ci α/cm^2 OF SURFACE
UNITED STATES	>10 nCi α/g
USSR	?
IAEA LIMIT ON SEA DUMPING	1 Ci α/TONNE (1000 nCi α/g)[a]

[a] CONVERSION BASED ON ASSUMED DENSITY OF 1.0 g/cc

to have a limit or some definition for the separation. As yet, there is nothing official.

India uses 1 uCi of alpha per cubic foot, which is an unusually low number. I began to wonder if the number in the literature was incorrect, and I checked with one of the professional staff in India. He said that the number was arbitrarily picked in the 1960s to force a strict segregation between alpha-contaminated wastes and beta-gamma wastes.

We have no numbers for Italy. Japan also has no definition for TRU waste. The United Kingdom uses 20 mCi alpha per cubic meter, which is about 20 nCi/g. Dr. Thackrah will talk about that later. The 20 nCi/g figure is based on a density of 1, but he has informed me that the density is more likely to be about 0.2, which would raise that number up to about 100 nCi. The United State's definition is one we have been discussing at this workshop. The IAEA limit on sea dumping is 1 Ci of alpha per ton or 1000 nCi/g at a density of 1 g/cm^3.

As you can see in Slide 3, there are many limits and different bases for those limits. The conclusion I came to from this is that the limit is based on the method of disposal selected (e.g., shallow land burial). I would expect that if a geologic repository is used for non-alpha waste, a higher level of alpha would be permitted. However, from the numbers that I have seen, the variance does not look extreme.

Next let's look at the practices used for treatment and immobilization of alpha-contaminated waste. In Slide 4, I have listed the countries that are the producers as indicated on Slide 2. Then, I have grouped different treatments under these headings. Decontamination, for example, would include chemical washing, electro-polishing, vibratory finishing, and operations intended strictly for decontamination purposes. Incineration would include acid-digestion, controlled air incineration, and slagging pyrolysis. The other treatment category includes volume reduction techniques such as cutting, grinding, and compaction. Under immobilization practices, cement and bitumen are obvious forms. Other forms include glass, ceramics, and fused residues.

Belgium is about to or is now operating a slagging pyrolysis incinerator and an acid digestion unit at Mol. They are immobilizing wastes in cement and bitumen. I believe that immobilization is being done on wastes going to the sea. The wastes collected on site are being held untreated until they are treated further. We know nothing about China. France has at least four incinerators and is proposing other work on decontamination and grinding for volume reduction. They have used cement and bitumen extensively for waste immobilization. Cement is used on hulls and dissolver residue; bitumen is used more on the liquid wastes. At one of the French sites, they have a plastic-type immobilization system.

Slide 4

PRACTICES USED FOR THE TREATMENT AND IMMOBILIZATION OF ALPHA-CONTAMINATED RADIOACTIVE WASTES

	TREATMENT			IMMOBILIZATION		
COUNTRY	DECONTAMINATION	INCINERATION	OTHER	CEMENT	BITUMEN	OTHER
BELGIUM		X		X	X	
CHINA						
FRANCE	P	X	P	X	X	X
WEST GERMANY	X	X	X	X		
INDIA		P	P			
ITALY		P			X	
JAPAN		P	P			
UNITED KINGDOM	X	X	P	X		
UNITED STATES	P	X	X			
USSR		X	X	X	X	

X = PRACTICE IN USE
P = PRACTICE IS PROPOSED

West Germany has a washing facility and has burned low-level wastes at Karlsruhe. They are planning some incineration work at Hanau where the mixed-oxide fuel fabrication plant is located. They are also talking about putting in a pyrohydrolysis unit for combustible waste and a hydrolysis unit for solvents. At Karlsruhe, they also have an equipment disassembly and scrapping plant. They have done quite a bit of work on bitumen in Germany, but a few years ago they switched from bitumen to concrete because of some trouble they had with storing the bitumen.

India performs no treatment, but holds their waste on site. They are putting in an alpha-waste treatment facility next to one of the reprocessing facilities and are proposing a wet-oxidation system along with compaction equipment in that facility.

According to the limited information we get, Italy is proposing an incineration plant, and it has been reported that they do have a bitumen plant operating. Japan performs no treatment on their alpha waste, but they are planning an alpha-waste treatment facility at Tokai. They are going to install an acid digestion system and compaction equipment in the facility.

The United Kingdom has extensive alpha-waste treatment facilities. They do limited decontamination. They have a controlled air incinerator at Windscale, and they are putting in or are planning some very large cutting facilities for large equipment items such as glove boxes. That was a subject of the workshop at Albuquerque recently. They use cement for immobilization. The United States uses incineration at Mound and Rocky Flats. We have been looking at electro-polishing and other ways of decontaminating waste and Los Alamos does some cutting of larger pieces of equipment.

For the USSR, the information is limited. We know that they have used incineration at one of their research institutions. They also do some compaction work on large equipment items, and they have reportedly used both cement and bitumen for fixation.

From this review of practices, it appears that incineration now is the most common treatment used, although there are others being introduced, particularly in decontamination. I imagine that the incentive for decontamination is the recovery of plutonium. As far as waste forms, bitumen and cement are the leading contenders when fixation is used. I do not want to imply by my discussion of treatment that all alpha wastes are treated. Much of the alpha-contaminated waste is left untreated in interim storage.

In Slide 5, I have listed the countries producing alpha-contaminated wastes and have then taken a look at what is done with them. The column headings cover interim storage and various disposal systems in use. Interim storage includes any method of storing wastes with intent to retrieve. Surface disposal implies shallow-land burial.

Slide 5

PRACTICES IN DISPOSAL OF ALPHA-CONTAMINATED RADIOACTIVE WASTE

COUNTRY	INTERIM STORAGE	SURFACE DISPOSAL	SEA DISPOSAL	GEOLOGIC DISPOSAL	DEEP-WELL DISPOSAL
BELGIUM	X		X	P	
CHINA	X				
FRANCE	X			P	
WEST GERMANY	X			P	
INDIA	X			P	
ITALY	X			P	
JAPAN	X			P	
UNITED KINGDOM	X		X	P	
UNITED STATES	X			P	
USSR	X	X		P	X

X = PRACTICES IN USE
P = PRACTICES IN PROPOSED

Sea disposal is sea dumping. Geologic disposal includes mined cavities in the earth. Deep-well disposal is injection to underlying geologic strata.

Belgium has interim storage facilities at Mol. In fact, the bitumen storage facility at Mol handles wastes remotely and is quite a showplace. Belgium disposes of wastes up to the limit permitted by IAEA, which is about 1000 nCi/g. They are also looking at disposal in clay at Mol and have an experimental mine under construction.

We know little about China except that they must use interim storage because the wastes must be placed somewhere and we know of no geologic or disposal work going on in China. France uses interim storage at a facility near La Hague. They are looking strongly at geologic disposal. I believe that Dr. Lavie will talk about their plans later. They are considering a second interim storage area in about 1985, and they hope to have a geologic system in place for alpha wastes in the 1990s.

West Germany has interim storage facilities at both Karlsruhe and Hanau. We are aware that they are looking strongly at salt for alpha and high-level waste disposal. India stores all of their alpha wastes on site in interim storage facilities, which from the pictures I have seen, resemble the Ontario Hydro facilities at the Bruce station. That is, they use concrete vaults and tiled holes. India is favoring granite for disposal and is looking at a former gold mine as a starting place for their investigations. Based on limited information, Italy does store on site, but they are beginning to look at clay formations for disposal.

Japan has an interim storage facility at Tokai, and they are looking at geologic disposal. The United Kingdom stores on site, and they also do some sea dumping up to the allowed limit. They had been looking at several ways of getting rid of wastes. You are probably familiar with those; they include burial underneath the sea bed, dropping the waste on the sea bed, and geologic disposal on the Isles. They made an interesting political decision recently, accepting the disposal of high-level and alpha waste as credible operations and stopping site-specific investigations. Extended interim storage is now planned.

The United States has interim storage at several sites and we are looking extensively at geologic disposal. The USSR must rely on interim storage. They are reported to be using surface disposal, and they have touted their deep-well disposal routes for waste; however, because of the age of some of the reports, I wonder if they might represent situations like what we had at Hanford a few years ago. Recently, I have noticed that the references from Russia are beginning to emphasize geologic disposal as a preferred route, like everyone else.

My conclusion from this work-up is that there will be big industry in the future on interim storage of alpha waste, and we seem to be moving unanimously into geologic disposal as the preferred route for disposal of alpha-contaminated waste.

Slide 6 lists active projects in geologic disposal and gives us a time frame for reference. I have listed five active projects, holes in the ground that are being used for any type of waste. I didn't stick strictly to alpha wastes. Belgium has a repository in clay called Project Hades. Dr. DeJonghe might explain more about it later. It was used initially as a test bed, but it is intended to become operational in the 1990s. West Germany had the Asse salt mine operational between 1967 and 1978. However, the mine has not successfully received relicense. Alpha waste was placed in Asse. West Germany is using an existing iron mine called Konrad for evaluation as a repository for non-alpha wastes. They are looking toward developing a salt mine at Gorleben, and they are still developing plans to determine when that salt mine would begin operations; it may be 1984 or 1985 before they have a schedule.

India is looking at a gold mine in the Kolar region. It is a granitic structure. Sweden has the Stripa project, which is a combination of research programs from several countries. Sweden is using an iron mine in granite for a test repository. Incidentally, Sweden is one of the countries that will reprocess waste, and they are planning an underground interim storage facility for spent fuel. Along with that interim facility, I believe they will have an alpha interim storage area. They are also planning an underground granite repository for spent fuel and for high-level waste and will have an alpha repository also. The United States has three active projects: Climax, which uses spent fuel; the Waste Isolation Pilot Plant (WIPP) project, which we heard about earlier; and the basalt project at Hanford.

To summarize the status of geologic disposal projects, it looks like the earliest operational project will be the United States' WIPP. France indicates that its project will be operational in 1990, but France doesn't have a hole in the ground yet. In addition to those listed in this slide, at least 11 other countries are considering geologic disposal. Canada has an underground research laboratory that is being proposed as a test bed. Switzerland has extensive plans for geologic disposal in granite, and it has plans for three types of repositories. Each will depend on the type of waste involved, but all will be underground. I mentioned the United Kingdom's plans earlier.

To summarize, alpha-contaminated wastes are produced in at least ten countries, and the list of producers is growing. There is no consensus on a numerical definition of alpha-contaminated waste. The definition depends on the route that the country or the producer has selected for disposal. Treatment plans seem to emphasize plutonium recovery and volume reduction, and it seems illogical to expect this

Slide 6

STATUS OF ACTIVE GEOLOGIC REPOSITORY PROJECTS

COUNTRY	
BELGIUM	REPOSITORY IN CLAY (HADES) UNDER CONSTRUCTION
WEST GERMANY	ASSE SALT MINE OPERATIONAL 1967-1978
	EXISTING KONRAD IRON MINE UNDER EVALUATION
INDIA	EXISTING KOLAR GOLD MINE UNDER EVALUATION
SWEDEN	EXISTING IRON MINE IN GRANITE (STRIPA) USED FOR TEST REPOSITORY
UNITED STATES	TEST REPOSITORY IN GRANITE (CLIMAX) OPERATING
	REPOSITORY IN SALT (WIPP) UNDER CONSTRUCTION
	TEST REPOSITORY IN BASALT (NSTF) OPERATING

emphasis when you are faced with interim storage, which is probably going to be expensive.

Incineration is the treatment most often used, although volume reduction by cutting or compacting seems to be gaining acceptance. Some decontamination activities aimed at recovering plutonium are appearing more. When a fixation form is used, cement and bitumen are the most prevalent, but I would imagine that if much decontamination or treatment is planned, fixation will not be used until those processes are finished. All alpha-contaminated wastes are going to interim storage of some type, and a geologic repository is the preferred method of disposal.

Dr. Hans Christensen, ASEA-ATOM, Sweden

Lakey: Dr. Hans Cristensen from ASEA-ATOM, Sweden, who is head of the Development and Design Group, Chemical and Rad Waste Systems, is our first foreign visitor to speak.

Christensen: A simplified flow sheet shows how we in Sweden have decided to handle and store alpha-, beta-, and gamma-contaminated wastes. We are dividing our waste categories into three categories: low-, medium-, and high-level wastes. The low-level waste consists of plastic scraps, garments, etc. They are classified. Part of the waste in this category is incinerated, and about 25% must be compacted and stored in drums. The drums are now stored on the reactor site, but will be transferred to the repository in 1989. We have finished our final repository for low- and medium-level waste. This repository was placed about 50 m below ground level in bedrock. The medium-level waste (i.e., the expected resins and filter sludges that are solidified in concrete or bituminized) is now stored on site, but will also be transferred to the final repository for low- and medium-level wastes. That leaves us with the high-level waste that is spent fuel. We are now sending this waste to Windscale for reprocessing. A new law was passed in 1977 that stated that we should show that we could take care of spent fuel from our nuclear powerplants in two different ways; therefore, we are now constructing the CLAP unit that is a central storage facility for spent fuel. This unit will be in operation in the middle of 1984. Then, we will transfer the spent fuel to the CLAP facility, and from the CLAP facility, we must show that we can go two different ways.

One way of handling spent fuel from our reactor is the KBS-I project. The KBS-I project is comprised of a reprocessing step, which returns vitrified waste for intermediate storage. The vitrified wastes will be encapsulated in stainless steel canisters surrounded by a lead canister and then surrounded by a titanium canister before they are stored in the final repository, which is placed about 500 m below ground level in bedrock. The second project is the KBS-II project, to which the spent fuel is transferred. It is dismantled, the rods are encapsulated in copper canisters, and the space around the rods is filled with copper powder. The final step of that process is the CRHIP process. From this station, which is a direct disposing method, the encapsulated rods will be stored in the final repository about 500 m below ground level. The rest of the residual solutions from the reprocessing facility will be solidified with either cement or bitumen. The metal scrap from this process will be encapsulated in cement and stored about 300 m below ground level.

Paul Dejonghe, CEN/SCK Boeretang 200, Belgium

Lakey: Our next speaker will be Dr. Paul Dejonghe, Assistant Director General of the Study Center for Nuclear Energy in Belgium.

Dejonghe: I have prepared a few slides. The first shows the present facilities in Belgium that are producing wastes. First are the power reactors. They are now producing about 25% of the electricity consumed in the country. This figure will increase to about 50% when the reactors under construction today begin operation. For fuel fabrication, we have uranium oxide and mixed uranium plutonium oxide facilities. For reprocessing, we have the small plant Eurochemic, which we hope to reopen. What we cannot reprocess ourselves, we try to have contracted with France.

A recent debate in Parliament has led to a positive result, which is still subject to confirmation by the Senate and by the industries that are directly involved. If the decision is confirmed, and we hope it will be before the end of the year, it will open the possibility for further increases in reactor capacity. These increases will include reopening of Eurochemic by a Belgium company (possibly with international contributions), confirmation of our participation in the fast breeder reactor programs in Europe, and better perspectives for the fabrication of uranium and plutonium oxide fuel (this is important in view of the production of radioactive wastes, including alpha-contaminated wastes).

I will briefly describe two situations in our radioactive waste management. The first is the situation that existed until a few months ago. The second is a new situation that was created by a mechanism that I will explain. Legally, the situation was very simple. A royal decree, from as far back as 1963, allowed us to live with and to organize our work. Radioactive waste management and radioactive waste treatment were organized so that, at the reactor stations, the concentrates were treated and some liquid and semi-solid wastes were conditioned. Eurochemic plans to condition its high-level wastes in the future, but now it conditions its medium-level waste by bituminization. Eurochemic organizes recovery of plutonium from wastes using the German system Alona, which was constructed by Carl Struer, and it conditions some solid waste. The CEN does all the rest and has done all the rest until now. That means temporary storage must be used. Treatment that could not be done at Eurochemic consisted essentially of the treatment of very low-level liquid and solid wastes. One of the treatments in which CEN has specialized is incineration. It also handles compressing, cutting, bailing, and ocean disposal.

We have been able to propose and largely to practice a system for radioactive waste management in which we start with low-level waste (shown at the left in the slide), medium-level wastes (in the center), and high-level wastes (at the right). For the low-level

wastes coming from around the institute and for the other types of waste already mentioned, we first concentrate by evaporation or incineration. Conditioning by concreting, bituminization, or high-temperature incineration will be discussed further later. This low-level material is disposed of in the ocean. For medium-level wastes, we make a distinction between what comes from the reactors and what comes from the fuel cycle. The fuel cycle wastes require a definition of the contamination with plutonium. Again, we have concentration by precipitation or evaporation if the waste is liquid, and the concentrates are either concreted, bituminized, or incinerated.

We still have certain amounts of high-level wastes remaining at Eurochemic from earlier operations. These are stored in tanks and will be vitrified. We foresee an interim storage of about 50 years for cooling, and I will explain why in a moment. Low-level and cooled or decayed medium-level wastes from the reactors are disposed of in the ocean, and all the other wastes are disposed of in the geological repository. We have not been studying in detail the possibilities for shallow land burial.

We perform ocean disposal in the framework of the London Convention. We have a maximum, as far as alpha is concerned, of 1 Ci/ton, and we add an additional restriction of 1 Ci of alpha-beta and not more than 0.1 Ci of radium. The rule of 15 g of plutonium per 200 L is what we use for internal accounting. Radium is important for us because we still have a radium facility, which was inherited from the past. We are now dismantling that plant.

The wastes are conditioned with bitumen or concrete, and high-temperature slagging incinerators will be used in the future. Already this year we have some high-temperature slagging incinerator residue in the material that will need disposal. To give you an idea of the importance of the volume in tonnage, this year we are going to have 5100 tons of material to be disposed of in the ocean. This tonnage comes from the reactors, 50% of it; 25% comes from dismantling (not from Eurochemic but from the radium facility that I just mentioned), and the remaining 25% comes from the fuel cycle, the CEN, and other producers. Altogether, this means that, in radioactivity, this tonnage is 1% in concentration, 1% of the limits that have been set with IAEA.

Recently, an organization somewhat similar, but not identical, to the French ANDRA has been created in Belgium. It is called Andre of Nehause. Andre of Nehause is an organization responsible for the radioactive waste management in Belgium and for fissile materials. A law was passed in August 1980 (Belgium law does not mean much unless it is confirmed by royal decree) and signed in March 1981. This organization is almost operational now. It has a Board and a General Manager. Its attributes are its competence, its transportation of fissile materials and wastes, and the disposal of the wastes. The organization has a complementary role in waste conditioning: it

must deal with storage; it must fix acceptance conditions and monitor conformity with acceptance conditions; it must charge producers the costs, because the polluters should pay; and it must constitute, compose, and run an organization. We have two major organizations, and a third minor one, that practice R&D.

The CEN operates largely, but not entirely, under contract to CFC. We developed a high-temperature incineration process called slagging incineration. This incinerator exists and is in operation; we are gathering operational experience. The incinerator is radioactive, but we have avoided introducing large amounts of plutonium. Although we hope to use the incinerator for the same quantities of plutonium as we have foreseen for ocean disposal, the main objective is volume reduction and total insolubilization of the residue. The solubility or insolubility that we obtain here is certainly comparable with that obtained by borosilicate vitrification. Quality control is, of course, very important for old wastes resulting from various operations and also for the wastes that are going to be sent back to Belgium from foreign reprocessing. Regarding conditioning of the hulls, we are doing work on melting, which also involves demonstration and development work. For vitrification, it has been decided to study and most probably to build an AVM plant. It is a French Marcoule-type vitrification plant. In fact, this plant should not be listed here; it should be listed in the industrial activities. The plant does not yet exist, but the studies are being conducted. A second facility that is already under construction is the demonstration facility for the German Pamela system. This facility is being constructed under contract with the German reprocessing company DWK. A wet-combustion facility is also under demonstration. The plant exists, but I don't think it is radioactive. The wet-combustion demonstration is being performed in cooperation with KFK and the European community. Finally, regarding geological disposal, we are in a very uncomfortable position because in Belgium we have no salt, and we were told by many people that salt was an ideal formation. Besides having no salt, we came to the conclusion that, in most of the country, we also had no good basalt or granite formations. We were told that we had to take care of our wastes and that we could not leave that to our neighbors. That is the reason we entered into this clay disposal business.

This slide gives a view of the high-temperature incinerator. This picture has already been shown many times. This plant is now in operation.

For high-temperature incineration, the kind of material that we burn includes combustible solids, paper, cloth, wood, plastics, glass, and sand. We are not strictly limited to combustible material. We have burned some metals, and we treat sludges. I think this is important. By melting, we reuse some of the slag that comes from burning. This is done to improve the concentration factor. The reduction factor in mass volumes of the process is 4.5 to 6, but this doesn't necessarily mean much. The throughput of the plant is

between 50 and 75 kg/h. The temperature is a little bit higher than it is here; it is more like 1400 to 1500°. We are happy to have below our site some interesting clay layers. These layers have been studied in the laboratory, have been sampled, and have seen an awful lot of experiments and drillings to verify the existence of the clay and to verify its uniformity, etc. Finally, we decided a couple of years ago to build an underground laboratory that is situated at the depth at which we want to or we could install a repository. The shaft shown in this slide has been finished down to there. Over the past few months the preparatory work for the laboratory has gotten under way. The horizontal drilling is going to start in September. The purpose of that underground laboratory is essentially to determine the mechanics. The machinery for this horizontal drilling in clay is perhaps the toughest problem. The problems of safety, water movement, retention, and reaction with oxygen are very well under control; one does know and one can know what to expect. But the major difficulty that remains is to install a large network of tunnels at that depth under very high pressure in the clay.

Dr. Jean-Marie Lavie, ANDRA, France

Lakey: Our next speaker will be Dr. Jean-Marie Lavie, director of ANDRA in France.

Lavie: I would like to present to you a short overview of waste management in France, and later Mr. Pradel and Mr. Frejaville will present short overviews on the basis for the limit between alpha and non-alpha waste. They will also discuss some technical means used to separate the non-alpha and the alpha wastes.

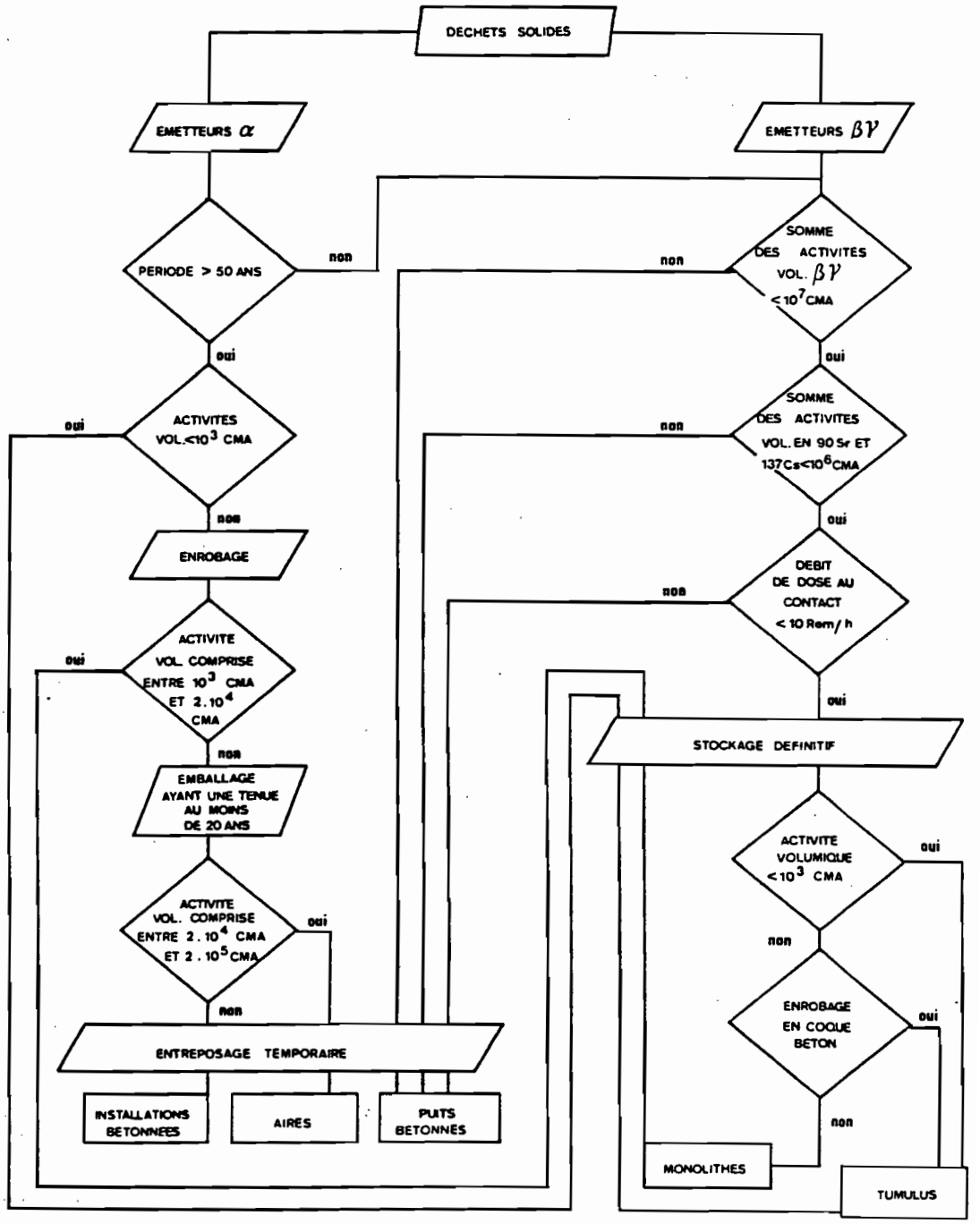
Our nuclear program in France includes a national commitment to reprocessing and recycling spent fuel. The management of alpha waste is one of the most important waste management problems in France (Slide 1). Confronted with the need to design, locate, and build waste disposal centers for all kinds of wastes produced by the French nuclear program, the National Radioactive Waste Management Agency (ANDRA) and other agencies have developed disposal concepts during the last 2 years. The basic technical safety option consists of: (1) isolation of waste for a few hundred years (first stage), and (2) control of waste dispersion for the next 10,000 years (second stage). Taking into account the limitations of immobilization techniques and of institutional control, the basic option is to classify radioactive wastes in two main categories: (1) the short-lived radioactive waste (less than 30 years) that can be disposed of in near-surface disposal under institutional control for 300 years, and (2) long-lived radioactive waste, which must be disposed of in deep geologic disposal centers protected by natural geologic barriers. The problem is to fix, for long-term waste management purposes, the limit threshold (i.e. contents in long-lived radionuclides) between these two categories. The second category includes, of course, vitrified waste, but the management of that is not a concern in this discussion.

Recent application of this basic safety option and the safety assessment of the Centre de la Manche show that the contents in long-lived nuclides of waste to be disposed of in near-surface disposal must not exceed 100 nCi/g of immobilized waste, with less than 1000 nCi/g in each package. These threshold values are deduced from the most pessimistic scenario possible: construction of a freeway through the site. The risk analysis shows that the dust resulting from such work presents a radiological risk higher than the one coming from the underground water pathway under the worst conditions.

Based on the present operational threshold (i.e. about 500 to 1000 nCi/g, depending on the density of the immobilized waste), the volume of waste produced in France will rise from 8000 m^3 to about 45,000 m^3 at the end of the century (Slide 2). Slide 3 indicates the origin of the wastes. Beyond 1988 you can see a noticeable increase of the production rate in connection with the start of new sections of the reprocessing plant at La Hague.

Slide 1

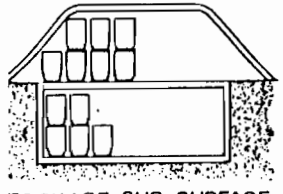
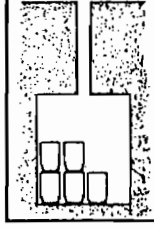
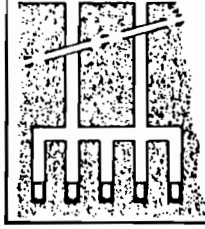
REGLES DE STOCKAGE ET D'ENTREPOSAGE DES DECHETS SOLIDES AU CENTRE MANCHE



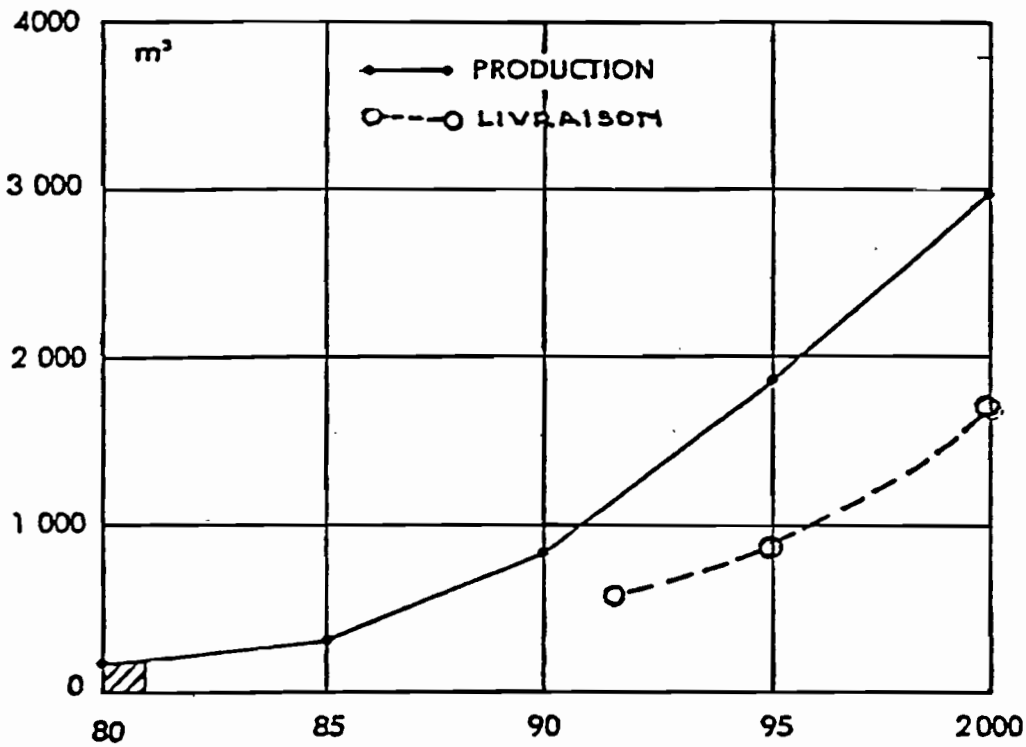
Slide 2

DECHETS RADIOACTIFS

CLASSIFICATION, VOLUME ET GESTION

CATEGORIE "A"	CATEGORIE "B"	CATEGORIE "C"
DECHETS BETA-GAMMA	DECHETS ALPHA	DECHETS VITRIFIES
PERIODES COURTES* : FAIBLE ET MOYENNE ACTIVITE ^{137}Cs 30 ANS ^{90}Sr 30 ANS ^{60}Co 5 ANS ^{55}Fe 2,5 ANS	PERIODES LONGUES* : FAIBLE ET MOYENNE ACTIVITE Ex ^{237}Np 210^6 ANS ^{239}Pu 2.410^4 ANS ^{243}Am 8.10^3 ANS ^{241}Am 4.10^2 ANS	PERIODES LONGUES* HAUTE ACTIVITE* Ex ^{237}Np ^{60}Co ^{239}Pu ^{90}Sr ^{243}Am ^{241}Am ^{243}Am
 STOCKAGE SUB-SURFACE	 STOCKAGE PROFONDEUR	 REFROIDISSEMENT STOCKAGE PROFONDEUR
TRANSPORT-MANUTENTION NON IRRADIANTS < 200 mrad/h IRRADIANTS > 200 mrad/h	TRANSPORT-MANUTENTION NON IRRADIANTS < 200 mrad/h IRRADIANTS > 200 mrad/h	TRANSPORT-MANUTENTION IRRADIANTS >> 200 mrad/h
PRODUCTION CUMULEE EN AN 2000 $\sim$ 800.000 m^3	PRODUCTION CUMULEE EN AN 2000 $\sim$ 45.000 m^3	PRODUCTION CUMULEE EN AN 2000 $\sim$ 3.000 m^3

Slide 3



DECHETS VITRIFIES
PRODUCTION CUMULEE
Jusqu'en 2000

Slide 4 specifies the impact of the threshold choice on the alpha waste mass, and, therefore, on the sizes of the disposal sites. Lowering the threshold by 10 increases by at least 4 the volume of waste to be stored in the geologic disposal sites. In fact, the growing technical difficulties that are associated with threshold lowering might lead to over-classification of some waste, increasing the volume of alpha wastes. Consequently, we must not only fix a threshold value, we must also ensure that the sorting method chosen for waste is technically possible. Another speaker will discuss possible techniques, and I will only give the approach used by ANDRA.

Waste can be categorized in three ways according to its origin. First, for nuclear powerplants and some research facilities, we can be sure without any kind of measurement that the wastes produced under normal operating conditions do not contain any alpha radionuclides. In 1982, this waste represents about 50% of the near-surface waste. Second, the alpha contents assessment for some waste can be made by simple measurement techniques. For example, the waste resulting from processes like liquid effluents treatment (e.g., filtration, evaporation, and incineration) has a homogeneous stage that allows sampling for radionuclide content in the laboratory. Also, waste containing a known homogeneous mixing of easily measurable gamma emitters associated in constant proportion to alpha emitters allows easy gamma external measure, which can be done on each package to give the exact alpha contents. This is the case for waste produced during the first stage of reprocessing. A final example is waste without too many beta-gamma emitters. For this waste gamma spectrometry gives direct assessment of alpha contents for each package. This is the case for light technological waste (e.g., clothes or plastic) contaminated by plutonium only, such as the waste of fast reactor fuel fabrication. In 1982, the second category of waste represents about 30% of the near-surface waste. The third approach concerns waste that cannot be sorted by the two preceding approaches. An assessment can be made package by package by more sophisticated procedures such as high resolution gamma spectrometry, prompt neutron counting, and neutron activation. In 1982, this category of waste represents less than 20% of the near-surface waste. These three techniques used alone or combined permit the sorting of waste containing more than 0.1 Ci/ton.

ANDRA has an insurance and quality control procedure for controlling the alpha radionuclide contents of packages. Waste cannot be accepted for near-surface disposal at Centre de la Manche unless the producer has proved that the alpha content has been determined by a safe and reliable method. ANDRA's control procedure begins in the producer's installation and concerns manufacturing and processes and the measurement techniques of the waste that will be submitted to ANDRA. The quality assurance system is completed by overcontrol at random on the delivered waste packages. If the measurements cannot ensure that the alpha content is below the threshold, or if there is any doubt about measurement reliability, the packages are not accepted

Slide 4

ALPHA CONTAMINATED WASTE PRODUCTION
IN FRANCE
(1,945 → 2,000)
(m^3)

	$\alpha < 0.05$ Ci/t	0.05 Ci/t $< \alpha <$ 0.5 Ci/t	0.5 Ci/t $< \alpha$
Reprocessing	85,000	29,000	42,000
Army	8,000	6,000	1,500
Fuel Fabrication	35,000	8,000	2,000
Total	128,000	43,000	45,500

for near-surface disposal. They are temporarily stored before final geologic disposal.

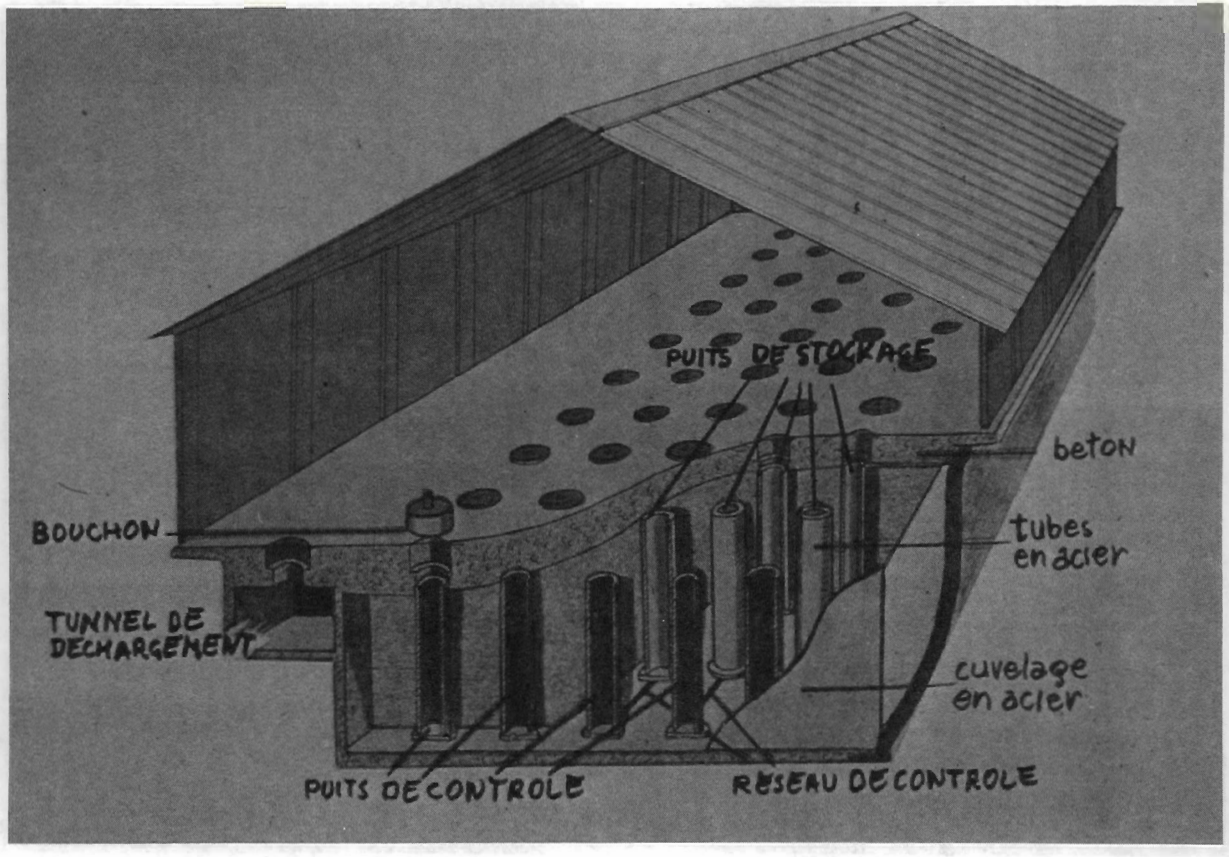
Alpha-contaminated waste management in France is, or will be, part of the national radioactive waste management program that is now under governmental examination. Only one disposal center, the Centre de la Manche, exists in France, and it is reserved for low-level radioactive waste with alpha content below 1 Ci/m^3 or between 500 and 1000 nCi/g (Slide 5). This waste is systematically immobilized in concrete or bitumen and disposed of in concrete if the alpha content is above about 25 nCi/g. Alpha waste is now temporarily stored on the production site at the Centre de le Manche. The following slides present facilities at Centre de la Manche. One, for small packages, has a well dug in a concrete block. Another is a cave for drums, an another shows a new installation for 200-L drums containing alpha-emitting waste. These facilities are located at Centre de la Manche.

Because alpha-waste production is increasing and temporary storage facilities are being saturated (and cannot be multiplied for safety reasons), ANDRA must be ready to build and operate an alpha-waste disposal by 1990.

Slide 14 gives a schedule of the program proposed by the French government. Discussions on proposals are continuing. You can see an increase in waste production after 1988 when the reprocessing plant will be in operation. I would like to add that France must find a clear choice of a technical fundamental option for the disposal of radioactive waste. We are determining a threshold value to distinguish between alpha wastes to be disposed of in geologic disposal and low- and medium-level waste that can be disposed of in near-surface disposal. This choice and this threshold are the objects of a general consensus by the national bodies concerned with nuclear waste management. The choice and the threshold should be soon officialized by the government as part of the national examination and management program. It is urgent that the government, in its national process, authorize the in-situ research and location of an alpha disposal site to be built by ANDRA around 1990. May I conclude by emphasizing our interest in an international consensus on the threshold of alpha contents for near-surface disposal of waste.

Slide 5

Slide 6


PUITS DE STOCKAGE
beton
BOUCHON
tubes
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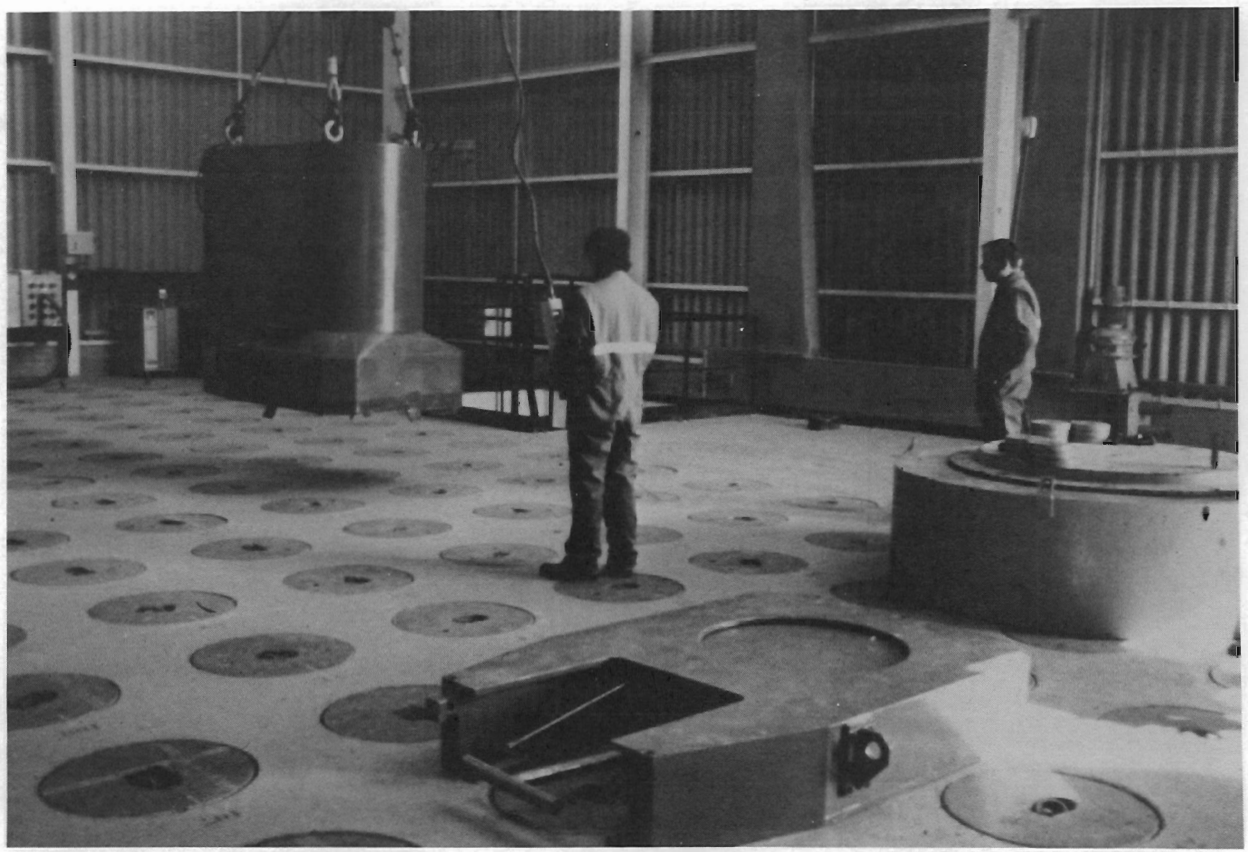
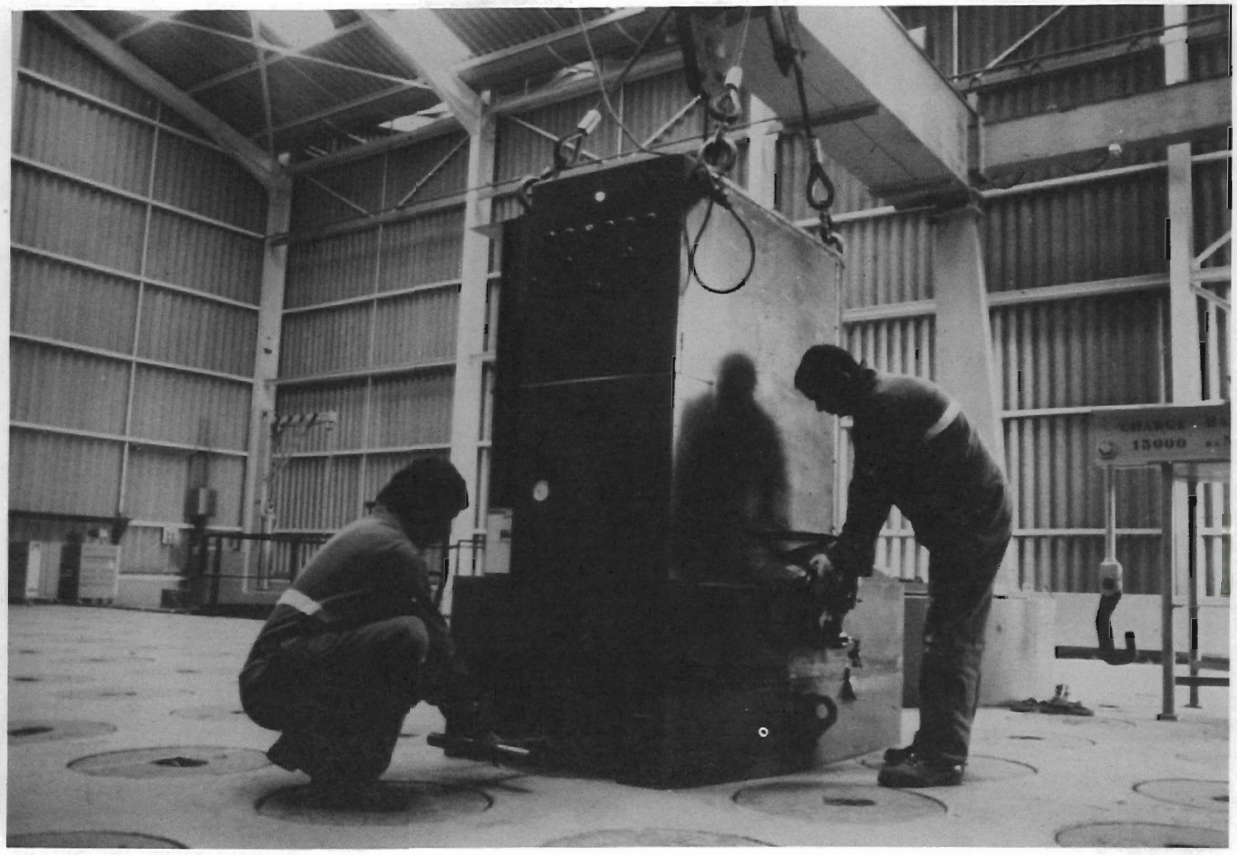
TUNNEL DE
DECHARGEMENT
cuvelage
en acier
PUITS DE CONTROLE
RESEAU DE CONTROLE

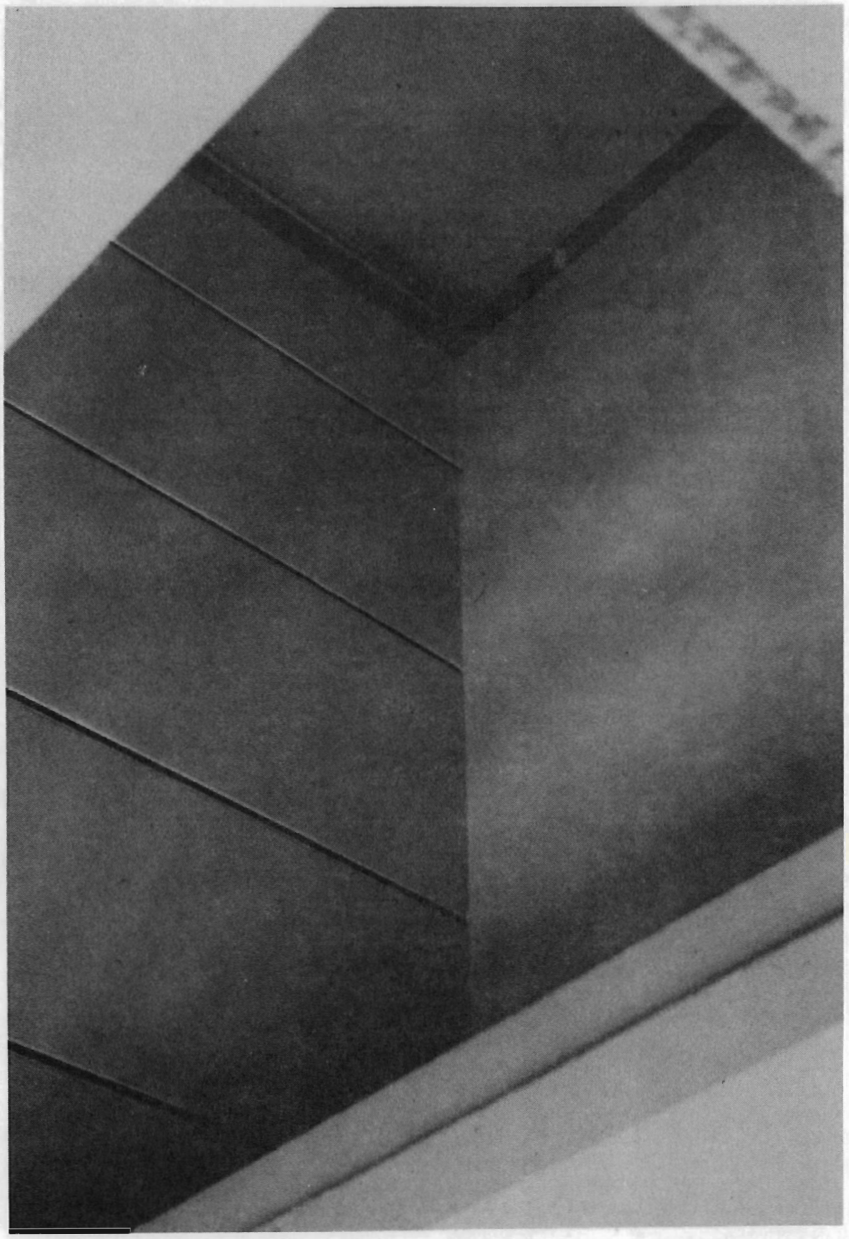
Slide 7



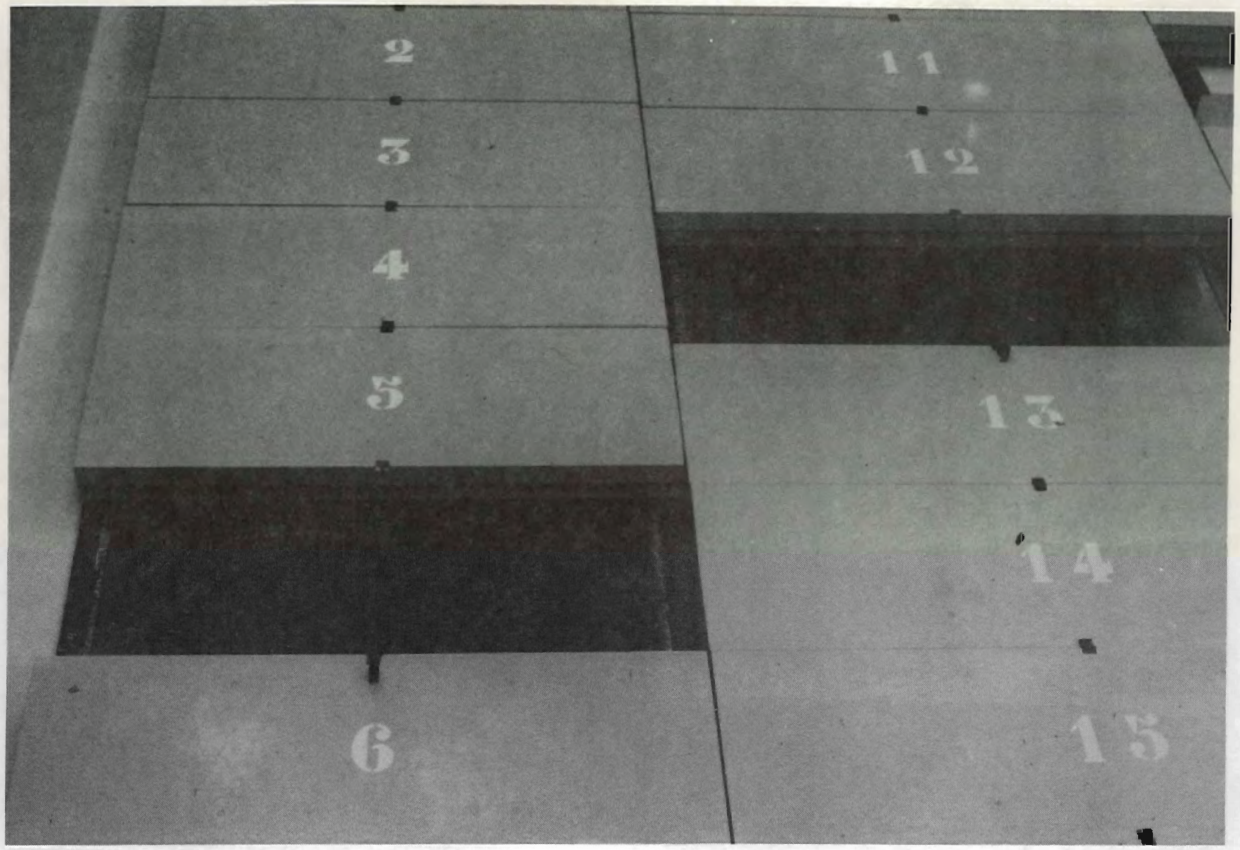
Slide 8



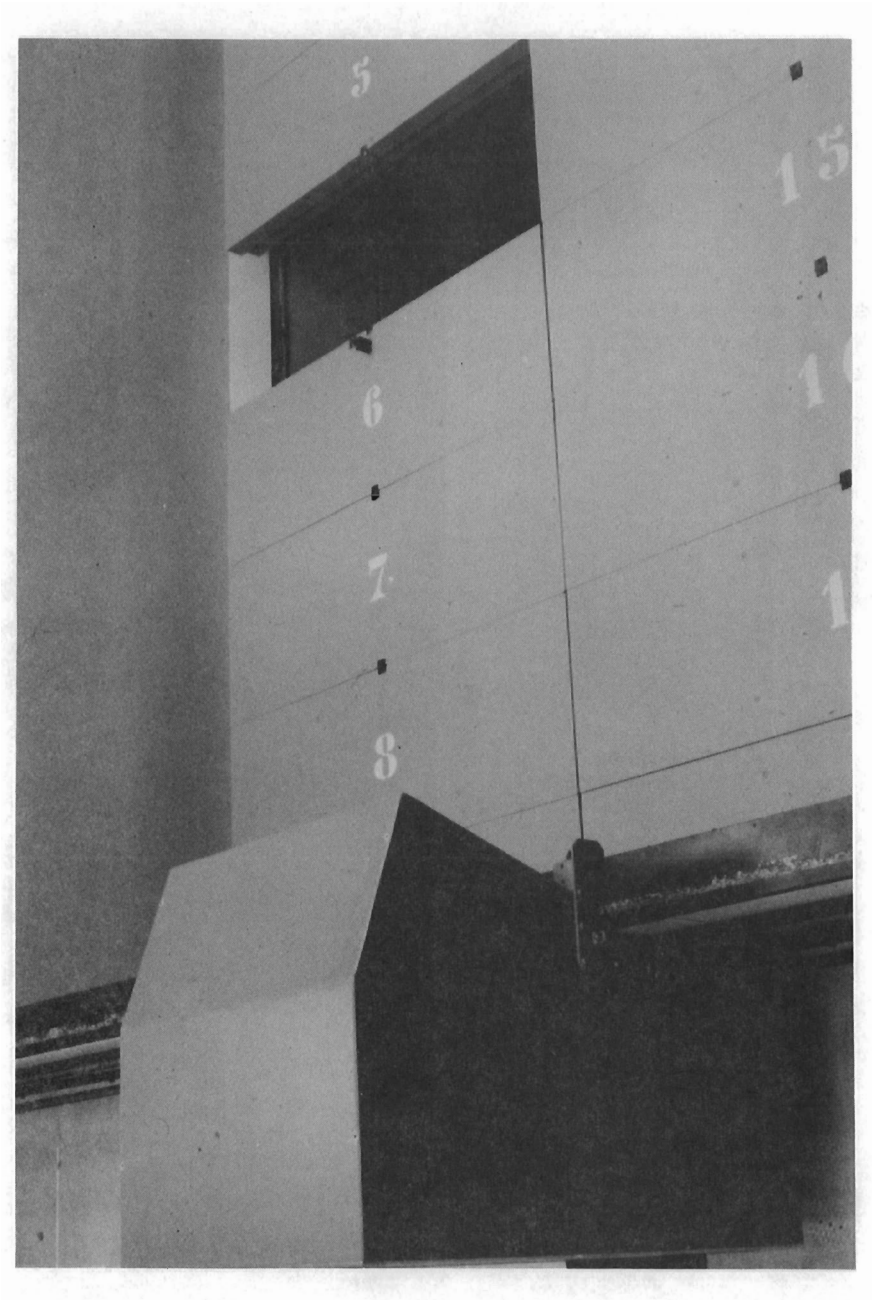
Slide 9



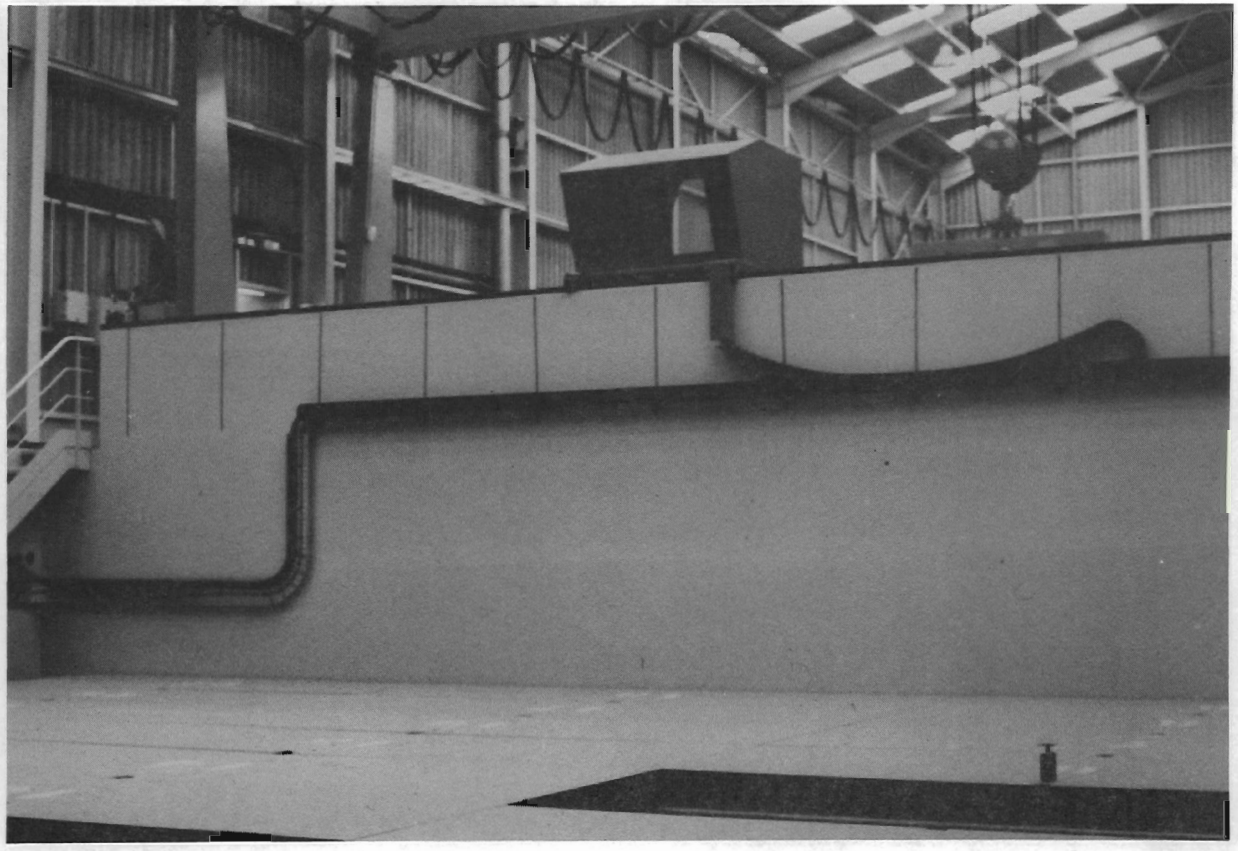
Slide 10



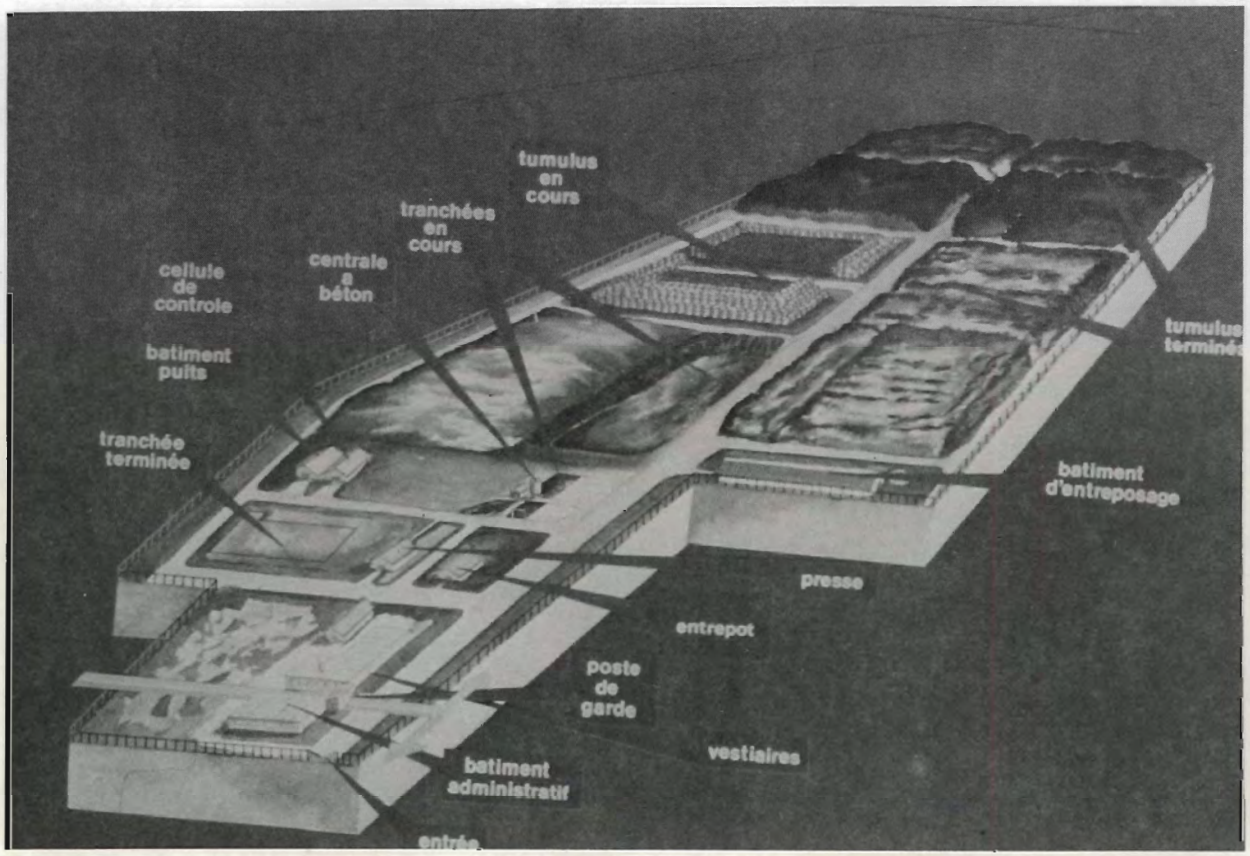
Slide 11



Slide 12



Slide 13


tumulus
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tumulus
terminé
batiment
d'entreposage
presse
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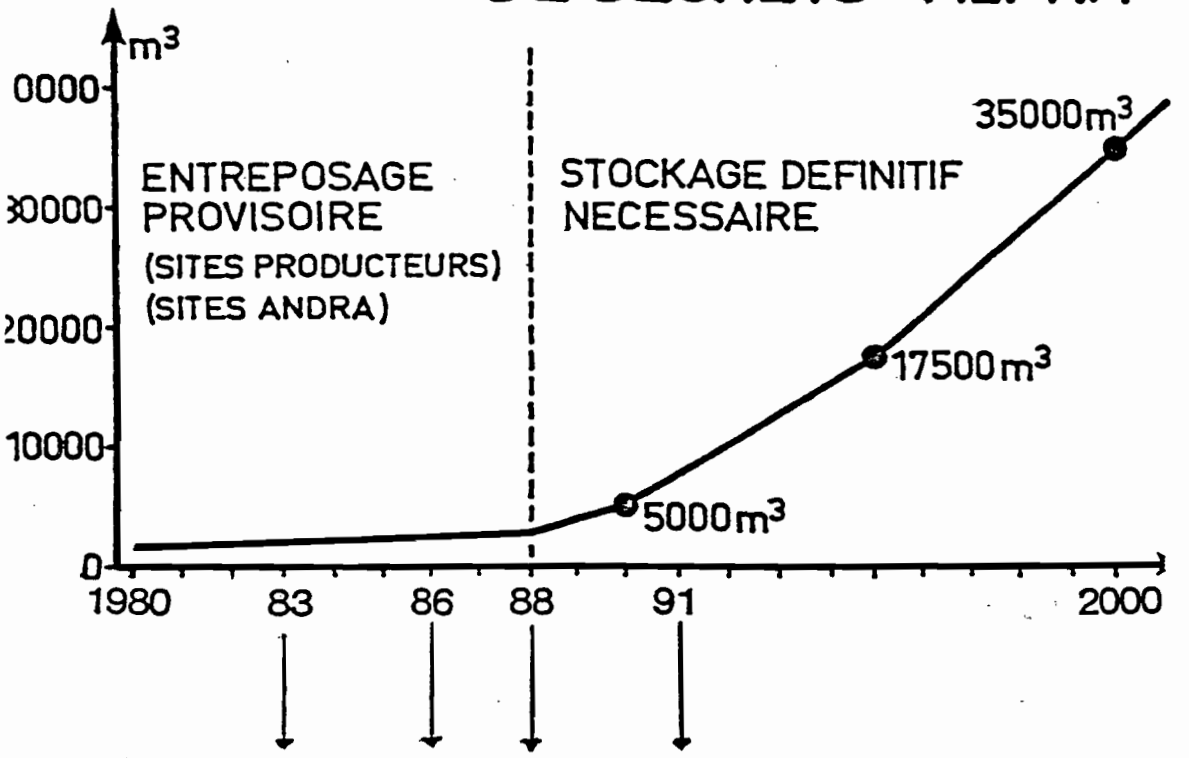
garde
vestiaires
batiment
administratif
entrée

Slide 14

PREVISIONS DE LIVRAISON DE DECHETS "ALPHA"



*PRESELECTION DES SITES

*CHOIX DU SITE

*DEBUT DES TRAVAUX

* MISE EN SERVICE

ANDRA

8-82

Dr. Jaques Pradel, CEA, France

Lakey: We have as the next speaker Dr. Jacques Pradel, chief of services of the Atomic Energy Commission in France.

Pradel: I shall be very short. Two of the criteria proposed by EPA are not in accordance with new concepts that we are developing in our country. First, we think that it is unrealistic to consider that no control can be maintained after 100 years. Society must maintain a general radioactive survey of disposal sites. That is done for other risks like chemical or bacterial contamination, especially for food and housing, because we know now that even these have natural radioactivity. A general survey can determine the importance and the source and allow us to control the source. If society loses its knowledge, dangers from low doses of radiation will not be taken into account because more important and difficult tasks will exist. Second, do we think that we know what will happen after 1000 years? Can projections actually be taken into account in deciding what we have to do now? Engineers and economists are unable to evaluate such long-term effects. Projections may provide best criteria, but they are not absolute equivalents.

Nuclear energy is the only field where people seem to be concerned with effects 10,000 years away. The problem of storing waste and how effective that storage will be in the future may be considered, but our approach must be general instead of considering the very small difficulty coming from low doses of radiation. I believe that the most important action is to expand our knowledge. We must trust our society. Life will last on the earth only if man continues to increase his scientific knowledge, because many risks will stay despite anything we can do. Many think we cannot accept the responsibility for harm to people who will be alive in 10,000 years, but we have to consider, philosophically or pragmatically, that we have no special reason to be more concerned about these people than we are about the people alive today. Our chance of saving the life of somebody now with the same money may be better than our chance of saving someone in the future. If these two criteria could be admitted, problems should be easier to solve and public acceptance might be obtained with less difficulty.

Dr. Gerard Frejaville, CEA-CEN Cadarache, France

Lakey: We have now Dr. Gerard Frejaville from the Atomic Energy Commission in France.

Frejaville: I shall try to present briefly how we have met regulation and engineering problems. I have to classify alpha waste differently than Mr. Lavie did; I use the engineering consideration in which the measurement of plutonium has to be made in a 220-L drum for different thresholds. However, the information in our presentations is compatible.

We have determined the quantity of plutonium corresponding to the threshold according to the quality of plutonium we have. In France we have two qualities of plutonium: the plutonium obtained in the natural uranium graphite gas reactors and the plutonium obtained in PWR reactors. The quantities of these two grades of plutonium are different. In nanocuries per gram, 1000 CMA (for matrix density of 0.2 g/cm^3) corresponds to 230 nCi/g. For clarity, in Slide 1 I gave you the isotopic composition we have taken for this classification of waste. This is for the plutonium we now have in the reprocessing plant with this burnup of 30,000 MWd/ton. The amount of plutonium-238 is very important for the radiotoxicity of this plutonium (Slide 2). This is a topic composition, and the amount of plutonium-238 has to be determined very precisely to have a good classification of the waste. However, we have no big problems with plutonium from the natural uranium graphite gas reactor, because the plutonium-238 production is low (Slide 3).

Slide 4 summarizes the problem that appears. You must check the waste for the influence of the grade of the plutonium you have (the 220-L drum corresponds with miltheuval). That is to say, for matters of zero density of 0.2 (230 nCi/g), the quantity of plutonium depends on the isotopic composition of the plutonium contained in the waste.

To monitor waste we have three principal methods in France (Slide 5): (1) high-resolution gamma spectrometry, (2) passive neutron counting associated with electronic, assuming separation by spontaneous fission of alpha and neutrons, and (3) active neutron counting with californium-252 source with the analyzer technique of delayed neutron counting, which is quite different from the Los Alamos presentation yesterday.

To monitor the waste of different radiation levels, we have built a device that combines the three methods. With the gamma spectrometer (Slide 6) we can scan all of the drum. You will see the detection block and the simulation of the neutron counters for passive or active neutron counting.

Slide 7 shows the storage of the californium source, which can be put in the detection block. To obtain a uniform irradiation of the drum,

Slide 1

WASTE CLASSIFICATION

QUANTITY OF PLUTONIUM IN 220 L TANK

	Pu UNGG	Pu PWR
1000 CMA	104 MG	28,5 MG
20000 CMA	2 G	570 MG
200000 CMA	20 G	5,7 G

FOR MATRIX DENSITY = 0.2 G/CM^3

1000 CMA $\Longrightarrow$ 230 NCI/G

Slide 2

RADIOTOXITY

PWR Pu TYPE 32000 MWD/T

NUCLIDE	ISOTOPIC COMPOSITION (%)	QUANTITY FOR 1000 CMA - TOTAL (MG/M^3)	PART (%)
Pu 238	1.74	2.26	77.3
Pu 239	57.9	75.0	9.3
Pu 240	22.8	29.6	13.4
Pu 241	11.9	15.4	-
Pu 242	5.7	7.4	-
		129.66	

1000 CMA LIMIT = 28.5 MG FOR A 220 L TANK

Slide 3

RADIOTOXITY

NUGG Pu TYPE 3500 MWD/T

NUCLIDE	ISOTOPIC COMPOSITION (%)	QUANTITY FOR 1000 CMA - TOTAL (MG/M^3)	PART (%)
Pu 238	0.1	0.47	16.1
Pu 239	78.0	367.8	45.3
Pu 240	18.0	84.9	38.5
Pu 241	3.5	16.5	-
Pu 242	0.4	1.9	-

1000 CMA LIMIT = 104 MG FOR A 220 L TANK

Slide 4

PLUTONIUM ISOTOPIC COMPOSITION INFLUENCE

REACTOR	IRRADIATION MWD/T	PLUTONIUM QUANTITY FOR 1000 CMA IN A 220L DRUM (MG)
NUGG	3500	102
	6000	78
PWR	15000	70.3
	24000	42.2
	33000	28.5

Slide 5

WASTE MONITORING

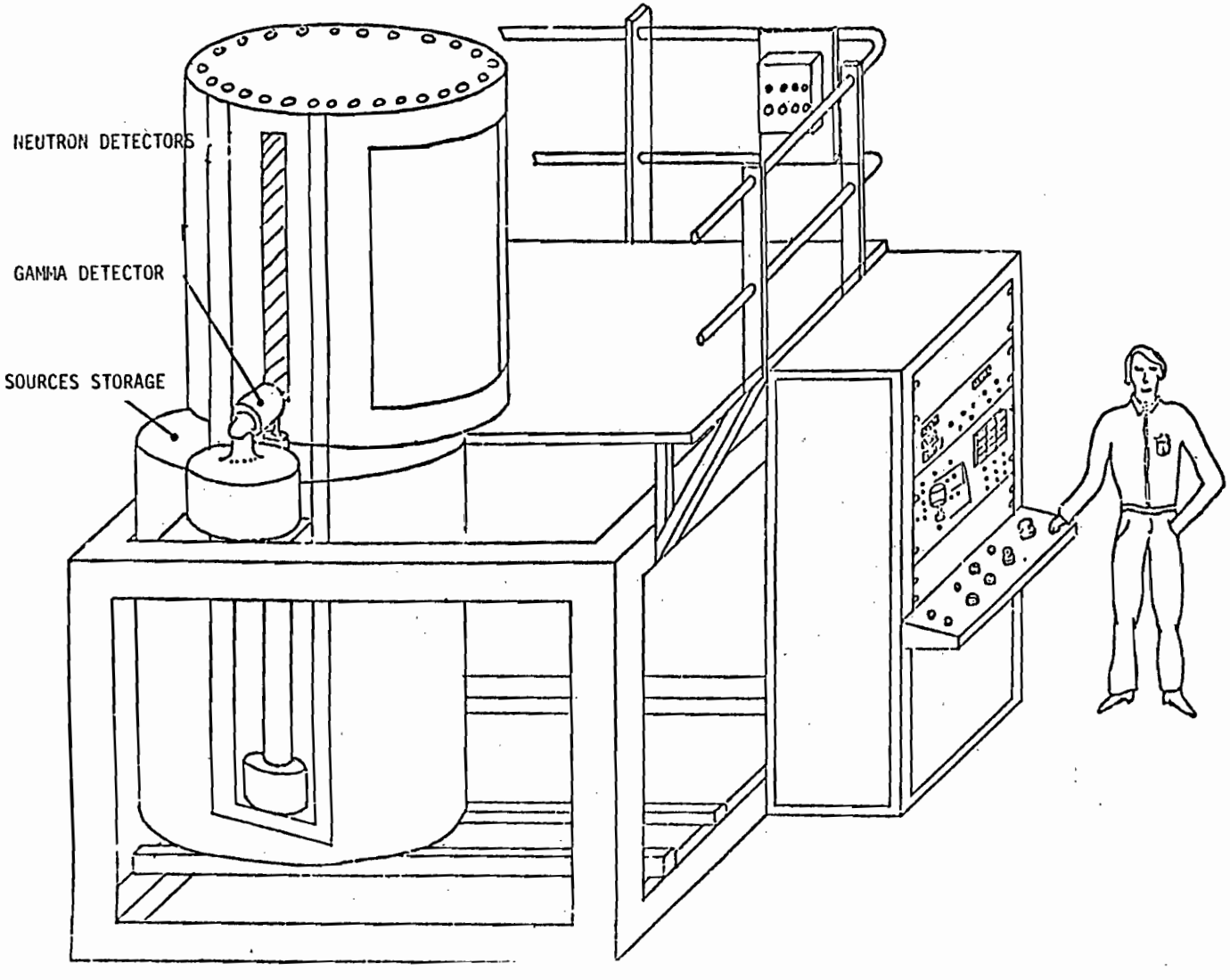
STUDIED METHODS

1 - HIGH RESOLUTION GAMMA SPECTROMETRY

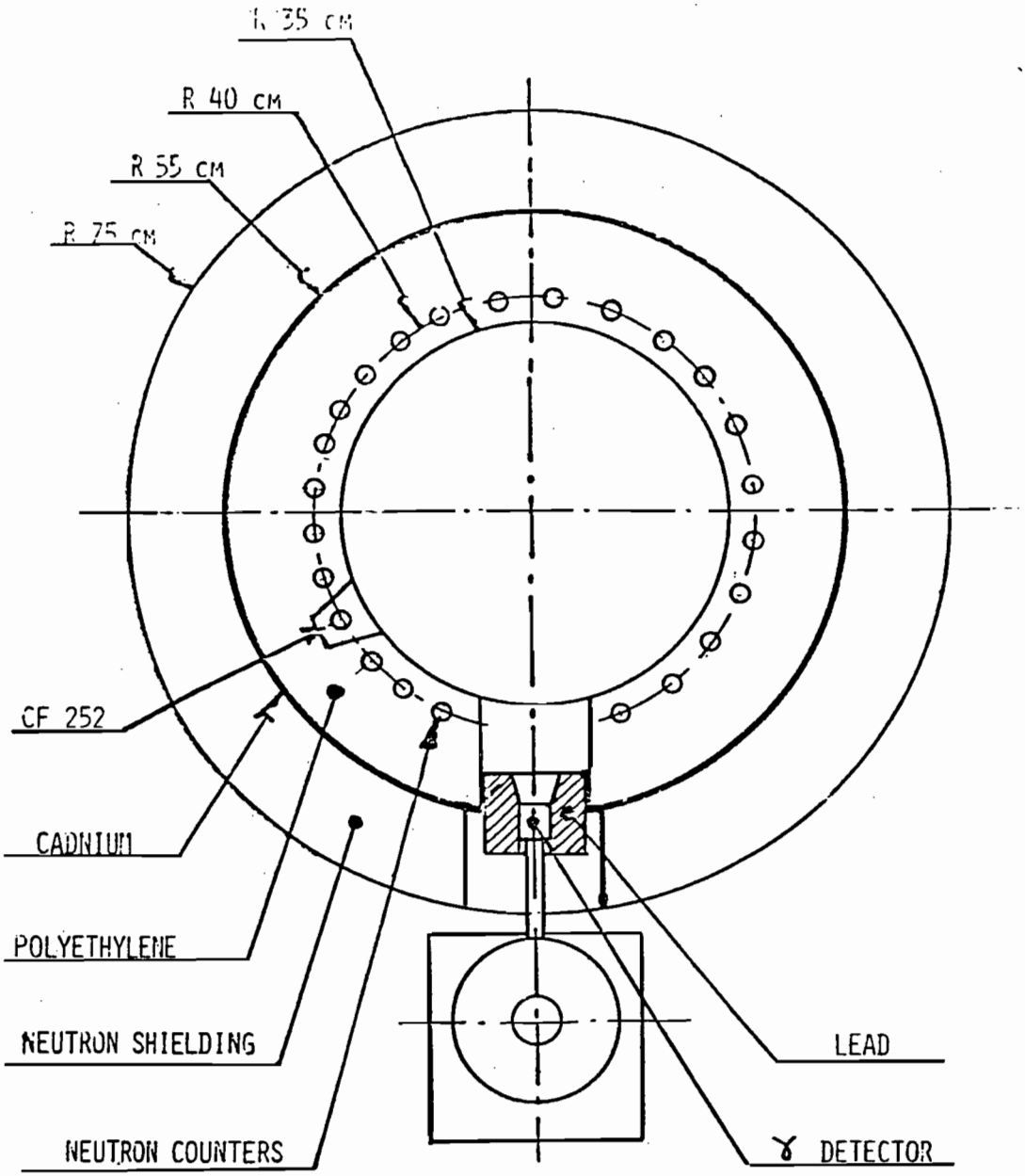
2 - PASSIVE NEUTRON COUNTING
(S.F. - α, N SEPARATION)

3 - ACTIVE NEUTRON COUNTING
(DELAYED NEUTRONS COUNTING)

Slide 6



Slide 7


R 35 CM
R 40 CM
R 55 CM
R 75 CM
CF 252
CADNIUM
POLYETHYLENE
NEUTRON SHIELDING
NEUTRON COUNTERS
LEAD
γ DETECTOR

we have three californium sources on different levels. These provoke fissions of the fission material in the drum.

Here you have the chain of the detection block. You have here the gamma detector with its collimation. (It is important to have collimation here.) The neutron counters and this channel can be used for passive neutron counting or to put the californium source in irradiation. This part is made of polyethylene to moderate for increased sensitivity countings. The neutron shielding, which has a cadmium sheet to cut all the thermal neutrons that can go from the environment on the neutron counters, is important.

Using this apparatus we have, I can try to give you the sensitivity limits we have reached for the three techniques (Slide 8). We have principally worked on the low density matrix; these wastes constitute about 80% of the low-level waste of the processing plant, and so we have work for matrix density minus and $0.3/cm^3$. The tank was limited to 220 L and no fission product contamination and we are considering only fresh alpha waste, so the emission content is very low compared to the plutonium content. The counting time is 1000 seconds. I have a comment on this point. Our counting time is always 1000 seconds because, for new reprocessing plants that are now under construction, this time is the upper limit of time that we can count the waste drum. It's a problem of currency and, in some cases, this counting time is a physical pathway for the dismantlement of some workshop.

We use a collimator addressed to the metric density. Using plutonium-241, our detection limit is 20 mg of plutonium (PWR plutonium obtained at 32,000 MWd/ton). For plutonium-239, our detection limit is greater than 1 g of plutonium.

When there are a few grams of plutonium in the 220-L drum of waste, we can measure the isotopic composition. Performance of this technique is limited mainly by the number of count in the peak, so in fact, statistical error in the surface area measurement with this limitation occurs. This number of count of the peak results from that attenuation factor because we are using low energy gamma rays and the metric density has a great effect on the attenuation of the gamma ray. The other limitation is the counting time.

For passive neutron counting (Slide 9) we have all the same conditions of measurement and we have to take into the configuration 24 helium-3 counters. This gives us an efficiency of about 8%. The counting time is always 1000 seconds.

Another detection limit is about 10 mg of plutonium from the PWR reactor. The performance limitation of this method is the level of background. In the laboratory you can reach a limit of performance lower than that, but when you are in the plant environment, the level of background is so high that you cannot reach the limit of performance that you reach in the laboratory. It will be necessary

Slide 8

GAMMA SPECTROMETRY

SENSITIVITY LIMITS

MEASUREMENTS CONDITIONS

- MATRIX DENSITY < 0.3 G/CM^3
- TANK ≤ 220 L
- NO FISSION PRODUCT CONTAMINATION
- AMERICIUM 241 < 1% PLUTONIUM
- COUNTING TIME = 1000 S
- COLLIMATOR ADJUSTED TO THE MATRIX DENSITY

WITH 208 KEV OF PU 241

DETECTION LIMIT = 20 MG PWR PU

WITH 414 KEV OF PU 239

DETECTION LIMIT = 1 G PWR PU

FOR A FEW GRAMMES OF PLUTONIUM IN THE SAME CONDITIONS, IT IS POSSIBLE TO CONTROL THE PLUTONIUM ISOTOPIC COMPOSITION.

LIMITATION OF PERFORMANCE :

NUMBER OF COUNTS IN THE PEAKS DUE TO : - ATTENUATION FACTORS
- COUNTING TIME.

Slide 9

PASSIVE NEUTRON COUNTING
SENSITIVITY LIMITS

MEASUREMENTS CONDITIONS

- MATRIX DENSITY < 0.3 G/CM^3
- TANK $\leqslant$ 220 L
- FISSION PRODUCT CONTAMINATION < 1 REM/H
- CURIUM CONTENT - $< 10^{-6}$ PLUTONIUM
- 24 HE 3 COUNTERS $\neq 8$ %
- COUNTING TIME = 1.000 S

DETECTION LIMIT : 10 MG PWR PU

LIMITATION OF PERFORMANCE :
LEVEL OF BACKGROUND

---

in this case to build another building to make some measurements in the plant.

For the active neutron counting techniques (Slide 10), we use californium source and 32 helium-3 counters, getting about 9% efficiency. The limit of performance is 0.1 g uranium-235 and roughly 1 g plutonium from a PWR. Again, the level of background is the limitation of performance. It's always the same problem for neutron countings, and another problem is the intensity of the neutron source with use of californium source; we have only 10^9 neutrons per cm^2.

Through all this study, we have reached the main conclusions of our waste measurement policy (Slide 11). We have concluded that there is no universal technique; to obtain a high level of confidence in the measurement threshold, a combination of two methods is needed. One important point is that in all cases the plutonium isotopic composition is needed. Sometimes you can work with an assumption of the isotopic plutonium composition. In other cases, like gamma spectrometry, you can't obtain the necessary verification that there is a great quantity of plutonium in the drum. We obtain the optimum measurement under conditions that contradict the engineering design in plants; we prefer to perform the measurement on the little volumes near the origin of the waste before treatment or conditioning. We recognize that the reprocessing plant will work on separated waste. The waste will be identified by identification sheet, in order to have minor isotopic plutonium composition of the plutonium containing the waste.

I will now give you the procedure we are using in the reprocessing plant (Slide 12). Again, the sensitivity limits that I have given are not sensitivity limits obtained in laboratory. Now, until modification, we work on 220-L tanks (metric density 0.3; counting time neutron plus gamma 1000 seconds). The measurements with passive neutron counting and gamma counting are performed simultaneously with the scanning done when the drum is rotating. We assumed the plutonium isotopic composition, and in preliminary calculations we have classified waste as a mass of plutonium that is correlated to the number of spontaneous fission neutrons.

We obtained spontaneous fission neutron counting in our experiments (Slide 13). We performed the correction of background and metric densities, so we have the spontaneous fission neutron counting.

For gamma spectrometry, we make the peak identification. Peaks affect measurement and a metric density correction for the attenuation factor, so we obtain two quantities for the peak at 208 KEV and 414 KEV. Then we apply the following procedure.

First, the number of neutrons is smaller than the number of neutrons associated with 1000 CMA. The gamma spectrometry result is not used

Slide 10

ACTIVE NEUTRON COUNTING

SENSITIVITY LIMITS

MEASUREMENT CONDITIONS

- MATRIX DENSITY < 0.3 G/CM^3
- TANK ≤ 220 L
- FISSION PRODUCT CONTAMINATION < 1 REM/H
- 252 CF SOURCE = 10^9 N/S
- 32 HE 3 COUNTERS - ≠ 9 %
- MEASUREMENT TIME = 1.000 S

U 235 ≠ 0.1 G

PWR PU ≠ 1 G

LIMITATION OF PERFORMANCE :

LEVEL OF BACKGROUND

Slide 11

MAIN CONCLUSIONS ON THE MEASUREMENT METHODS

- THERE IS NOT ANY UNIVERSAL TECHNIQUE
- IN ORDER TO OBTAIN A HIGH LEVEL OF CONFIDENCE IN THE MEASUREMENT RESULT A COMBINAISON OF TWO METHODS IS NEEDED.
- IL ALL THE CASES PLUTONIUM ISOTOPIC COMPOSITION IS NEEDED. IN SOME CASES VERIFICATION IS POSSIBLE
- OPTIMUM MEASUREMENT CONDITIONS :
  - NEAR THE ORIGIN OF THE WASTE
  - LITTLE VOLUMES
  - PRIOR ANY TREATMENT OF CONDITIONING
  - SEPARATED WASTES WITH IDENTIFICATION SHEET

Slide 12

MEASUREMENT PROCEDURE

MEASUREMENT CONDITIONS

- 220 L TANK
- MATRIX DENSITY < 0.3 G/CM^3
- COUNTING TIME (N + γ) = 1.000 S

PLUTONIUM ISOTOPIC COMPOSITION APPROXIMATIVELY KNOWN
(FOR EXAMPLE PWR FUEL - 25.000 MWD/T < BU < 35.000 MWD/T)

PRELIMINARY CALCULATIONS GIVE :

1.000 CMA $\longrightarrow$ M_0 (Pu G) $\longrightarrow$ N_0 (S.F. N)

20.000 CMA $\longrightarrow$ M_1 (Pu G) $\longrightarrow$ N_1 (S.F. N)

200.000 CMA $\longrightarrow$ M_2 (Pu G) $\longrightarrow$ N_2 (S.F. N)

Slide 13

MEASUREMENT PROCEDURE

EXPERIMENTAL RESULTS

PASSIVE NEUTRON COUNTING

CORRECTIONS PERFORMED

- BACKGROUND
- MATRIX DENSITY

⇓

S F N

GAMMA SPECTROMETRY

- PEAK IDENTIFICATION
- PEAK SURFACE MEASUREMENT
- MATRIX DENSITY CORRECTION

⇓

G 208 (Pu 241 - 208 KeV)

G 414 (Pu 239 - 414 KeV)

in this case, and the alpha wastes are classified under 1000 CMA (Slide 14).

In the second case, the neutron counting is between the 1000 and 10,000 CMA limits, so with the neutrons you have mass of plutonium with 208 gamma rays (Slide 15). We have another mass of plutonium determined by gamma spectrometry, so we have two determinations of the same amount of plutonium. If the difference between the two determinations is less than 30%, the waste is classified 20,000 CMA. If the difference is greater than 30%, we go to the other case.

In the other case, we are between the two upper limits (Slide 16). We determine, by neutron of mass of plutonium or by the two gamma rays used, two masses of plutonium determined by gamma spectrometry. We take the average value of the two, and we apply the correlation test of 30%. If the agreement is good, we use the average of the values of plutonium of the two determinations.

If internal correlation is less than 30% (we have no correlation between the results), we check on the two masses in fact, which can permit us to verify each assumption on the isotopic composition of plutonium. In this case, we use only the plutonium-239 for the mass of plutonium (Slide 17). Also in this case, the last case, we have much the same procedure; we have the gamma rays, and we apply the same correlation test, but in this case all the gamma peaks permit verification of the isotopic composition to be taken into account. In this case, the amount of plutonium is generally the wastes that are treated to recover the plutonium, but in the reprocessing plant we are now using the two techniques for passive neutron and gamma counting. Experience will show us if the active neutron counting technique is needed when the isotopic composition and the metric density are well known.

Slide 14

MEASUREMENT PROCEDURE

CASE N° 1

$$\boxed{N < N_0}$$

GAMMA SPECTROMETRY RESULT NOT USED

↓

$$M\ Pu < M_0$$

α WASTES < 1.000 CMA

Slide 15

MEASUREMENT PROCEDURE

CASE N° 2

$$N_0 \leq N \leq N_1$$

$$N \longrightarrow M_N$$

$$G\ 208 \longrightarrow M_\gamma$$

I F

$$\left| \frac{M_\gamma - M_N}{M_N} \right| \leq 30\ \%$$

$$M\ Pu = \frac{M_N + M_\gamma}{2}$$

α WASTES < 20.000 CMA

I F

$$\left| \frac{M_\gamma - M_N}{M_N} \right| > 30\ \%$$

SEE CASE N° 3

Slide 16

MEASUREMENT PROCEDURE

CASE N° 3

$$N_1 \leq N \leq N_2$$

N	M_N
G208	$M_{\gamma 1}$
G414	$M_{\gamma 2}$

$$\longrightarrow \quad M_\gamma = \frac{M_{\gamma 1} + M_{\gamma 2}}{2}$$

I F $\left| \dfrac{M_\gamma - M_N}{M_N} \right| \leq 30\ \%$

$$\longrightarrow \quad M_{Pu} = \frac{M_N + M_\gamma}{2}$$

α WASTES < 200.000 CMA

I F

$$\left| \frac{M_\gamma - M_N}{M_N} \right| > 30\ \%$$

- CHECH ON $M_{\gamma 1}$ AND $M_{\gamma 2}$
- USE OF $M_{\gamma 1}$ ALONE
- SEE CASE N° 4

Slide 17

MEASUREMENT PROCEDURE

CASE N° 4

$$N_2 \leq N$$

G 208 $\longrightarrow$ M Pu 241

G 414 $\longrightarrow$ M Pu 239

USING CALCULATED TABLES, FROM M Pu 241/ M Pu 239 RATIO WE DEDUCE :

$$M_N$$

$$M_\gamma$$

I F

$$\left| \frac{M_\gamma - M_N}{M_N} \right| \leq 30\ \%$$

$$\downarrow$$

$$M\ Pu = \frac{M_N + M_\gamma}{2}$$

WASTES > 200.000 CMA

I F

$$\left| \frac{M_\gamma - M_N}{M_N} \right| > 30\ \%$$

$$\downarrow$$

PARTICULAR PROCEDURE

Denis Thackrah, Nuclear Installation Inspectorate, England

Lakey: Our last foreign speaker is Dr. Denis Thackrah, from Nuclear Installation Inspectorate, United Kingdom.

Thackrah: I shall not speak very long, and I shall confine my remarks to our disposal policy.

First, let me say what the, United Kingdom (UK) does now about disposal of alpha wastes. We have two disposal routes open to us. The first is trench burial at the Drigg site in Cumbria. The authorization there, as Pete Lakey indicated, is 20 nCi/m^3. I've done some unusual isometrical juggling with that number, using an average density of 0.2 (a specific gravity of 0.2). The waste that goes into the trench at Drigg is mainly paper, fairly light-weight, non-compacted material. I estimate that 20 nCi/m^3 is equivalent to 100 nCi/g. I must stress that although 100 nCi/g is the authorized limit, the operator of the trench, British Nuclear Fuels Ltd., does not use the trench for the disposal of known alpha-contaminated materials. It is only used for suspect alpha material so that, in actual fact, the disposal there is very much lower than the authorized 100 nCi/g.

Our second disposal route is sea dumping, which we share with Belgium. The limits we adopted are the same as the ones that have just been indicated to you: one alpha curie per ton with a separate limit of 15 g of plutonium per 200-L drum. We are now dumping into the Atlantic Ocean something over 2000 alpha Ci/year.

Now let me go on to our future plans and proposals. Pete Lakey, in his excellent talk, was slightly wrong in the statement he made about the UK government policy. The UK government intends to store heat-generating wastes above ground for at least 50 years. We intend to search for suitable disposal sites for intermediate-level wastes and to dispose of wastes into those sites as soon as possible.

We are considering several types of intermediate-level waste disposal sites. First we are considering an engineered trench 20 to 30 m deep. We think it may be possible to have an alpha disposal limit there of 3 Ci/m^3. We hope to have that facility operating by 1990.

Next, we're searching for a modified mine or specially-built facility about 100 m deep, which we feel could accept alpha-contaminated material up to 50 alpha Ci/m^3. We feel that could be commissioned by about 1992.

Finally, we're considering specially-built repositories 300 m or considerably more than 300 m deep for the unrestricted disposal of alpha wastes. Commissioning date is likely to be beyond 2030. These dates I've indicated (1990 for the trench, 1992 for the modified mine, and 2030 for the specially-built repository) are dates that we consider technically achievable. I stress the word "technically"

because political considerations may cause delays. By political considerations, I mean questions raised by governmental bodies, planning boards, and local citizen groups.

How will we justify the limits on alpha content that I've just indicated: 3 alpha Ci/m^3, 50 alpha Ci/m^3, and the unrestricted? We feel that the numbers are indicative only, and we don't wish to establish a limit on alpha content that would be immutable. We would prefer to establish an alpha-content limit that was site specific. The limit would be set after evaluation of the waste form, the disposal site, and available alternatives.

We are endeavoring to determine these limits by two approaches: (1) a deterministic analysis carried out by our National Radiological Protection Board, which is looking at pathways, doses, and risks and (2) a parameter variability approach based on the method the Canadians used when they were considering disposal of spent fuel.

Finally, I'd like to say a word about our new Nuclear Industry Radioactive Waste Executive (NIREX). This is an executive directed by the various waste producers: British Nuclear Fuels, Atomic Energy Authority, and the Ministry of Defense. The executive has been established to search for disposal sites and to organize sea dumping. Its first land disposal site will be an engineered trench. Its second will be a modified mine (if one can be found) or specially-built repository.

Lakey: Thank you Dr. Thackrah. We have time to entertain about five or six questions.

Alan Moghissi, Environmental Protection Agency: Some of us who have been concerned with the management of waste and its environmental impact have favored volume reduction whenever possible by incineration, evaporation, or other techniques. In some cases the values from our foreign participants were given in nanocuries per gram. In other cases the values were given in equivalent values per volume. If volume reduction practices were exercised, regardless of the threshold, some of the wastes suddenly would jump over the threshold and would no longer be considered low-level waste. This appears to be a dilemma. I wondered how this dilemma is solved in other countries.

Thackrah: What I say is really a personal rather than a UK comment. I've never been in favor of volume reduction because you don't get rid of any curies by reducing the volume. You still have the same amount whatever you do, and the more processes you have, the more you increase worker doses and the potential for accidents. I can see little merit in volume reduction.

Dejonghe: I'm not in agreement with our British colleague, but I confess that the question is a difficult one to answer. You can

approach this problem in at least two ways. First is economics. In Belgium, disposal is extremely expensive. To give you numbers, for disposal at a depth of 250 m, each cubic meter of area will cost about 2 million Belgium francs or $400,000. Faced with such figures, we would do the opposite of our English friends and say to push the concentration as far as you can but, at the same time, try to make it insoluble. I must confess that until now we have not paid much attention to threshold values, because the important thing to us is not how active the material is, but how much radioactivity can be leached out of the material. As far as we are concerned, this is certainly a matter for further study.

Bill Lennemann: This is not a question, but a point I want to bring up that has been bothering me for a long time. It was ably presented by the Frenchman from Cadarache. When you talk about curies of plutonium, you don't know what you've got. A curie of plutonium-239 takes about 16 g of plutonium for 1 Ci, and our so-called weapons grade plutonium, on which I think a lot of these regulations are based, takes about 1.5 g of plutonium for a curie. I believe specific activity is somewhere between 0.8 and 0.9. As you get into higher exposure level plutonium, you have fewer grams of plutonium per curie. You get down to fractions, and as you get into the LFMBRs, only very, very small quantities of plutonium are needed to hit 20 Ci. I think you'll have to take into consideration what quantities of plutonium you're talking about; each one changes depending on the source of the plutonium.

Timothy C. Johnson, Nuclear Regulatory Commission (NRC): I would like to comment on the question that Alan Moghissi brought up about volume reduction. I don't really consider it a dilemma, as you are probably aware. The NRC came out with a volume reduction policy sometime last year. What it said was that we encourage waste generators to evaluate volume reduction in terms of many things. Based on their own needs, economic capabilities, and so forth, waste generators must judge whether or not they want to purchase expensive systems, go to inexpensive compactors, or just go to volume minimization. It's not simply saying that volume reduction is good. I think you have to look at a lot of things. You have to look at increases in personnel exposure and costs (capital and operating). One important thing to consider is how disposal methods will be affected when your particular waste advances from Class A to B, or Class B to C, or even from Class C to a waste form that isn't necessarily acceptable for a near-surface disposal.

RISKS FROM PRINCIPAL COMPONENTS AND THEIR DAUGHTER PRODUCTS IN ALPHA-CONTAMINATED WASTE

Vern Rogers, Rogers and Associates Engineering Corp.

I have been asked to give an overview on risk assessment, particularly as it applies to limits for alpha-contaminated waste. First, I will briefly mention several items, many of which will be discussed more fully by other speakers.

The purpose of risk assessment is to examine the sensitive parameters and the critical factors and issues in waste management and disposal and to ascertain whether or not qualitative or quantitative objectives and criteria can be met. Because of major uncertainties in many of the parameter values, the exact quantitative results of risk assessments are questionable. Only a foolish risk assessor states that his groundwater calculation of the contaminant concentrations released to a certain river in the year 9023 will actually match the concentrations that may be measured then. Fortunately, risk assessors performing such calculations don't have to worry about being proven wrong. It isn't necessary to expect risk assessments to obtain exact numbers; the assessments are intended to show relative relationships and sensitivities to parameter values. Two major factors must be considered to evaluate risks. First, as shown in Slide 1 the source term must be characterized. Many efforts to classify or categorize radioactive waste focus on source terms, either total quantities or concentrations or hazard indexes that relate just to the source term and its relationship to maximum permissible concentrations (MPC). Second, fully evaluating a risk or a dose and a related impact requires characterizing the disposal facility and the surrounding environment. This characterization generally leads to several forms of environmental pathway analyses. Some involve offsite transport, where either a mechanistic calculation such as diffusive-advective transport for groundwater migration is performed, or analog comparisons to toxic materials occurring naturally in the environment are made. Other environmental pathway analyses involve intrusion scenarios. Considerable discussion has already taken place concerning the intrusion scenario.

An additional general point I would like to make is that evaluating risk involves evaluating both the consequence and the probability that the event would occur. Risk is not necessarily the simple product of these two factors. Dixie Lee Ray stated in her talk that the public's evaluation of risk often emphasizes the consequence more than the probability. Sometimes we ignore the probability function or treat it in a very elementary way.

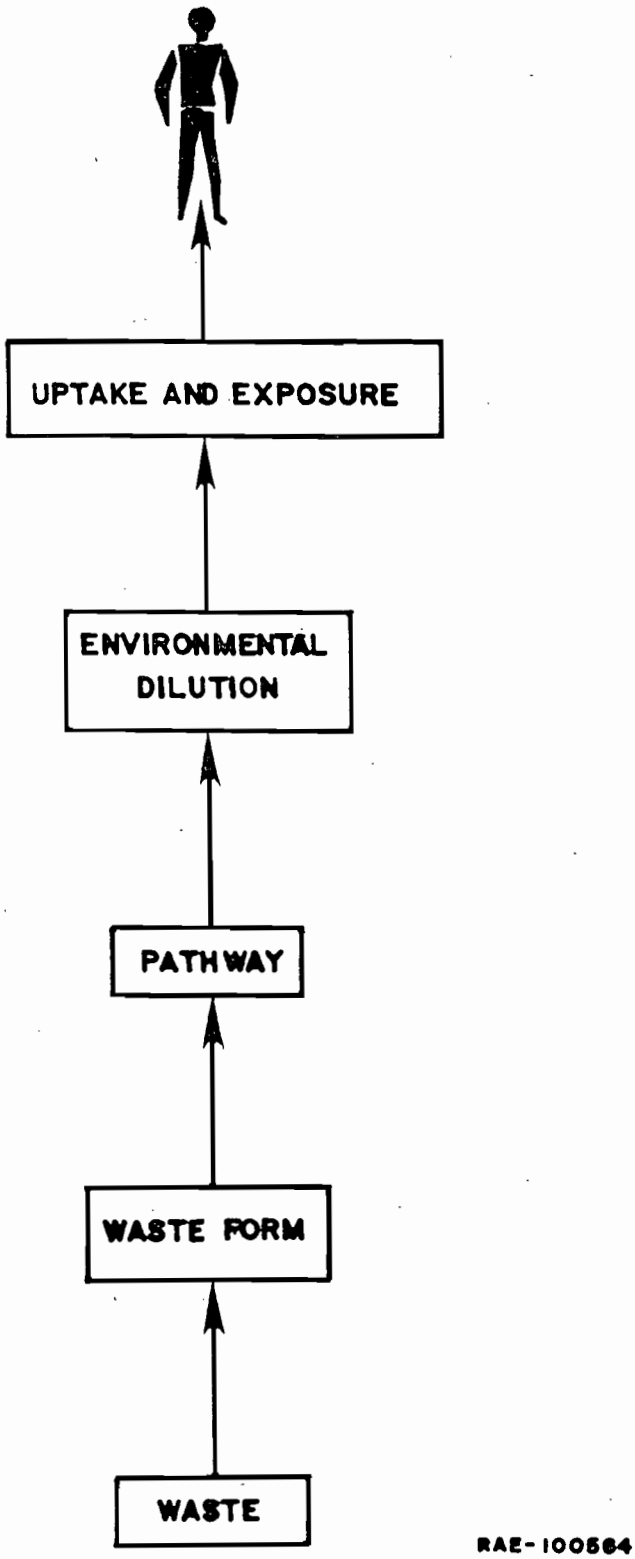
Slide 2 shows the elements of risk analysis. First, the waste must be characterized by quantity, concentration, half-life, and other properties. The next item is evaluating the waste form. For risk analysis this usually means specifying release fractions, availability

Slide 1

INTRODUCTION

- RISK - SOURCE AND DISPOSAL FACILITY
- ENVIRONMENTAL PATHWAY ANALYSIS
  - OFF SITE TRANSPORT
  - INTRUSION INTO WASTE
- RISK - CONSEQUENCE AND PROBABILITY

Slide 2



ELEMENTS OF RISK ANALYSIS

fractions, leach rates, and other similar parameters that relate to the rate at which the nuclide enters the pathway or at which humans can come in contact with it. The pathway analysis includes an evaluation of nuclide migration through the various pathways such as the groundwater transport. The environmental dilution pathway may or may not be combined with the pathway component, but it is an important factor in mitigating potential risks. The final item is the uptake by humans and the exposure evaluation. The exposure can be evaluated in doses, dose rates, or various kinds of equivalent doses and dose rates. It can also be expressed as cancers or similar factors. Dose rate evaluations are called just that--dose rate analyses--and cancer evaluations are often called risk analyses. The exposure evaluation usually involves maximum individual evaluations and population exposures. For disposal concepts other than deep geologic, maximum individual exposures are generally more limiting than population exposures.

Often, cost-benefit analyses are performed as adjuncts to risk analyses. Because the largest population exposures occur via the groundwater or surface water pathway, exposures from this pathway are usually used in cost-benefit analyses. This usually yields optimal limits of risk values that exceed the regulatory limits for maximum individual exposure. Cost-benefit analyses often use extreme alternatives. Shallow-land burial, with 1 or 2 m of cover, will be compared to a deep geologic repository. Another reason cost-benefit analyses are performed as adjuncts to risk analyses is the uncertainty associated with the parameters used in cost-benefit analyses.

Slide 3 shows a few characteristics of alpha-contaminated waste that should be considered. First, there is nothing special about alpha-contaminated wastes or transuranic (TRU) wastes for risk analysis. These wastes are just one more group of radioactive isotopes that are not vastly different from other radioactive isotopes. Their half-lives are not shorter or longer than those of many other nonalpha-emitting isotopes. Their leach rates are not significantly different, either. Retardation coefficients of alpha-contaminated wastes for groundwater transport do tend to be lower than for other isotopes, but their dose factors are similar. Therefore, although it is convenient from a generator's or shipper's viewpoint to consider alpha-contaminated waste as a group, risk analysis generally looks at the simplest building block, the individual isotopes.

One item often overlooked in risk analysis is the uncertainty associated with the final result. Some of the uncertainty is associated with the functions describing the pathway, and some is associated with the input values of the parameters. Most risk analysts use standard reference lists for these key parameters and avoid examining the uncertainties in the parameter values. For example, Regulatory Guide (2) 1.109 by the Nuclear Regulatory Commission (NRC) contains uptake factors and dose conversion factors. These factors are often used in risk analysis without considering

Slide 3

ALPHA CONTAMINATED WASTE (ACW)

- NOTHING SPECIAL ABOUT ACW
  - HALF-LIFE
  - LEACH RATES
  - RETARDATION COEFFICIENTS
- INDIVIDUAL ISOTOPES
- MANNER OF PRODUCTION

their uncertainties or their applicability. It would be very helpful and would add perspective to risk analysis if those people who formulate reference lists of parameter values would clearly present the uncertainties that are associated with the lists.

Slide 4 illustrates some trends of alpha-contaminated wastes in a risk analysis of near-surface disposal. The waste inventory used in the analysis is the NRC's reference low-level waste inventory. The safety factor shown in the figure is the ratio of the dose rate criteria to the calculated dose rate, so it is inversely proportional to the dose rate that was determined with this pathway analysis. As the safety factor increases, the dose rate decreases.

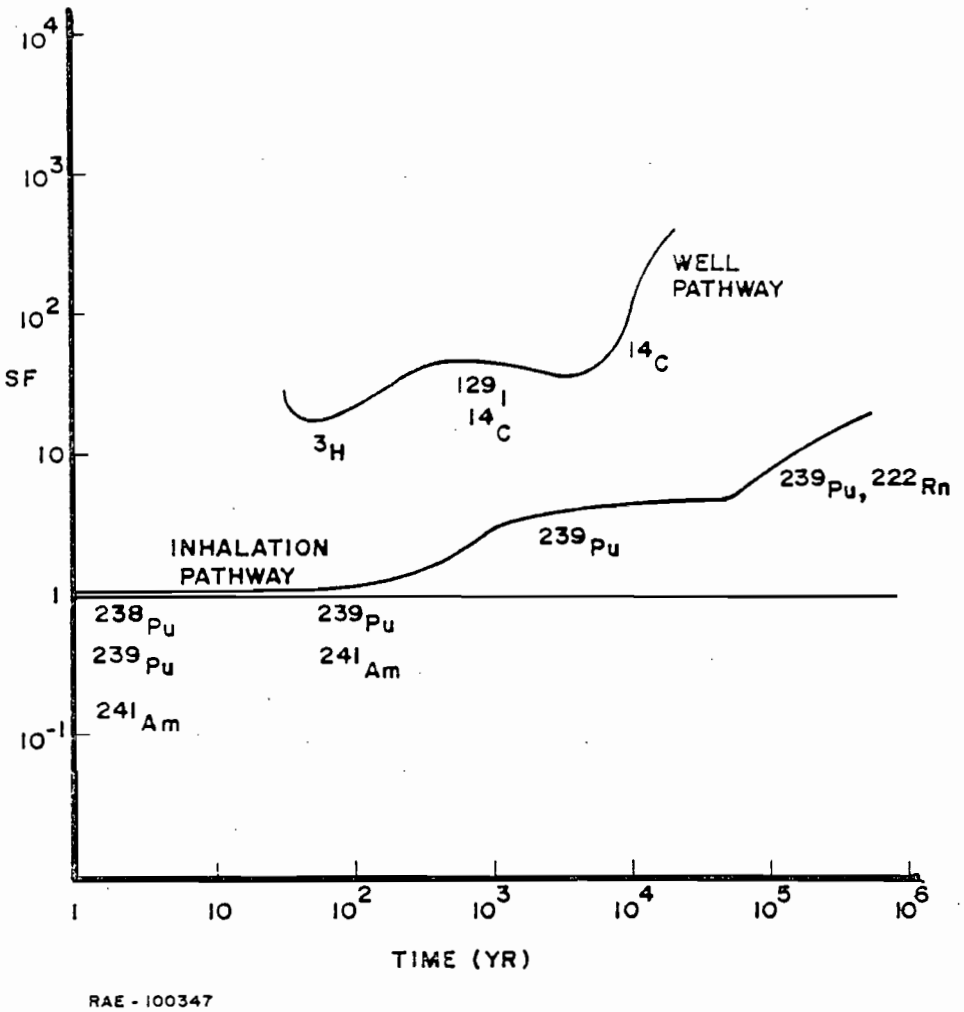
The inhalation pathway is generally the predominant pathway and exposure mechanism for alpha-contaminated wastes.[13] The well-water pathway for this particular example is dominated by tritium, carbon-14, and iodine-129, not the alpha-emitting isotopes.

The alpha-emitting isotopes have one main difference from other fission products and activation product isotopes and that is the impact from decay daughters that are also radioactive. The effects of daughters are generally not major because the daughter activity does not exceed the initial parent activity. However, under some circumstances, daughter effects can be significant and should be considered. First, as shown in Slide 5, if the purpose of an analysis is to establish a limit and some period for control, then the daughter products that in-grow during that period of time should be determined to find out if the combined residual parent and in-grown daughter impacts exceed the limits established by considering the parent only. Another related problem can occur if the daughter isotope has a significantly higher dose conversion factor or uptake factor than the parent; in this case, a small amount of daughter in-growth can greatly influence the risks that are calculated. A third item is the in-growth of daughter products in the groundwater pathway, where the concentration of the parent nuclide may be extremely low at the accessible environment, but the daughter concentrations could be significant.

An example [1] of the impacts from daughters is shown in Slide 6. The calculations shown involve Bateman-type equations for calculating the in-growth of daughters. The concentrations are divided by the MPC. All curves are normalized so that the value for the parent plutonium-241 is unity at 150 years. The relative impact of the daughter americium-241 exceeds that of the parent after about 30 years. The second daughter, neptunium-237, also later becomes significant.

Impacts from daughter nuclide dose conversion factors are demonstrated in Slide 7, in which the dose conversion factors for the same chain, plutonium-241, americium-241, and neptunium-237 are given.[3] The inhalation dose conversion factor for the chain increases

Slide 4



SAFETY FACTOR FOR THE INHALATION AND WELL WATER PATHWAYS. KEY NUCLIDES ARE ALSO LISTED

Slide 5

EFFECTS OF DAUGHTERS

- DAUGHTER ACTIVITY DOES NOT EXCEED INITIAL PARENT ACTIVITY
- DECAY AND INGROWTH TO THE END OF ADMINISTRATIVE CONTROL
- HIGHER UPTAKE OR DOSE FACTORS FOR DAUGHTER
- RECONCENTRATION OF DAUGHTERS IN GROUNDWATER

Slide 6

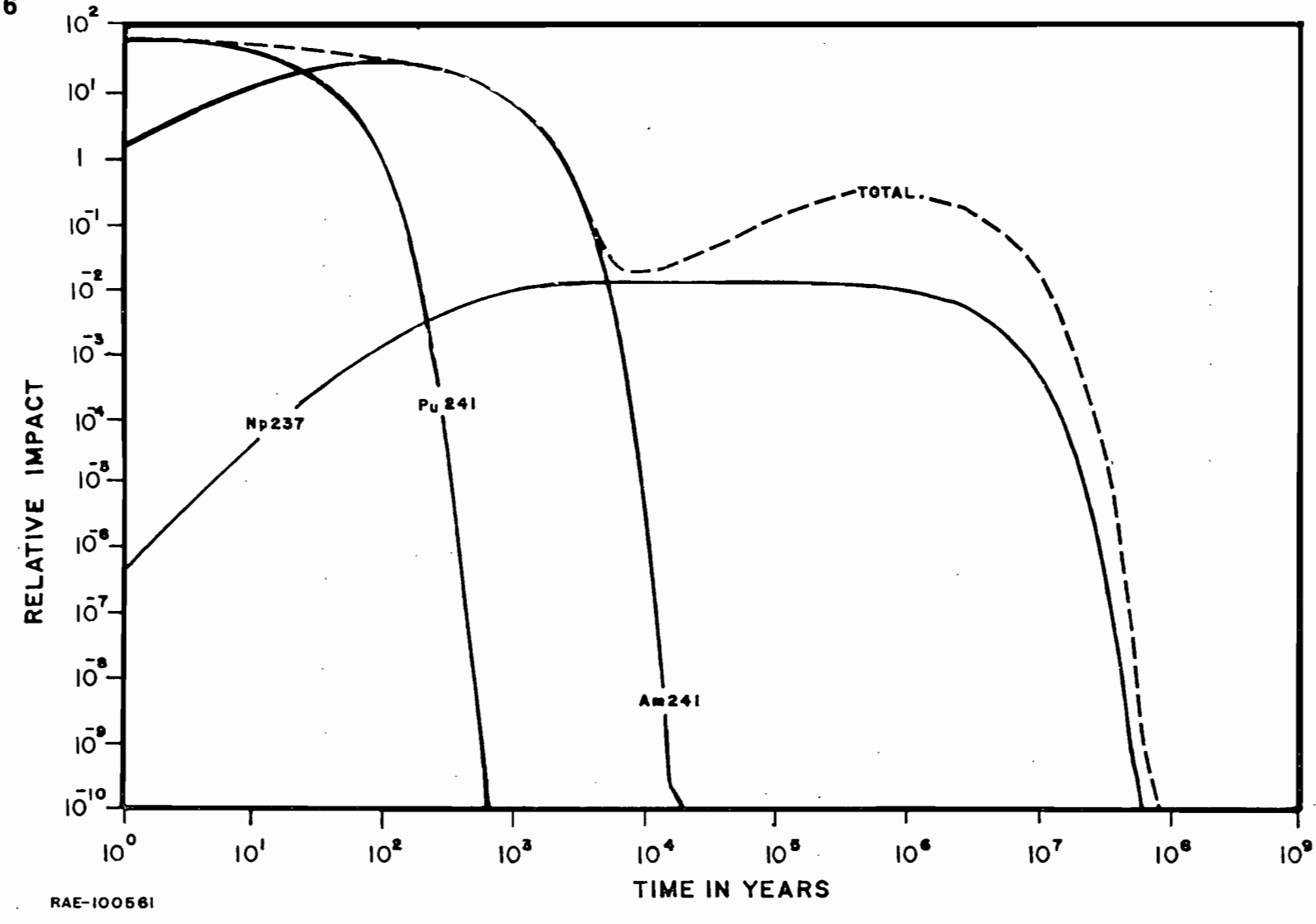
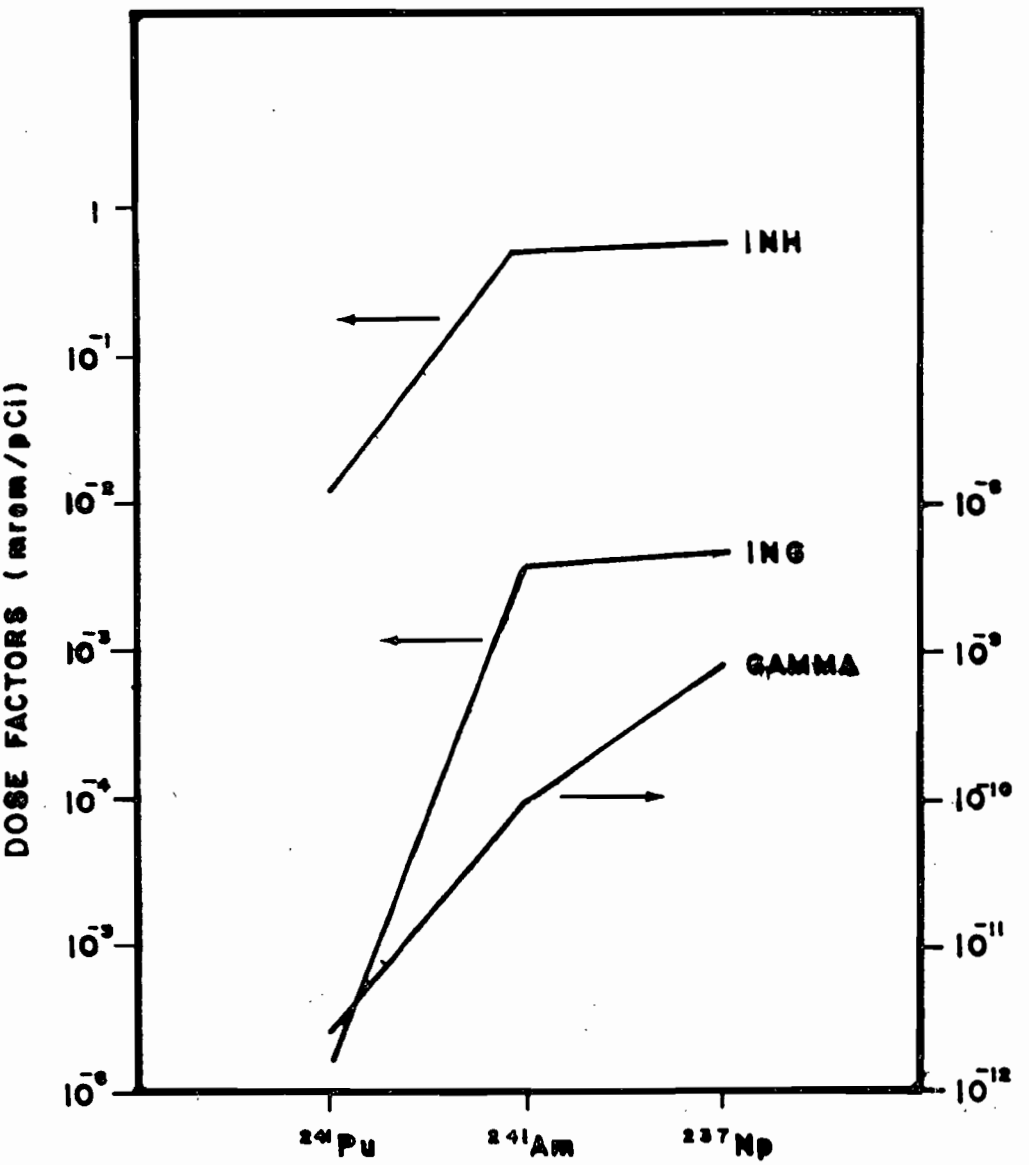


FIGURE 6. RELATIVE IMPACT OF THE MEMBERS OF THE ^{241}Pu DECAY CHAIN



DOSE FACTORS FOR ^{241}Pu CHAIN

Slide 7

from plutonium-241 to americium-241 and then is about the same for neptunium-237. These factors are equivalent whole-body dose conversion factors using International Commission on Radiological Protection (ICRP) 26[5] weighting factors with ICRP 30 organ dose factors.[6] For the ingestion pathway, the dose factor increases by a factor of 3 or 4 from americium-241 to neptunium-237. The dose conversion factor shown in the figure has different units, but it exhibits an even more severe increase.[3] The direct exposure pathway for alpha-contaminated waste chains can be important for shallow-land burial if erosional effects are taken into account. For example, if the erosion rate is 0.1 cm/year, then after 1000 or 2000 years, the waste is exposed and a significant gamma dose could occur.

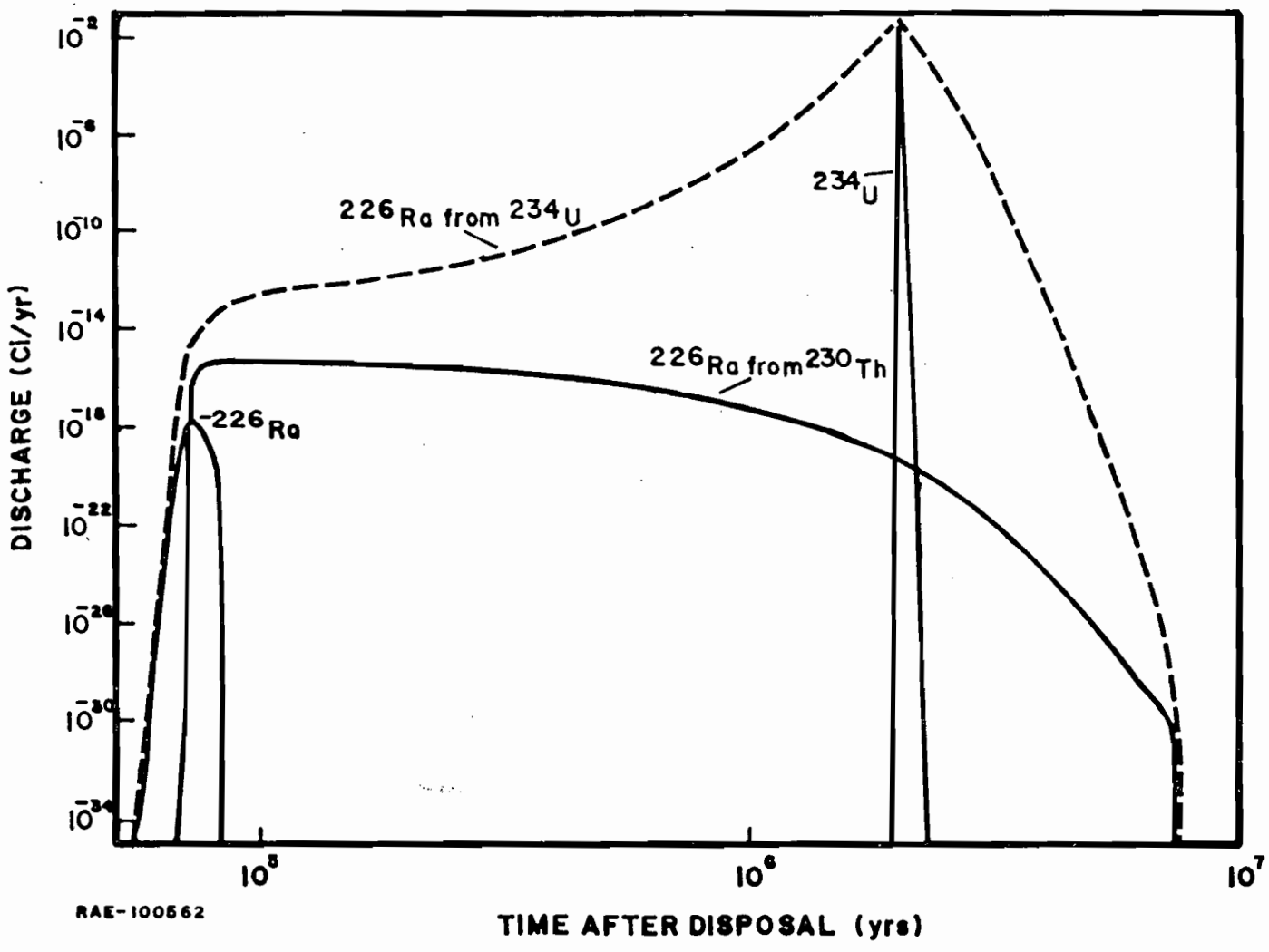
The third effect of decay daughters is in the groundwater pathway. An example[7] of the discharge rate of the radium-226 decay daughter is shown in Slide 8. This analysis applies to high-level waste in geologic repositories, so the releases occur after 10^5 years. For this particular example, the peak radium-226 release from original radium occurs at a magnitude of about 10^{-16} less than the actual radium peak that occurs from the decay of the original uranium-234 in the pathway. Also shown in the figure is the discharge rate of radium-226 from the decay of thorium-230 in the waste. The radium wastes can be as severe as the impacts from the original uranium-234. Analyses of near-surface disposal facilities and different aquifer conditions can yield qualitatively similar results in a much earlier time frame.

The next parameter to be addressed is the release fraction. Leach rates are highly variable and not very well known. As shown in Slide 9 they can be as large as unity in some instances. However, quite often time-averaged leach rates are in the 10^{-2} range. Many leach models for alpha-contaminated waste and heavy-metal materials yield leach rates in the range of 10^{-4} and 10^{-5} per year. If release rates are associated with geologic analogs, such as uranium ore bodies, then rates of 10^{-6} or 10^{-8} are implied.

For intrusion events, the availability factor of the waste is considered to be unity, although some models allow a smaller availability factor to be used.[4]

Risk calculations for different pathways result in the risk being proportional to different characteristics of the waste. If the pathway is an offsite transport, then in general the risk is proportional to the total amount or the total activity (Q) of each isotope in the waste. If the analysis is to determine a concentration limit, then Q must be divided by the active volume of the site to obtain an overall concentration limit. The final result is somewhat site-specific. On the other hand, for most surface intrusion events, the inherent characteristic of the waste that relates to the risk is concentration of each isotope.

Slide 8



DAUGHTER TRANSPORT IN GROUNDWATER

Slide 9

RELEASE FRACTION

- LEACH RATES HIGHLY VARIABLE
  - 1 FOR CHELATING AGENTS
  - 10^{-2} - 10^{-3} CONSERVATIVE
  - 10^{-4} - 10^{-5} LEACH MODELS
  - 10^{-6} - 10^{-8} GOELOGIC ANALOGS
- AVAILABILITY FACTORS FOR INTRUSION
  - 1 GENERAL ASSUMPTION
- RISK PROPORTIONAL TO Q - OFF SITE
- RISK PROPORTIONAL TO C - INTRUSION

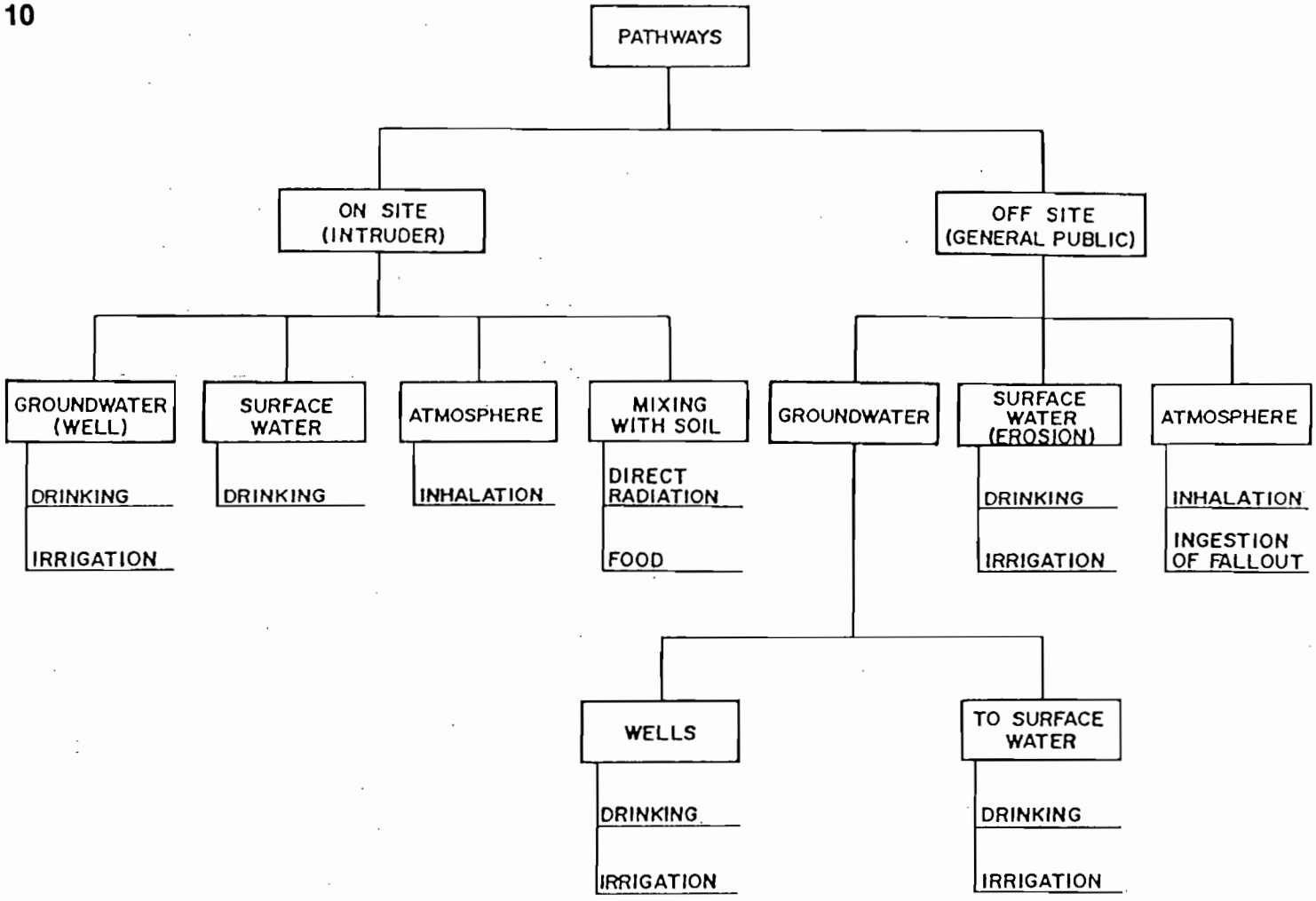
I will address the particular pathways used in risk analysis next. Some representative pathways are shown in Slide 10. The pathways can be divided into two categories. First are onsite categories in which the intruder encounters the waste. Examples are the well water and surface water consumption scenarios, dust suspension, atmospheric transport and subsequent inhalation, mixing with cover soil by man's direct intervention or by plant or animal biointrusion, subsequent consumption of the plant and animal products, and direct radiation. Second are offsite transport categories, which involve the groundwater pathway to surface water or wells projected at various distant locations, surface erosion by wind or water, and atmospheric transport.

Significant dilution generally occurs in offsite transport pathways. However, these pathways are site-specific. If a generic risk analysis is made for an offsite transport pathway, usually a specific site is considered, although it might be called a generic or reference site. But the site analyzed is well defined, with distances and aquifer properties specified. Another important factor in groundwater offsite transport, especially for near-surface disposal, is spatial dispersion, which arises from the spatial extent of the disposal facility. Spatial dispersion has a significant impact on maximum concentrations and releases.

One problem with intrusion events is the degree of protection that should be provided to a possible intruder. Regulations usually consider only the inadvertent intruder.[8] An intruder that purposely encounters the waste must provide sufficient protection for himself. There is a wide variety of inadvertent intrusion events. How should the limiting event be defined? It can be an extreme scenario such as a child eating the waste directly. That is not now considered a reasonable scenario, but few guidelines for defining reasonable and unreasonable inadvertent intrusion scenarios exist. Another example of a questionable scenario is the archaeologist digging into the waste. Is the archaeologist an inadvertent intruder or is he a determined intruder who should accept radiation risks as an occupational hazard? Intrusion events are subject to the "what if" game. What if someone dreams up a new intrusion scenario? Should the probability of the intrusion be included in the analysis? The NRC has given credit for the probabilistic nature of the intruder by allowing him to receive a higher dose rate: 500 millirem/year versus 25 millirem/year for off-site dose rates.[4] The intrusion scenarios have much smaller dilution factors than the off-site scenarios, because man intercepts the wastes rather than the waste being transported to man. Consequently, intrusion scenarios are critical in establishing waste limits. They are also much less sensitive to specific site parameters.

The probabilistic nature of intrusion events can also be considered in quantitative terms. One study[9] used average population densities and projected the sizes of low-level waste disposal facilities

Slide 10



PATHWAYS FOR PERFORMANCE ASSESSMENTS

to obtain an average probability of an intrusion event of about 10^{-5}/year. An approach like this might allow intrusion scenarios to be placed in perspective to offsite pathway events.

A simple way of averting the intrusion scenario is to bury waste deeper. Our alternatives for disposing of radioactive wastes are not limited to shallow land burial or deep geologic disposal. Between those alternatives are a world of choices that might be suitable for various levels of contamination.

Some of the depth-dependent risk factors that have been employed[9] in evaluating the surface intrusion scenario are shown in Slide 11. Curve A is a linear dependency with depth down to a certain value. Curves B and C are exponential and inverse dependencies, and curve D had a $1/(1+x^n)$ dependence. Intermediate-depth burial reduces the probability of intrusion, and intermediate-depth burial is also cost-effective. Slide 12 shows an example of the variations of risk with depth of burial.[3] In this analysis the safety factor is calculated using the NRC low-level waste inventory[4] with a 2 m cover and a 5 m cover. The slightly deeper burial improves the safety considerably.

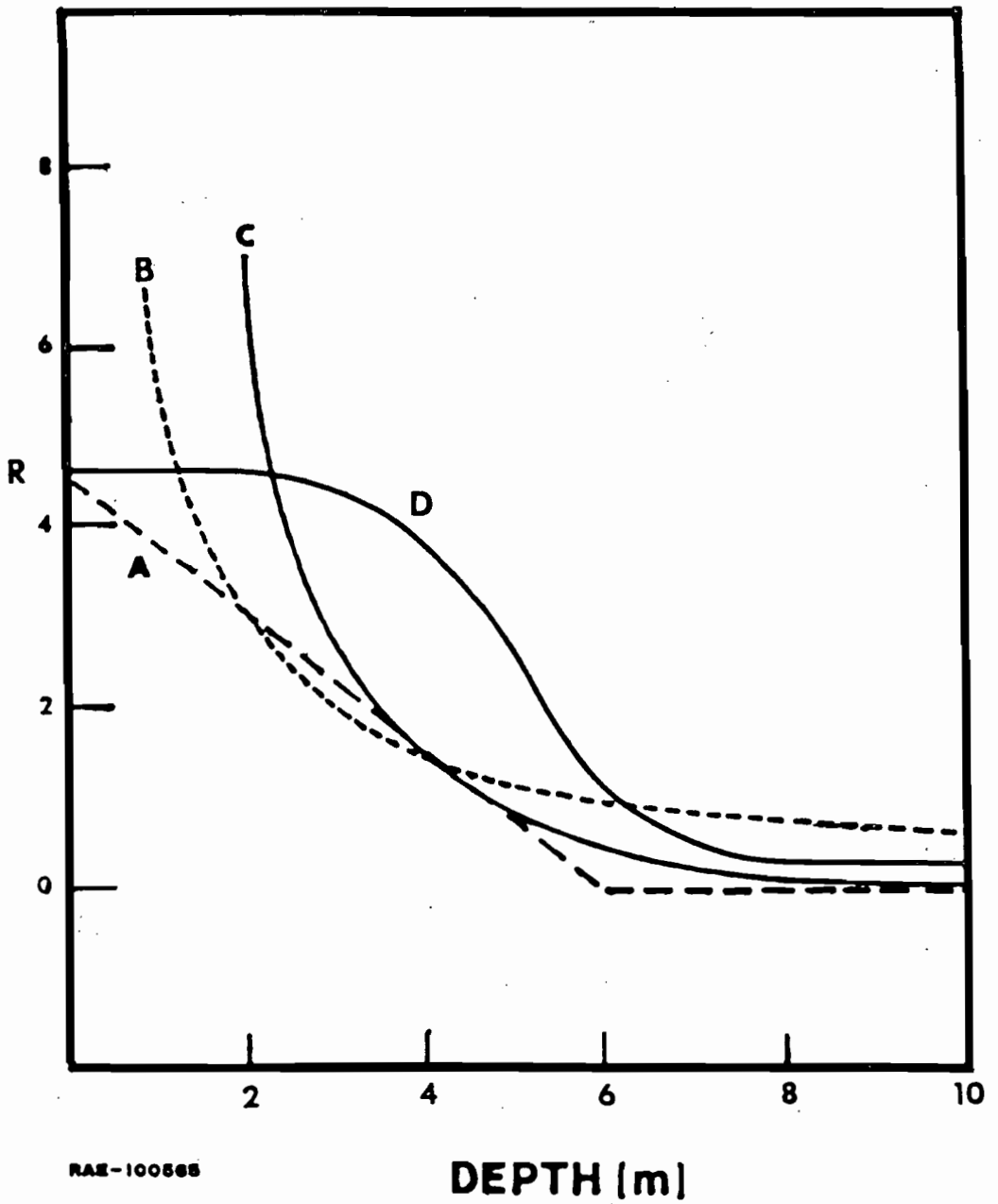
Finally, Slide 13 illustrates the magnitude of concentration limits that I have obtained for alpha-contaminated wastes. These calculations apply to near-surface disposal and were made for different purposes over the last 5 years. In the first one[1], reported in 1978, the alpha-contaminated waste limits were roughly 30 to 300 nCi/cm^3, depending on the isotope. If only the predominant isotopes are considered, the limits are about 100 nCi/cm^3, which is equivalent to about 60 nCi/g. Another recent analysis performed for the Electric Power Research Institute[3] yielded alpha-contaminated waste limits ranging from 17 to 3000 nCi/cm^3. The lower limit mainly applies to the curium isotopes with short half-lives. If credit for a hundred years of administered control was included, then the limits were from 150 to 3000 nCi/cm^3. A limit of 0.4 nCi/cm^3 applies to radium because of a radium and radon gas scenario. Radon gas can be a problem if radium is in the waste and if the waste is in near-surface burial.

The most recent analysis shown involves a total systems interaction in which material quantities are conserved so that if some material is lost via the groundwater pathway, that material is not available for intrusion. This analysis also gave a limit for alpha-contaminated waste in the range of 0.1 to 650 nCi/cm^3. If these values are weighted with a reference distribution of alpha-contaminated isotopes, then a limit of 340 nCi/cm^3 is obtained.

I have introduced many factors of risk analysis in this presentation, and they will be addressed in more detail in other papers of this session.

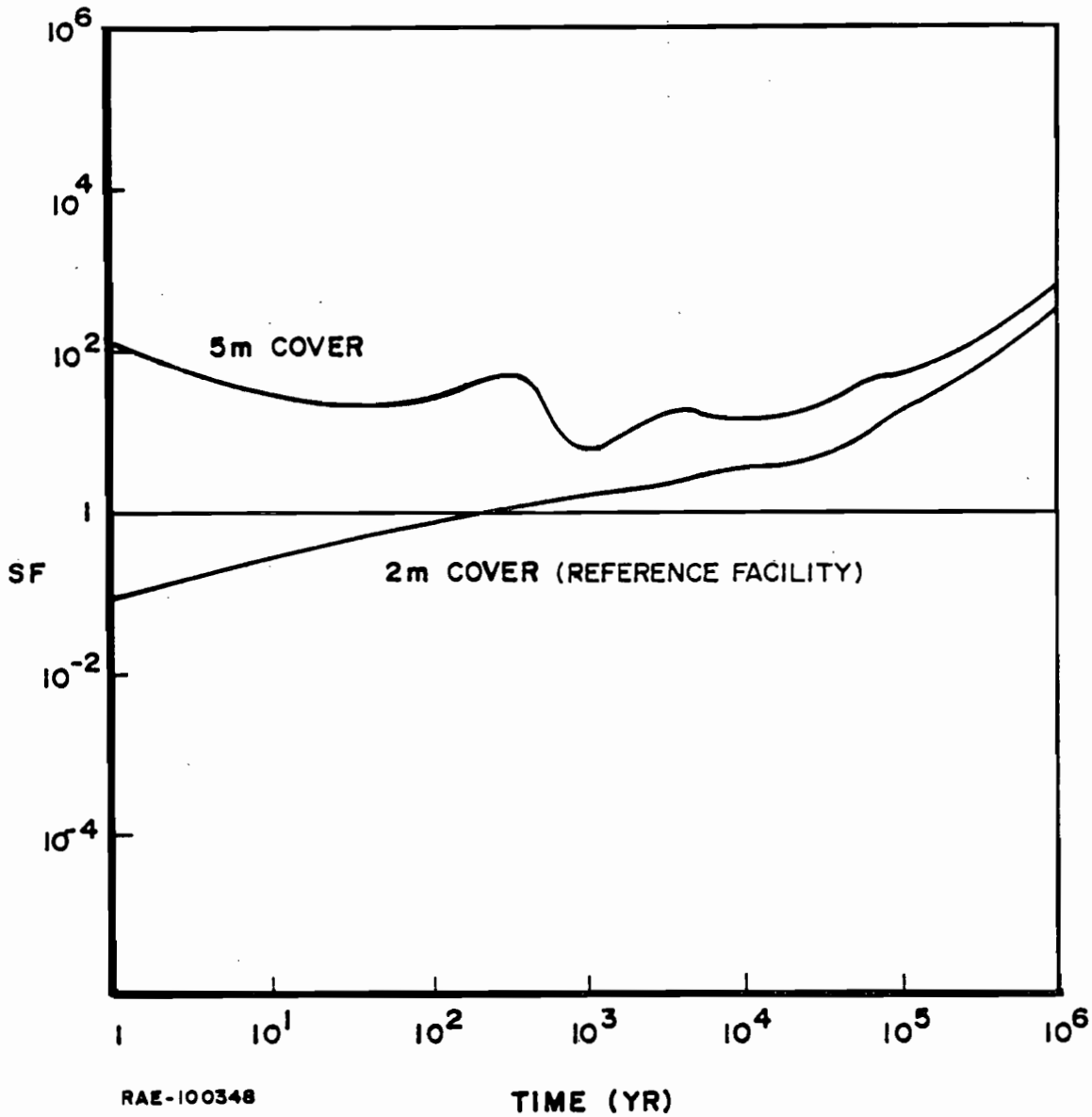
<u>Bill Kennedy, Battelle-Pacific Northwest Laboratories</u>: Looking at the last figure, I wondered what the conditions were for those calculations. As you pointed out, the numbers are highly dependent on

Slide 11



RISK FACTORS FOR SURFACE INTRUSION

Slide 12



SAFETY FACTOR FOR BASE CASE AND FOR DEEPER BURIAL

Slide 13

SAMPLE RESULTS FOR ACW

1. 1978 - CLASSIFICATION

   ACW: 30-300 nCi/cm^3

   MAJOR: 100 nCi/cm^3 = 60 nCi/g

2. 1981 - RQ/PQ

   ACW: 0.4,17 - 3000 nCi/cm^3

   (150-3000 IN 100 YRS)

3. 1982 - SYSTEMS DESIGN -GCD

   ACW: 0.1 - 650 nCi/cm^3

   MEAN: 340 nCi/cm^3

the scenarios and the conditions involved. Were they surface numbers or were they at a disposed depth? Were they for the intruder? What were some of the modeling assumptions and steps behind those numbers?

Rogers: The details are contained in the pertinent references, but I can go into some detail if you'd like. Basically the first two had about 2 m cover in a standard shallow land burial facility. For the first analysis the dust inhalation intrusion scenario was limiting. The intruder dug a basement to build a house. In the second analysis the dust inhalation and food consumption scenarios were limiting. For the food scenario, the reclaimer grew half of the vegetables he consumed on site and had a large enough site so that half of his meat consumption came from contaminated beef. The last analysis balances the risk from various pathways. The waste was at a depth of 5 m, but the surface intrusion scenarios were food grown with contaminated well water and a conservative drilling scenario that brings waste to the surface over a long period of time.

Charles King, Savannah River Laboratory: You showed some interesting numbers on leach rates. I assume that you were talking about the waste from soil release rates or leach rates. Could you give an example of the geologic analogs that you talked about?

Rogers: In examining the geological analogs, one might consider a uranium ore body or the toxicity and availability of natural elements in the top 2 to 10 m of the earth's crust.

King: Is regulatory guide 1.109 still the best available source of information for meat, milk, transfer co-efficients, and things of that sort?

Rogers: It is useful, but it has been around a long time; furthermore it is complete, so it is widely used. I haven't found anything better.

Gary Roles, Nuclear Regulatory Commission: When we did the 10 CFR 61 environmental impact statement, we started with regulatory guide 1.109, but we updated the numbers in the transfer factors. We considered about eight or ten different sources, so the impact statement for 10 CFR 61 had updated numbers.

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AN OVERVIEW OF 10 CFR PART 61 "LICENSING REQUIREMENTS FOR LAND DISPOSAL OF RADIOACTIVE WASTE"

Paul Lohaus, U.S. Nuclear Regulatory Commission

I'd like to limit my discussion today to the Nuclear Regulatory Commission (NRC) rules that are set out in 10 CFR Part 61, licensing requirements for land disposal of radioactive waste.

I'd like to cover four areas today. The first is to review the approach that we're following in the development of regulations; I will look at Part 61 in the context of some of NRC's other regulations development efforts and in particular examine how we are addressing the disposal of transuranic (TRU) waste through these regulatory efforts. Second, I'd like to review the current status of Part 61. I would like to bring us all up to date on where we are with the rule, and at the same time I'd like to review the process that we've gone through to develop the rule as it stands today. Third, I'd like to review the principal provisions that are established by Part 61 and in particular to look at the concentration limits that are established for near-surface disposal of wastes containing TRU radionuclides. Finally, I'd like to present a broad overview of the methodology that we developed and applied to analyze the impacts of disposal in our environmental impact statement and to help make decisions on the technical requirements that are set out in Part 61.

The first point I'd like to emphasize is that we are not now planning to develop a separate regulation for TRU waste. Rather, through our existing regulations development efforts, we are addressing the disposal of waste containing TRU radionuclides. Considering today's commercial wastes, we do not really see the need for a separate TRU waste regulation. With few exceptions, most commercial waste (particularly reactor waste) contains TRU nuclides as a trace contaminant. This is opposed to some DOE wastes, which predominantly contain TRU nuclides. Some commercial TRU wastes, for example those from the decommissioning of plutonium fuel fabrication plants, will have high amounts of TRU nuclides, but these wastes are limited in number and should be generated over a relatively short time frame. If the current situation does change, for example, if we develop a new reactor type or resume reprocessing, we will examine our rules to make sure that they are keeping pace and are compatible with any new wastes that might be commercially generated. As some of you may recall, Atomic Energy Commission (AEC), back in 1974, had a proposed rule that did deal with TRU waste. This rule proposed to apply the then AEC limit of 10 nCi/g to commercial wastes. But, when AEC was divided into NRC and Energy Resources Development Agency (ERDA), the supporting environmental impact statement for that rule was withdrawn and at about the same time NRC started work on a classification system that was directed at establishing classification limits for the disposal of wastes containing the full range of radionuclides, not just TRU radionuclides.

This brings me to the second point. Our efforts have culminated in Part 61, which does establish a classification system for near-surface disposal of waste. Through Part 61, upper bound concentration limits are established for the disposal of wastes containing TRU and other radionuclides.

The question then that remains is, "What can be done with wastes that exceed the limits established by Part 61?" We plan, as follow-up to work we've completed so far, to deal with this issue in two ways. The first would be to examine what can be done within the existing context of near-surface disposal to accommodate these wastes. For example, through improvements in waste form or improvements in design and operations, we may be able to accommodate many of these wastes at existing near-surface disposal facilities. The second way, as Vern Rogers touched on, is to use other methods (such as deeper burial) that can provide greater isolation or greater confinement but that would be short of requiring that these wastes be disposed of in a deep geologic repository. Part 61 now requires a minimum of 5 m of cover for Class C waste, which establishes the upper bound for waste acceptable for disposal under the rule. Greater confinement could be provided by deeper burial, 10 to 15 m of cover, and this seems to be well within current state-of-the-art. Trends at the existing commercial sites are toward deeper depths (50 to 60 ft in normal trench depth) and arid sites. Until we have completed follow-up work for Part 61, Part 61 does contain provisions, specifically Section 61.58, that would enable case-by-case determinations of wastes that exceed the Part 61 limits. So we've tried to incorporate flexibility into the existing rule.

The last point is that, although the high-level waste rule, Part 60, does not specifically address disposal of TRU wastes, it does allow the disposal of such wastes in a repository, provided they meet the waste form and other requirements in the rule.

I set out the major steps that we've gone through leading to development of Part 61 and where we are today. The point I'd like to emphasize is that we've gone through a fairly active and open public involvement process. We started with an advance notice in October 1978 asking for advice and views on the issues that should be addressed in the rule. We prepared a preliminary draft rule in 1979, which was widely distributed for review and comment. During 1980 we held four regional workshops to present an open forum for dialogue among everyone who was involved to try to focus and gain consensus on how some of these issues should be resolved. Based on that work and on a draft environmental impact statement, we prepared and issued a proposed rule in July 1981 for 90 days public comment. In October we published the draft supporting environmental statement and extended the comment period on the rule an additional 90 days to coincide with the comment period on the environmental impact statement. The comment period ended January 14. We received 107 comments in response to the proposed rule and 42 comments in response to the environmental

impact statement. These comments came from a broad range of interests and, in general, about half of those commenting on the rule expressed explicit support for the rule and the approach that we were taking in Part 61. Fifteen comments expressed outright opposition to the rule; most of these were from individuals. It seemed that the opposition generally stemmed from objections to nuclear power, to the use of radioactive materials, to shallow-land burial as a disposal technique, and to the disposal of TRU waste near surface. The remaining 45 comments on the rule had constructive suggestions, but really took no position one way or another for the rule. We've subsequently completed an analysis of comments on both the rule and the environmental impact statement. We've prepared a final staff-recommended rule and a final environmental impact statement. These were sent to NRC in May. In a briefing on July 14, we presented staff recommendations to NRC, and we've since responded to some questions that were raised during the briefing. We're looking forward to a positive and an early decision from NRC.

What will happen when NRC makes its decision? We will first publish the final environmental impact statement and provide copies of that to the Environmental Protection Agency. Thirty days after that, we would publish the final Part 61 rule. We've recommended to the Commission that provisions in the rule dealing with the site-suitability aspects, site design and operations, institutional control, financial assurance requirements, and licensing procedures should be effective 30 days after publication. We've also recommended that requirements placed on waste generators dealing with waste classification, waste form requirements, and preparation of the waste manifest that would accompany the shipments would be effective 1 year after publication in the Federal Register. We feel this is a reasonable time for licensees to work this into their programs and also time for us to work with the states in establishing a program of orderly implementation.

Part 61 establishes provisions in seven major areas. The approach we've followed is to establish both overall performance objectives and also prescriptive requirements when possible. Four performance objectives are established. First is protection of the environment: a 25-millirem whole body limit would be applied at the site boundary for potential environmental releases from the site. The second objective would be protecting an inadvertent intruder. We're not trying to protect a willful or a purposeful intruder, just someone who would unknowingly contact the waste at some point in the future. The third objective is to ensure an adequate level of occupational safety during operation of the site; we're applying the limits in 10 CFR Part 20 that are applied to other NRC licensed facilities. We feel the final objective is important. It deals with ensuring long-term stability of the site. This should help minimize the long-term need for maintenance and also reduce long-term care costs.

Part 61 also establishes technical requirements for near-surface disposal, which are set out in the four logical areas of a disposal

system: (1) the site characteristics, (2) how the site is designed and operated, (3) the form and content of the waste, and (4) institutional controls.

Sections are reserved in the technical requirements for other than near-surface methods of disposal. Sections are reserved for amendments to the rule to deal with these methods. Part 61 also establishes financial assurance requirements to ensure adequate funding for closure and long-term care. It also pulls together and presents in one place the licensing procedures that NRC would apply in licensing future sites and, also, some additional procedures for state and tribal participation in the licensing process. Finally, amendments to Part 20 deal with the preparation of waste manifests and require that waste generators comply with the waste classification and waste form requirements regarding any transfers of waste to a commercial disposal facility.

The technical requirements collectively provide a classification of waste for near-surface disposal. Basically three classes of waste are established through the rule: Classes A, B, and C. Class A wastes have low specific activities and would be required to be disposed of separately from stable Class B and C wastes. They must meet only minimum waste form requirements that would apply to all wastes. The minimum requirements are important with respect to handling the wastes and helping to ensure an adequate level of occupational safety.

Class B wastes have higher specific activities and would be required to meet both the minimum and an additional waste stability requirement. The waste stability requirement is intended to help provide long-term structural stability of the waste under disposal conditions so that there will be no degradation that would lead to increased water infiltration and percolation into the disposal unit and also so that the waste would be recognizable over the long term. We tried to maintain flexibility in ways an individual licensee could meet the waste stability requirement. Stability can be provided by the waste itself (e.g., an activated piece of structural steel), by processing the waste to a stable form (solidification of liquids), by placing the waste into a container that would provide stability, or by engineering design of the disposal facility. In this last case, the structurally stable container would be created through the design of the facility. I would also like to add that stable Class A wastes may be disposed of along with stable Class B and Class C wastes. What we're trying to do is to separate the compressible wastes from stable wastes.

Class C wastes have higher specific activities. They must meet the minimum waste form stability requirements and also must be disposed of with an additional barrier to help reduce the potential for someone contacting the waste in the future. This can be provided by deeper burial at a minimum of 5 m or with some other engineered barrier that would help isolate the wastes from surface activities.

I've set out the concentration limits that we've calculated based on the work performed in our environmental impact statement. Given some of the discussion this morning, I would first like to go through a few points dealing with the factors that we considered in developing the waste classification requirements. The actual concentration limits were developed based on limiting exposures to an inadvertent intruder to 500 millirem/year. The kinds of exposure scenarios that were considered involved those, for example, of constructing and living in a house at the site, consuming food grown in a small garden at the site, and also a pathway that we call the intruder discovery scenario. In this case an individual would contact the solid remains of waste, realize that something is wrong, and cease his activities. Such a pathway would provide for a much lower potential exposure. I also want to emphasize that other factors were considered and applied in arriving at these limits. In particular, we considered the need for long-term stability, which will help reduce long-term care costs and the potential for long-term environmental releases. The point I'm trying to make here is that we have established concentration limits based on intruder considerations and on other considerations such as requiring stability of some high activity wastes and requiring disposal of wastes having even higher activities on the bottom of disposal trenches. As many of you are aware, existing limits deal with the solidification of reactor resin and filter sludge waste that would exceed 1 nCi/cm^3 of nuclides having a half-life greater than 5 years.

I've set out (in nanocuries per cubic centimeter, not nanocuries per gram) the concentration limits for TRU radionuclides that we calculated for routine near-surface disposal of waste. The limits for Class A waste range from about 4 nCi/cm^3 to well over 500. Most of them are around 10 nCi/cm^3. For Class C waste, the limits range from about 4 up to about 7800 nCi/cm^3. Again, the long-lived components for Class C waste seem to center close to 10 nCi/cm^3. If we were to convert these to nanocuries per gram assuming an average waste density of about 1 to 2 g/cm^3, we would still be in a range of around 10. Given this information and the limit of 10 nCi/g that has been in effect at the existing sites for some time, we set an upperbound limit for near-surface disposal of 10 nCi/g in the proposed Part 61 rule. This was consistent with our approach in establishing other provisions in the rule; we tried to base requirements not only on analysis but also on existing practices at the existing sites.

In response to the proposed waste classification requirements, we received the most comments and attention on the proposed 10 nCi/g limit. Of the 23 comments received, 4 thought that the limit should be retained or lowered. Nineteen suggested that the limit should be raised. Of those that suggested it should be raised, most suggested raising it to 100 nCi/g. Reasons cited were: our analyses were too conservative; we hadn't taken into account dilution that would occur by the lower activity wastes; and, raising the limit would be consistent with other studies and would also make compliance with the

classification requirements much easier. Those that supported keeping the limit at 10 nCi/g endorsed the limit now in effect at the existing sites and also expressed concern that waste containing TRU nuclides should not be disposed of near surface.

In response to these comments, I would first like to emphasize that we have not changed our analyses. We've reconsidered some of the assumptions to temper any over conservativeness, and in particular, to look at the assumption of not accounting for dilution by lower activity wastes. We have recommended in the final Part 61 rule that the upperbound limits for near-surface disposal of waste containing TRU nuclides, the Class C limits, should be raised to 100 nCi/g. For Class A waste, we have retained a limit of 10 nCi/g. The rationale for raising the Class C limit by a factor of 10 is based on consideration of dilution by lower activity wastes and consideration that Class C wastes are buried with a minimum of 5 m cover or some additional barrier that, even after 500 years, would make the wastes much more difficult and inaccessible to surface activities. We considered dilution by two means: the expectation that the average concentration in the waste would be less than the maximum concentration value that was calculated and the expectation that the 5 m of lower activity Class B waste covering the Class C waste would decay to a relatively low level at the end of 500 years assumed for Class C waste and would provide additional dilution.

We do not believe the Class A limits should be raised any higher. If you consider the distribution of TRU nuclides in commercial wastes and normalize these to the calculated concentration limits, a gross value of about 10 to 20 nCi/g results. If you assume an average waste density of 1 to 2 g/cm^3, a value of about 10 nCi/g results for routine reactor wastes. By increasing the Class C limits to 100 nCi/g and by setting out higher limits for two of the shorter life components, plutonium-241 and curium-242, we feel we have provided flexibility that should accommodate the majority of the commercial wastes that are generated today.

For those wastes that would exceed the Class C limits, as discussed earlier, a mechanism in Part 61 would enable case-by-case determinations, provided that the performance objectives set out in the rule would not be exceeded.

Finally, I would like to provide a broad overview of the impact analysis methodology that we developed for Part 61. At the beginning of the project, we recognized the need for a methodology that would be able to handle the large number of alternatives that we would have to consider. Our analysis is generic, not site-specific. Through other areas of our program we are developing more detailed methodologies that would be applied in the analysis of specific sites. The methodology considers only commercial waste generation on a regional basis. It consists of several interrelated computer codes. One of these, INTRUDE, calculates exposures to an inadvertent intruder at

different points in time. GRWATER calculates the groundwater impacts at varying distances from the site. The OPTIONS code pulls everything together. It takes a particular waste form, a particular design and operation practice, and a particular institutional control period and calculates exposures to an intruder, groundwater impacts, occupational exposures, and costs for that particular alternative. The last code, INVERSE, really works the system in reverse. It calculates a particular concentration of material that would be acceptable for disposal, given a particular disposal condition and a particular assumed dose guideline. Finally, and I think most important, the methodology is capable of analyzing a broad range of alternatives in a short time.

To further narrow the number of alternatives, we divided the data base logically into three components. The first was to develop some alternative site characteristics so that we would be able to analyze a range of typical site environmental conditions. Second, we prepared a detailed description of the characteristics, properties, and content of commercial waste and developed mechanisms to account for various ways that the waste could be processed and packaged. Finally, we characterized a range of alternative design and operating practices that could be applied in the near-surface disposal of waste.

With respect to alternative site characteristics, we first divided the United States into four major regions that correspond to the NRC regions. We developed a northeast region that corresponds to region I, a southeast region that corresponds to region II, a midwest region that corresponds to region III, and one region in the west that combines NRC regions IV and V. Within each region a hypothetical regional facility was characterized to reflect typical environmental conditions. The kinds of properties that were characterized included precipitation, percolation, soil characteristics, groundwater depth, and travel times. We ended up with three humid sites that reflected differing environmental conditions and one arid site.

With respect to waste characteristics, we divided the commercial wastes into four major groups containing 37 individual waste streams. One group was light water reactor process wastes, which included PWR and BWR resins, filter sludge waste, and concentration liquids. The second group involved trash-type waste, which included trash not only from reactors but also from industrial, academic, medical, and institutional sources. The third group encompassed waste streams containing relatively low concentrations of material that would be generated by various industrial processes and academic and institutional facilities. The final group included what we felt were special wastes having very high activities: e.g., wastes from non-fuel reactor core components, sealed sources, and isotope production facilities. The physical, chemical, and radiological properties of each stream were characterized in detail. Up to 23 radionuclides were included. Ten of these were TRU radionuclides.

Finally, with respect to alternative designs and operating procedures, we try to characterize a broad range of techniques that might be applied with respect to their costs, occupational exposures, and other factors. Some of the more important ones we considered were: disposal unit design (whether the disposal unit used was a regular soil wall trench or concrete walls); emplacement procedures (whether the waste was randomly dumped in the trench or neatly stacked); backfill material (the type of material, how it was put in, and whether any special efforts were made to compact the material as a part of the backfilling operation); cover material and thickness (including the extent of compaction that might be performed); segregation (whether the compressible wastes were segregated from those which were stable); layering (whether the higher activity wastes were preferentially placed on the bottom of disposal trenches); and finally, closure (the type and extent of activities that would be required to close the site and how they related to the kind of design and operations that would have been carried out through the operating life of the site).

On the next two slides, I've tried to show the range of impact measures that the methodology is able to calculate. We divided the impact measures into three phases: processing, transportation, and disposal. For waste processing, the methodology calculates costs, energy use (equivalent gallons of fuel oil), occupational exposures occurring during waste processing, and population exposures that would result from waste incineration. For completeness we included waste transportation, which essentially calculates the same impacts--costs, energy use, occupational exposures, and population exposures.

For disposal, the methodology calculates the cost of facility design and operations, energy use, the amount of land that would be committed, occupational exposures, and, from a number of pathways, exposures to individuals and populations for operational accidents. For example, exposures resulting from a dropped container that would release a portion of its contents and a fire that might occur in a trench are calculated. Groundwater impacts are calculated at four different points: a well located on site, a well located at the site boundary, one located between the site boundary and the point of surface water discharge, and one located at the point of surface water discharge. Exposures to an inadvertent intruder are also calculated at different times. In the final environmental impact statement, we also added the capability to analyze trench filling-bathtubbing and overflow and leachate treatment impacts.

<u>Bill Kennedy, Battelle-Pacific Northwest Laboratories</u>: I have a question concerning my understanding of the support of this work in the draft environmental impact statement and the interpretation of the intruder scenarios and how the scenarios applied to each of the classes of waste. It seems that you've defined a construction scenario with an intruder digging a 3-m deep basement. I think the radius for your agriculture scenario was 25 m. The limits are derived by the most restrictive, if external, or, if internal, pathways that

control each of the radionuclides in the table. To me it was not at all clear how the construction scenario was modified to arrive at the Class C condition where the wastes are 5-m deep. If the basement only penetrates the top 3 m, how are the subsequent concentrations arrived at for surface activities, including any inhalation by the farmer or by the person digging and ingestion of the farm crops? How can it only mean a factor of 10 different in the concentration of the TRU radionuclides? How was that scenario modified to arrive at that number?

Lohaus: The factor of 10 was not based directly on the exposure scenario. As I indicated we calculated values for both Class A waste and Class C waste. Limits for Class A waste were calculated assuming inadvertent intrusion into the waste in 100 years. In 100 years, the intruder would not contact the Class C wastes because of the 5 m of cover. The limits for Class C waste were calculated assuming the same exposure, but pathways occur at 500 years and no credit was taken for the 5 m of cover. When we calculated the limits for Class C waste, we essentially assumed that we are uncertain about what might happen in 500 years and the kinds of activities that might occur. So we essentially assumed no credit for the 5 m of depth.

In looking at the Class A and Class C wastes, the values that were calculated for individual radionuclides were in the range of 10. Somer were lower and some were higher. In going from 10 nCi/g to 100 nCi/g for Class C, we did not change the exposure scenarios. We did this: we took the limits that were calculated and considered dilution of the Class C wastes by the lower activity wastes that decay through that time, and we felt we could allow a factor of 10 above the limits that had been calculated.

Kennedy: It might be helpful to add a clarifying statement about that in the text because some of those numbers cannot be recalculated.

Alan Moghissi, Environmental Protection Agency: You mentioned that for TRU waste with specific activities exceeding 100 nCi/g, you would make decisions on a case-by-case basis. Would you elaborate on the kinds of conditions? For example, if someone came to you with 900 nCi/g or 1 uCi/g, what additional requirements would you place on these wastes?

Lohaus: We might look at the actual distribution of the various TRU nuclides within the waste. For example, the waste might have a gross alpha concentration of 150 nCi/g, but the distribution of those nuclides within the waste might meet the individual concentration limits. That might be one way. You could also have burial below 5 m. That might be a second consideration. There might be things that could be done with the waste form itself or, possibly, a special facility could be constructed as a part of the normal facility to handle something like that. We are trying to maintain flexibility and not close off any options, and we would hope that a licensee would

suggest ways that the waste could be accommodated within the rule itself, provided the waste did not exceed the performance objectives set out in the rule.

Craig Smith, Science Applications, Inc.: Does the factor of 10 adjustment that you have on Class C values apply only to TRU nuclides and if so, why?

Lohaus: We have applied a factor of 10 for all the Class C wastes. It does not apply just to the TRU nuclides.

Charles King, Savannah River Laboratory: In your intruder dose calculations, do you interpret 500 millirem as a 1-year dose commitment, a 50-year dose commitment, or a 70-year dose commitment and why?

Lohaus: It was a 50-year dose commitment.

Question, Battelle-Pacific Northwest Laboratories: You mentioned the use of some computer codes, I think about four of them: intruder, groundwater, options, and inverse. Have these codes been documented?

Lohaus: Yes, they have. They are available and they are set out in Appendix H of the draft environmental impact statement.

Don Woods, Rockwell Hanford: I notice that you now have the limits for TRU nuclides and Class A waste. As I recall, the column in Table 1 of the draft rule was blank for TRU, implying zero. Have you changed that?

Lohaus: The way we had the TRU limit for the proposed rule shown in Table 1 was confusing. The limit, as it was set out there, would apply to either Class A, Class B, or Class C waste. However, many people interpreted that as an upperbound limit for Class C; they thought the limit meant that Class A and Class B wastes could have no TRU contaminants. That was not intended. We have corrected that in the final proposed rule.

Bill Lennemann: I'm a little bit confused about your inadvertent intruder or advertent intruder, whatever it may be. In the first place, I think he takes his own risk, but your 500 millirem is, as I recall, an exposure to an individual limiting factor. On the other hand, you can go to a radiation worker, which is the classification I think the intruder should be given. My question is this: "Why didn't you just consider him a radiation worker and jump up to 5 rem here, rather than protecting something that very likely will not happen, with 10^{-7}/year probability? If it's safe enough for radiation workers, it should be safe enough for an inadvertent intruder. Why do you let such an unlikely event control your whole waste burial characteristics and regulations?

Lohaus: The first point I would like to reemphasize is that the intruder is not the sole consideration that was applied. Other factors are considered. Stability is probably the most important; it limits the long-term need for maintenance, the long-term costs, and helps reduce the potential for groundwater migration. The intruder was the basis for calculating the actual concentrations, but we may very well have arrived at similar concentrations based on some of the other considerations. As I noted during the talk, there are existing limits in effect at the commercial sites dealing with when you should begin to stabilize waste because the activity is rising.

In terms of the 500 millirem dose limit itself, we have gone through a rather long process and there are many reasons we selected 500. One is the public input. Everyone seemed to settle on 500 as being an acceptable exposure limit. Through the draft environmental impact statement, we also looked at limits below and above 500 millirem. We looked at 25 millirem and also the occupational limit of 5 rem. We had some difficulties with the argument of using 5 rem on the basis of its being the occupational limit. When you consider a radiation worker, he understands the risks and potential hazards of the additional exposure that he is receiving and acknowledges this. It is a part of his livelihood. But the inadvertent intruder is a little bit different. He unknowingly contacts the waste. A combination of factors lead us to that value. The 500 millirem per year limit has been removed from the performance objective in the rule itself. The performance objective still requires assuring an adequate level of protection to an inadvertent intruder, but it doesn't state 500 millirem per year. the 500 millirem limit has still applied, however, basis for calculating the concentration levels.

Jack Healy, Los Alamos: We keep hearing 500 millirem, 10 millirem; what is this dose to, an organ or what?

Lohaus: It is the whole-body or organ exposure.

Healy: Any organ?

Lohaus: Yes.

Jerry Cohen, Science Applications, Inc.: To what degree do you believe that the results calculated by your models are objectively or arbitrarily determined at either end of the spectrum? For example, is there any possibility that the parametric assumptions used to calculate the 10 nCi/g limit might have been just as reasonable to calculate 100 or 1000 -- or would they have been obviously unreasonable assumptions?

Lohaus: What we have tried to do is to select some potential exposure pathways that are neither unreasonable nor overly conservative. I think even assuming that some of these exposure pathways may occur may be conservative--intrusion, for instance, is hypothetical. Intrusion

may never occur, but if it should we're trying to ensure that there will be an adequate level of protection to the individuals involved. Maybe I'm not answering your question directly, but I think we've tried to use realistic assumptions, given the somewhat conservative nature of some of the pathways. We have tried to analyze those using the best data we could, then to present the results.

Cohen: Then you believe you have incorporated a reasonable degree of conservatism.

Lohaus: Yes.

Preston Hunter, Ford, Bacon, and Davis: Philosophically, I tend to support the NRC position of considering something like intrusion in terms of evaluating a worst case dose to an individual for near-surface disposal. On the other hand, I question the scenario by which a factor of 10 modification was applied to Class A waste. I need a little further direction. Is it reasonable, considering engineered barriers and other methods that might be applied to inhibit intrusion into the Class A waste? You said engineered barriers would be considered as part of the containment for Class A waste; then you commented that greater confinement at greater depth, for example, is going to be investigated. Would you consider greater confinement, simply by deeper burial, as being one of the engineered design features that would be sufficient for Class C waste disposal?

Lohaus: We would. Part 61 establishes 5 m for Class C waste. We would consider that something greater than 5 m, for example 10 m or 15 m, would provide greater confinement.

APPLICATIONS OF MODELS FOR DISPOSAL OF ALPHA-CONTAMINATED WASTE

Jack Healy, Los Alamos National Laboratory

Because we are talking about modeling, I would like first to share my favorite quotation.

> The result is a work of art, sometimes good, sometimes bad, but almost always giving us, the creators, a feeling of euphoria. This euphoria often lives on for some time unless we make the mistake of comparing our creation with God's. For, unfortunately, he rarely agrees with us, and he is, by definition, always right.
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> J. B. Passioura, "Sense and Nonsense in Crop Simulation," J. Australian Inst. of Agric. Sci., Sept. 1973, pp. 181-183.

I find the British have a very elegant way of expressing things, and we have talked before about uncertainty. I call your attention to the last few lines, "... this euphoria often lives on for some time unless we make the mistake of comparing our creation with God's, for unfortunately, he rarely agrees with us and he is by definition, always right." I believe that this characterizes many of the models we find, particularly those done on computers, because somehow computers do seem to compete with God nowadays, especially in the number of significant figures.

I am going to talk today about a number of miscellaneous things. Some of these may be pertinent, but some are things that have concerned me for some time as I have reviewed reports on waste management. The first one I am going to bring up is the question we heard yesterday about dose factors; in that speech, dose factors were indicated as something that helps produce an answer--you multiply the dose factors and the final answer from the waste management modeling to get an answer. Unfortunately, it is not quite that simple. A large number of dose factors have been created, and a particular dose factor depends on the author, on the particular metabolic model he used, and on the particular model of the human that he used. For example, some very common dose factors that have been around for a long time are those derived from the International Commission on Radiological Protection's ICRP-II, a report issued in 1959 and written between 1950 and 1959. That is a little old; we now have considerable information on transuranic (TRU) metabolism that has been gained since that time. There are also new models, such as the ICRP lung model.

In case you think the lung model gives you an actual answer, I refer you to a report, ICRP-31, which describes very nicely the state of the lung model. The lung models were derived for radiation protection, in other words for control of radiation. We now have three retention and transfer categories in the lung model. There is actually a continuum

of information on those retention and transfer factors, and the three categories were chosen simply for convenience and simplicity. We have heard, for example, of the 500 day half-life in the lung. Well, at Los Alamos we have been following some people who were exposed during the Manhattan project. We have autopsy results on one person who had a large fraction of the plutonium in his body in the lung, not in the lymph nodes but in the lung. Please use these models and results with a great deal of discrimination.

As a matter of fact, I recommend that we all learn to calculate these doses ourselves and not rely on a model calculation done by somebody else. The procedure is simple. The algebra sometimes gets messy, but the procedure is simple as long as you confine yourself to the accuracy that is inherent in the data. However, you will find the calculations difficult if you start calculating like the ICRP has and calculate the gamma dose from one organ to the other. (For example, you have a deposition in the liver and you are calculating how much radiation the lung gets from this.) In most cases this complication is unnecessary. Look for ways to simplify without compromising accuracy; I think you will find that you can simplify.

I would like to say one or two words about the committed dose equivalent. It has been proposed that we should integrate the dose received by people over the full lifetime of the radionuclide. I find this suggestion preposterous. In the first place, I do not know what the world will be like tomorrow, much less 24, 30, 100,000 years from now. But we do this integration, and what is more, we seem to put credence in the values. We heard yesterday that the integration should be cut off at 10,000 years. I am not sure that I can differentiate between 10,000 and a million years in terms of integrating the dose. I would also like to point out that we frequently find that over 10,000 years we are going to have 1000 deaths. I would add the term "hypothetical deaths" as our basic limit. Do you realize that if we assume that the population of the United States remains constant over the next 10,000 years, there will be about 3×10^{10} deaths? Therefore, we are talking now about numbers on the order of 10^{-8} of all those deaths as our limit. I am not saying that the number should be higher; I am simply saying that when such numbers are given, the information that puts those numbers into perspective should also be given. Uncertainties in the dose models are not the only uncertainties; there are uncertainties in the metabolic factors, and there are inherent uncertainties because people are people. Many modelers are concerned with the uncertainties in their own models, but dose factors are treated as being completely certain. This is especially true of the computer output that gives five to nine significant figures.

We do not consider a number of sources of uncertainty. The dose factors are calculated by using the organ weights and metabolic factors from a standard, or reference, man. That is, all of the organs and many of the metabolic patterns are described by single

numbers that do not have uncertainty associated with them. They represent an individual male who is about average. Perhaps the numbers are a little conservative; the organ weights are somewhat smaller than they actually would be for an individual of that size. However, you need only look around this room to see that the human species comes in a variety of sizes, shapes, and, for those of you who have not noticed it before, there is also another sex. (There is a model for the standard female, but most of the dose factors use the standard man.)

As you know, we have individual differences. Not all people will metabolize the same radionuclide in the same way. This knowledge is frequently used in medicine as a diagnostic test for certain malfunctions. Even with normal functioning organs, however, there are individual differences in metabolism. Too little work has been done on this type of variability in dose and dose rate for a given intake. However, it is important for you as modelers and as decisionmakers to be aware that the numbers you come up with may not represent reality.

I would like to switch now to a topic that has been discussed before, but I would like to try to make it more explicit. This topic is the basis for limitation. We have started to derive some limits for TRU waste or any other waste. First we must ask, "What will be the basis of the limits?" Any number of alternatives is possible. We can limit the average dose, or the total dose, to some surrounding population. We can use the dose to a maximum exposed individual. We can limit on the basis of risk to either of these. We can apply the concept of ALARA and balance cost versus future risk. The final limit may depend on the basis of the limit, even if the modeling and the numbers used are the same.

Each basis has advantages and disadvantages. Many people would use the total dose to the surrounding population. However, in most of the calculations, the risks do not occur today; they occur sometime in the future. Consequently, characterizing the population, including food sources, medical practices, and numbers of people, is very difficult. I believe we tend to use the existing population as the basis. This may not be bad, but I believe that if we are going to take this course, we should use an average dose to the members of the population instead of using the total dose, such as man-rem. Using an average dose eliminates consideration of the number of people.

Personally, I have always liked the use of the maximum exposed individual, an individual who has certain habits and characteristics that I can define. I think he should be as realistic as possible. The theory behind the use of the maximum exposed individual is that if you protect the maximum exposed individual you protect the population. Incidentally, we have had radiation protection limits based on this theory for many years. I prefer this concept because I believe that I can better describe an individual of the future than I can a population. There will always be those who like to

get out and grub around in the soil, grow food, do all those things that lead to inhalation or ingestion of the radioactive material. The characteristics of the population may change, but even if we begin to manufacture food directly from the raw materials without going through the plant intermediary, I think this individual will be around. However, some care must be taken in describing this individual. People do have funny habits. Some years ago we were doing an assessment at Hanford and our environmental people found an individual who just loved to eat grass and would eat great quantities of grass each day. You have to be a little imaginative.

The risk approach is becoming more popular as the epidemiological studies are paying off and we are getting reasonable risk coefficients. In practice, this approach differs little from the dose approach; we multiply the dose by a constant and come up with a risk. However, when we do arrive at an answer, it is frequently more difficult to interpret because we do not have the same acceptance standards on dose that we do on risk.

The ALARA concept has, in my opinion, become a major "knee-jerk" reaction of the radiation community and the regulatory agencies. The impulse is to forget everything else and apply the particular individual's opinion of ALARA. This is particularly dangerous for TRU waste management because we are talking about great uncertainties in possible risks to future populations. How do we balance the social and economic benefits obtained from foregoing risks that have orders of magnitude or more uncertainty? [Incidentally, the Nuclear Regulatory Commission's (NRC'S) safety goals for reactors, which have been recently issued for comments, suffer from the same problem. They contain an ALARA statement, yet we cannot get a probability of reactor accident that any two people will agree on.]

We heard yesterday that the Department of Energy (DOE) has accepted a limit of 25 millirem/year. I do not know where this is written down, and I do not know where it came from. To me it seems a mystical number that is just picked out of the air, but if in fact DOE has decided to go with 25 millirem/year, it will drastically affect the purpose of this workshop. I am concerned that we have set up a series of basic limits, but when each new problem comes along the regulatory agencies seem to find an excuse to develop a new limit. I think we are going to lose public confidence completely, if we have not already, because the public is confused. Remember, the public considers a limit to be a limit. We do not have 20 different limits for lead. If the lead limit is exceeded, the public believes that the condition is unsafe. I think this belief is justified. I would put in an appeal; we should stop and think before we promulgate too many more limits.

A few words about scenarios. Scenarios are largely exercises in trying to foresee the future, in trying to predict the pathways to man according to the environment that we believe will exist and the ways

that we believe people will live. I will not go into the predictions themselves, but it seems that there are two main alternatives, each with an approximate probability. First, civilization might be far advanced, much more able to control risks than we are. Second, it might be reduced to savagery or subsistence technology; other risks will far outweigh any residual risk from TRU elements controlled to the levels accepted today. We do not, however, have general agreement on the types of scenarios to be used in estimating doses and, therefore, the limits. I think that has been apparent in the meeting so far.

There has been a great emphasis on the water pathway, probably because this is one pathway that a group of people are interested in modeling--it is highly important for high-level waste. However, this pathway does not seem to be of great importance for TRU waste. We have seen one pathway using water for irrigation. Radioactive material might absorb on the soils, remain in the surface of the soils, accumulate year after year, and eventually become a source for resuspension and inhalation.

One pathway that engenders confusion is the erosion pathway, in which the wastes are uncovered and people then live on the area. (This is categorized by the NRC as an intrusion pathway, but I do not like the word intrusion in this case because the situation is different from a person getting a pick and digging into the waste. I believe erosion is a better characterization.) In the study John Rodgers and I did, the limiting case was people living on an area that has been contaminated by the waste with very little dilution. If sheet erosion occurs, inhalation will occur maybe 10,000 years in the future and this, of course, is another issue. Should we really be concerned with what happens 10,000 years in the future? However, there are other ways to contaminate an area, a large number of pathways that we have not defined such as gulley erosion spreading the material over the flood plain below it. This scenario has been controversial because of the long period, but we operated on the basis that we do not wish to bury booby traps that could result in serious harm for people of the future.

The most controversial of the pathways, and probably the hardest to evaluate, is intrusion, which results in exposure of the intruder and may well result in secondary exposure of others. If, for example, the intruder takes home an item from the disposal area, or sells it, then other people could also be contaminated. Evaluating these exposures with our present technology is almost impossible, but they will occur.

We have both voluntary and involuntary intrusion. The probability of 10^{-7} that we heard yesterday was probably for involuntary intrusion where an individual digging something like a pipeline or a foundation digs directly into the waste.

I have been more concerned about the voluntary intruder. In the early period after the burial ground is closed, there will be some memory of the things that are buried there. Look at what is in your burial ground: cars, trucks, some very sophisticated machine tools, all sorts of hand tools, and even precious metals--the whole range of things people use in operation. The people who work at that plant know where this material goes. I believe that the second you stop guarding that fence, these people will be digging. In the longer time period, our concern has been with the archaeologists. On our committee, several people thought we were nuts. They said no self-respecting archaeologist would go digging around in a place like this. However, when they talked to an archaeologist, they found out trash heaps are exactly where archaeologists dig. I think in 200 to 1000 years, there will be a great interest in this era, which is essentially the dawn of advanced technology application. (That is, if we have anything left at all.) I am concerned about the individual intruder or intruders; however, I do believe that one could allow a higher dose to these people. One possible basis for higher dose would be the estimated risks. One rarely used method is to avoid reducing the individual's life span by any great amount; the calculation can be done with life tables. It is amazing how much dose you can give to an individual without making any significant difference in the probability of living to age 70 or 80.

Some people have said that we should mark the site and this will eliminate the pathway, or anyone who ignores the marker deserves what he gets. The problem is the permanency of the marker. Man is an incurable scavenger. If we put up permanent markers, someone will come along and show that they are not permanent, and before long the marker will grace the room of a high school or college student. At the burial grounds of Los Alamos, we are experimenting, placing a network of plastic ribbons that have the words "radioactive waste" just above the waste. The approach seems reasonable, but we can only speculate on its usefulness.

Regardless of how you feel about these scenarios and their validity, it seems to me that we must agree on the ones to be used and some of their specific features if we are to have any agreement at all in the results of our calculations. I can compare this situation to the 1940s when a number of people were calculating maximum permissible concentrations for air and water. Each individual was using his own numbers (body size, breathing rates, etc.). Naturally everybody came up with a different answer, and chaos reigned. But these people voluntarily got together under the sponsorship of Tri-Partite meetings; much of the work on the standard man was done in Tri-Partite meetings. I believe standardization is also necessary for the evaluation of TRU waste limits and burial sites.

Let me also comment on strategy. We have heard a lot about site specific limits as opposed to generic limits. I do not like site specific limits, primarily because of the bureaucracy and what one

has to go through to get them established. First you go through your pathway study and derive a limit; then you propose it. Next you get the approval of the people in your area, which takes a lot of time. In fact, you may have to write an environmental impact statement, which costs time and money. Multiply your estimate of the time required to do the study by 10. I am also concerned about the reaction to different limits. Suppose we have, at Hanford and Idaho, a factor of 10 difference in the limits. How do you justify the reason for this difference, not to fellow scientists but to the public? Why is one 10 times safer than the other? Until we do education, I would play it cool. Finally, I doubt that there will be any real difference between the generic limit and the site specific limit in the intruder characteristics and the erosion scenario. You can say less resuspension occurs in the East because of all the rain. However, we have absolutely no data on this.

One final point: we need to define what we are trying to do. We are defining a universal limit; anything that is above X is TRU waste. I wonder if this is the proper strategy. The TRU limit was originally intended for the trash coming out the back doors of our plants, but now the Hanford tanks, the soil at Idaho, and the cribs at Hanford may be considered TRU waste. These are specific situations; applying, without thinking, a limit that was derived for trash may get us into trouble.

Ed Watson, Battelle-Pacific Northwest Laboratories: I would like to comment on site specific versus generic limits. We might be referring to these as limits improperly. If you establish a dose limit and then establish a secondary limit (you can call it that although I prefer to call it something else) that permits you to achieve the performance standard of the dose, then you can say to the people in the northeast and the southwest that they are receiving the same protection. The limit is 5 millirem, 15 millirem, or whatever regardless of that secondary concentration number.

Healy: I agree, but I think you still have the same problem. The Environmental Protection Agency (EPA) is doing this in the proposed soil standard. (And if we have another weapon accident, I think we will have a few irate generals around.) The problem lies in doing this and then convincing people that calculations of 5 millirem, 10 millirem, or 1000 millirem give numbers different by a factor of 10. You will have trouble proving that to me, much less the public. Also remember the time this will take; by the time it goes through all the reviews and all the hearings, you may have spent much more time and money than you wanted to spend. It can be cheaper and easier to get one number agreed on, even if that number is a bit conservative for some sites.

Mike Barainca, DOE, Idaho Operations Office: Earlier in your discussion you said that each of the different numbers had a lot of variables. If you compound all this uncertainty, could you give us

your judgment on the range of uncertainty? We have been discussing whether the limit should be 10 nCi or 100 nCi. Is the range 1 to 100,000 nCi? What range should we be considering?

Healy: Certainly the range is within 1 to 100,000 nCi. I wrote down some notes this morning on this point, but I dropped them from the presentation. Sometimes we get confused about what we are really trying to do. We are trying to calculate a limit of a certain number of nanocuries to meet a dose limit. Is that really our objective, or is our objective simply to make sure that the waste will not pose any undue problems? Should the dose limit be prescribed simply to give you a basis to avoid problems? I have done some work on plutonium and soils, and I am concerned that many people immediately say, "Well, that number is equivalent to 500 millirem/year." I say, "No, it is not." I used that as the basis, but the uncertainties are such that I will not say the number is 500 millirem/year although I think it is a safe number. I think the uncertainties are greater than we are willing to admit. However, I can accept a factor of 10 on the dose calculation for individuals (variation in individuals) with no difficulty.

Joe Lieberman, Nuclear Safety Associates: Your last comment precipitated this question. All those sites have a job to do. I agree with your comments about uncertainties, but how do you deal with the uncertainties? How do you deal with the state of affairs as you characterize them, contend with the public's perceptions, and get on with the job that each site has to do? I know there is no magic answer to that, but you have had experience in a variety of regulatory environments, and I think it might be helpful if you could make some suggestions.

Healy: There is no answer to this question. I took my stand on the generic versus the site specific limit because I tend to be practical and I know that many sites do not have the people needed to do the study. I also do not believe the answer will be greatly different unless you eliminate certain of these pathways. You might get a factor of 1.5 because somebody used one calculation and somebody else used a different one, but I do not think orders of magnitude differences will occur. In that case, why would we use site specific limits?

Watson: I think it is a practical matter if you start talking about 600 sq miles at Hanford going to a repository. The difference between 10 and 100 nCi/g can make quite a difference in cost.

Healy: That is why I would not apply the limit for trash to your 600 sq miles at Hanford. Hanford is a specific situation and should be handled specifically. I am talking about a trash limit.

Don Box, Oak Ridge National Laboratory: You mentioned that an autopsy revealed that most of the plutonium one person had inhaled remained in

the lung. Would you recommend continued ethylenediamine tetraacetic acid (EDTA) inhalations over his lifetime, possibly removing more and more of this plutonium?

Healy: I am no medical man, but from what I have seen of the results of EDTA or any of the chelators, they must be given early. You do not get a great increase in elimination rate at later times, perhaps a factor of 10, but by that time the elimination rate is so low that you do not do a lot of good. You have to look at each individual case; because this was discovered after the man was dead, the chelating agent was not given.

A REVIEW OF RISK ASSESSMENTS FOR DEFINING THE ALPHA-CONTAMINATED WASTES

Craig Smith, Science Applications, Inc.

The purpose of my presentation (Slide 1) is to review and discuss the history, approaches, and results of studies that have been carried out to define appropriate disposal limits for alpha-contaminated or transuranic (TRU) wastes. Yesterday, Vern Rogers pointed out that, contrary to popular belief, there is nothing special about TRU wastes simply because they are of a TRU nature. They are not unique in terms of half-life, toxicity, or transport potential. Nevertheless, in this country they have been treated as a special category. In my presentation, I will discuss the history of TRU wastes and waste management, particularly the 10 nCi/g limit. Next I will consider approaches used in TRU waste assessment. I will review and summarize several studies to identify disposal limits and the current regulatory situation. Finally, I will offer some general conclusions.

First, the history of TRU waste management (Slide 2). Shallow-land burial has been used for the disposal of radioactive wastes since the early days of nuclear weapons research in the 1940s. The Atomic Energy Commission (AEC) operated burial facilities to handle private-industry and AEC wastes. During this time, no distinction was made between TRU and low-level waste. During the 1950s, sea dumping was instituted for the disposal of mixed wastes at sites off the Atlantic and Pacific coasts. Eventually, sea disposal became limited and burial facilities were established by the AEC at Oak Ridge National Laboratory (ORNL) and at the National and Reactor Testing Station in Idaho. After separate commercial burial grounds were established in Beatty in 1962 and Maxey Flats in 1963, the AEC discontinued acceptance of private-industry waste, but continued to operate burial facilities for radioactive wastes generated by government activities.

In 1970, the General Manager of the AEC prohibited the disposal of wastes containing TRU elements in excess of 10 nCi/g from burial in AEC burial grounds. Temporary storage in retrievable form was also mandated for newly generated government TRU wastes. Temporary storage was to be for a period of 20 years.

In 1973, the AEC issued Chapter 0511 of the AEC Manual in which TRU disposal limits became fully operational (Slide 3). Chapter 0511 defines TRU wastes as "those contaminated with certain alpha-emitting radionuclides of long half-life and high specific radiotoxicity to greater than 10 nanocuries per gram." The radionuclides covered in this definition included uranium-233 with its daughter products and plutonium and the transplutonium nuclides americium and curium, except for plutonium-238 and plutonium-241. The 10 nCi/g limit had a quasi-technical basis in that it was based on the upper range of concentrations of radium-226 radioactivity in the earth's crust. I

Slide 1

PURPOSE: TO REVIEW THE HISTORY, APPROACHES, AND RESULTS OF STUDIES TO DEFINE CONCENTRATION LIMITS FOR THE DISPOSAL OF TRANSURANIC (TRU) WASTE.

- HISTORY OF THE 10 nCi/g LIMIT
- APPROACHES USED IN TRU ASSESSMENT
- DISCUSSION OF RELEVANT STUDIES
- REGULATORY STATUS
- CONCLUSIONS

Slide 2

HISTORY OF TRU DISPOSAL

- PRE-1970

  -AEC BURIAL FACILITIES BEGINNING IN 1940s

  -SEA DUMPING DURING 1950s

  -COMMERCIAL BURIAL AT ORNL AND NRTS

  -SEPARATE COMMERCIAL SITES IN 1962-63

- SINCE 1970

  -10 nCi/g LIMIT FOR SLB

  -RETRIEVABLE STORAGE MANDATED

Slide 3

AEC MANUAL, CHAPTER 0511, ISSUED IN 1973

- DEFINED TRU WASTES
- LIMITED SLB TO LESS THAN 10 nCi/g
- QUASI-TECHNICAL BASIS FOR LIMIT
- LIMIT "SUBJECT TO MODIFICATION"

say radioactivity to distinguish it from toxicity or environmental hazard. I will say more about this point later.

It should be pointed out that Chapter 0511 recognized the limited technical basis for the value of 10 nCi/g and stated that the limit was "subject to modification" based on studies of nuclide behavior in the environment. Subsequent regulatory action by the AEC included the issuance in 1974 of a proposed rule to establish the 10 nCi/g limit for the disposal of TRU materials at commercial sites. Although this rule was subsequently withdrawn, disposal in commercial sites was effectively prohibited by this and previous actions. By 1975, burial at all commercial sites other than Hanford was limited to wastes containing less than 10 nCi/g.

Regarding the original basis for the 10 nCi/g limit, Slide 4 shows the relationship between uranium-238 concentrations in the earth's crust and the resultant radium-226 concentrations in nanocuries per gram. Although typical soil is well below the 10 nCi/g limit value for radium, a 3% uranium ore provides this concentration. This slide also shows the corresponding plutonium-239 concentration, where equivalence is based on ingestion MPCs. If the TRU limit had been based on relative ingestion toxicity, for example, rather than on radioactivity alone, the 10 nCi/g value for radium-226 would correspond to 2500 nCi/g of plutonium-239. Conversely, a 10 nCi/g plutonium limit would be equivalent in toxicity to the radium contained in ordinary soil at the upper range of soil variability and not to that contained in a 3% ore body.

Next, I would like to discuss some alternative approaches (Slide 5) to the assessment of TRU waste limits. These alternatives include the natural analog method, deterministic and probabilistic approaches, the application of cost-benefit analysis, and various combinations of these techniques. Let me briefly describe each of these in turn.

The analog technique (Slide 6) for assessment of waste disposal has been discussed previously at this workshop. The technique is based on the existence of natural chemical and physical analogs in the environment from which insights can be drawn concerning the behavior or impacts of waste disposal. The relationship between environmental concentrations of certain materials (e.g., arsenic and selenium) and human health has been well documented.

A good example of the use of the analog approach can be seen in the use of radioactive and chemical tracer techniques to understand the behavior of materials under various circumstances. The similarity between the tracer and the material under study can be direct (e.g., when a different isotope of the same chemical element is used) or indirect (e.g., when a different chemical element from the same group on the periodic table is used). Examples can be found of radioactive tracers being used to study the behavior of nonradioactive materials, and also of the other way around. Radioisotopes are frequently used

Slide 4

COMPARATIVE RADIUM/PLUTONIUM
CONCENTRATIONS FROM SELECTED NATURAL
URANIUM VALUES

U-238 CONCENTRATION (PPM)	EQUILIBRIUM RA-226 CONCENTRATION (nCi/g)	EQUIVALENT* PU-239 CONCENTRATION (nCi/g)
10 (SOIL)	.003	0.75
130	.04	10
30,000 (3% ORE)	10	2500
100,000 (PITCHBLENDE)	30	7500

*EQUIVALENCE BASED ON INGESTION MPC'S

Slide 5

ALTERNATIVE APPROACHES TO ASSESSMENT

- ANALOG
- DETERMINISTIC
- PROBABILISTIC
- COST/BENEFIT
- COMBINATIONS

Slide 6

THE ANALOG TECHNIQUE IS BASED ON NATURAL CHEMICAL AND PHYSICAL ANALOGS IN THE ENVIRONMENT FROM WHICH INSIGHTS CAN BE DRAWN

- TRACER TECHNOLOGY

  -DIRECT

  -INDIRECT

- THE 10 nCi/g LIMIT
- WHAT IS ACCEPTABLE?

in tracer studies because of their direct similarity to the analog under study and because of their high degree of detectability at low environmental concentration levels.

The original basis for the 10 nCi/g limit represents a crude use of the analog method. A recent National Committee on Radiation Protection (NCRP) study considered a more logical application of a similar analog method. Their results suggested that, including environmental transport potential and relative toxicities, radium-226 would result in at least a factor of 1000 greater dose than plutonium-239 in the environment on a curie per curie comparative basis.

The question of what is acceptable in terms of waste management issues can also be considered from an analog standpoint. The approach of relating waste management criteria to uranium ore body risks is one such example. Another example points out the problem with our preoccupation with intrusion scenarios as the driving force in our TRU disposal considerations. A study that is currently in progress has found that many deaths occur in this country because of inadvertent intrusion into toxic or hazardous natural formations. These are formations that are not radioactive in nature. In addition many naturally toxic areas exist in the western United States. At these sites, the additional hazards of siting a waste disposal facility would be very small on an incremental basis because of the highly toxic character of the naturally occurring deposits on the site.

The deterministic approach (Slide 7), sometimes referred to as "worst-case," is perhaps the most widely used assessment technique. In this approach, particular scenarios are evaluated mechanistically without regard to relative likelihood. To determine disposal limits, basic criteria, scenarios, and data are selected and applied using transport and dose assessment models. Some of the problems with this approach have been pointed out by several previous speakers and they include the compounding of conservatism, false precision, the arbitrary nature of assumption and scenario selection, and the extension of models beyond their range of validity.

Compounding of conservatism can occur when conservative criteria are used along with pessimistic or unlikely scenarios and conservative data as input to intentionally conservative models. Although the resulting calculated disposal limits may be conservative, they may be so conservative that they are unreasonably restrictive. False precision occurs when values are presented to many more significant figures than the analysis justifies. This point has also been addressed by several speakers. Just as a chain is only as good as its weakest link, it makes little sense to model a parameter in great detail when another part of the model controls the accuracy of the final results.

Slide 7

THE DETERMINISTIC APPROACH IS THE MOST WIDELY USED TECHNIQUE

CRITERIA

SCENARIOS

MODEL

DISPOSAL

LIMITS

DATA

Generic studies are rarely truly generic from the standpoint of representing all conditions. Rather, the tendency is to arbitrarily select assumptions and scenarios to represent a highly specific, although hypothetical, situation. Frequently, any particular result can be achieved through judicious selection of data and assumptions from within ranges of reasonable values.

The probabilistic approach (Slide 8) extends the deterministic method by weighting event consequences with calculated or estimated probabilities. In this way, the consequences of unlikely events can be related to expected occurrences in a meaningful way. The Reactor Safety Study is probably the landmark study that used this technique, but it has not yet found great application in the waste management area. The probabilistic approach normally uses realistic calculations of consequences rather than conservative or worst-case results. However, the same types of deterministic models are normally used. Some of the disadvantages of the method include the requirement for an additional step in the assessment (i.e., the evaluation of probability data) and the need for probabilistic criteria to establish whether objectives have been met.

The cost-benefit approach (Slide 9) incorporates the concept of economic optimization by recognizing that there must be trade-offs between costs and health risks. This approach is consistent with International Commission on Radiological Protection (ICRP) guidance and with the application of the principal of ALARA. The existence of a cost-effectiveness guideline in Appendix I of 10 CFR 50 offers a useful criterion for extension to general cost-benefit analysis. I'm not going to go into any greater detail on the cost-benefit approach because Jerry Cohen will be presenting an application of the approach in a later paper.

Now let's consider some previous studies (Slide 10) to indicate TRU concentration limits. The first of these is a study by Leddicotte et al. (1978), of the Utility Waste Management Group. From this slide, you can see some of the key results of this study. Let me point out some of the areas in which assumptions were made. The individual dose limit criterion that was used in this study was 500 millirem/year to an intruder; 5 millirem/year whole body off-site dose to the general public; and 15 millirem/year as a limiting organ dose off-site.

The site considered was 160 acres. It included 2,000,000 m^3 capacity; 30,000 m^3/year burial rate; 1.2/cm^3 density; 7000 m distance to water emergence; 0.1 cm/day water flow rate; 0.1 soil porosity; and 2.5 g/cc soil density. The site involved multiple scenarios, including intrusion, and assumed a 100-year institutional control period. The study used conservative distribution coefficients; it considered some pathways out to 10,000 years to allow daughter product build-up. Other assumption areas included air resuspension, breathing rate, erosion rate, water course dilution, and consumption rates by various food paths. My point here is that there are many assumption areas

Slide 8

THE PROBABILISTIC APPROACH EXTENDS THE DETERMINISTIC METHOD BY INCORPORATING EVENT PROBABILITIES

- REALISTIC CALCULATIONS
- PROBABILITY DATA NECESSARY
- NEED PROBABILISTIC CRITERIA

Slide 9

THE COST/BENEFIT APPROACH INCORPORATES THE CONCEPT OF ECONOMIC OPTIMIZATION

- TRADEOFF BETWEEN COST AND HEALTH RISK
- COST EFFECTIVENESS CRITERION

Slide 10

PREVIOUS STUDIES DEFINING TRU LIMITS

LEDDICOTTE ET AL., 1978

CONCENTRATION LIMIT
(nCi/g)

NUCLIDE	LIMIT	PATHWAY
Ra-226	30	FOOD GROWN ON SITE
Pu-239	500	INHALATION BY INTRUDER
Am-241	3000	INHALATION BY INTRUDER

involved in this and other disposal limit studies. The results are influenced by many of these assumptions and, as Jack Healy just pointed out, this really is a problem. As a result of this, the calculations that are carried out in the various studies are not generally comparable.

Another study was conducted by Adams and Rogers in 1978 (Slide 11). Once again you can see the calculated limits for this study. There were basically six exposure scenarios considered, with a dose criterion of 500 millirem to an intruder and 5 millirem to the general population. Many other assumptions, generally different from those of the previous study, were made. However, the intruder, or reclaimer, scenario was the limiting scenario as it was in the previous study.

Slide 12 shows some of the results from the work of Healy and Rogers. Again, assumptions were made on a reasonably conservative basis in this study; a very good job was done of stating exactly what the assumptions were. The study included humid site conditions; other conditions included such assumptions as that the waste was placed at the bottom of the pit lying directly above the aquifer. The limits derived from this study result from the erosion or reclaimer activities after erosion, with the farmer living on top of the waste material. This scenario was assumed to occur after a period of perhaps several thousand years. In this particular scenario, an arbitrary dilution factor of 2 was used to account for the mixing of uncontaminated soil with the waste material over that period of time.

Slide 13 shows a summary of the three studies previously described, together with several others that have been conducted over the last few years. I should point out that it is predominantly the intrusion, or reclaimer, scenario that was the limiting factor in these studies. I should also point out that these guidelines inferred or are extracted values for the plutonium limits only and that they were based on various assumptions, scenarios, and basic underlying criteria. The principal exceptions to the statement that critical doses are based on the reclaimer or intruder scenario would be the study by Root (1981). In this study, the critical pathway was a farming and direct water-use scenario. The EPA and the NCRP are the other two studies that might be exceptions.

I would like to say a few more words about the NCRP study. This study did not recommend a single concentration limit; however, it did state that there is substantial evidence that the 10 nCi/g limit is conservative under many, but possibly not all, conditions. The NCRP study also used two natural analog arguments. The first of these was a radium-226 plutonium-239 analogy. The NCRP found that, considering several different pathways, a factor of 1000 in overall hazard between the radium and plutonium values would be appropriate considering relative toxicity and transport potential. The second analog discussion in this report relates to the disposal of lead in the form of lead storage batteries. This study found that the

Slide 11

ADAMS AND ROGERS, 1978

CONCENTRATION LIMITS
(nCi/cm^3)

NUCLIDE	LIMIT	PATHWAY
Am-241	3600	
Pu-239	1000	RECLAIMER INHALATION
Pu-238	3700	

Slide 12

HEALY AND RODGERS, 1979

SLB LIMITS
(nCi/g)

NUCLIDE	RANDOMLY CONTAMINATED MATERIALS	UNIFORMLY CONTAMINATED MATERIALS	PATHWAY
Pu-238	3000	100	
Pu-239,240	50	2	RECLAIMER
Am-241	5	0.4	
Pu-241	200	10	

Slide 13

SUMMARY OF STUDY RESULTS

AUTHOR(S)	CITATION	DATE	Pu-239* GUIDELINE (nCi/g)
LEDDICOTTE ET AL.	WM-78	1978	500
ADAM AND ROGERS	NUREG-0456	1978	1000
ROGERS	NUREG/CR-1005	1979	100
COHEN AND KING	UCRL-52535	1978	1000
HEALY AND RODGERS	LA-UR-79-100	1979	2-50
ROOT	SRL DO-MS-80-24	1981	700
DOE	INEL DEIS	1981	2000
NRC	NUREG-0782	1981	10
EPA	40 CFR 191	1981	100
NCRP	SC 38	1982	--

*BASED ON VARIOUS CRITERIA, SCENARIOS, AND ASSUMPTIONS. VALUES INFERRED OR EXTRACTED FROM THE CITED STUDIES.

disposal of lead storage batteries represents an equivalent toxicity concentration level of about 80 times TRU waste at the 10 nCi/g limit. From this, one might say that the disposal of lead storage batteries is basically equivalent to disposal of TRU at an 800 nCi/g value.

Slide 14 shows a few of the uncertainty values that were reported by Healy and Rodgers. This is only a partial listing of the values that they reported. If you take these values and evaluate the different exposure pathways and compound the different limits of these ranges, you find that there can be variability of results over several orders of magnitude.

Slide 15 briefly summarizes the current regulatory status. Based on what we have heard from the EPA and the NRC at this meeting, perhaps these figures are a little bit out of date. As an EPA regulation, 40 CFR 191 has not yet been officially proposed; it is still circulating in unofficial draft form. Basically, the EPA proposal includes a 100 nCi/g limit for TRU wastes.

The proposed NRC regulation on high-level waste (10 CFR 60) basically does not include TRUs. They are included in 10 CFR 61, which is the proposed low-level waste regulation. Yesterday, we received a good briefing of what that regulation includes and how far it goes and what it does. The original value of 10 nCi/g is still in the regulation for the Class A type of waste; however, the Class C waste is being revised upward to 100 nCi/g.

Let me finish by offering a few conclusions (Slide 16). First of all, I think it is clear that there is an emerging consensus that the disposal limits can be and possibly should be raised. This is not a unanimous opinion, but there is quite a considerable consensus. I would also like to emphasize the subjective nature of the deterministic approach. Difficulties with the deterministic and other available methods may indicate that there is no single best way to derive a particular disposal limit. You may have to use various approaches to come to any conclusion. I would like to agree with one of the speakers yesterday about the urgent need for some kind of regulatory philosophy or statement regarding the intrusion scenarios. As it stands now, we have seen that the intrusion scenario is driving the whole show; whether it should be is probably a philosophical question. I would be interested in seeing the EPA establish the philosophy for the application of such considerations. I think it would be appropriate if such a regulatory philosophy applied to all activities over which the EPA has jurisdiction. I think if this were pursued, we would either bankrupt the country or we would come up with something reasonable. In the same regard, I would suggest that there is a need for overall objectives and criteria from a regulatory standpoint. Hopefully, this would help sort out the diversity of assumptions, scenarios, and studies that are being used and it might help reduce the confusion and bring some consistency into the study of TRU waste limits.

Slide 14

UNCERTAINTY RANGES FOR KEY PARAMETERS*

PARAMETER	VALUE USED	RANGE	EFFECT ON DOSE
LUNG WEIGHT	500g	300-600	.6-1.2
BONE WEIGHT	5000g	2000-8000	.6-2.5
QUALITY FACTOR	10	10-20	1-2
BONE DIST. FACTOR	5	5-15	1-3
PARTICLE SIZE	1μ	0.1-10	0.5-2
INHALATION RATE	$20m^3$/day	10-27	0.5-1.4
GI-BONE FRACT.	$4.5x10^{-5}$	$9x10^{-6}$-$3.5x10^{-4}$	0.2-8
BIOLOGICAL INCORP.	0	0.2-13	0.6-8
LEACH RATE	10^{-6}/yr	10^{-7}-10^{-5}	0.1-10
EROSION RATE	6T/acre/yr	0.1-20	0.3-60

*FROM LA-UR-79-100

Slide 15

SUMMARY OF REGULATORY STATUS

PROPOSED REGULATION	AGENCY	TRU LIMIT
40-CFR-191**	EPA	100nCi/g
10-CFR-60	NRC	NOT INCLUDED
10-CFR-61	NRC	10nCi/g

* UNDER REVISION
**NOT YET OFFICIALLY PROPOSED

Slide 16

CONCLUSIONS

- EMERGING CONSENSUS TO INCREASE LIMIT
- SUBJECTIVE NATURE OF DETERMINISTIC APPROACH
- NEED FOR REGULATORY PHILOSOPHY REGARDING INTRUSION SCENARIO
- NEED FOR DETAILED OBJECTIVES AND CRITERIA

Bill Lennemann: I notice that the 10 nCi/g limit obviously was based upon plutonium-239 and all the isotopes that go with it, which add further radioactivity to this counting. Pure plutonium-239 is never found in waste, and yet we do have the criterion or the goal based upon that. That is not realistic to me. This plutonium-239 limit was then applied to all alpha-bearing wastes. Now that is a step that really did not have much basis except that there did not seem to be anything else to do. On the tables you presented, you still only use plutonium-239. Does that stand for a grouping or is this essentially only plutonium-239? What are you going to do about the rest of them?

Craig Smith: There were several studies shown on the table that I presented and, as I said, I extracted the values for plutonium-239 for comparison purposes. Some of the studies included nuclide mixes, which were then represented in terms of an equivalent plutonium concentration. Others had limits that were nuclide-by-nuclide. There is a basic question about going from generic to specific analysis and about whether there should be limits based on individual radionuclides. I think it is an important question. It becomes a question of how much detail you want.

Jerry Cohen, Science Applications, Inc.: One of those earlier studies was mine. One of the simplifying assumptions was that we calculated the consequences on the assumption that all alphas were emitted from plutonium-239, and we compared that with the consequences of actual observed mixtures. We found out that it was close enough for government work, that it is a reasonably conservative assumption. The assumption is not precise, but considering the nature of the analysis, it was good enough.

Tom Smith, EG&G Idaho, Inc.: On that large comparison table of the different study results, I was a little nervous that the only entry there under DOE was the INEL-DEIS, and I just wanted to point out that the DEIS did not recommend a limit. Apparently, there were some numbers that you back calculated.

C. Smith: Actually, that number was reported in the NCRP study as a limit that would be derived from the INEL study.

T. Smith: I did not want to take responsibility, credit, or blame for that number.

V. S. Arakali, West Valley Nuclear Services Co.: When you were discussing approaches to waste evaluation, you said that the probabilistic approach is not good for waste management. NRC is publishing a guide for PRA-type safety analysis, which tells me that they have recognized the strength of this approach. Could you elaborate on why you feel the approach is not appropriate?

C. Smith: I think you misunderstood what I said. My comment was that the PRA technique has not found widespread application in the

waste management area. I am all in favor of the technique. I think it is the way we need to go, but it just has not found widespread application. There are a few studies that have included probabilistic considerations. One of them is Tom Smith's EIS work at INEL and another one is an SAI report that considered greater confinement disposal limits. These are, however, a few small first-step kinds of studies that really have not gone into the detail for which I think there is potential.

CRITICAL EVALUATION OF THE LIMITS OF ALPHA CONTAMINATION IN LOW-LEVEL WASTE

Joe Lieberman, Nuclear Safety Associates

Walt Rodgers of Nuclear Safety Associates had undertaken what I'm going to call a preliminary or rough ALARA analysis of the proposed 10 CFR 61, including transuranic (TRU) considerations. Yesterday, Paul Lohaus did an excellent job of summarizing for us what the current status of that important proposed regulation is, and I am going to present a rather cryptic summary of the result I've derived from Walt's notes.

The analysis that Walt was working on is based on the data and information contained in the draft environmental impact statement (DEIS) for 10 CFR 61. I'm sure many of you are familiar with that; it's NUREG 0782. The DEIS addresses selected waste disposal alternatives and their costs and has a lot of information in it. The DEIS provides data on maximum doses to individuals from intrusion and population doses to small populations using groundwater or surface water from a small adjacent stream. The reference case in those alternatives is essentially present practice. One interesting, but at least to me not terribly surprising, conclusion that seems to come out of this analysis is that, based on $1000/person-rem, it looks like very little, if any, modification from present practice would be justified. That number was first put out by the Nuclear Regulatory Commission (NRC) in 1975, and I suppose it should be escalated to account for inflation. I think that number would be something like $1700 or 1800 now if you escalated for inflation. Some reasonable practices would be segregation of wastes with higher concentrations to the burial trench bottom, improved trench covers, and things like those that Paul Lohaus noted yesterday. No cost-benefit analysis would seem to justify any significant modification of present shallow-land burial practice.

With respect to the TRU considerations, based on data in Appendix D of the DEIS relative to power reactor waste, it appears from the arithmetic that the TRU content of the so called spectrum-1 waste, as defined in NUREG 0782, turns out to be about 40 nCi/g rather than 10 nCi/g. If one applies the factor of 10 that Paul Lohaus noted yesterday as being contained in the revision of 10 CFR 61, this would seem to be equivalent to about 400 nCi/g in the trench. The analysis leads to the conclusion that from an ALARA standpoint, TRU concentration values higher than 100 nCi/g would indeed appear to be justified. To go down from 100 nCi/g (as now proposed in 10 CFR 61 at least for Class C waste) to 10, a typical 1000-MW reactor would only be justified in spending about $1000/year. From a cost-benefit standpoint, therefore, the 100-nCi/g limit seems quite supportable.

Another conclusion that seems to be coming out of the analysis is that the individual dose limitation of 500 millirem/year would preclude

levels much higher than several hundred nanocuries per gram. Above a few hundred nanocuries per gram, you begin bumping up against that individual dose limit fairly quickly. Again, as has been indicated by other speakers, as one approaches the lower, or more stringent, TRU limits, more waste would have to go to a repository, and cost would be increased. I was pleased, however, to hear Vern Rogers' comments noting that there are alternatives between a near-surface land burial facility and a repository. Certainly from a utility standpoint, there's increased analytical difficulty and cost as you tighten that limit. Also, from a reactor operations standpoint, there would be greater difficulty to prove or support generic classification or waste streams such as trash or dry-active waste.

One final point that I think might be worthwhile making is that (as Paul Lohaus indicated yesterday) in the revised version of 10 CFR 61, the NRC has proposed an increased (less stringent) limit for all isotopes, except cesium-137, in Class C waste by a factor of 10 for three reasons. First, there is a reduced likelihood of intruder exposures because of the incorporation or the use of passive warning devices or systems, despite Jack Healy's caveat that you might find these warning devices in some college student's classroom. I expect that one could come up with the system that would make it difficult for even the ingenious college student to pick it up and put it in his room. Second, it is difficult to contact the waste because it is being disposed of at greater depths. If you put the Class C waste at the bottom of the trench, it would be tougher to get to. Third, from the dilution consideration, the average concentration of the waste would be expected to be considerably less than the peak concentrations. I think these three reasons are valid, particularly with respect to isotopes that have relatively short half lives. However, for the long half-lived isotopes, like the TRUs, I would suggest that (for long periods of time only) the last reason might still be viable (i.e., significant peak-to-average ratios or a kind of dilution). In its analysis, NRC essentially treated all wastes as Class A after 500 years.

Because the number of Class A shipments, primarily with respect to commercial waste, containing higher levels of TRU would be quite small and because much of the Class A trash would contain no TRU at all, the peak-to-average ratio for TRU in Class A waste would be expected to be much higher than that ratio for Class C waste. Class C work reasonably could be expected to be less variant with respect to TRU concentration. Furthermore, the EIS analysis suggests that only about 0.1% of the total TRU content of waste shipped to the burial ground is associated with trash and, further, that this trash is only about 30% of the total waste volume.

Thus, the logic that led the NRC to increase all Class C limits by a factor of 10 would seem to me to apply even more so to TRU in Class A waste. It is suggested, therefore, that the 100-nCi/g limit might be considered to apply to all classes. From a power reactor operational

standpoint, when one considers the potential waste classification difficulties (e.g., getting representative samples of Class A waste), the analytical difficulties of measuring down to 10 nCi/g, and the absence of significant radiological impact, the application of this factor of 10 nCi/g for TRU to Class A waste seems sensible.

Ed Watson, Battelle-Pacific Northwest Laboratories: At the annual meeting of the Health Physics Society, Paul Voelke presented a paper with some reasonably good data supporting a figure of about $30/man-rem. On the surface, it looks like it's pretty good data he's presenting. As you know, the $1000/man-rem had relatively little scientific endeavor or any other kind of endeavor behind it. What effect would such a change have on the statement that you made that no change of present practices is warranted?

Lieberman: It would make that statement that much more valid. I would be interested in seeing that paper. It reminds me that many years ago Joshua Lederberg did a fair amount of work in trying to arrive at a value for a man-rem. As I recall, he came up with something between $50 and $100. That kind of number, if it's really well developed, might be a very useful contribution.

Jerry Cohen, Science Applications, Inc.: I've got to tell a story here if we've got a few minutes. I think I have the distinction of being the first individual ever to have published a paper suggesting $1000/man-rem quantity. This was back in 1969, and I won't go into details, but the number we suggested was $250/man-rem. It was presented at a Health Physics Society meeting and met with great gales of laughter. That was about 5 years before Appendix I. In the next couple of years, several other papers came into the literature suggesting values. John Dunster in England and Bo Lindell in Sweden were two of the authors. Anyway, I subsequently wrote a letter to the editor of the Health Physics Journal compiling all of these values into a little table. Walt, then, in his testimony before the NRC, brought that table out and he said, "Well look, the highest value on this table is equivalent to $980/man-rem averted; let's just round it off to $1000." I think that's how the $1000 finally came into being. Having written the paper, I know where that $980 came from. It was from a paper by Harry Ottway, who was an associate of mine at the time I was working at the International Atomic Energy Agency (IAEA). He was two offices down the hall. I brought the Federal Register announcement over and said, "Harry, where did that $980 come from?" To which he replied, "What $980?" I showed him a Federal Register Notice, and I said, "See, it's the law of the land, your work has been the basis for it." He said, "Oh, that piece of crap." He said it had something to do with the cost of pilot ejector seats on military aircraft. We sat down and composed a letter, which was never sent, addressed to the NRC suggesting that they were moving in the right direction by setting $1000/man-rem, except that they missed it by a factor of 4. It should have been $250/man-rem as God had originally

intended. It is interesting to find out how these laws get on the books.

Paul Lohaus, Nuclear Regulatory Commission: I want to respond to the comment about the dilution of the Class A wastes as providing even more of a rationale for raising the limit from 10 to 100 nCi/g. Even setting aside the fact that the limits that we calculated were in the range of around 10, if you look at the distribution of the TRU radionuclides (particularly in commercial reactor wastes), they range around 10 to 20 nCi/cm^3 as a normalized gross limit based on the actual calculated values for each one of the nuclides for the total waste volume. If you were to apply a density of about 1 to 2 g/cm^3, you would come out pretty close to 10 nCi/g. We pushed this in retaining 10 for the Class A waste because there are many other factors that would either drive this value up or down. As we go through and begin to look at specific waste streams, make some determinations on a waste-stream basis, and remove some of these streams from control, the place where most of these are going to come from will be the Class A wastes. This would seem to remove a lot of the streams that would provide dilution. Given the fact that disposal costs have increased, I think there is interest in volume reduction. Again, I think in the Class A waste we have compressible, combustible-type streams that would again tend to increase the concentration rather than decrease it.

Lieberman: I appreciate that elaboration, and I am particularly pleased to hear about the de minimis possibilities. The time before one could arrive at conclusions and really establish a de minimis level for dry-active waste from reactors, I think, is going to be pretty long. In the meantime, it seems to me that it would simplify some waste classification and waste management matters a great deal and would not interfere with volume reduction possibilities. There would be really no significant public health impact if indeed that factor of 10 increase in TRU was applied to Class A waste as well.

ALPHA-CONTAMINATED WASTE MANAGEMENT AND ENVIRONMENTAL IMPACT AT THE SAVANNAH RIVER PLANT

Charles M. King

I'm new to your business, having been in waste management about 1 year. Fortunately, I was assigned to Ed Albenesius and John Wiley at Savannah River Laboratory on an interesting and challenging program. I've been working in the nuclear business for 3 years after 10 years with Du Pont Commercial. This is an interesting week to me because I'm learning. I'm asking many questions because I'm trying to understand what your business is about.

Mine is the first in a series of talks about alpha-contaminated waste management at actual Department of Energy (DOE) sites. I'll concentrate on our situation at Savannah River Plant (SRP). We've been burying waste since 1953 when production started. Alpha waste burial started in 1955 and continued through about 1965 when retrievable storage of most of the transuranic (TRU) activity began.

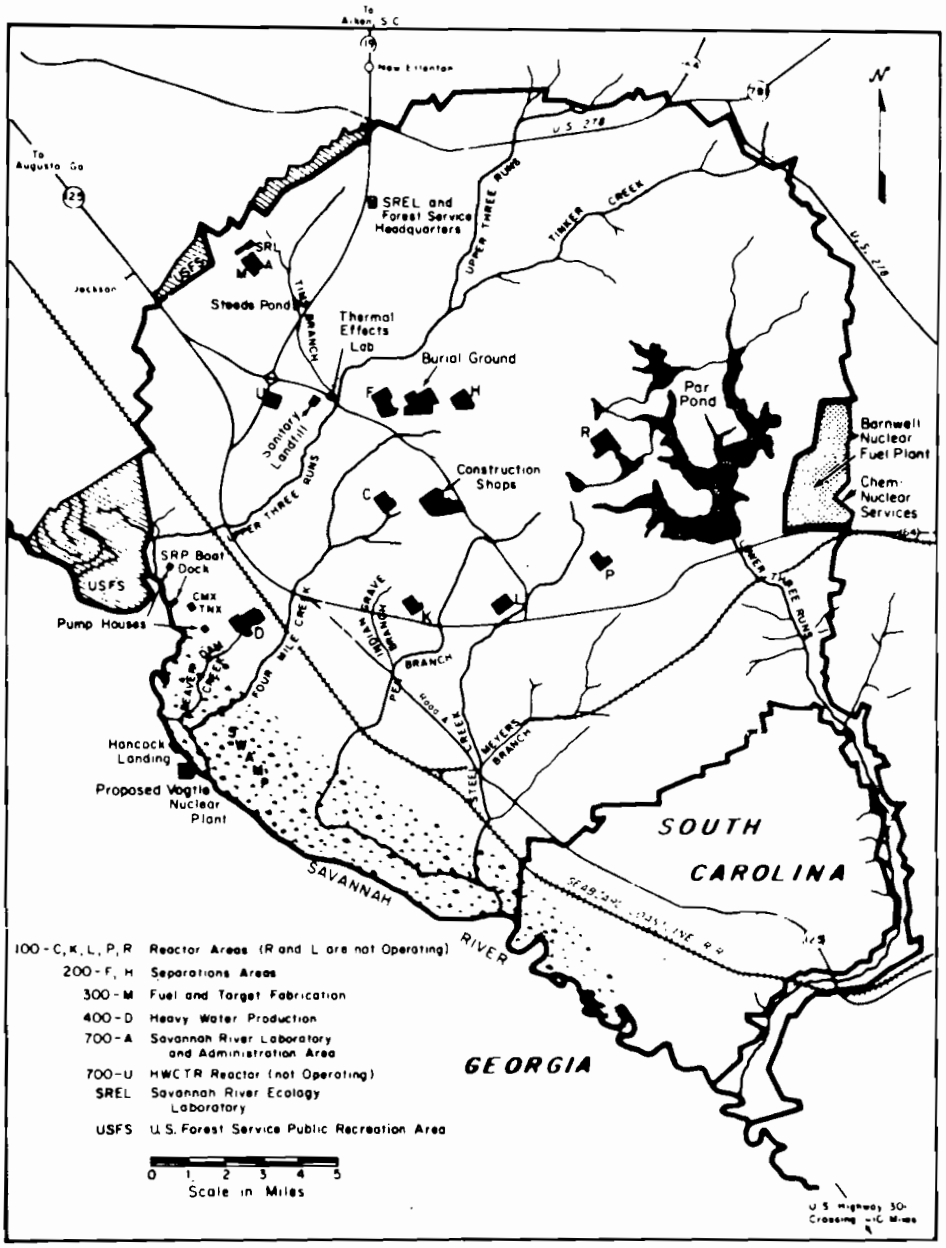
Slide 1 shows the burial ground at SRP. SRP is now a 195-acre shallow land burial facility. The original site, 75 acres, went into use in 1953 and was filled with waste by 1972.

The new burial ground, 125 acres, is located between the F- and H-Area chemical processing plants. F-Area is a Purex process for plutonium processing, and H-Area is a modified Purex process in which neptunium-enriched uranium and plutonium-238 processing occur. The burial ground was located in the 200-Area between chemical processing plants because most of the waste to be buried is produced by those plants. The burial ground is about 1700 ft from a tributary stream called Four Mile Creek, which eventually flows into the Savannah River, and the river eventually dumps into the Atlantic Ocean.

Part of the input into environmental transport modeling involves knowledge of the topography and hydrology of the site. Slide 2 is a simple diagram of the topography around the burial ground. The 200-acre burial ground lies on the so-called Barnwell formation of the Coastal Plain Geologic Province in South Carolina. The Barnwell formation consists of clayey sands and sandy clays that have some ion exchange capacity. In the eastern part of the United States, the water table is shallow. At the burial ground, the average depth to the water table from the surface is about 45 ft. We are now looking for new burial sites and finding places where the average depth to the water table may be as great as 75 ft.

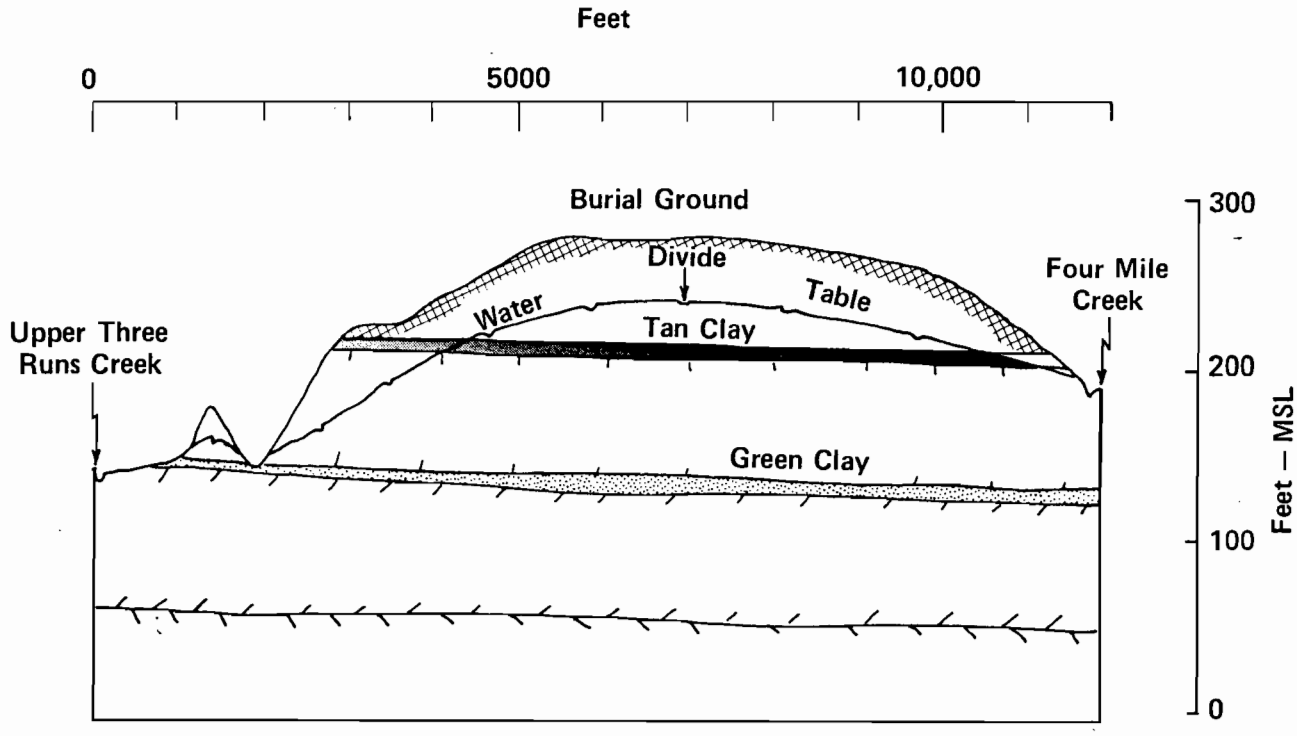
Slide 3 summarizes the extent to which we have disposed of nuclides in earthen trench burial through 1975. According to DP-1537, the Environmental Impact Statement on SRP Waste Management Operations, about 3000 Ci of plutonium isotopes have actually gone into the ground. Fission products and a variety of other isotopes,

Slide 1



The Savannah River Plant Site

Slide 2


Feet
0
5000
10,000
Burial Ground
Divide
Water
Table
Tan Clay
Upper Three
Runs Creek
Four Mile
Creek
Green Clay
300
200
100
0
Feet – MSL

Slide 3

BURIAL GROUND SOLID WASTE

(THROUGH 1975)

RADIONUCLIDE	EARTHEN TRENCHES*	RETRIEVABLE STORAGE*
Pu^{238}	2,500	245,000
Pu^{239}	490	1,700
Cs^{137}	23,300	2,000
Sr^{90}	23,300	2,000
H^{3}	2,450,000	100,000
Co^{60}	970,000	–
Cm^{244}	1,300	32,000

*Curies, corrected for decay
Source: DP 1537-EIS on SRP Waste Management Operations

particularly tritium, are also disposed of. Since 1974, most TRU waste has gone to retrievable storage in drums and culverts on concrete pads, primarily based upon the 10 nCi/g limit. Since 1974, only about 1 Ci of TRU waste has gone to earthen trench burial each year.

Slide 4 presents data from DOE/NE-0017 that compare volumes of waste at the earthen trench buried at SRP to volumes of waste buried at other DOE sites. We have about 360,000 m^3 of low-level waste at SRP, which is a larger volume than most of the other sites have.

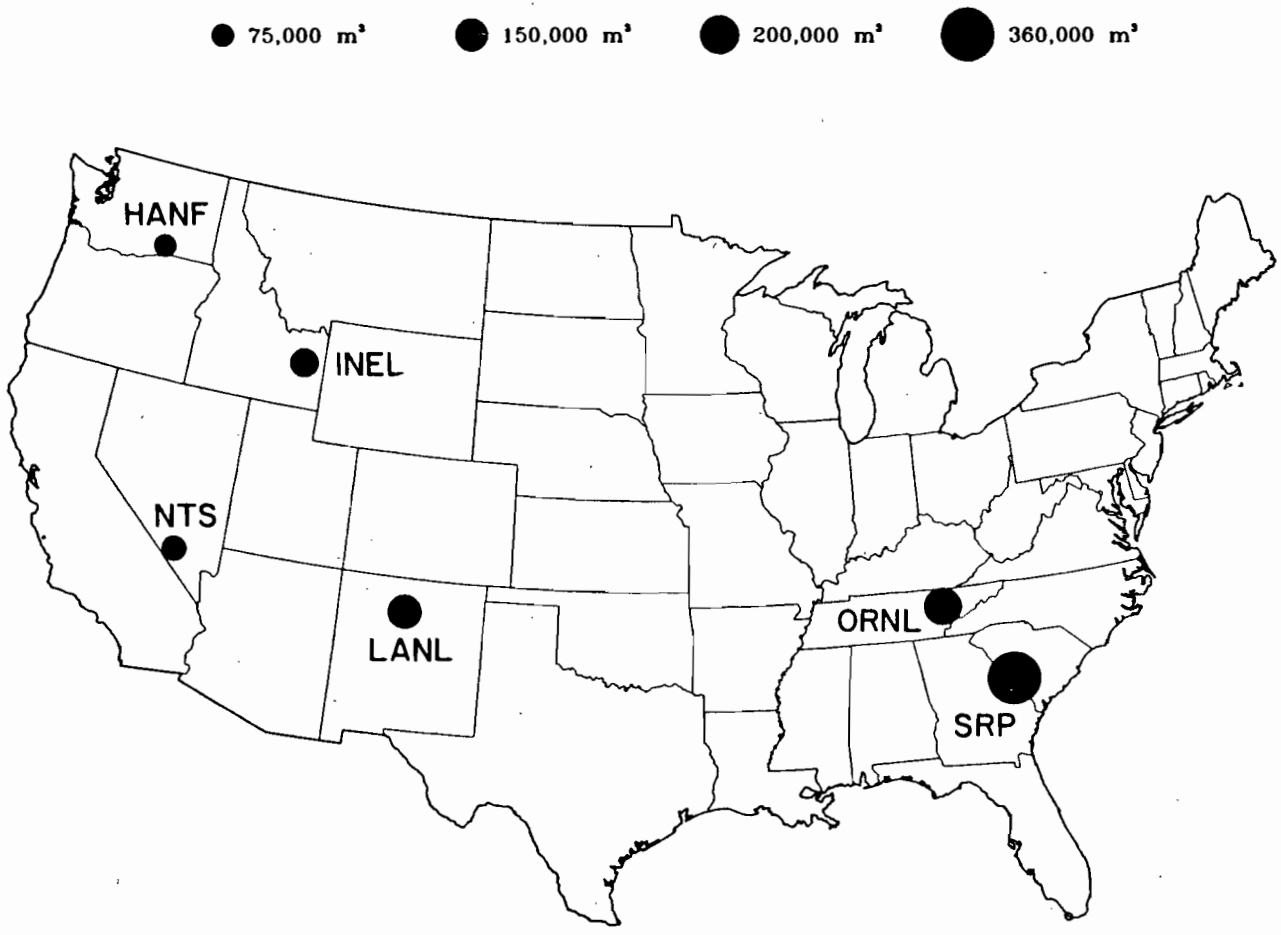
Slide 5 gives the specific standards as a function of nuclide that we use for burial limits. TRUs are now at 10 nCi/g. The purpose of transport modeling is to arrive at a scientific analytical approach to justify these burial limits and to validate burial ground operational methods, and today I will address burial limits on TRU waste, plutonium isotopes in particular.

Two of our inventory estimates (500 Ci of plutonium-239 and 2500 Ci of plutonium-238 in trenches) translate to levels of plutonium isotopes greater than 100 nCi/g (Slide 6). We estimate that the plutonium-239 inventory would be equivalent to an average concentration of 200 to 300 nCi/g of waste actually in the ground; similarly, plutonium-238 is about 5 times higher.

Since 1978, we have evolved a transport equation, a site-specific risk assessment of burial ground operation, to model the situation of buried waste (Slide 7). We considered the burial ground that is now in operation and any greater confinement disposal alternatives that are proposed for use at our site. This equation is quite a useful tool. As you have heard from some previous speakers, nuclide-specific information is needed for transport modeling. Key parts of the information are (1) nuclide soil adhesion property (distribution coefficient), which is the sticking or adhesion parameter of the nuclide to soil, (2) plant and animal concentration factors, and (3) waste to soil migration rates. Also needed are dosimetry data and an understanding of the hydrology and topography of the site you are trying to model, including unsaturated zone and groundwater flow rates.

Our approach has been to compartmentalize the environment and to express the rate of movement of a nuclide from one environmental compartment to another in the form of differential equations (Slide 8). Terms for the rate of movement into a compartment, out of a compartment, source and sink terms, and radioactive decay are included in a simple differential equation. The modeling complexity arises when one equation is calculated for each pathway in the scenario being modeled. The key inputs to these equations are the transfer coefficients (gamma), which estimate the fraction of a nuclide that will move in time from one environmental compartment to another. The

Slide 4



Location and Accumulated Volume of LLW at Principal DOE Sites Through 1980

Slide 5

BURIAL GROUND ANNUAL TECHNICAL STANDARDS

BETA/GAMMA FISSION AND ACTIVATION PRODUCTS

Cs^{137}	500 Ci.
Sr^{90}	500 Ci.
Co^{60}	3×10^5 Ci.
He^3	4×10^5 Ci.
Other nuclides ($T_{1/2}$ >10 yr.)	1×10^3 Ci.
Other nuclides ($T_{1/2}$ <10 yr.)	5×10^5 Ci.

TRANSURANICS

< 10 nCi/g of Waste

Slide 6

ALPHA CONTAMINATED WASTE DISPOSAL at SRP

ISOTOPE	ASSUMPTIONS
Pu^{239}	500 Ci 1953 – 1968 50,000 CUBIC FT./Yr 6 LBS./CUBIC FT.

AVERAGE CONCENTRATION = 200 – 300 nCi/g

Pu^{238}	2500 Ci 1953 – 1968 50,000 CUBIC FT./Yr 6 LBS./CUBIC FT.

AVERAGE CONCENTRATION = 1000 – 1500 nCi/g

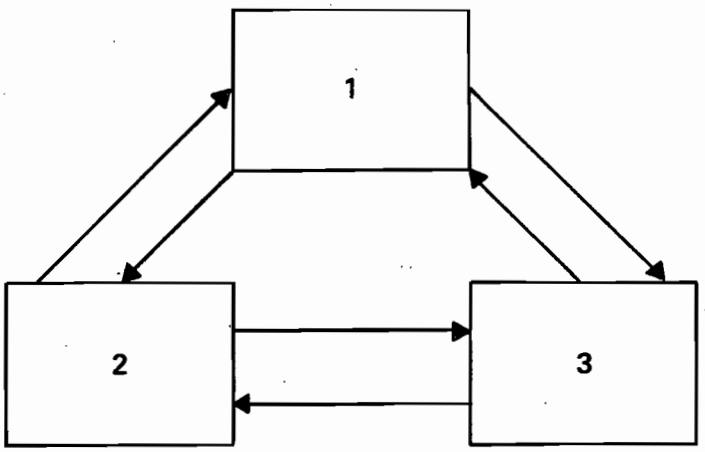
Slide 7

DOSE–TO–MAN MODEL

- SITE SPECIFIC RISK ASSESSMENT OF BURIAL GROUND OPERATIONS
- KEY INPUT
  NUCLIDE SPECIFIC
  - K_D, DISTRIBUTION COEFFICIENT
  - C_F, PLANT AND ANIMAL CONCENTRATION FACTORS
  - λ_S, WASTE TO SOIL RELEASE RATE

  BURIAL GROUND TOPOGRAPHY/GEOLOGY

Slide 8



$$\frac{dQ_n}{dt} = \sum_{m=1}^{n} \lambda_{n,m} Q_m - \sum_{m=1}^{n} \lambda_{m,n} Q_n$$

$$\pm S_n - \lambda_r Q_n$$

Compartmentalized Concept

transfer coefficients have some physical meaning. They are a function of the distribution coefficients (e.g., plant uptake factors).

Slide 9 is a simple illustration of the compartmentalization procedure in which we describe the transfer coefficient from buried waste to burial soil as a reflection of leach rate or release rate. It is useful to have experimental data on this particular transfer coefficient. Dr. Rogers talked about release rates yesterday. Based on his data, our release rates are conservative. We generally use 10^{-2}, or 1% per year. This rate is based upon exhumation in 1975 of a single piece of equipment that had actually been buried. We retrieved the equipment and measured the nuclide content of the soil, relative to the surface contamination to make an estimate of the release rate and rate of movement in that short period of time. Movement from buried soil through the unsaturated zone to the groundwater table will be a function of the retardation equations, which have parameters of distribution coefficient, soil porosity, and bulk density. Movement to other parts of the environment (i.e., animal and vegetative pathways) is generally described by concentration factors, which have been documented by a variety of groups. The Nuclear Regulatory Commission (NRC) Regulatory Guide 1.109 and its updates provide information on herbivore and plant vectors.

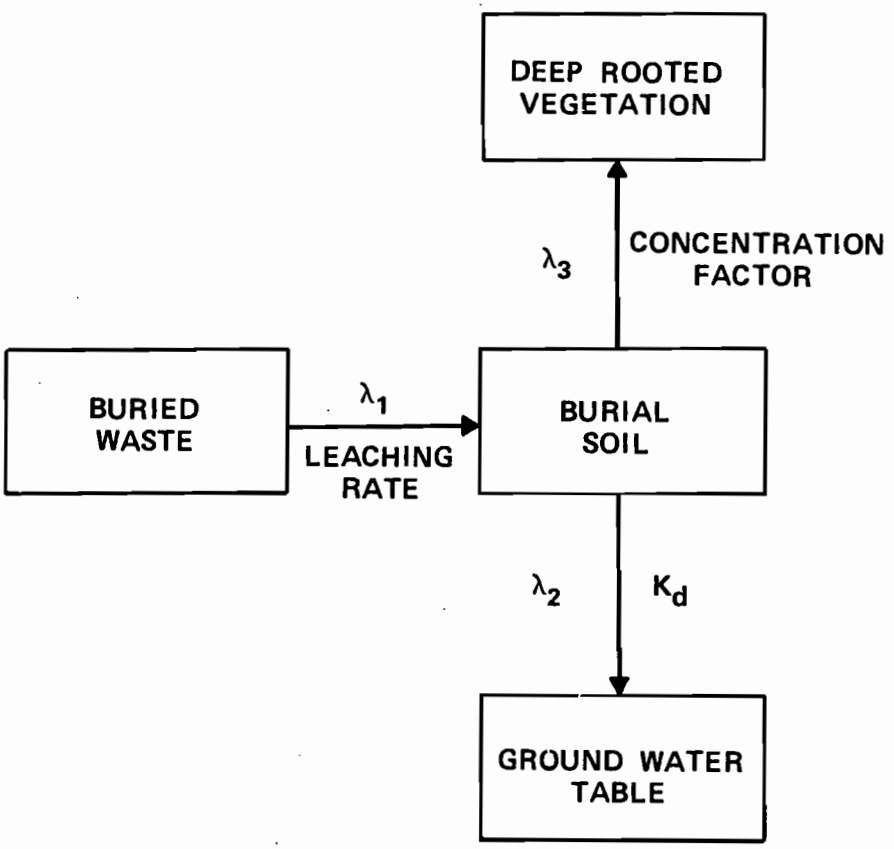
Slide 10 shows a complete flow diagram for transport of buried waste into the environment. We have included numerous pathways in the description of nuclide-to-environment transport, consistent with a scenario being modeled.

Slide 11 gives some of the specific pathways that we have incorporated into the model, including waste to soil migration, particle and hydrological transport, vegetative uptake, herbivore and fish assimilation, erosion, resuspension, recreation, intrusion, human ingestion, inhalation, and nuclide physiology in man.

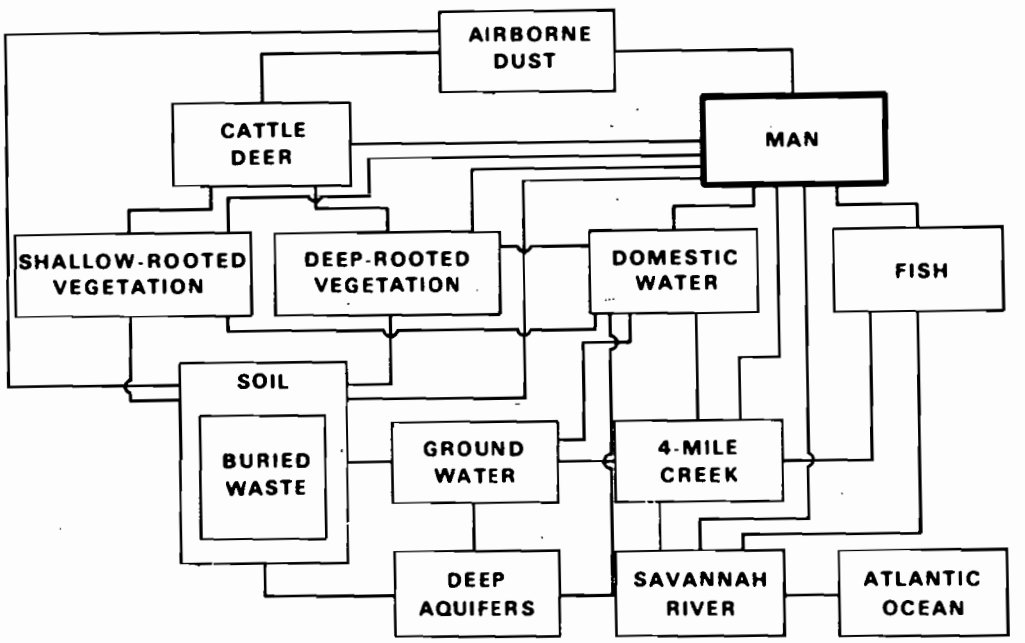
Slide 12 is a representation of the full 70 x 70 matrix that has evolved in our description of the environment. The arithmetic is a typical eigenvalue problem similar to problems in quantum mechanics or in physical chemistry for solution of chemical bond energies in a polyatomic molecule. The arithmetic is quite analogous to other problems that have been dealt with in physical science. Hence, a 70 x 70 matrix with about 200 transfer coefficients and quite a bit of input data is solved by finite difference, matrix inversion methods. The output is the the decayed nuclide level in each compartment with time.

The land occupation scenario (Slide 13), which is one of several that we have evolved, is a small-population land use example consistent with the historical use of the SRP prior to occupancy by the Atomic Energy Commission. We had a study conducted by the University of South Carolina's Institute for Southern Studies in which property

Slide 9


DEEP ROOTED VEGETATION
λ_3
CONCENTRATION FACTOR
BURIED WASTE
λ_1
LEACHING RATE
BURIAL SOIL
λ_2
K_d
GROUND WATER TABLE

Slide 10



DOSTOMAN Diagram

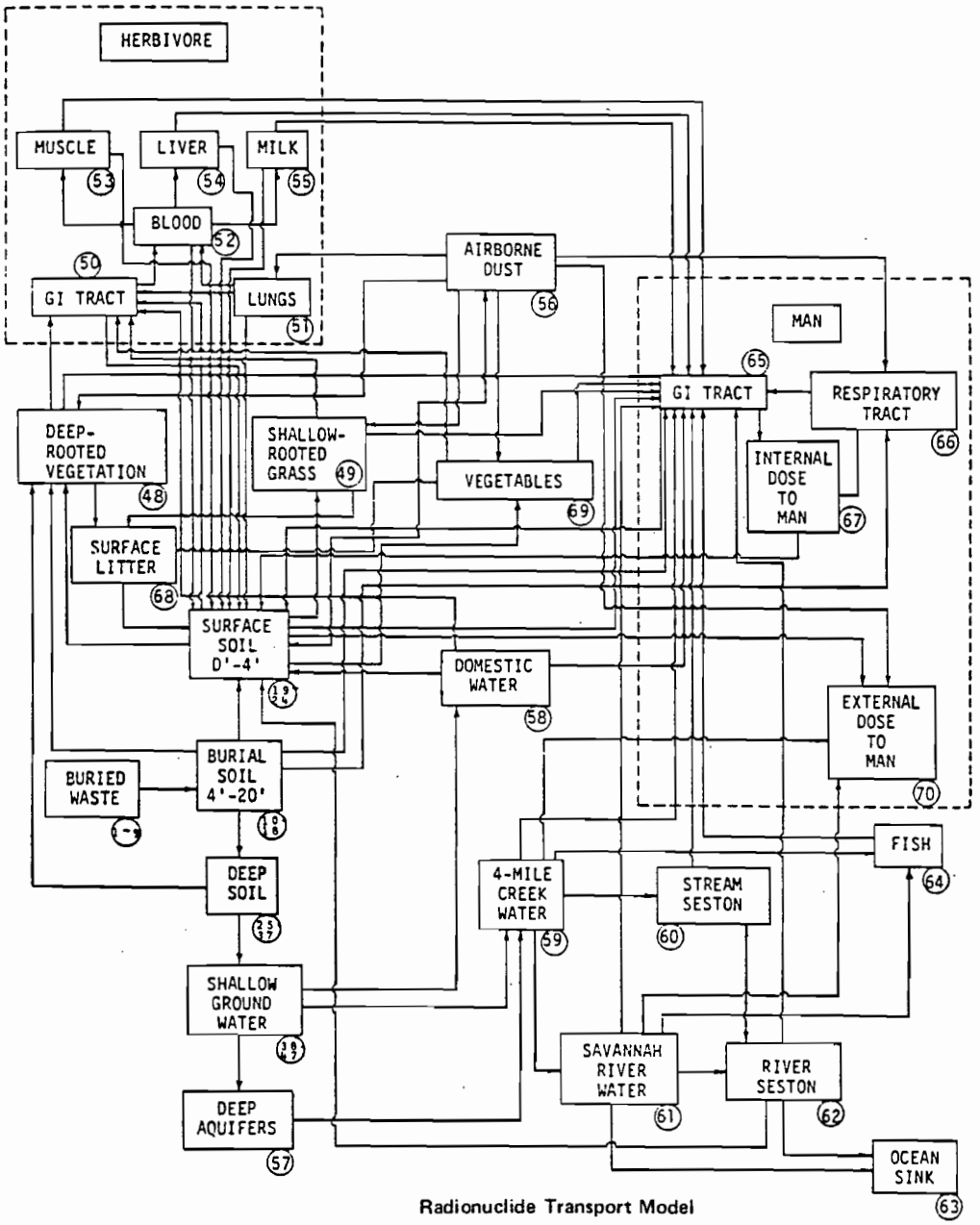
Slide 11

BURIAL GROUND NUCLIDE MIGRATION MODEL

PATHWAYS

- WASTE TO SOIL
- PARTICLE TRANSPORT
- HYDROLOGICAL TRANSPORT
  SOIL, GROUNDWATER, STREAMS
- VEGETATIVE UPTAKE
  GRASS, VEGETABLES, TREES
- HERBIVORE INGESTION & PHYSIOLOGY
- FISH ASSIMILATION
- EROSION/RESUSPENSION
- INTRUSION
- HUMAN INGESTION, INHALATION & PHYSIOLOGY
- RECREATION

Slide 12



Radionuclide Transport Model

Slide 13

HOME FARM SCENARIO

EXTREME CASE

- INHABITANTS: FOUR PERSONS, 40 CATTLE, 60 DEER (INTRUSION)
- LAND USE
  - VEGATABLE GARDEN (2 ACRES)
  - PASTURE GRASS FOR GRAZING (150 ACRES)
  - FRUIT AND MISCELLANEOUS TREES (48 ACRES)
- ALL SUSTENANCE FOR PERSONS AND CATTLE PRODUCED ON FARM
- WATER COMES FROM WELL SUNKEN INTO THE GROUNDS
- SWIMMING IN SAVANNAH RIVER AND ITS TRIBUTARIES

deeds back to 1800 were examined to trace the historical land use of the site. This scenario is consistent with that historical land use.

Some of the basic input data (plutonium inventory, release rate, distribution coefficient, and soil adhesion properties) for analysis of migration of the plutonium isotopes are well documented (Slide 14). In the absence of solubilizing ligands, plutonium has a large adhesion tendency in cation-exchangeable soils, which generally means extremely slow downward movement. The question is, "How slow is slow?" We are trying to make a quantitative statement about rate of movement relative to radioactive decay. Plant uptake factors are generally small for plutonium compared to the other elements. Plutonium-238 has a fairly short half-life; plutonium-239, quite long. In both cases, based upon International Commission on Radiological Protection (ICRP)-2 and ICRP-30 dose commitment factors, plutonium isotopes tend to concentrate in bone and bone marrow.

Slide 15 compares some of the physical property data that are input to the model for several radionuclides. The distribution coefficient of plutonium is much higher than, for example, that of strontium. Plant uptake factors are much lower relative to other fission byproducts. Release rates, based on our exhumation work, are the same for most of the radionuclides.

Some of the projections that we have made from this modeling effort are shown in Slide 16, which represents model-projected bone deposition of plutonium as a function of time. Please bear with us on the time axis. Like Jack Healy at Los Alamos National Laboratory, we don't pretend to be able to predict into these time spans, but it is easy to let the computer run. The important point is that for plutonium-239 there is an interesting bimodal pathway that comes out of our model, which is a consequence of the long plutonium-239 half-life. The period for maximum deposition of plutonium-239 in bone is about 1000 years, which translates to about 2 millirem/person annual dose commitment. The primary or critical pathway in this time period is vegetative uptake and ingestion of that vegetation, as in the scenario. As time goes on, plutonium-239 with its long half-life will tend to move downward. The dose becomes more significant way out in the future as a consequence of hydrological transport, contamination of the groundwater, and the assumption that wellwater is a source of drinking water. Plutonium-238 eventually decays. The critical pathway to dose is primarily vegetative uptake. The dose consequence is comparable.

Inventories buried at Savannah River Plant (500 Ci of plutonium-239 and 2500 Ci of plutonium-238) translate to nanocurie per gram levels significantly greater than 100. Our impact analysis predicts that in reasonable periods of time (less than 1000 years) the dose consequence of this burial is very low, much less than 10 CFR 61 criteria.

Slide 14

RADIONUCLIDE MIGRATION MODEL
Pu CASES

$I_0^{238} = 2500$ Ci

$I_0^{239} = 500$ Ci

$\lambda_s = 1\%/yr$

$K_D = 1600$
- LARGE SOIL RETENTION
- SLOW DOWNWARD MOVEMENT

C_F PLANTS $= 10^{-6}$
- LOW PLANT UPTAKE

$T_{1/2}^{238} = 87.8$ yrs.

$T_{1/2}^{239} = 2.44 \times 10^4$ yrs.

HUMAN PHYSIOLOGY
- BONE

Slide 15

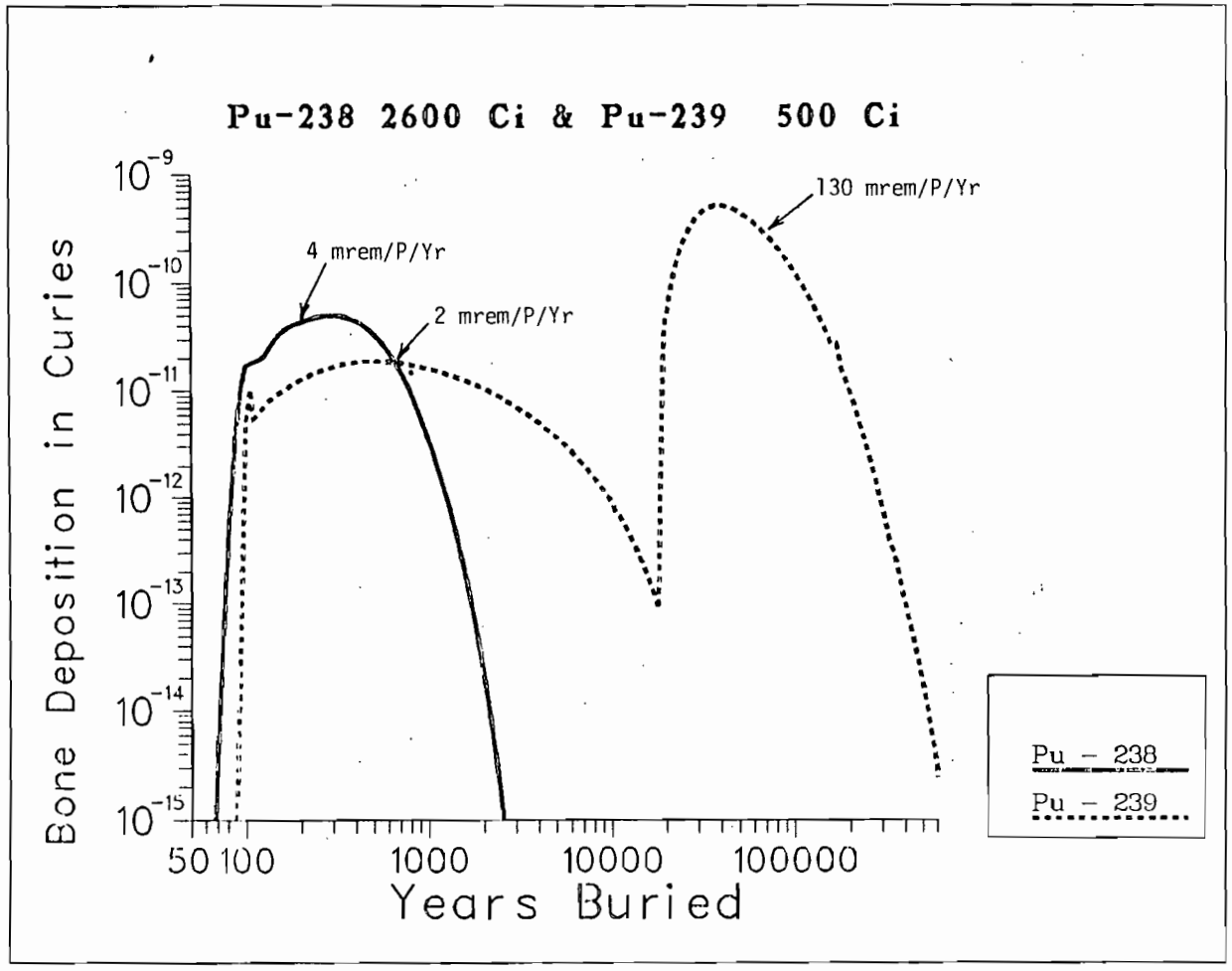
DOSE-TO-MAN

NUCLIDE-SPECIFIC PARAMETERS

	K_D [1]	C_F [2]	λ_S [3]
Pu	1600	10^{-6}	10^{-2}
Cs	500	0.10	10^{-2}
Sr	160	0.35	10^{-2}

1. K_D, DISTRIBUTION COEFFICIENT – SOIL/WATER
2. C_F, PLANT/SOIL CONCENTRATION FACTORS
3. λ_S, WASTE TO SOIL RELEASE RATE

Slide 16



Dose-to-Man from Unencapsulated Pu Waste

Slide 17 is a summary, similar to Dr. Smith's presentation, of some of the projections that we and others have made via the modeling approach. We would estimate, with a safe margin, 500 nCi/g is not unreasonable. Plutonium-238 rates could be somewhat higher. Healy/Rogers, Ford/Bacon/Davis, INEL, and Cohen results from Lawrence Livermore compare favorably with SRP estimates.

Parameter sensitivity work must be done in every environmental impact and pathway analysis, and we do it routinely. As shown in Slide 18, the most important factors that enter into this analysis include institutional control period, soil/water distribution coefficients, waste soil leach rates, plant and animal concentration factors, and the ability to pin down plutonium inventory, the source term itself.

Keep in mind that every model is only as good as the data that go into it, substantiating the physical basis of the approach (Slide 19). As we mentioned yesterday, the value of the results is relative, not absolute. Complexity does not necessarily mean credibility. Results are scenario-dependent.

Validation is a key to any model analysis, so we are using our model to confirm by calculation the actual migration of nuclides that has occurred from buried wastes at SRP. Dr. Albenesius said yesterday that tritium, for example, has been monitored for many years in groundwater below the disposal site. We're attempting to model tritium migration and compare the model with actual measurements on tritium plumes and tritium concentrations in the groundwater. Validation is essential to any modeling analysis.

From experience at SRP, we can say that shallow-land burial of TRU waste has been disposal at greater than 100 nCi/g levels (Slide 20). Pathway analysis indicates that critical routes are (1) vegetative uptake from root penetration of waste and (2) hydrological transport for the long-lived nuclides. The individual exposure consequence of this burial is very small. Based on our analysis and results of other modeling efforts, 100 nCi/g seems to be a reasonable figure with a safety margin. The impact of a 100 nCi/g limit at SRP would be a diversion of 10 to 30% of waste from TRU pads to shallow-land burial. The economic significance of this cannot be ignored. If you assume that the TRU waste stored above ground is eventually designated for the Waste Isolation Pilot Program (WIPP), you can add another economic increment to that cost incentive analysis.

The SRL DOSTOMAN methodology, User's Guide, and published examples of its use are available on request.

Bill Kennedy, Battelle-Pacific Northwest Laboratories: I don't know that you ever really validate a model. You can calibrate it against a known situation and set of circumstances, but whenever you attempt to extend the analysis beyond that calibration point, which by necessity has to be done to predict results for more complicated

Slide 17

TRU WASTE

MODEL PROJECTIONS vs 10nCi/g

SOURCE	PATHWAY	Pu^{239} in WASTE(nCi/g)
– SRL DOSTOMAN DP-MS-81-24 DP-MS-81-98Rev	FARMING/ WELL WATER	200–500
– HEALY-RODGERS(LANL) LA-UR-79-100	INTRUSION/ EROSION	$\leqslant$ 360 (SLB) $\leqslant$ 800 (GCD)
– FORD/BACON/DAVIS NUREG/CR-1005 Vol1	INTRUDER	100 – 400
– INEL (Draft EIS, Management of Defense TRU Waste at INEL, Vol 1, 1981)	EXCAVATION/ FARMING	2000
– J.COHEN/W.C.KING UCRL-52535(1978)	RECLAMATION/ AIRBORNE	1000 nCi/cc.

Slide 18

PLACKETT – BURMAN SENSITIVITY ANALYSIS

MOST IMPORTANT

- CONTROL PERIOD AFTER SHUTDOWN
- SOIL/WATER K_D
- WASTE TO SOIL LEACH RATE
- PLANT/SOIL C_F
- GI TO ORGAN TRANSFER RATE
- INVENTORY

Slide 19

MODEL LIMITATIONS

- VALUE OF RESULTS: RELATIVE NOT ABSOLUTE
- COMPLEXITY $\neq$ CREDIBILITY
- SCENARIO
- VALIDATION
- ALTERNATIVE/OPTION ANALYSIS

Slide 20

CONCLUSIONS

- ACTUAL EXPERIENCE AT SRP WITH SLB OF TRU AT > 100 nCi/g
- CRITICAL PATHWAYS (FARMING SCENARIO)
  - SHORT TERM : VEGETATIVE UPTAKE
  - LONG TERM : HYDROLOGICAL TRANSPORT
- 100 nCi/g ?
  - REASONABLE WITH SAFE MARGIN
- IMPACT OF 100 nCi/g AT SRP
  - 10 – 30 % DIVERSION FROM TRU PADS TO SLB

conditions, you're leaving that zone of calibration somewhat. You may be confident that you've calibrated it for a known set of conditions, but I doubt that you've ever really validated the results.

King: That's a good point. Of course, any attempt at validation can only validate actual data in real-world time: the recent past or the present. Whether the validation reflects the ability to project into the future is the major part of the uncertainty in the analysis. Let me give an example. We just went through some meaningful validation of equations, and we hope to report about it in detail soon. One fission byproduct that we have in shallow-land burial is technetium-99, which has a fission yield comparable to that of strontium-90 on a weight basis. On a curie basis, technetium-99 fission yield is much less because of its extremely long half-life. We have calculated that, at the most, 100 Ci of technetium are buried in shallow trenches at SRP. Technetium mostly exists in the chemical pertechnetate anionic form. SRP clay soils have very low anion-exchange capacity, so technetium, in most environments, will tend to move, like tritium. Using our fission-yield inventory and soil retention properties as input to our model, we have projected contamination of the groundwater at a factor of 50 to 100 less than any Environmental Protection Agency (EPA) drinking water standard for technetium-99. Contamination occurs at 50 to 100 fCi/mL levels in the groundwater. We then measured technetium-99 contamination in the groundwater (work by S. Oblath at SRL) and found the predicted levels of technetium-99.

Preston Hunter, Ford, Bacon, and Davis: Regarding your comparison table, I'd like to make a comment similar to the comment Tom Smith made on the 100 to 400 nCi/g Ford/Bacon/Davis figure. The values derived from these comparison tables are interesting and nice to look at, but I think we should recognize that the results depend on the assumptions and preconditions that are put into these tables. I think comparing the different assumptions from which those numbers were derived would be valuable. For example, you have in a table that Ford/Bacon/Davis came up with, a 100 nCi/g limit with one set of conditions for TRU waste disposal. I could show you some other input conditions, including the intrusion scenario, where we would support the NRC's position that Class-A waste should have a 10 nCi/g limit. When you take all these things into account, particularly when you're dealing with models that have a 70 x 70 matrix, it's important to recognize that the input data and scenario assumptions must be explicit and clear.

King: That's a good point. I think we have a perfect opportunity here if analytical transport modeling is going to be one of the approaches used to establish criteria. The people who are doing some of this transport modeling have a perfect opportunity to sit down and document the input data and the nature of the model to help justify and establish the criteria that we're debating. SRL has such documentation.

Joe Lieberman, Nuclear Safety Associates: In line with the question that Bill Kennedy asked, I agree that we're talking about calibration rather than validation. You mention technetium. Have you done any work on any other nuclide? If you haven't, can you, based on what you've done, speculate at all about how the transfer factors for other nuclides might develop?

King: We've done quite a bit of work on the analysis of the predominant fission byproducts, cesium and strontium. A lot of what I talked about today, including some information on cesium and strontium, is published in the Tucson Waste Management 1982 Proceedings, which are available to the public. The fission byproducts, particularly strontium, present an interesting problem. Strontium has different physical properties. Soil adhesion is less of a problem; although it is cationic and, relative to plutonium, distribution coefficients are generally lower. Strontium-90 is more subject to movement, and certainly its dose commitment factors (DCFs) are greater than DCFs for nuclides like cesium. We are now examining strontium and cesium to ascertain whether the burial limits used by our production people are valid. In the future, we will consider potential greater confinement disposal of byproducts, including technetium, iodine, and ruthenium, from the Defense Waste Processing Facility. We are now modeling greater confinement disposal and the disposal concepts that are a spinoff of the Defense Waste Processing Facility programs. Considering ICRP-30 statements, perhaps neptunium-237, as a TRU waste nuclide, should also be considered, because the ICRP-30 dose factors for neptunium-237 increase by a factor of 200 to 300 relative to ICRP-2. Is this increase a concern to those of us who are dealing with neptunium processing and waste disposal?

Bill Lawless, Savannah River Laboratory: Because simplifying assumptions were used in the model, have you had a chance to calculate your range of uncertainties?

King: Bill is our main DOE contact, and he is constantly skeptical, and rightfully so. A perfect Devil's Advocate! I would "guesstimate" a 100% uncertainty in these numbers, primarily resulting from uncertainty in the source term. If you talk about 2 millirem per person, that may be 4 millirem per person. If you talk about 500 nCi/g as a reasonable plutonium-239 model projected limit, there's uncertainty; it may well be 250 nCi/g. But the model projected limit would still be greater than 100 nCi/g.

RISK AND SAFETY ANALYSES FOR DISPOSAL OF ALPHA-CONTAMINATED WASTE IN INEL

Tom Smith, EG&G, Idaho

Today, I'll be summarizing some very preliminary risk evaluations done on the transuranic (TRU) waste at the INEL (Slide 1). This represents about 75% of the stored TRU waste from defense activities in this country and about 25% of the buried TRU waste. This work was funded as part of the Department of Energy's (DOE's) National TRU Waste Management Program. My coauthor, Fran Keneshea, is unable to be here today.

First, the paper will not do certain things (Slide 2). I will not defend or attack the DOE 5820 order. I will not derive the proposed disposal limit, contrary to previous discussion. We will discuss the results of our risk analysis and add a list of problems to those that have been mentioned by other people. The risk analysis I'll be describing is reported in three large documents, and if anyone's interested, I can get you copies of those documents, which give the details of the assumptions that were used.

I will now give a brief outline of my presentation (Slide 3). I will first discuss the context, objectives, and scope of the risk analysis. Then I will give some background on the waste and how it's managed, including the alternatives that we looked at for long-term management of the waste because this was the risk analysis that we did. Our approach, the results, and, perhaps more important, the conclusions and the problems that were faced will also be discussed.

The context of these risk evaluations is most important because they were not done as a separate study (Slide 4). They were done as part of a series of environmental documents under the National Environmental Policy Act (NEPA) activities, and they began back in 1977. This situation is somewhat similar to Wayne Hansen's situation at Los Alamos. These studies came out of the same type of effort.

Risk is only one of the factors we evaluated in looking at these long-term management alternatives for the waste at Idaho. The risk analysis study I'm referring to here began in 1977, so it took about 4 years. That is a little misleading because it only represents about 3 man-years. I think it took 1 man-year to do it the first time and then 2 more man-years to redo it every time the world changed in the last 5 years.

The objectives were to provide some very preliminary estimates of risk to the public, to determine the dominant scenarios of nuclide release and where the uncertainties lay, and to decide when one might be justified in doing more detailed studies later if the opportunity presented itself, which it hasn't in our case (Slide 5). The risk evaluations were site-specific to Idaho, waste-specific to our waste,

Slide 1

Risk and Safety Analysis for Transuranic Waste at the Idaho National Engineering Laboratory

T. H. Smith
EG&G Idaho Inc.

F. J. Keneshea
Quadrex Corporation

ENERGY SAFETY ENVIRONMENT
IDAHO NATIONAL ENGINEERING LABORATORY

EG&G Idaho, Inc.

Slide 2

This Paper Will Not:

- Defend DOE Order 5820
- Attack DOE Order 5820
- Derive a proposed disposal limit for TRU concentrations

This Paper Will:

- Discuss the results of a risk analysis of INEL TRU waste
- Discuss some problems encountered in performing such an analysis

S2 9908

Slide 3

Outline

I. Context, Objectives, Scope

II. The Waste; Past and Current Management

III. Alternatives for Long-Term Management

IV. Risk Evaluation Approach

V. Risk Evaluation Results

VI. Conclusions and Problems

INEL-S-24 402

Slide 4

I. Context, Objectives, Scope

Context of the Risk Evaluations

- Prepared for Environmental Documents Under National Environmental Policy Act (NEPA) Beginning in 1977
- Risk Is One Of Several Factors Evaluated For Alternatives for Long-Term Waste Management

INEL-S-24 403

Slide 5

Objectives of the Risk Evaluations

- Provide Preliminary Estimates of Risk To Public
- Identify
  - Dominant Scenarios of Radionuclide Release
  - Major Uncertainties
  - Topics Requiring Detailed Study

INEL-S-24 405

and highly application-oriented (i.e., produce results quickly). They covered both the buried and stored contact-handled (CH) waste, but not the remote-handled (RH) waste. We looked at short-term (within the first 100 years) risk and, for releases, we looked at the consequences, in terms of 50-year dose commitment, and at release frequency (Slide 6). For the long-term evaluations (after 100 years), we looked at consequences. In some cases, we estimated frequency, and in some cases we didn't.

Now, I will give a brief description of the waste (Slide 7). This waste is from DOE defense and research programs. I am only talking about the CH solid TRU waste. The principal activity in our waste is plutonium-241, americium-241, plutonium-239, and plutonium-238, pretty much in that order. There is also a lot of uranium buried with the TRU waste. However, there is a very small percentage of combustibles in the waste.

Slide 8 shows an aerial overview of where the waste is located in Idaho, west of Idaho Falls, showing the Radioactive Waste Management Complex and showing where the buried waste and the stored waste are located. There are about 5 acres of stored waste and about 25 acres of buried waste. Those white structures you see are air support buildings that are used for experimental retrieval or for covering newly received waste until enough accumulates to be a unit cell.

Slide 9 presents a cutaway of the waste in a 55-gal drum. This is mockup waste, ranging from anticontamination clothing on the left to sludge on the right. About half the waste is in drums like these. The other half of the waste is in plywood boxes, 4 x 4 x 7 ft. Before 1970, the TRU waste was buried in pits and trenches (Slide 10). These containers are now badly deteriorated. The volume of such waste at Idaho is 2 million ft^3. Mingled with the TRU waste is some low-level, or beta-gamma, waste amounting to about 500,000 ft^3, and there is some contaminated soil.

Slide 11 is one of my favorites. It shows the disposal practices in the early days. You can well imagine what happened to some of the containers after this kind of practice, as shown in the next slide, 12, which is another one of my favorites. This is what some of those containers looked like when we conducted pilot retrieval programs.

Since 1970, the waste has been stored above ground on asphalt pads (Slide 13). Those containers are sound, and the volumes are listed for the inventories. We listed 1977 because that is when we started this study, and we listed 1985 because in 1977 that was the projected date of opening the waste isolation pilot plant (WIPP).

Slide 14 shows the procedure used now, emplacing waste on asphalt pads stacked about 15 ft high under the air support cover. When we've accumulated a sufficient quantity of waste, we take away the air support cover and cover the waste with plywood in plastic sheeting

Slide 6

Scope of the Risk Evaluations

- Site-Specific, Waste-Specific, Application-Oriented
- INEL Buried and Stored Contact-Handled Transuranic Waste
- Short-Term Risk
  - Releases Occurring in First 100 Years
  - Release Consequences
  - Release Frequency
- Long-Term Evaluations
  - Releases Occurring After 100 Years
  - Release Consequences
  - Some Estimates of Frequency

INEL-S-24 395

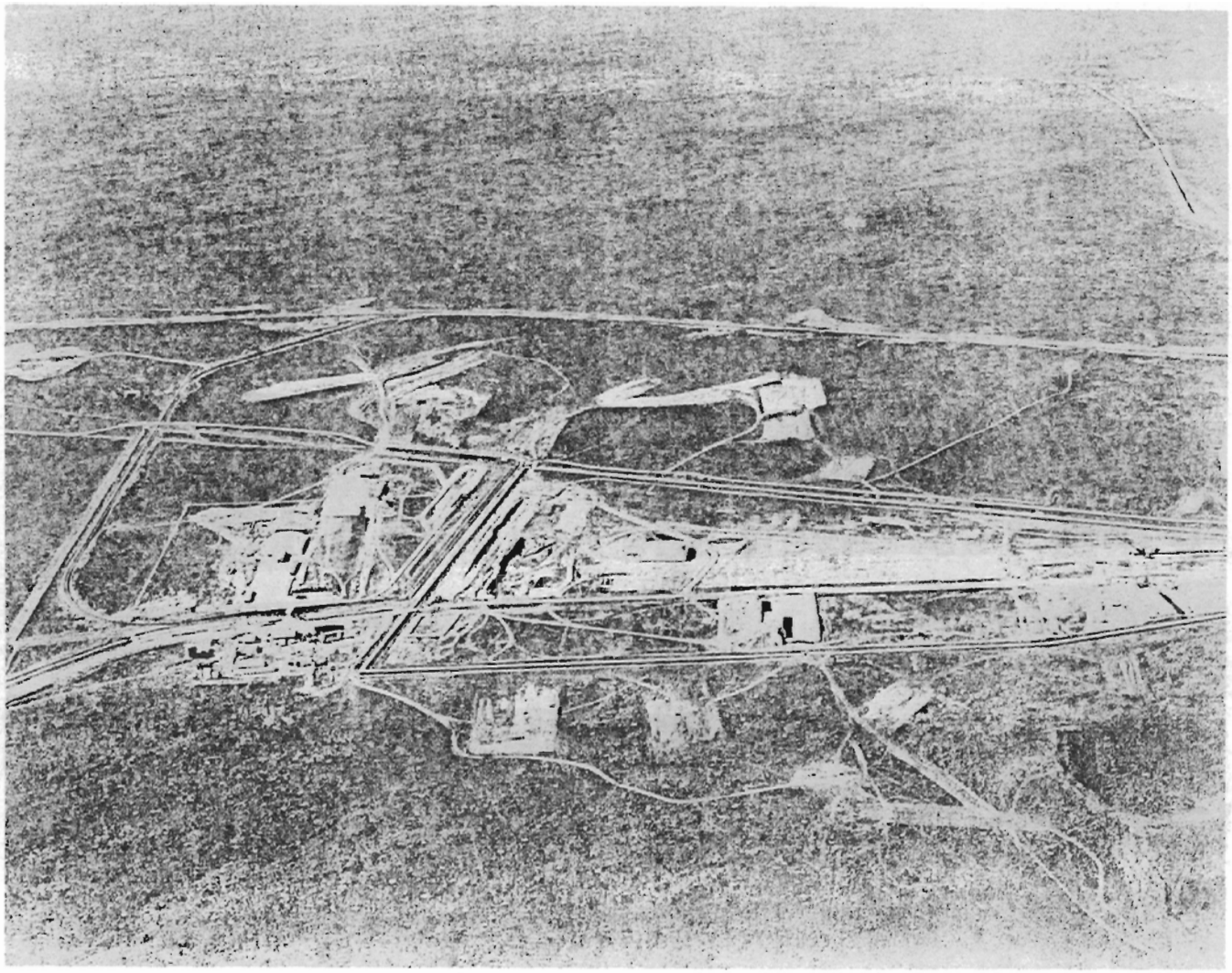
Slide 7

II. The Waste; Past and Current Management

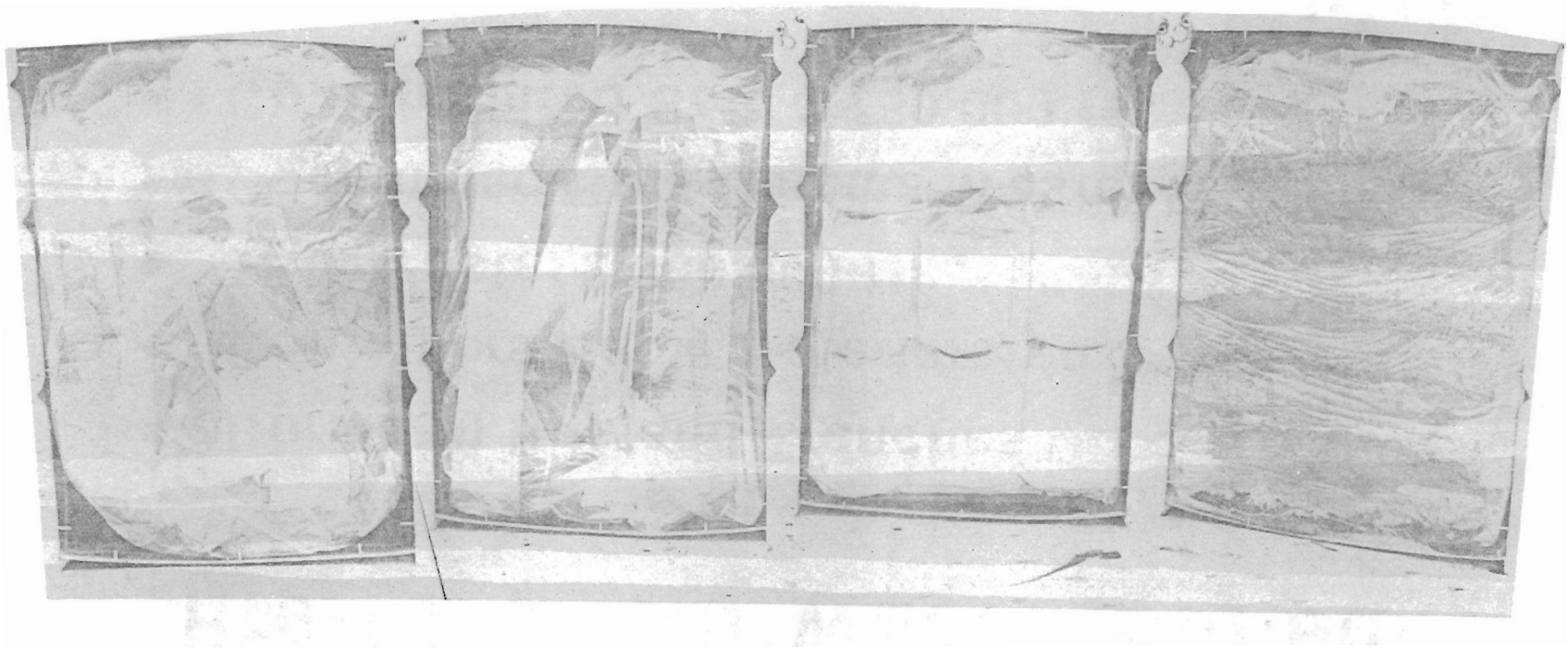
- From DOE Defense and Research Programs
- Contact-Handled, Solid, Transuranic
- Principal Transuranic Activity: ^{241}Pu, ^{241}Am, ^{239}Pu, ^{238}Pu. Also Some Uranium
- 20% - 25% Combustibles

INEL-S-24 406

Slide 8



Slide 9



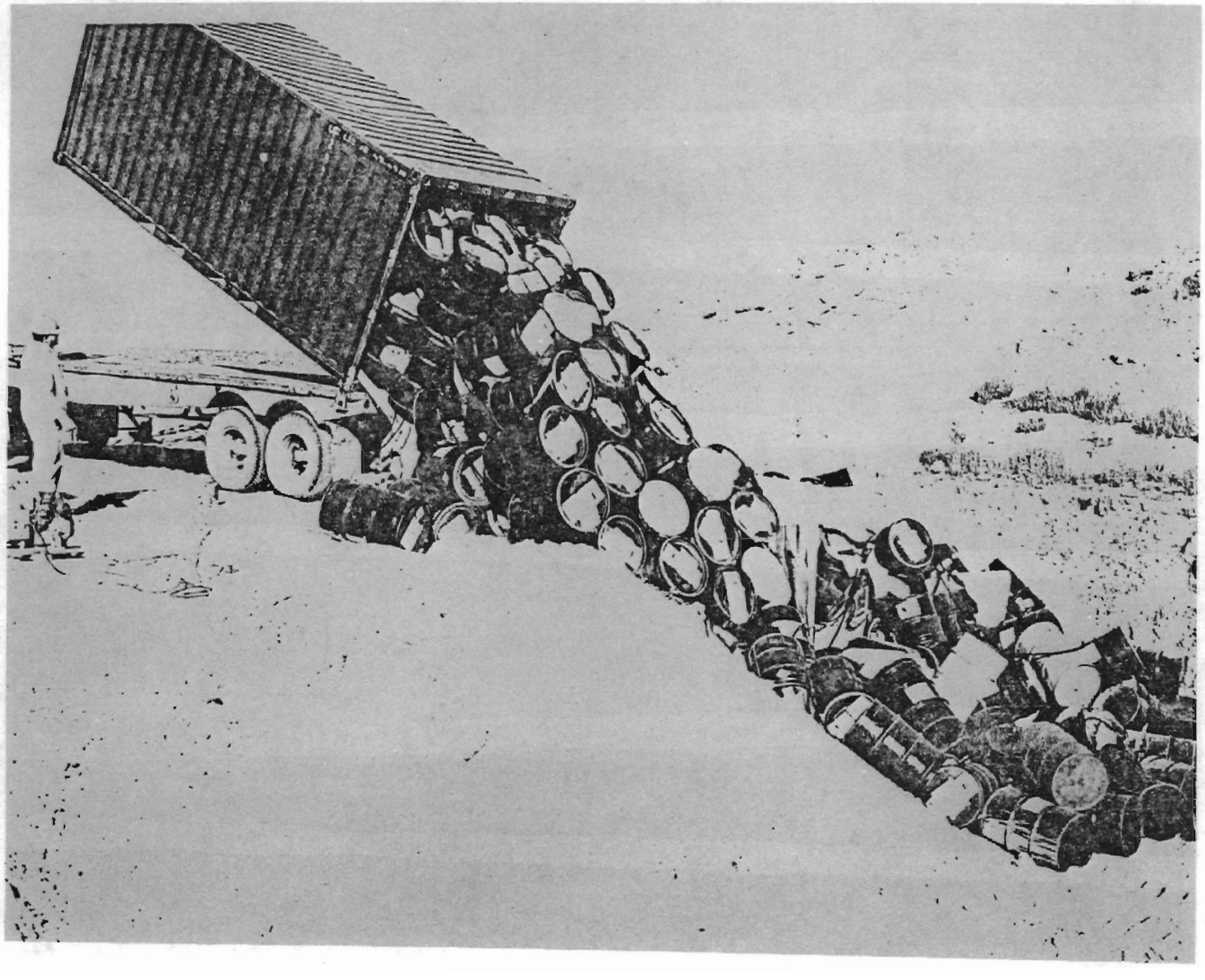
Slide 10

Pre-1970 TRU Waste (Buried)

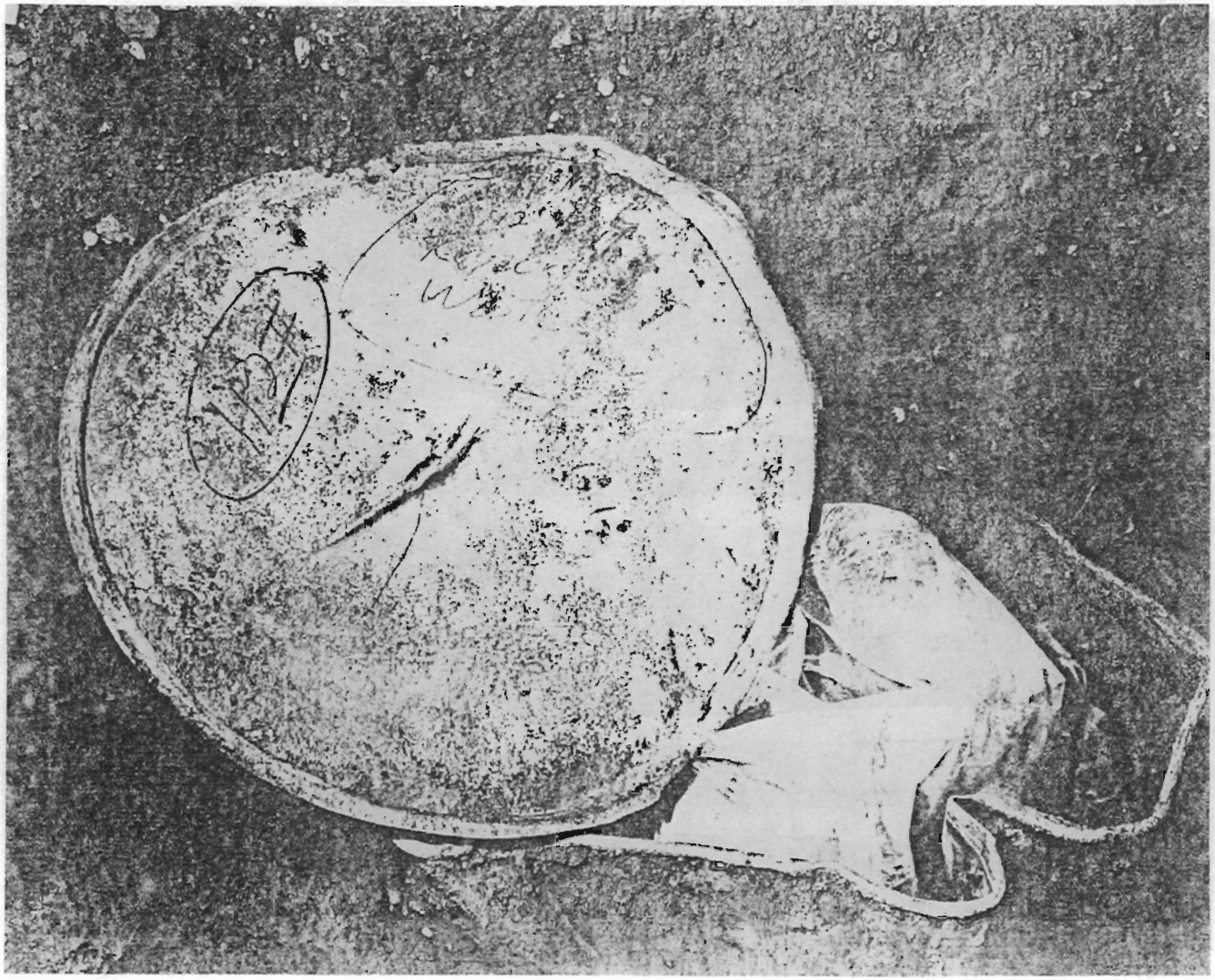
- Buried In Pits and Trenches
- Containers Badly Deteriorated
- TRU Waste: 2,000,000 ft^3
- Co-Mingled Beta-Gamma Waste: 500,000 ft^3
- Contaminated Soil: 3,750,000 ft^3

INEL-S-24 41

Slide 11



Slide 12



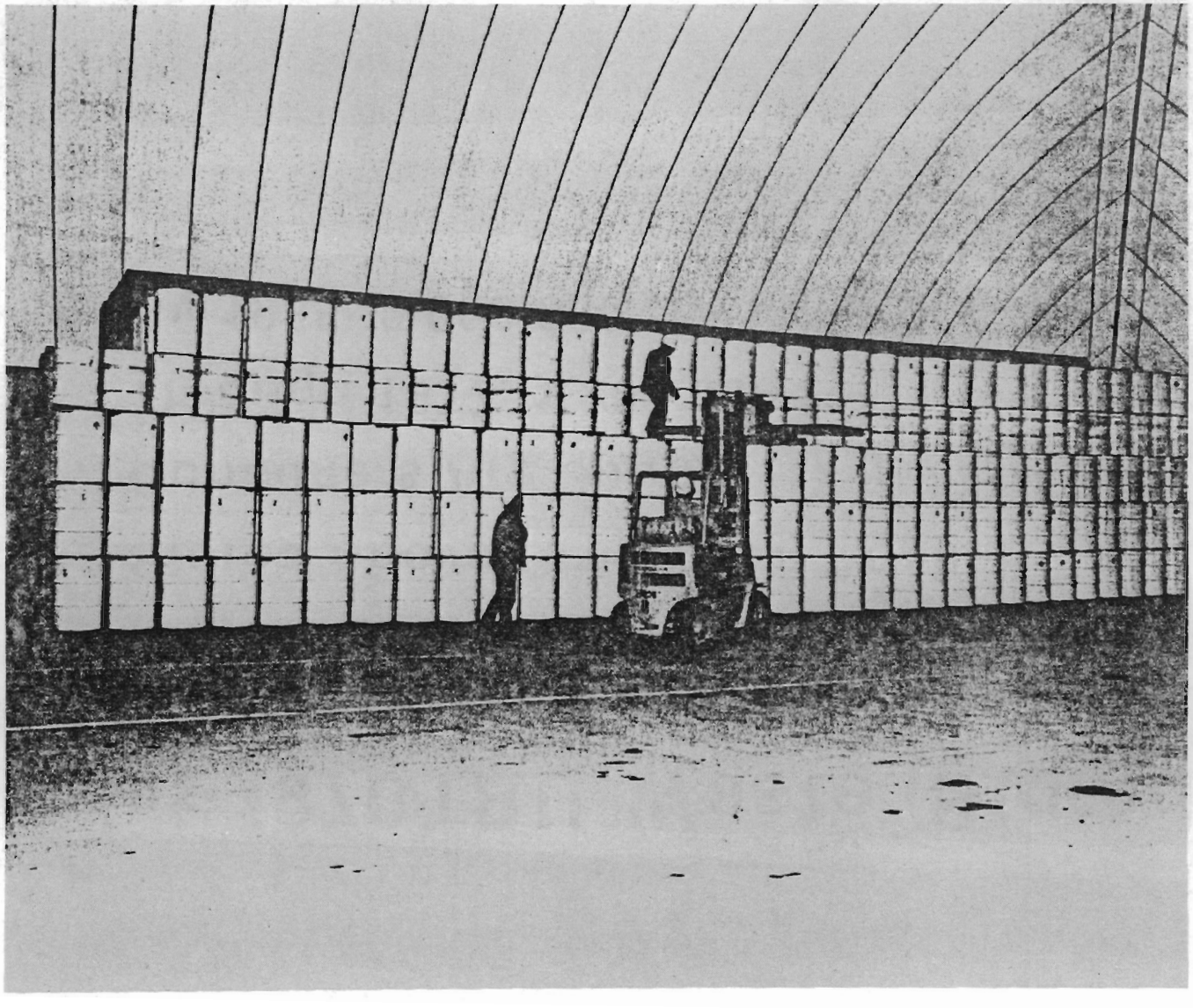
Slide 13

Post-1970 TRU Waste (Stored)

- Stored Above Ground on Asphalt Pads
- Containers Are Sound
- Through 1977: 1,200,000 ft^3
- By 1985: 2,000,000 ft^3

INEL-S-24 410

Slide 14



and about 3 ft of soil. The waste is then considered to be placed in interim storage awaiting retrieval for shipping to a repository. Opening that waste containment about 8 years later shows what is indicated in Slide 15. There was some minor rusting on some of the containers; however, all the containers were intact and the projected lifetime based on the corrosion measurement was about 40 years. This is what I refer to as the stored TRU waste.

It is interesting to think about the hazard of this waste before one plunges into the risk analysis. We did a simple hazard index based on the maximum permissible concentration (MPC) in air of the various nuclides and their daughter products just to get an idea of the scope of what we were facing. For various years after 1985, Slide 16 shows what the hazard index would be for buried waste and stored waste if you normalized it to unity in 1985. It shows the decay, if you will, of the hazard index. It also shows that the wastes are very long lived in terms of hazards. The buried wastes drop by only a factor of 50 in a million years. The stored waste decays somewhat faster.

The alternatives we examined for long-term management of the waste (Slide 17) are listed as (1) leave as is in the current location (or the no-action alternative); (2) improve the in-place confinement in various ways; (3) retrieve the waste, process it in various ways, and ship it to an offsite repository (this alternative was evaluated in other DOE programs); or (4) retrieve, process, and dispose of the waste on site. Among these various alternatives and subalternatives for buried and stored wastes, there is a total of about 60 alternatives, which really limited the depth to which we could go on any one alternative or any one scenario. The evaluations we conducted on these alternatives included radiological risk, hazards to workers, environmental effects (which is where we chose to put the routine releases), and budgetary costs (Slide 18).

As for the risk evaluation approaches, I could probably talk at length on this, but I won't (Slide 19). The number of assumptions required is voluminous. I think we have about 15 pages of guidelines and assumptions in one place in the report. I'll mention the quantities that we calculated, the time periods, pathways, calculational methods, and scenarios very briefly. Slide 20 shows what we calculated (50-year dose commitment and release frequency), although some frequencies were not estimated for the long term.

The organs we studied are also listed in Slide 20. Part of the way through the study, we switched over and began studying International Commission on Radiological Protection (ICRP) 26 and 30. Today, I will report whole-body equivalent doses. I am certainly not an advocate of this method.

We looked at maximum individual and 50-mile population. The time periods we looked at started with an assumed implementation date of 1985 (Slide 21). We used 100 years for short-term releases, and

Slide 15

Slide 16

Time Dependence of Relative Hazard Index For Waste Radionuclides

	Normalized, Relative Hazard Index	
Yr. After 1985	Buried Waste	Stored Waste
0	1.0 (Arbitrary)	1.0 (Arbitrary)
10^2	0.95	0.74
10^3	0.65	0.37
10^4	0.42	0.22
10^5	0.04	0.02
10^6	0.02	0.002

Index Is Based on MPC in Air.

INEL-S-24 404

Slide 17

III. Alternatives for Long-Term Management

For Either Buried or Stored INEL TRU Waste:

- Leave As Is ("No Action")
- Improve In-Place Confinement
- Retrieve, Process, Ship to Offsite Repository*
- Retrieve, Process, Dispose Onsite

* Offsite Repositories Evaluated in Other DOE Programs

INEL-S-24 409

Slide 18

Preliminary Evaluations for Comparing Alternatives

- Radiological Risk to Public (Uncontrolled Releases)
  - Short-Term
  - Long-Term
- Hazards to Workers
- Environmental Effects (Includes Routine Releases)
- Budgetary Costs

INEL-S-24 408

Slide 19

IV. Risk Evaluation Approach

- Quantities To Be Calculated
- Many Guidelines and Assumptions Required
- Time Periods
- Pathways
- Calculational Methods
- Release Scenarios

INEL-S-24 401

Slide 20

Quantities Calculated

Quantity	Short Term	Long Term
Dose commitment	X	X
Release frequency	X	Some

Organs	Persons
Whole body Bone Lung Other organs Whole body equivalent	Maximum individual Population within 50 miles

S2 3035

Slide 21

Time Periods

- Implementation of Alternatives: 1985
- Short-Term Releases: 1985-2085
- Assumed Date of Short-Term Release: 1985
- Societal Control Ends: 2085
- Long-Term Releases: 2085 - On
- Long-Term Releases Assumed to Occur After Implementation
  - 100 Yr (2085)
  - 400 Yr
  - 2000 Yr
  - 25,000 Yr
  - Waterborne Pathways Require Up To 10^6 Yr For Transport To Receptor

INEL-S-24 400

generally, we assumed they would occur in 1985, the year of maximum inventory. We also used 100 years for the societal control, with long-term releases occurring after 2085. Then we looked at various times for the occurrence of long-term releases.

We also studied airborne puff releases--the so-called instantaneous releases from an energetic event (Slide 22). We looked at continuous releases (e.g., those from erosion and groundwater releases). Pathways (Slide 23) probably include the standard list. I'll talk a little more about intrusion a couple of slides later. We tried to use methods (you'll see a lot of familiar computer codes and people's names) that were recognized broadly rather than using the INEL types of methods (Slide 24). I guess that we succeeded partially in doing that, but there is more than just the method; the specific assumptions are also important.

We looked at a very long list of release scenarios (Slide 25). I'll just mention a few of them here. We looked at local flooding events, earthquakes, and volcanos (which may sound like a peculiar scenario to most people, but the waste site that I showed you is located at the edge of the Arco Rift Zone, and the most recent volcanic flow under the waste is 50,000 years old). If you go a few miles away, you can find flows that are 1500 years old; therefore, that was a scenario we had to look at. We looked at long-term natural changes (e.g., glaciation). Because we covered retrieval and processing, we had to look at many operational events, which makes this risk analysis different from most of those discussed today. For intrusion, we covered similar scenarios to those discussed today. We had the digging scenario (someone digging into the waste looking for artifacts). We had the farming scenario (someone living on top of the waste, growing crops in the soil, and plowing). We also looked at radon release, particularly because we had a large amount of uranium-238 in the buried waste.

The risk analysis results for most of the dominant scenarios are presented in Slide 26. This is the retrieve, process, and ship to WIPP alternative for the buried waste. The results would be similar for the stored waste. The various columns include scenario, inventory release fraction (which is the fraction of the entire inventory, not the fraction of the containers that are affected), estimate of event frequency, and whole-body equivalent dose commitment.

The scenario that was of the greatest interest was the transfer accident with a fire occurring during waste removal from the retrieval site to the processor. We used frequencies based on some of the Sandia work that was written in about 1976. Tornadoes were fairly important. For our waste processor, the slagging pyrolysis incinerator, the gasifier rupture and criticality were events of interest. For shipping, we show two types of accidents. The first was the extra severe, which is a fairly standard defined accident of about 70 miles/h impact. We were requested by DOE to look at a worst-

Slide 22

Types of Release

- Airborne "Puff"
- Airborne Continuous (Wind Pickup After Flooding or Erosion)
- Groundwater

INEL-S-24 399

Slide 23

Pathways

- Airborne
- External Exposure
- Drinking Water
- Food Chain

Intrusion: A Special Case

INEL-S-24 397

Slide 24

Calculational Methods

Airborne/Inhalation	MESODIF, Pelletier & Voilleque, Healy, Bagnold, DACRIN
External Dose	EXREM III
Ingestion	INREM
Groundwater	Codell & Schreiber, Bredehoeft/Robertson

INEL-S-24 413

Slide 25

Release Scenarios

- Natural Events (e.g., Flooding, Earthquakes, Volcanism)
- Long-Term Natural Changes (e.g., Glaciation, New River Channel)
- Operational Events (e.g., Dropped Containers, Explosions)
- Airplane Crashes
- Intrusion
- Near-Term Sabotage Not Included

INEL-S-24 396

Slide 26

V. Risk Analysis Results

Dominant Release Scenarios for Retrieve-Process-Ship Alternative for INEL Buried TRU Waste

Scenario[a]	Inventory Release Fraction[b]	Event Frequency (yr^{-1})	Whole-Body-Equivalent Dose Commitment: Maximum Individual (rem)	Whole-Body-Equivalent Dose Commitment: Population (man-rem)
Retrieval				
Transfer accident with fire	1×10^{-7}	2×10^{-6}	1×10^{-4}	2×10^{-1}
Tornado	6×10^{-7}	5×10^{-7}	6×10^{-4}	1
Slagging pyrolysis				
Gasifier rupture[c]	1×10^{-5}	1×10^{-4}	1×10^{-2}	2×10^{1}
Criticality	NA	5×10^{-6}	3×10^{-4}	2×10^{-1}
Shipping				
Extra severe rail accident	9×10^{-12}	4×10^{-8}	9×10^{-9}	1×10^{-4}
Worst-case rail accident	2×10^{-6}	$< 1 \times 10^{-11}$	2	3×10^{3}

NA = Not applicable.

a. All scenarios were assumed to occur in 1985.

b. Fraction of total inventory.

c. Assumes offgas system fails.

S2 9905

case rail accident. We assumed that the train carrying waste would be parked in the Denver rail yard next to a car-load of explosives. We didn't feel too good about putting a frequency on that scenario because it is very low, vanishingly low. Compared with the age of the earth, it is not worth thinking about. The frequency is 10^{-9}, or once in the age of the earth. The largest dose commitments would have come from that accident. Other than that, these other dose commitments are extremely small, and the events are generally quite unlikely.

These are the results for the buried waste no-action alternative (Slide 27). We added one new column in this table to show the time at which the scenario was assumed to occur at various times in the future. Subsurface migration is one alternative about which the Idaho public has been interested, although the doses we calculated for that are extremely small. We looked at two volcano scenarios: when the flow comes from outside over the waste and when the explosive volcano flow comes up through the waste. The U.S. Geological Survey (USGS) in Idaho devoted 2 or 3 years to the study of these scenarios. Therefore, on a relative scale, I feel more comfortable with some of these frequencies because the USGS did a lot of age-dating of the various flows. I would qualify this by saying that the lava-flow scenario may have a release fraction of zero if the flow went over the waste and simply entombed it. We took a worst-case approach here and assumed that the flow would push aside the cover and that the heat of the flow would ignite combustibles in the waste. So that's a very controversial scenario.

The three intrusion aspects that I mentioned are listed at the bottom of the table. We did not estimate frequencies for those. I had no idea how to do that. Those could contribute fairly significant individual doses. I need to discuss the population doses because, in a couple of cases, they are less than the doses for individuals. These are the offsite individuals, whereas those are the individuals who are right at the waste. That is the reason why the population dose is less than the maximum individual. For the farming scenario, we assumed that there were 10 individuals living at that farm; that is where the 1400 comes from.

From these results, we can conclude that operations-related risk to the public is extremely small (Slide 28). The long-term releases could have some significant effects in the areas of intruders and volcanos. However, there are major uncertainties in those scenarios. The scenarios that the public views as hazardous [based on their comments on previous environmental impact statements (EISs)] would have very small consequences (e.g., nuclides would migrate to the aquifer and through the aquifer, and earthquakes). They were concerned about earthquakes upsetting the buried waste, and we had to really work to come up with any scenarios.

Slide 29 is a supplementary list of the problems that have been discussed before. The first bullet refers to my belief that for

Slide 27

Dominant Release Scenarios for Leave-As-Is Alternative for INEL Buried TRU Waste

Scenario	Time (yr in future)	Inventory Release Fraction[a]	Event Frequency (yr^{-1})	Whole-Body-Equivalent Dose Commitment: Maximum Individual (rem)	Whole-Body-Equivalent Dose Commitment: Population (man-rem)
Subsurface migration	10^2	1×10^{-4}	2×10^{-3}	1×10^{-5}	2×10^{-4}
Lava flow	10^2	1×10^{-2}	6×10^{-5}	8	5×10^4
Explosive volcano	10^2	2×10^{-4}	3×10^{-8}	0.2	900
Intrusion					
excavation	10^2	NA	NC	35	3[b]
farming	2×10^3	NA	NC	140	1400[c]
radon emission	10^6	NA	NC	10	0.5[b]

NA = Not applicable; NC = Not calculated

a. Fraction of total inventory

b. Offsite dose only; does not include dose to individual intruder

c. Assumes a community of ten intruders

S2 9904

Slide 28

VI. Conclusions and Problems

A. Conclusions

- Operations-Related Risk to Public is Extremely Small
- Effects of Dominant Long-Term Releases Could be Significant
  - Intrusion
  - Volcanism
- Large Uncertainties in the Dominant Scenarios
- Scenarios Viewed as Hazardous by Public Would Have Small Consequences
  - Radionuclide Migration to Aquifer
  - Earthquakes

INEL-S-24 398

Slide 29

B. Some Problems in Performing Risk Evaluations of TRU Waste

- Need for site-specific studies
- Inventory uncertainties
- Containment uncertainties
- Event frequencies and release fractions
- The "Moving Target" problem
- Murphy triumphs again

S2 9907

site-specific results you need site-specific studies. There were such large differences between sites in waste, soil, and groundwater characteristics and in the population distribution. I guess I'm not so rigid on the intruder scenario. A lot of things will cancel out or the differences will be smaller, but for some of these others (e.g., volcanos), few problems will be caused at most sites. It is ridiculous to even think about the volcano scenario.

There are large uncertainties in inventory. There are also uncertainties in containment. We've got many types of TRU containers. For example, some of our drums have polyethylene liners and some don't. You'll find various physical decay rates for the container depending on what's in the container and what type of liners are used in the container. I don't feel comfortable projecting erosion rates at the Radioactive Waste Management Complex. That site is in a major depression area and it tends to get flooded. We have had three floods in the last 20 years, despite anti-flood measures. Therefore, I'm not sure that it is going to erode. There are the usual uncertainties in the event frequencies and release fractions. We were not able to get good data for most of those events. We have handled about 100,000 containers; of that number, zero were dropped and two were speared. In the two speared incidents, the contamination was confined to an area smaller than this podium.

The moving-target problem was one of our biggest. In the course of the 4 or 5 years of rewriting this study, the baseline processing method changed three times for this TRU waste. One of Murphy's laws is that the part of the system you know the least about will become the controlling part of the system. That certainly was true in reference to volcanos and intrusion.

One of the questions a person might logically ask is, "What would be the effect on the risk analysis if the waste disposal limit had been 100 nCi/g instead of 10 nCi/g?" A short answer is that it would have a minimal effect. In looking at the long answer, I thought I could present some instructive data concerning the inventories because they tie in very strongly. I think we need to keep in mind what this waste is in terms of inventory. The waste is far from being uniform.

So, I concluded that it is difficult, for many reasons, to do risk analyses of real TRU waste in terms of nanocuries per gram (Slide 30). Not all the TRU waste that we have (and we have 75% of the stored waste) is directly assayed for TRU content. The concentrations are calculated based on process mass flows. Rich Jensen has been doing the inventory calculations for shipping, and I am reporting the inventory calculations for receiving. They are not always totally in agreement. There is a lot of suspect waste that is not readily assayed. Containers of waste vary widely. There is no standard density for this. We hear that the waste is 1 g/cm^3 or 0.5 g/cm^3; however, the figure varies widely, from 0.1 g/cm^3 to 4 g/cm^3.

Slide 30

It is Difficult to do Risk Analyses of Real Waste in Terms of nCi/g:

- Not all TRU waste containers are assayed for TRU content (some calculated, some "suspect waste")
- Containers weights vary widely
- Assay resolution (or reporting level) is sometimes only to 0.1 g, or 100-1000 nCi/g
- Even current assay equipment has difficulty with large containers on production basis
- TRU content of some reopened containers does not match that in records

S2 3041

We are not routinely assaying precisely to 10 nCi/g or to 100 nCi/g in some cases. The equipment is simply not there, at least not in the part of the system that I am familiar with. A key point is that in much of the waste that comes in, a large percentage lists the plutonium inventory as less than 0.1 g. The people at Rocky Flats chose to interpret that as zero. You can round down to zero, and you can round up to 0.1 g. The people in Idaho have rounded up to 0.1 g. That might not sound like such a big deal, but although 0 g is obviously 0 nCi/g, 0.1 g will typically turn out to be 100 to 1000 nCi/g. The latter figure puts you past the range of argument we've had at this conference. It would stop any further discussion of changing the limit from 10 nCi/g to 100 nCi/g. Depending on how you round your reported number, you can swing clear past the area of controversy based on today's instrumentation. This is particularly true with large containers such as the boxes. In fact, the goal is to assay on a production basis in a real facility, not a laboratory, to 100 nCi/g on the boxes. We cannot assay to 10 nCi/g on a production basis.

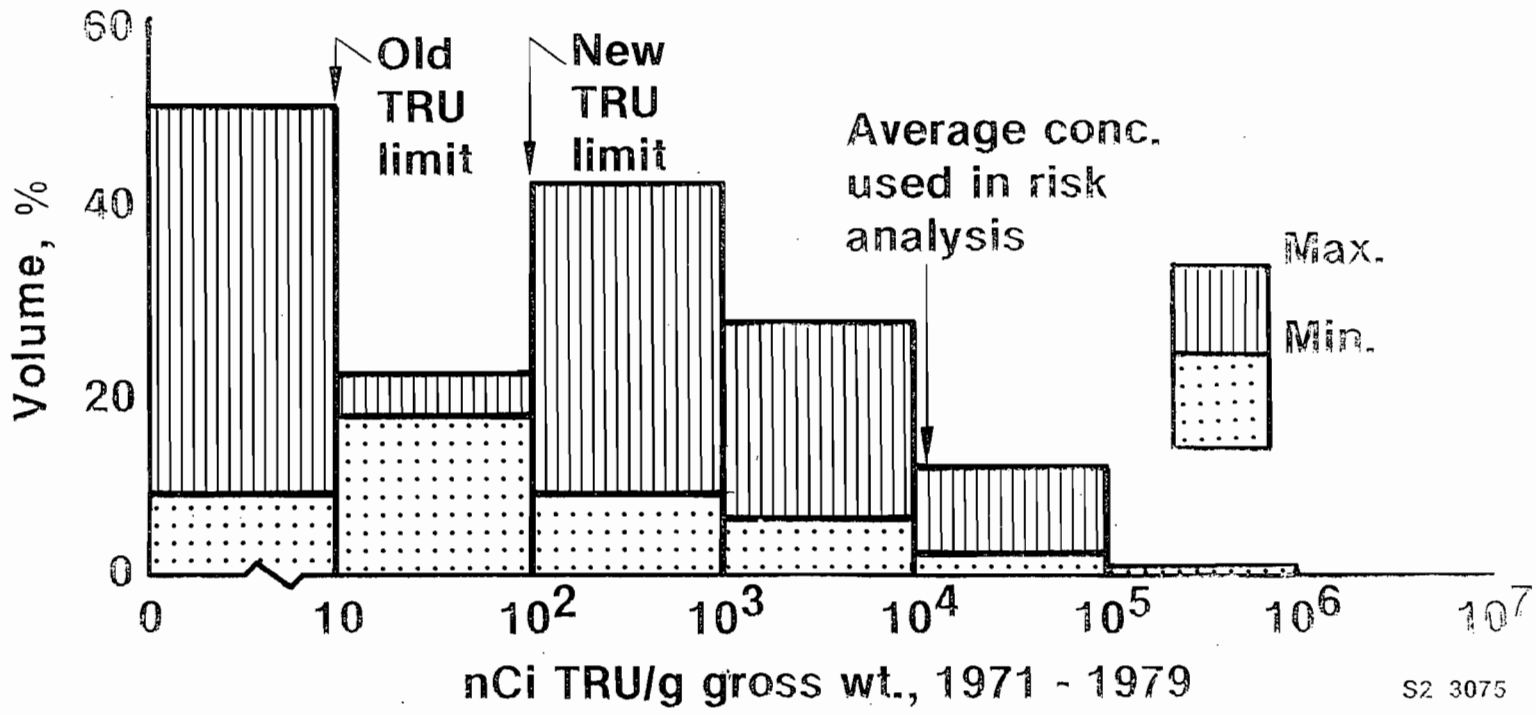
One interesting point here, we recently opened some of the TRU waste containers to check the actual amount of plutonium present against what was on the records. One was recorded as 5 g, but when we opened it, it turned out to be about 50 g.

This histogram (Slide 31) shows an existing inventory of waste stored from 1971 to 1979. I must qualify this before I discuss it further by saying that, to force some numbers to come out of the records in this time frame, I had to have people assume uniform density. That is a very big assumption. We assumed one standard weight for all drums. The horizontal axis shows the various ranges of nanocuries per gram: 0 to 10, 10 to 100, 100 to 1000, etc. The vertical axis shows the percent of the waste volume that would fall in that category. I have also shown the old TRU limit and the new TRU limit. For our risk analysis, we imagined that the waste was stirred around so that it was uniform, but in individual containers. If you go through the calculations on inventory, the concentration of waste on the pad is about 10,000 nCi/g. The maximum and minimum are shown, and the dotted area constitutes the minimum. If you add in the vertical striped area, you go up to the maximum. The graph represents different ways of interpreting the records: how you round numbers up and down. It shows that there is quite a bit of waste on the pad that can be interpreted as being less than 10 nCi/g. In this case, the Rocky Flats people would give the higher number and the INEL people would give the lower number. I can't really claim that one number is right or wrong until we actually retrieve this waste and assay it with state-of-the-art instruments. That will be about 1985 or 1986.

There is not much waste between 10 and 100 nCi/g. It constitutes about 15 or 20%, and that is one of the points we agree on. There is a lot of waste in the 1000 to 10,000 nCi/g category. Bear in mind that this is the existing waste on a pad.

Slide 31

Based on Shipping Records, Little INEL Stored "TRU" Waste Lies Between 10 and 100 nCi/g



The next histogram (Slide 32) looks at the most recent year. It represents the best look at today's waste as opposed to yesterday's waste. Other than that, everything else is the same on the diagram. You can see that there is a smaller fraction of the less than 10 nCi/g, or "suspect waste." Also, the area between 1000 and 10,000 nCi/g has grown. Because this is a logarithmic plot, the risk analysis is swung by this area and this area. In other words, you could delete the waste that is out here, forget about it. The total plutonium quantity would be minimally affected. The volume would go down by 20 to 40%, which means your average concentration would go up by, at most, a factor of 2. Therefore, the risk analysis is very little affected by what goes on out here.

If the limit is changed to 100 nCi/g, the results would change very little because little of the waste is between 10 and 100 nCi/g or even between 10 and 1000 nCi/g (Slide 33). We do not know the accurate TRU content, particularly at the low concentrations. The source term we used is based on average waste and an assumed number of breached containers, except for the intrusion scenario, where it was based on a concentration. I feel that the uncertainties and other aspects of the risk analysis outweigh the uncertainties in changing the limit from 10 to 100 nCi/g.

In conclusion, I think that risk analysis can be an important tool in setting the limit if the uncertainties are kept in mind. However, I would hope that it is not the only tool because there are operational and cost considerations that need to be included.

Question: I'm fascinated by your volcano scenario. I can picture Pompeii or a volcano erupting in Idaho and wiping out the city of Salt Lake. But the real problem is that 100 man-rem you might get.

Smith: The real problem is also how fast you can get away from the volcano.

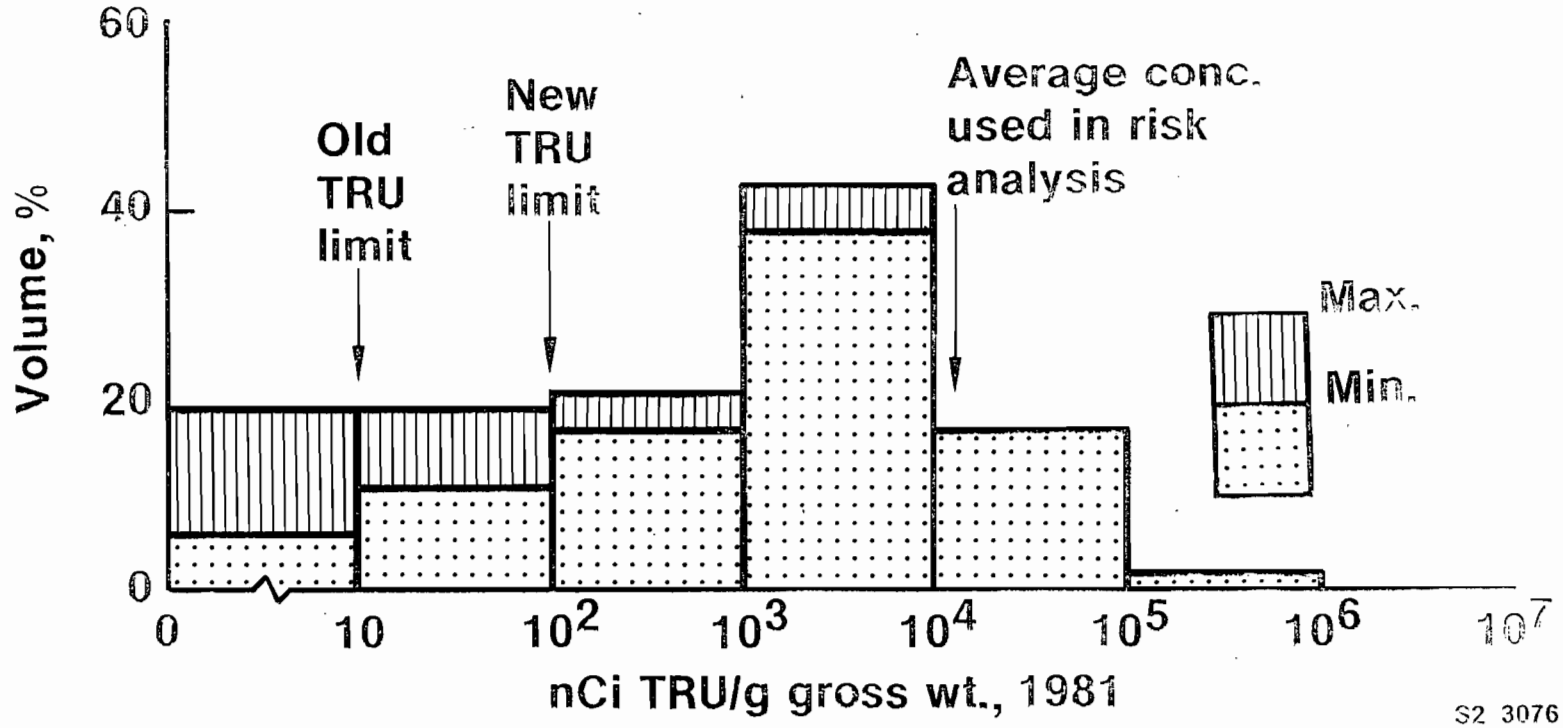
Question: What release fraction did you use for airborne in your volcano scenario?

Smith: The overall release fraction ranged from about 10^{-4} to 10^{-2}. There is not too much data on this. The Oak Ridge study on partitioning assumed a 50% release for airborne. We did not achieve that efficiency in the Plowshare program.

Bill Lennemann: This is just an explanation on the burial ground with which I am familiar. When you said it was flooding, it is in a low place. However, the cause of the flooding is a dike that runs across one end. The dike is a volcano dike, a basalt dike. All the water runs into the burial ground from a drainage area and then does not run off. In other words, you would have a fill going on in there instead of an erosion scenario. That is why you talk about this burial ground getting flooded. The water can't get out.

Slide 32

Based on Shipping Records, Little INEL Recently Generated Waste Lies Between 10 and 100 nCi/g



Slide 33

If the TRU Limit had been 100 nCi/g, not 10 nCi/g, the Risk Analysis Results Would Have Changed Very Little

- Most "TRU" waste is either <10 nCi/g or >100 nCi/g
- Do not know TRU content accurately, particularly at low concentrations
- Risk analysis source term based on "average" waste and assumed number of breached containers
- Uncertainties in other aspects of risk analysis are orders of magnitude

S2 3040

Smith: That is correct. It is a local drainage basin; it is not a river flood that we're speaking of. It is snow melt runoff in the spring. I'm not a geologist. I would expect, however, that the area would tend to fill over time rather than erode.

RISK AND SAFETY ANALYSES FOR DISPOSAL OF ALPHA-CONTAMINATED WASTE AT LOS ALAMOS NATIONAL LABORATORY

Wayne Hansen, Los Alamos National Laboratory

First, I would like to point out that a number of people were involved in this effort, not just me (Slide 1). John Rodgers contributed some of the data we are presenting. Lou Walker prepared some of the information, and we had the good fortune of having Jack Healy in the Health Division help us out with some observations and occasional comments.

To look at the problem at hand, which is risk analysis of waste management areas, we have to have a very clear crystal ball. Mine seems to be cloudy all the time. Vern Rogers covered many of the same problems with doing risk analysis and the calculations involved with it in his paper. As Tom Smith pointed out, he and I were involved in doing most of the work for preparation of an alternatives document for the Savannah River Laboratory. That document was to look at the different alternatives we had, or should develop, to deal with both the stored transuranic (TRU) waste and those wastes that were buried before 1970, when a limit was set to determine what went into storage and what went into low-level waste areas.

I'll try to cover some topics more briefly than others because a lot of information has been presented so far in the meeting on methodologies for each one of these categories. Our first problem is to establish a probabilistic, quantitative estimate of what the release event is (Slide 2). As you'll find out, we gave up and assumed the release event in many cases because of the long time periods to be considered when dealing with TRUs. Source terms for release were not much easier because we were dealing with waste areas that were old. For the purpose of waste management, records may have been complete, but they didn't include the information we need for pathways analysis. We did some pathways analysis, went to dose assessment, and later I'll put up a slide on health effects. We attempted to calculate some general observations on health effects rather than health effects for every scenario. I'll try to give you the reasons why we stopped at different points in the analysis. Then we tried to play some games with communicating the meaning of the risk from this effort, and we've been experimenting with that for some time.

We can break the analysis down into three general areas. The first is the near term, less than 100 years, which was, I guess, arbitrary. If there is any defense, the regulatory agencies had used 100 years so we did too. We tried to assess our second area, accidents or acts of God, like Tom Smith did in his analyses. We categorized these acts of God as an earthquake or a volcano, as Tom had too. We emphasize the third area, the long-term, in our analysis. In our case, long term means more than 100 years. I guess at this point I have a question.

Slide 1

RISK AND SAFETY ANALYSES
FOR SHALLOW LAND BURIAL OR DEEPER BURIAL

DISCUSSION OF METHODS FOR RISK ANALYSES

- Probability of Event For Release
- Source Terms For Release
- Pathways Analysis
- Dose Assessment
- Health Effects
- Communication of Meaning of Risk

Slide 2

PROBABILITY OF EVENTS
RELEASING RADIOACTIVITY

- NEAR TERM (LESS THAN 100 YRS)
- ACCIDENTS OR ACTS OF GOD
- LONG-TERM

QUESTION: IS THERE LOGICAL POINT TO STOP THE ANALYSIS AFTER DETERMINATION OF THE PROBABILITY?

I mentioned we stopped the analysis. Is there any logical way to look at this in terms of stopping the analysis after you've determined what the probability is? Maybe I chose a poor word--not logical, but a way of looking at it.

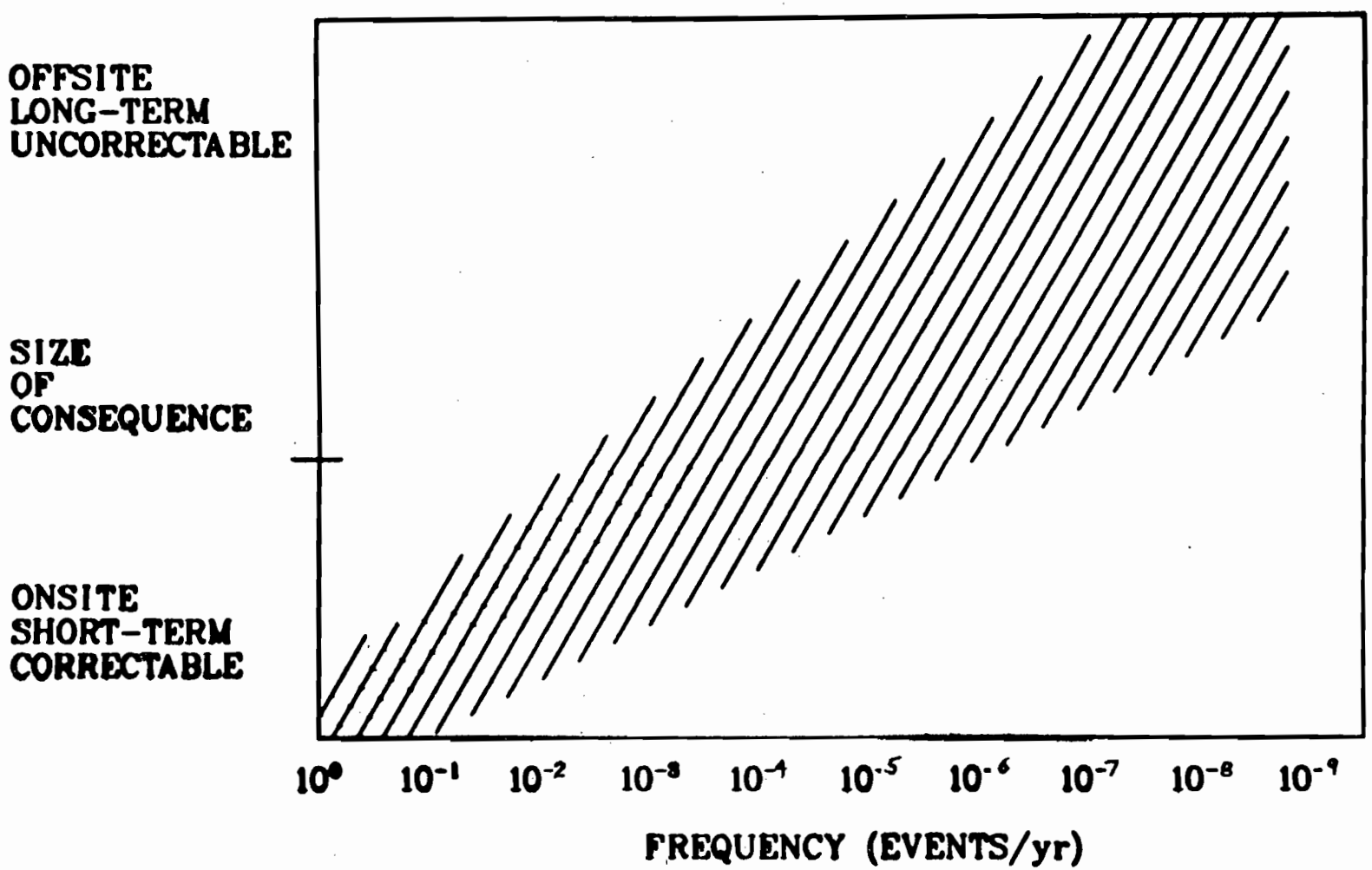
Slide 3 shows a method we have been experimenting with. We are biased in favor of this method because we are looking at it from the standpoint of preparing environmental documents. Accidents or catastrophic events can have two forms. They can be on site and correctable if the consequences of the accident are totally contained on the site of interest. The accident or catastrophe can also have offsite, long-term, uncorrectable aspects. The graph indicates frequency or probability of a catastrophe or an accident occurring in a year. Notice that this is a large scale, going from 10 to 10^{-9}.

Slide 4 is an overlay for the previous slide. From an environmental standpoint, we aren't particularly interested in the onsite aspects of an accident. The exception to that, of course, is the intruder scenario. However, we assumed, "Okay, if it's on site, it is correctable. We won't bother to go any further now that we have a probability for it. You have to do some consequence analysis to make sure the consequences are all retained on site."

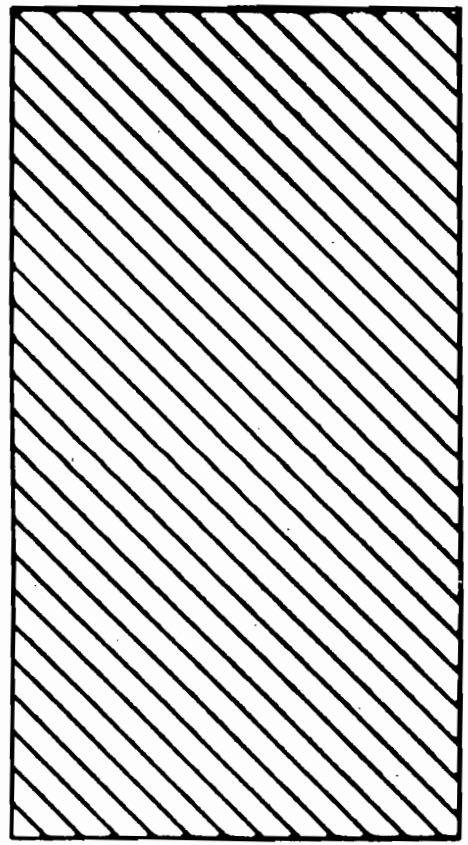
Slide 5, which is an overlay, picks a cut-off point for what is an incredible time period and what isn't. If the time period is incredible, you determine that probability or the consequences; then you stop. Spend your time on catastrophes or accidents that have a greater probability of occurring and producing some offsite uncorrectable impact. Determining credibility has worked for us quite well in doing safety analysis events for facilities. For waste management, it has some definite disadvantages, like attempting to apply it to things like intrusion. We also had some trouble coming up with the frequency, and therefore, it didn't work very well. When looking at catastrophic events, this technique works reasonably well. For example, a geological study that said volcano intrusion into the waste area had a probability of 10^{-7}/year. That is where we stopped. It can be argued that the baseline of 10^{-6}, one chance in a million per year, is arbitrary, but 10^{-6} is a number that is used occasionally in the regulations. If I translate the 40 CFR 191 number into 1 chance in 100 in 10,000 years, the chance per year is about 1 in 1 million.

When I start looking at long-term, general release mechanisms for radionuclides from the site outside the site boundary, I start getting into a large number of prophecies that have been discussed at great lengths in past papers. Again, we looked at most of the same pathways as everyone else, biological intrusion by plants and animals and inadvertent human instrusion (Slide 6). We also looked at water infiltration, erosion processes, catastrophic events, and some of the combinations of these processes like erosion, which bares the waste and takes off the soil cover; biological intrusion by plants and

Slide 3

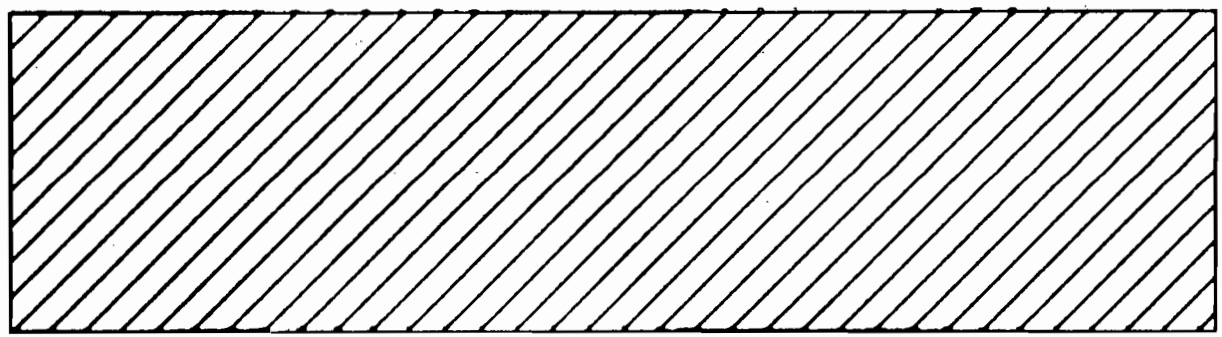

OFFSITE
LONG-TERM
UNCORRECTABLE
SIZE
OF
CONSEQUENCE
ONSITE
SHORT-TERM
CORRECTABLE
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
FREQUENCY (EVENTS/yr)

Slide 4



FILTER 2
FREQUENCY $>10^{-6}$/yr

Slide 5



FILTER 1
OFFSITE/LONG-TERM/
UNCORRECTABLE

Slide 6

GENERAL RELEASE MECHANISMS FOR SHALLOW LAND BURIAL

- Biological Intrusion by Plants and Animals
- Inadvertant Human Intrusion
- Water Infiltration
- Erosional Processes
- Catastrophic Events
- Combinations of Release Mechanisms

animals; or human intrusion when the wastes were on the surface. Although it isn't on the list, we also looked at a deliberate intruder.

Slide 7 shows a little more detail on the pathways for human intrusion. We calculated hypothetical utility trenches. We dug a hypothetical trench through the waste area, commercial properties, gardens, drives and roads, lawns (by the way, these are all very simplistic), agriculture, crops and pasture, parks, resource exploration (drilling or well drilling), and undeveloped land use (natural succession). In our naivete 8 years ago, the natural succession scenario was the one we though we ought to put some effort on because we have several waste areas at Los Alamos that are already into natural succession, areas that were closed as early as 1948. Therefore, we had probably a better start on that than on some of these other scenarios.

We've been talking about 100 nCi/g in waste and discussing possibly going to that level. We analyzed (Slide 8) an old 12-acre site that had been closed before 1970. We had a survey, done in the mid-1960s, of the waste coming out of the plutonium facility for about 9 months. In the mid-1960s, our plutonium facilities were generating about 2% waste in the 10 to 100 nCi/g range and another 2% waste above 100 nCi/g. If you remember, John Umbarger's slide showed today's plutonium facilities generating about 1% in the 10 to 100 nCi/g range and 1% greater than 100 nCi/g. We had to come up with a source term for these pathways. We averaged the source term across the trench volume for those pathways that involved a whole area. That's not very satisfying, but that is about what we thought we could do with general invasion pathways with plants growing over the entire area. We came up with about 0.1 nCi/g. This approach does indicate what the dilution of low-level waste with these TRU wastes does, however. Our general approach was to follow ecosystem dynamics, looking at the processes for moving waste out of the area: dispersal or dilution, translocation, and reconcentration into pathways (Slide 9). As most people have indicated, and John Rodgers indicated very well, reconcentration is not a big problem with TRU elements.

Land use was a problem: how do you set up a scenario that sounds like common sense? Vern Rogers helped us determine some methods for categorizing land use around Los Alamos. The soil conservation and soil survey people can suggest some limits on what future land use might be. These limits are general, but they turned out to be helpful in determining some of the crops that might actually grow on the land in an intrusion scenario versus those that might not. Other speakers at this seminar discussed long-term climatic and geological processes, so I won't discuss those to any great extent. That's more a sensitivity analysis, asking what will happen if the climate changes.

Slide 7

HUMAN INTRUSION

- URBANIZATION
  - Utility Trenches
  - Commercial Properties
  - Gardens
  - Drives and Roads
  - Lawns
- AGRICULTURE
  - Crops
  - Pasture
- PARKS
- RESOURCE EXPLORATION
  - Drilling
  - Archaeology
- UNDEVELOPED (Natural Succession)

Slide 8

SOURCE TERMS

AT 100 nCi/g OF TRU SOURCE TERM IS MUCH LESS
BECAUSE OF DILUTION WITH LOW LEVEL WASTES

EXAMPLE:

Los Alamos National Laboratory Area C
12 Acres Used Before 1970
Wastes from Pu Facility for 9 Months

91%	Less Than 1 nCi/g
5%	1 - 10 nCi/g
2%	10 - 100 nCi/g
2%	100 - 5000 nCi/g

Used Average 0.1 nCi/g for Scenarios that Consider Whole Area.

Slide 9

EVALUATION METHODOLOGY

1. ECOSYSTEM DYNAMICS FOR PROCESSES

   - DISPERSAL
   - DILUTION
   - TRANSLOCATION
   - RECONCENTRATION

2. LAND USE

3. LONG-TERM PROCESSES

   - CLIMATIC
   - GEOLOGICAL

The pathways are the same ones that have been described previously (Slide 10). Inhalation from widespread air contamination or resuspension might occur if the wastes are in a large area exposed to the surface. Inhalation from local resuspension might occur if an intruder digs a trench and brings some of the waste to the surface. Ingestion would involve plants, animal products, water--again in the standard pathways--and ingestion of contamination directly. We also looked at the pathway of a deliberate intruder going in, perhaps an archaeologist who handles materials and contaminates himself. What radionuclides does he intake directly?

We have used computer models that are cussed, fussed, and a lot of other things. I'm going to say some more (Slide 11). We believe computer models should not be believed as predictors, but rather they should be used to compare cases or compare alternatives. We find that the person who makes the model really believes his model puts out an accurate prediction and will defend it to the death. However, we believe, as everyone pointed out, there are large uncertainties; the model is not a true predictor, but can be an indicator of order of magnitude. The other observation, which I think might just as well go unsaid, but that is an observation we have, is that the uncertainties in making estimates go up with greater confinement and better, deeper burial of the material.

We have combined a number of models for our use (Slide 12). Most of the models, because releases are a time-step function, combine the release mechanism, the source term determination, and the pathways analysis. Instead of using any one model or trying to develop new models, we have borrowed from other people as much as we could, with one exception--the Biological Transport Model (BIOTRAN). Rather than a straightforward deterministic compartment model, BIOTRAN is a climate-driven, dynamic model. By that, we mean that we use the climate to drive plant growth, water history in an area, and radionuclide uptake and transport off the area. BIOTRAN has modules that can deal with animals. For instance, it can take a cow grazing and go through milk pathways and so forth. I think Oak Ridge is developing a similar model.

The Universal Soil Loss Equation is a simple model that we used for our calculations on surface erosion. Once we have set our materials available in water as a sediment from erosion processes (if you've been to Los Alamos, you are familiar with our Mesa-Canyon structure), materials tend to go to the canyons. We've used the Agricultural Runoff Model, a common model used by the Agricultural Research Service, for transport of those sediments in sheet erosion. The In-stream Sediment Transport Model is a development model that we worked on with Battelle-Pacific Northwest Laboratory.

For water infiltration, we used several simple one-dimensional models to "make" a complex, three-dimensional water infiltration model. Our reports and data that I'll discuss later come from a model that is

Slide 10

PATHWAYS TO MAN

- INHALATION FROM WIDESPREAD
  AIR CONTAMINATION OR RESUSPENSION

- INHALATION FROM LOCAL RESUSPENSION

- INGESTION
  PLANTS
  ANIMAL PRODUCTS
  WATER

- INGESTION OF CONTAMINATION

Slide 11

MODELS

PHILOSOPHY - CALCULATED OUTPUT OF SOURCE TERMS SHOULD BE USED FOR COMPARISON OF ALTERNATIVES, NOT BELIEVABLE PREDICTIONS

OBSERVATION - THE GREATER THE CONFINEMENT THE GREATER THE UNCERTAINTY IN RISK ESTIMATES

Slide 12

MODELS

COMBINE:	RELEASE MECHANISM SOURCE TERM PATHWAYS
PLANT AND ANIMAL INTRUSION:	BIOTRAN - DYNAMIC MODEL CLIMATE DRIVEN, SITE SPECIFIC
EROSION:	UNIVERAL SOIL LOSS EQUATIONS AGRICULTURAL RUNOFF MODEL (ARM) INSTREAM SEDIMENT TRANSPORT MODEL
WATER INFILTRATION:	SIMPLE 1 DIMENSIONAL COMPLEX 3 DIMENSIONAL

quasi three-dimensional. It's a Dames and Moore prepared model that was published by the AIF. Aikens is the first author, and one other name you might recognize is Octav Ostinalli.

Slide 13 is a summary of the doses. The urbanization scenario doses for the short term, around 100 years, range from 11 to 700 millirem/year. This is an annual dose in the maximum year or, in case of bone, the dose in year 70 of intake of TRUs. The dose goes down for long term because we lose, for periods longer than 1000 years, some of the TRUs (e.g., plutonium-238 and americium-241). I put down 80 millirem/year (short term) for agricultural pathways; it could also be expressed as a range, 2 to 7 millirem/year in the long term.

Deliberate intruders is an interesting scenario. We had about 150 millirem, but if we make it a little more realistic and this intruder gets into a hot spot, getting more than the average concentration, then the dose goes up to around 800 millirem/year in the short term and should be scaled proportionally for the long term. That summarizes the doses we estimated for the TRU alternatives document.

We've been asked to look at the problem a little differently, from the standpoint of 100 nCi/g. What limits should Los Alamos have (or what limit is Los Alamos capable of holding) in the mesa tops in low-level wastes? This map is courtesy of the Coors Beer Company. It is a little bit modified. Looking south from the border of Colorado into New Mexico, Los Alamos is located on the east side of a mountain range called the Jemez Caldera, the remains of a former volcano. The laboratory and waste areas are on the east shoulder of a mountain, and our waste pits are dug into volcanic tuff or ash, and welded--but soft enough for regular bulldozers with scrapers to dig our waste pits. The location gives the site some stability. The Rio Grande River flows out of Colorado, on down past Taos, and past the east side of a community called White Rock that borders on the lab property. The distance from the currently active waste area to the river is about 3.5 miles. The elevational change, however, is significant. The waste area is about 700 ft above the river, and the elevation continues to go up as you go towards the laboratory to the west.

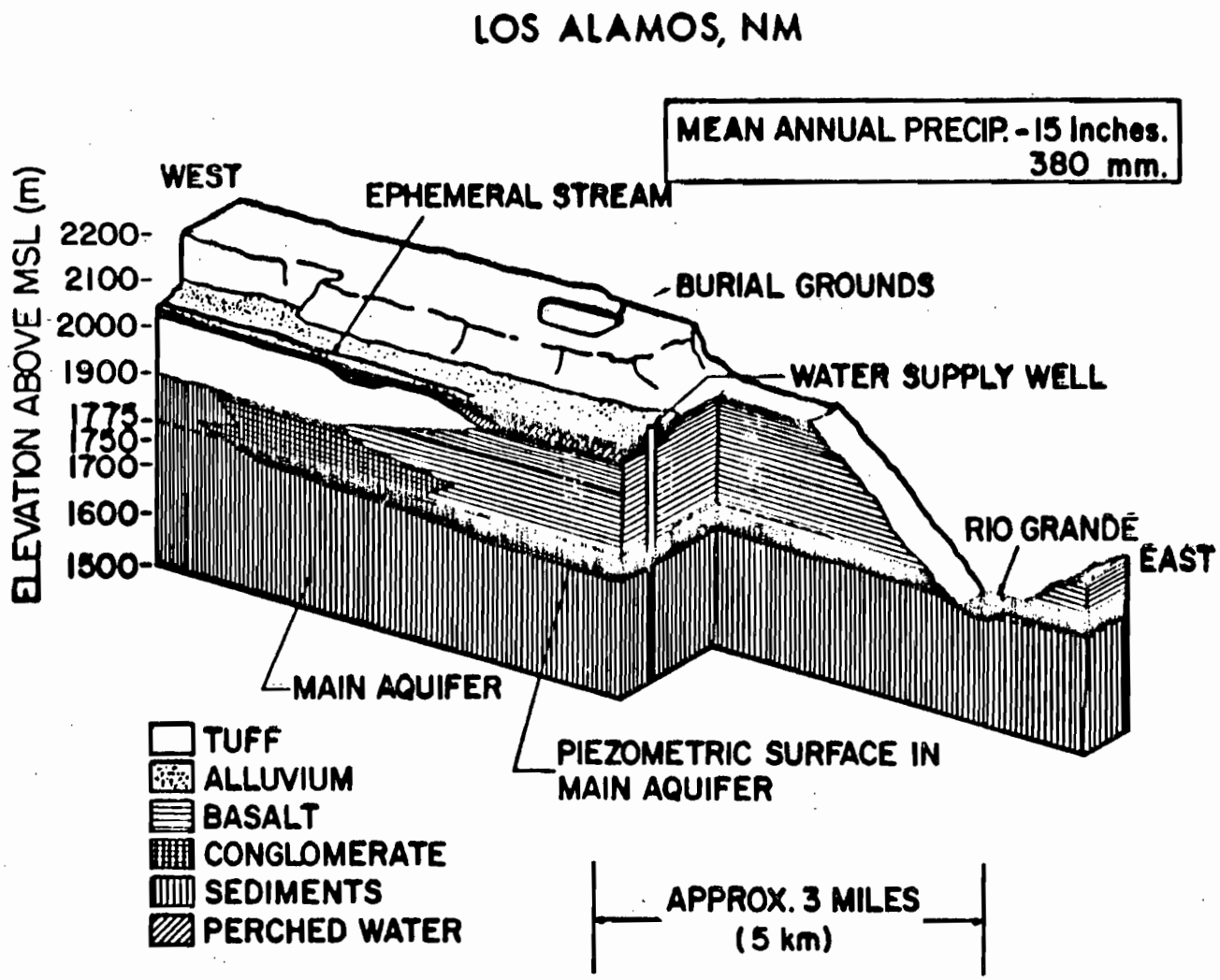
Slide 14 is a simple depiction of the area. Our burial grounds are located on a mesa top. The burial grounds have rather steep sides, particularly on the north side of the canyons, and the canyon bottom has alluvium in it. Some of these areas have perched water from runoff during the spring snow melt, but later in the year the surface water dries off. The thunderstorms common in July and August may cause water runoff. The distance from the current waste area to the water table is about 700 ft. Interspersed in that 700 ft is about 200 to 300 ft of tuff, then the formations start getting complex because of volcanic action east of the river. We hit basalt flows that came from the east over some older ash flows from the other volcano to the west. Finally, we reach the area of the Santa Fe Formation, which is a sandstone. The river, as I pointed out, is to the east. The main

Slide 13

HUMAN INTRUSION INTO LOW LEVEL AREA
WITH NO SEPARATION OF TRU WASTES

CONTACT SCENARIO	SHORT TERM	LONG TERM (>1000 YR)
URBANIZATION	11-700 MREM/YR	1-28 MREM/YR
AGRICULTURAL	80 MREM/YR	2-7 MREM/YR
DELIBERATE INTRUDER	147 MREM/YR	36 MREM/YR

Slide 14


LOS ALAMOS, NM
MEAN ANNUAL PRECIP. - 15 Inches.
380 mm.
WEST
EPHEMERAL STREAM
BURIAL GROUNDS
WATER SUPPLY WELL
RIO GRANDE
EAST
ELEVATION ABOVE MSL (m)
2200
2100
2000
1900
1775
1750
1700
1600
1500
MAIN AQUIFER
PIEZOMETRIC SURFACE IN MAIN AQUIFER
TUFF
ALLUVIUM
BASALT
CONGLOMERATE
SEDIMENTS
PERCHED WATER
APPROX. 3 MILES
(5 km)

aquifer surfaces at about river level in springs here and there along the whole edge of the river. We have sampled about 21 springs along the river for surveillance. Water wells can hit water at about 700 ft, but our production well--the last one was drilled this summer just west of the waste area--is upstream of the flow of the aquifer, and we hit water at 800 ft. However, to get usable water, the production well is 3100 ft.

Annual precipitation is 15 in., but this is not quite accurate for this burial ground. The 15 in. number is from 6 miles west, and believe it or not, 6 miles makes quite a difference in our area. We now have a meteorological station, and 2 years of data indicate that rainfall is more like 11 to 13 in.

We made two efforts (Slide 15) to examine water infiltration from a modeling standpoint. If we put 100 nCi/g in all the drums, put the drums in an area 100 x 100 m, and stack them 20 high, what does our hydrological model tell us? As you are aware, we have a dry climate, and it is hard to get saturated flow. Our evapotranspiration is over twice the annual input from rainfall. Therefore, we fudged it and assumed that the annual rainfall that can occur in July and August occurred all at once. That way, we get a pulse of water traveling through this stack of drums. We have done a permeability analysis on our annual rainfall, and it does indicate that we can get some extreme events, so we can get pulses. However, the probability of occurrence is not great. The once-in-100-year range is several orders of magnitude above our annual rainfall, but it does not occur very often. One aspect that is misleading in our analysis is that we moved a band of water through the waste on an annual basis. However, we believe it maximizes the change. The inventory in the set of drums in Slide 15 was 16,000 Ci in 27,000 drums.

First, we looked at movement of water to the river (Slide 16). Our assumptions on distribution coefficients are high. They are actually averages of geological medium with a porosity of 0.1. As I pointed out, the distance to the river is 3.5 to 4 miles, and the distance to water is 700 ft. These two distance numbers are the only ones I stand behind. We can measure those. You start getting into some problems with this effort. We calculated the time to exhaustion of the radionuclides in the waste. For plutonium, we came up with 10^{11} years, which exceeds the age of the earth. This is not very realistic. We did come up with a travel time for the plutonium (for breakthrough at the river) of 10^{8} years, but by that time our concentration was down to 0 because it had all decayed. Uranium-235 came out in in 10^{8} years, and we did see some breakthrough because of the long half-life of the daughter. (This is not a true daughter analysis. It makes the assumption that these activities in the waste are also 100 nCi/g.) Again, the isotopes, which are daughters further down the chain, have long travel times, when we saw 0. These are zeros on a computer, so they are very small. I think that is illustrated on the next slide. We were not very happy with our

Slide 15

WATER INFILTRATION

DRUMS: 20 HIGH STACK
100m X 100m
100nCi/g IN ALL DRUMS

TOTALS 27,000 DRUMS
16,000 CURIES

Slide 16

CASE 1

MOVEMENT TO RIVER

POROSITY - 0.1

DISTANCE - 21,000 FT
DISTANCE TO WATER 700 FT

Kd(Pu) = 10,000
Kd(U) = 14,300

Kd(Pa) = 16,700
Kd(AC) = 5,000

RADIONUCLIDE	TRAVEL TIME	CONCENTRATION
Pu-239	10^8 yr	0
U-235	10^8 yr	2×10^{-13} Ci/ft^3
Pa-231	10^9 yr	0
Ac-227	10^8 yr	0

results because we did not get any positive numbers. The effort did not tell us much about what was going on.

We decided to get a little more restrictive for our second effort (Slide 17). We do have a production well in the canyon next to the waste area. Instead of making the production well 210 ft away from the waste area, instead of making it go into the main aquifer, we put the well into this perched aquifer that is in the bottom of the canyon and about 70 ft distant. Also, now we are up in an area where we have a few measured KDs on the tuff, and they're much lower. For plutonium, we assumed that the radionuclides are about the same and started examining travel times assuming our annual rainfall band is moving through once a year. We ended with about a million-year transit time.

I pointed out that we had a computer do this. We got 10^{-26} Ci/ft^3 (we used cubic feet because hydrologists still like to work in English units). I'd like to point out that 10^{-15} Ci is about one alpha particle per year. That's pretty small. In fact, I have trouble dealing with that small a number. We did get an exponent for uranium that comes close to the realm we are used to thinking about, which is about 10 pCi/ft^3 of water produced in that well. Even a million years later, you might not be able to drill a well there because we are speaking in geological time.

We also tackled the erosion scenario (Slide 18). Because we have cliff faces and a waste area on top of the mesa, erosion works two ways against us, and that makes Los Alamos a little different from most sites. We calculated using the Universal Soil Loss Equation, setting an acceptable surface soil limit at 200 pCi/g for exposed waste. We back-calculated what number of years would cause the cliff faces to fall away until the waste was reached. Then, we calculated what level of activity would be present after radioactive decay when the waste was reached. For 5 m down and 5 m away from the cliff face, fortuitously, we had 100 nCi/g at 5 m deep. However, the lateral erosion started giving us trouble because we were fairly close to the cliff face. We were down around 600 pCi/g. If we bury at 10 m deep and go back 10 m from the edge, the vertical number goes up, and the lateral number creeps up a little bit because the actual surface erosion rate is disproportionate to the lateral rate (the cliff face falling away). The numbers we used estimated the surface erosion rate at about six times less than the lateral erosion rate.

If we start examining deeper depths, we start getting larger limits. Again, the computer printed out a huge exponent. I did not know what to do with it, so I called it a criticality limit, speaking of the number of nanocuries per gram. What does this mean at our site? If we change the limit to 100 nCi/g, we calculated that we would have to be about 72 ft or 22 m back from the face of the cliff and 5 m or 16 ft deep (Slide 19). Time to surface in that case would be about 220,000 years, and the second significant digit is not that important.

Slide 17

CASE 2

MOVEMENT TO WELL

POROSITY - 0.43

DISTANCE TO WELL - 210 FT
DISTANCE TO WATER - 70 FT

Kd(Pu, U, Pa, Ac) = 680

RADIONUCLIDE	TRAVEL TIME	CONCENTRATION
Pu-239	10^6 yr	10^{-26} Ci/ft^3
U-235	10^6 yr	10^{-11}
Pa-231	10^6 yr	10^{-22}
Ac-227	10^6 yr	0

Slide 18

PRELIMINARY FOR LOS ALAMOS

EROSION LIMITED CONCENTRATIONS OF Pu-239

Depth (m)	Time to Expose (Years)		Derived Limits (nCi/g)	
	Vertical	Lateral	Vertical	Lateral
5	2×10^5	4×10^4	100	0.6
10	4×10^5	1×10^5	82000	3
40	2×10^6	3×10^5	Criticality Limit	700
100	4×10^6	7×10^5	" "	Criticality Limit

LOS ALAMOS
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Slide 19

DEPTH AND DISTANCE AT LOS ALAMOS FOR 100 nCi/g of Pu-239 to RESULT IN 500 MREM/YR WHEN EXPOSED TO SURFACE BY EROSION

Disposal Depth	Distance from Canyon Wall
5 m (16 ft)	22 m (72 ft)

Time to Surface - 220,000 Years

Soil Activity - ~200 pCi/g

LOS ALAMOS

Los Alamos National Laboratory

We were using an acceptable soil activity of 200 pCi/g of plutonium on the surface. That figure does not allow for any erosion from upstream or upsurface on the mesa top, so it indicates that we would have to change to handle this level of waste as a low-level waste. If the waste is at 99 nCi/g, we would have to handle it as a low-level waste. We would have to change our operations in Los Alamos for low-level waste because right now we assume 50 ft back from the cliff edge is acceptable. That change would be easy to make. Also, our normal operating depth in our trenches is from 50 to 60 ft deep. The imposition also is unimportant from that standpoint.

These calculations also pointed toward one other operational aspect: we could go greater than 100 nCi/g for a special case, perhaps a large piece of equipment or something that could not be processed economically to get to the Waste Isolation Pilot Plant (WIPP). Our calculations show that we have a means of dealing with some special-case TRU wastes that might demand the processing facility to be oversized to get materials to WIPP.

One of the advantages of going deeper to a greater confinement for the TRU wastes is that we have simpler scenarios (Slide 20). We certainly eliminate plant roots, especially at 30 ft, and animal intrusion--you have probably heard about our gophers at Los Alamos. We also put a limit on some of the early human intrusion scenarios.

I have a few comments on health implications (Slide 21). We have been experimenting with ways to express the health implications of risk. Using general risk conversion factors, at 500 millirem/year, one would expect 50 cancers in 1 million people. I cannot get a million people on the waste area, but that is one way to express risk to the population. That risk, for the individual, means that his chance of getting cancer if he is exposed to that amount is 5 chances in 100,000. That is pretty low. We always compare to natural background also; for natural background, the annual risk of cancer for an individual is three chances in 1000. I include this because, much to our surprise, we have been successful talking to some reporters this way. One of my other hats is to run operational surveillance programs. Reporters came in and wanted to know about our annual surveillance report. It turns out that this method was one we did not stumble on in explaining the health implications of the operation of the laboratory to the reporters. There are other ways to express risk, but this method works best in giving the public, one of our audiences, an understanding of the risk. This method gives them a comparison, and natural background, with short explanation, may be understood quite well. We actually were covered in a television news report that was positive about the laboratory's impact and about radiation released to the environment.

To summarize, we do not look a lot different from Idaho. Some of the doses for some of the intrusion scenarios are similar. The approaches are generally the same, and we can argue a lot about assumptions.

Slide 20

MAJOR RELEASE MECHANISMS
FOR RADIOACTIVE WASTES BURIED 30 FEET DEEP AT LOS ALAMOS

- LATERAL EROSION
- WATER INFILTRATION

UNIMPORTANT MECHANISMS

- PLANT ROOTS
- ANIMAL BURROWS
- INADVERTANT HUMAN INTRUSION

Slide 21

HEALTH IMPLICATIONS OF:

OVERALL RISK OF CANCER

RISK	OVERALL RISK OF CANCER POPULATION	OVERALL RISK OF CANCER INDIVIDUAL
500 MREM/YR	50 CANCERS IN 1,000,000	5 CHANCES IN 100,000
NATURAL BACKGROUND RADIATION (100 MREM/YR AVERAGE)	10 CANCERS IN 1,000,000 PEOPLE	1 CHANCE IN 100,000
ANNUAL RISK OF CANCER (70 YEARS OF LIFE)	3 CANCERS IN 1,000 PEOPLE	3 CHANCES IN 1,000

RADON-SPECIAL CASE IF RA-226 INCLUDED

LOS ALAMOS
LOS ALAMOS NATIONAL LABORATORY

Some of our assumptions are different because they are site-specific to Los Alamos.

Bill Lawless, Savannah River Laboratory: Why are you using a hydrologic transport model? If you were at Savannah River or Oak Ridge, I could understand that. Somewhat tongue in cheek, I wonder why you are not using a gopher logical transport model. I too read in Science News last week about the gopher problem that you have, and I wonder if you could comment on the transport vector through animal burrowing.

Hansen: I'll make a stab at the answer and when Tom Hakanson hears my answer, he can modify it if he wishes. We do have burrowing animals in the area. Apparently, the pocket gopher has a maximum depth of burrowing of about 7 ft. These gophers are fairly common burrowing animals throughout the arid states, but I am not sure they occur in the southeast at all. They turn over a large amount of earth. We do not have any conclusions yet, but the low-level waste people at Los Alamos are looking at cap barriers that would prevent water infiltration and plant invasion--and burrowing. They are asking, "Can you put something like cobble on top of the waste before you put your cover on?" Gophers are reasonable, adaptable animals. They are not going to burrow into rock where there are no plant roots or food for them to eat. They stay pretty much in the plant root zone. Tom's measurements on earth turnover are from one of our inactive areas on the current waste site, and indeed his calculations look reasonable. Yes, gophers turn over a lot of earth. We simply need enough cover so that they do not enter the waste or we need some kind of a barrier to prevent them from going into the waste.

Don Wood, Rockwell Hanford: I have three rather quick questions on numbers that I missed as you went by. You mentioned a criticality limit that produced some very low consequences from high concentrations. What is that limit?

Hansen: I do not really know off the top of my head. For WIPP, the limit is 200 g/barrel. I just got a number that said 10^{22} nCi/g, which exceeds criticality.

Wood: You also mentioned an acceptable limit of 200 pCi/g. Where does that one come from?

Hansen: It is a slight modification of Jack Healy's studies on soil limits for plutonium surface contamination.

Wood: This would be a limit, then, for low-level waste or for something that is on the surface?

Hansen: It is the limit for surface soil contamination, not surface contamination. It is a specific number, volumetric rather than thin

layer, just as surface contamination is sometimes considered a thin layer rather than something that goes into the depth distribution.

Wood: Something on the order of 1 to 5 cm. You also mentioned a 50-ft depth near the end of the talk, and I missed what that was for.

Hansen: That is our current operating criterion for how close to the cliff edge our trenches can get considering the spill point at the cliff.

Wood: Is the 50 ft, then, the lateral distance backward rather than depth?

Hansen: It is lateral distance.

Bill Lennemann: I noticed that in your long-term projections into the never-never land, you used U-235 and also various isotopes of plutonium. All the projections I've seen into this never-never land say that after 10 million years or so the predominant hazard comes from U-238, nothing else, because of its long half-life compared to others. Why didn't you include that?

Hansen: Because we've got U-235 also. We are looking at it in a narrow sense. This is not a complete analysis I'm reporting on. We went through the Pu-239 scenario first because that was the one people wanted answers on first. We will go back and look at other daughter products from other TRU isotopes.

Jack Healy, Los Alamos National Laboratory: I have a quick question. You indicated that the maximum lateral erosion time was 220,000 years, just about the full lifetime of Pu-239, which is one of the longer isotopes. Did you forget to put a decay correction in your equations?

Hansen: No, the decay correction is there.

Healy: What was the isotope then?

Hansen: 239.

Healy: But that's down by a factor of 1000.

Hansen: Right.

Healy: If I multiply your concentration in the soil--assuming all waste is 200 pCi--by 1000, I get 200 nCi/g. I know it's only a factor of two, but computers don't usually do that.

Hansen: Quite well taken.

Bob Boland, Nevada Test Site: I was curious about your statement

concerning the greater uncertainty with greater confinement and I wondered if you would elaborate a little bit on this.

Hansen: When we are working in the first 100 ft of surface at our site, we have hydrological parameters measured for the geological structures, we have some distribution coefficient data, and we have some idea what radionuclide absorbtion looks like. Those measurements have not been made for greater depths, 500 ft deep into formations. We know what the formations are and we know the physical characteristics of thickness and perhaps some fracturing, but that's about where our data stop because we're getting our data from logging drinking water wells that have been drilled in the area. I don't know if you have ever seen a large well drilled with an oil rig. Getting a sample and knowing where it comes from doesn't leave you much confidence in knowing that you have sampled a given strata in that formation. You almost have to drill special exploratory holes, or at least that's what my hydrologists tell me, to get samples to measure parameters that make you feel more comfortable with these kinds of speculations.

Charles King, Savannah River Laboratory: Wayne, you showed data in your two cases on movement to the river and movement to the well of KDs greater than 10,000 in the first case, KDs less than 1000 in the second case. What's the soil difference?

Hansen: The first set took only KDs that were in the literature for the general geological formations where we moved radionuclides to the river. We were crossing several formations, starting with tuff, through basalt, through some ash flows, into sandstone. The second KD, for the well case where we were close to our waste area, was an area where we have some indication of what the KD is from measurements. The plutonium KD is measured, and the KDs for other radionuclides were assumed to be about the same. The KD is much lower in tuff when it is measured than it is in the literature we quoted for KDs for general geological formation. If you remember John Rodgers' talk, he also had KDs that were much lower than those for some geological formations. So it adds a lot of uncertainty. Those KDs are usually adsorption KDs; I haven't seen too many cases where people have measured desorption KDs. I don't know if they are different or not. I would like to know.

Jerry Cohen, Science Applications, Inc.: You calculated values for U-235 and you are going to calculate for U-238, I understand. Have you considered the entire mesa as an entity and calculated the naturally occurring uranium?

Hansen: We know what the measurements are right now.

Cohen: It would also be a test to your model.

Hansen: That's a good suggestion.

Preston Hunter, Ford, Bacon, and Davis: Wayne, I have to compliment you on your presentation, particularly the perspective you have on the believability of risk numbers. I think it's wise for all of us to remember that when we put in garbage we're going to get garbage and that we always have to keep that believability coefficient in perspective. I want to make two comments. First, on the question that Bob Boland asked about the uncertainties with greater confinement, we agree that there is greater uncertainty of numbers and input used as you go deeper in depth, but we also recognize that some of those uncertainties may actually work to your favor in some of those inputs. Although you tend to get greater uncertainty, even if you have to assume kinds of inputs to avoid getting trivial release solutions and even if you are in an unsaturated zone, as you might be there, and are relying purely on groundwater convective transport making your releases nil but recognizing the possibility of diffusion of dispersion, you do come up with numbers. Those values are uncertain, but even if we could measure them, which we probably couldn't even with millions of dollars to get the data, the resulting numbers would still result in variable small releases. The other comment I would like to make concerns your use of the comparisons to background. We've done recent studies for the Department of Energy and realize that there is a great advantage to comparing health effects and cancers to actual background effects. One other comparison we made compared the health effects from radiation induced sources to the actual number of health effects from all cancer sources, including hereditary sources. When we did that, background became maybe only one hundredth of the total cancers that could be created; then when you are dealing with small increments of health effects on top of that, our risk becomes a very small percentage.

Hansen: I guess I'd like to comment on your comment on the fraction of cancers caused by natural background. That can be a real touchy issue if you get a lot of radiation biologists in the room. I learned the hard way once.

ANALYSES OF THE DISPOSAL OF ALPHA-CONTAMINATED WASTE AT HANFORD

Bill Kennedy, Battelle-Pacific Northwest Laboratory

As Slide 1 indicates, I've changed the name of the presentation a little bit, to Transuranic (TRU) Advanced Disposal Systems, Preliminary Plutonium-239 Waste Disposal Criteria for Hanford. Co-authors on this effort are Bruce Napier and Joe Soldat of Battelle-Pacific Northwest Laboratory (PNL). Slide 2 reviews the long-term master plan for defense waste management. This document states as a goal that the Department of Energy (DOE) will develop and implement long-term TRU waste management capabilities that are technically feasible and effective yet affordable and politically acceptable. To accomplish this goal, as Slide 3 shows, deep geologic emplacement of the wastes is favored because it will isolate the TRU radionuclides with their long half-lives and high radiotoxicities from the environment, reducing potential threats to public health and safety. The deep geologic emplacement method selected is to use the Waste Isolation Pilot Plant (WIPP) facility, as we have heard discussed.

According to the long-term master plan, DOE is, or will be, responsible for an estimated 334,000 m^3 of solid TRU waste, as Slide 4 shows. Much of that waste is in a retrievable form (like INEL's waste inventories). WIPP is designed to receive about 175,000 m^3 of contact-handled (CH) waste and about 700 m^3 of remote-handled (RH) waste over the 20-year life of the facility. Although WIPP was designed as a retrievable storage facility during the pilot plant period, the ultimate goal of WIPP is to achieve permanent disposal of these TRU wastes.

At the Hanford site (Slide 5), estimates show that between 2 and 12 million m^3 of TRU-contaminated soil with contamination levels in excess of 10 nCi/g are present. (Rich Jensen estimated 8 million m^3.) If we compare 12 million m^3 to the national projected inventory of TRU waste of 334,000 m^3, we find that the contaminated soil at Hanford is roughly 35 times more than this national inventory of solid wastes. Thus, TRU advanced disposal systems to be emplaced at the Hanford site over the soil wastes are considered a common sense solution to this difficult disposal problem. TRU advanced disposal systems, as shown in Slide 6, will complement WIPP in achieving permanent disposal of selected TRU waste forms like the soils at Hanford. They are intended to provide greater confinement than shallow land burial.

The purpose of this paper (Slide 7) is to discuss the results of our preliminary evaluation of the feasibility of various TRU advanced disposal systems at the Hanford site. Preliminary results of our systems analysis associated with various advanced disposal techniques are presented, and our development of preliminary plutonium-239 waste disposal criteria for Hanford is discussed.

Slide 1

TRANSURANIC ADVANCED DISPOSAL SYSTEMS: PRELIMINARY ^{239}Pu WASTE DISPOSAL CRITERIA FOR HANFORD

W.E. KENNEDY, JR.
B.A. NAPIER
J.K. SOLDAT

Battelle
PACIFIC NORTHWEST LABORATORY

Slide 2

LONG-TERM MASTER PLAN FOR DEFENSE TRU WASTE MANAGEMENT

- DEVELOP & IMPLEMENT LONG-TERM TRU WASTE MANAGEMENT CAPABILITIES
- TECHNICALLY EFFECTIVE
- AFFORDABLE
- POLITICALLY ACCEPTABLE

Slide 3

DEEP GEOLOGIC EMPLACEMENT IS FAVORED:

- ISOLATE TRU FROM ENVIRONMENT
- MINIMIZE POTENTIAL THREATS TO PUBLIC HEALTH & SAFETY
- WASTE ISOLATION PILOT PLANT WIPP

Slide 4

DOE IS RESPONSIBLE FOR:

- 334,000 m^3 OF TRU SOLID WASTE

WIPP IS DESIGNED FOR:

- 175,000 m^3 CH WASTE
- 700 m^3 RH WASTE

THE ULTIMATE GOAL OF WIPP IS PERMANENT DISPOSAL

Slide 5

AT THE HANFORD SITE:

- BETWEEN 2 AND 12 MILLION m^3 OF CONTAMINATED SOIL ARE PRESENT IN EXCESS OF 10 nCi/g

- THIS VOLUME OF SOIL IS UP TO 35 TIMES THE TRU INVENTORY FROM ALL OTHER SOURCES

Slide 6

TRU ADVANCED DISPOSAL SYSTEMS:

- COMPLEMENT WIPP IN ACHIEVING PERMANENT DISPOSAL OF SELECT TRU WASTES (SUCH AS SOIL)
- PROVIDE "GREATER CONFINEMENT" THAN SHALLOW-LAND BURIAL

Slide 7

PURPOSE:

- TO DISCUSS THE RESULTS OF OUR PRELIMINARY EVALUATION OF THE FEASIBILITY OF VARIOUS TRU ADVANCED DISPOSAL SYSTEMS AT THE HANFORD SITE (SYSTEMS ANALYSIS RESULTS)

Historically, the soil contamination at Hanford resulted from a variety of liquid disposal methods. Liquids generated from fuel reprocessing facilities at the Hanford site were disposed of to the soils for percolation to the ground. Some of the liquid discharges included TRU radionuclides. Shown in Slide 8 are some of the methods used, including cribs, ponds, trenches, ditches, tile fields, french drains, and reversed wells. I would like to point out that most of these methods are no longer used. In fact, use of reversed wells was discontinued at the Hanford site in 1949.

Advanced disposal systems (Slide 9) use systems of engineered barriers for in situ stabilization of the wastes. Advanced disposal systems included (1) greater depth of disposal, accomplished through the use of soil and riprap to cover the waste sites; (2) injection of grouting materials to stabilize waste forms in place; and (3) a technique called in-situ vitrification that we are developing at the Hanford site.

Slide 10 discusses soil and riprap covers. Many of the papers indicate that greater depth of the waste would help reduce the potential for intrusion, both by man and by plants and animals, into the waste zone. The cover stabilizes the land surface, perhaps reducing the erosion rate or altering the surface of a given site. The Nuclear Regulatory Commission (NRC), in its draft environmental impact statement, has defined thin and thick covers for shallow land burial. A thin cover is a 2-m cover layer; a thick cover is an additional 3 m on top of the 2-m layer, for a total of 5 m. To do the systems analysis, we examined cost data from the NRC draft environmental impact statement and from cost of construction literature for the construction of soil and riprap covers. The construction of earthen barriers is a fairly well known technique. In addition to moving simply soil, we can also move riprap, an assortment of rocks, and even large boulders to put them in place over the waste zone. Or we could use a composite barrier of all three.

Slide 11 shows a second technique, grouting. We considered two basic types of grout material: particulate grouts (like clays, cement, or lime) and chemical grouting materials (like silicates, urea formaldehyde, resins, and emulsions). Again, for the systems analysis we obtained cost data from NRC estimates and from a report by Oak Ridge National Laboratory (ORNL) that compares costs of different grouting systems.

In-situ vitrification, shown in Slide 12, is a technique being developed and demonstrated by PNL at the Hanford site. It uses electric melter technology originally developed for the high-level waste program. In-situ vitrification causes the materials in the contaminated soil to dissolve or be encapsulated in a molten zone of glass as the process occurs. For the systems analysis, we obtained cost information from a PNL report.

Slide 8

HANFORD SITE SOIL CONTAMINATION:

- CRIBS
- PONDS
- TRENCHES
- DITCHES
- TILE FIELDS
- FRENCH DRAINS
- REVERSE WELLS

(PAST PRACTICES)

Slide 9

ADVANCED DISPOSAL SYSTEM USE ENGINEERED BARRIERS FOR IN-SITU STABILIZATION:

- SOIL AND RIPRAP COVERS
- GROUTING
- IN-SITU VITRIFICATION

Slide 10

SOIL AND RIPRAP COVERS:

- DEPTH REDUCES INTRUSION
- COVER TO STABILIZE LAND
- NRC DEIS FOR 10 CFR 61 DEFINES "THIN" AND "THICK" COVERS
- COST DATA FROM NRC AND CONSTRUCTION DATA

Slide 11

GROUTING:

- PARTICULATE TYPE : CLAY, CEMENT, AND LIME
- CHEMICAL GROUTS : SILICATES, UREA - FORMALDEHYDES, RESINS, AND EMULSIONS
- COSTS FROM NRC AND ORNL

Slide 12

IN-SITU VITRIFICATION:

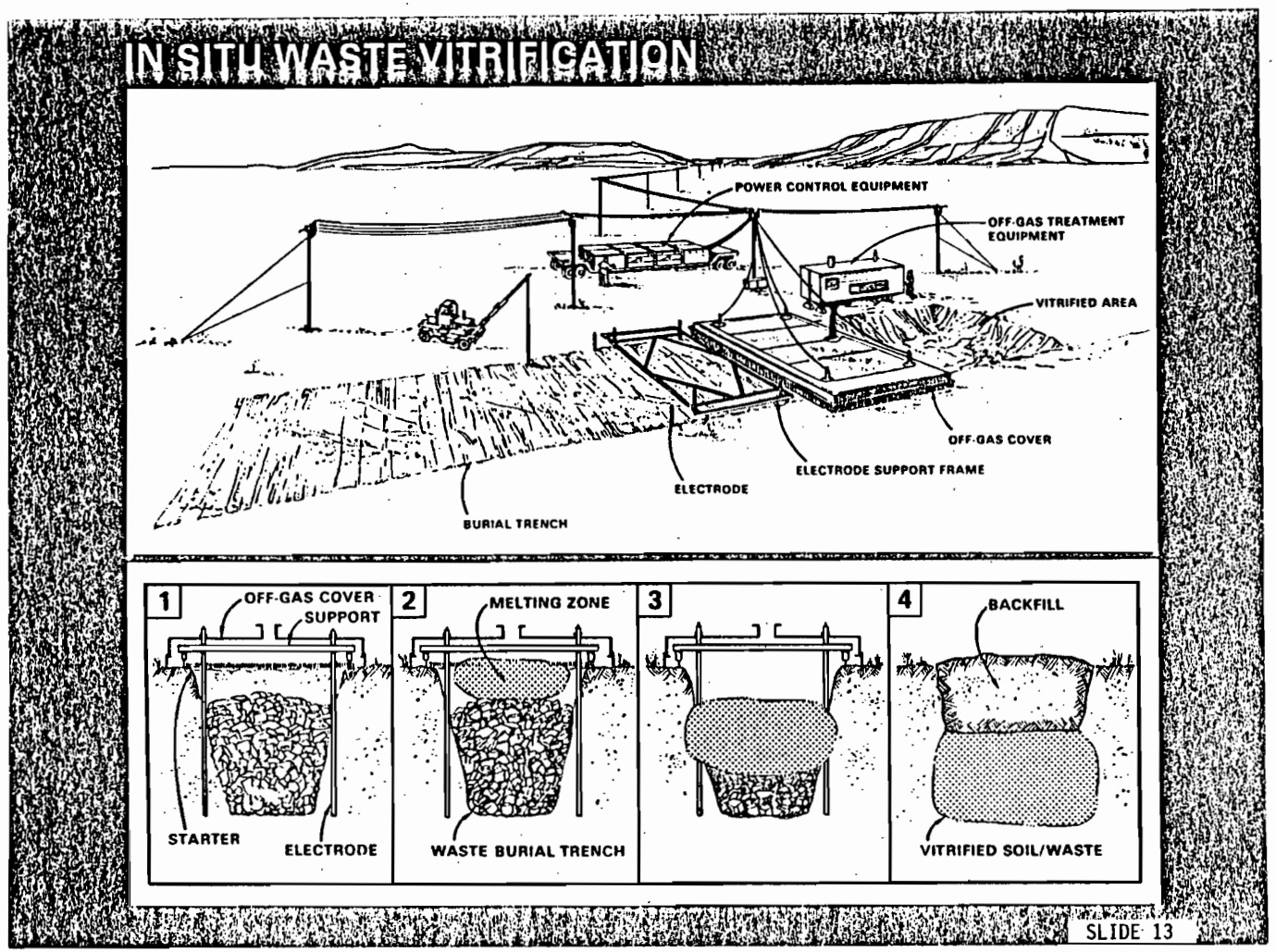
- DEVELOPED AND DEMONSTRATED AT PNL
- ELECTRIC MELTER TECHNOLOGY
- MATERIALS DISSOLVE OR ARE ENCAPSULATED IN GLASS
- COSTS FROM PNL-SA-9924

Slide 13 is an artist's conception of the process of in-situ vitrification and of a burial trench application. Across the bottom of this figure are boxes numbered 1 through 4. Box 1 shows a schematic of the buried waste zone and what is done is to emplace electrodes into the ground and starter material across the surface. This schematic also shows an off-gas recovery or treatment system. The process is started by electrical resistance heating. The molten zone is shown in box 2. The starter material moves down the length of the electrode through the waste zone creating, as shown in box 3, a moving molten zone, which can penetrate the full depth of the buried waste. As the soil melts, it reduces the volume of the waste, and the result is that backfill is required over the site. The top part of Slide 13 shows an artist's conception of the use of this process in a trench application. Preferably, equipment can be moved along the surface of a burial trench. At a recent demonstration of this technique, a few nonradioactive trace materials resulted. The point of the experiment was to recover the resulting glass waste. A series of experiments is being conducted on the glass waste. Layers of rocks float to various levels within the molten zone. The black glass material that results from the molten soil is much like obsidian in appearance and in properties.

A summary of the costs used in our systems analysis is shown in Slide 14. The data came from many sources. For soil and riprap covers, NRC estimates about $\$1.40/m^2$ of applied surface for a 2-m cover and about $\$15.50/m^2$ for a 3-m additional cover for a total of 5 m of cover. (These estimates are per million square meters of applied surface.) Using the construction cost data, we compared costs with a similar 5-m intruder cover and got a higher number, $\$80/m^2$. For a 15-m intruder cover of soil, the cost of material was about $\$200/m^2$ of applied surface. The costs of excavating, hauling, and spreading soil riprap and boulders were \$12, \$26, and $\$46/m^2$, with boulders being most expensive. For injection grouting material, we looked at cement bentonite. The ORNL study estimated its cost at $\$113/m^3$ of waste. Finally, for in-situ vitrification, assuming a 10-year lifetime of the equipment and electric power costs at \$0.10/kWh, we estimated $\$600/m^3$ of vitrified waste.

To determine our preliminary disposal criteria for plutonium-239, we performed example calculations with our systems analysis techniques. The plutonium-239 disposal criteria were developed using the Allowable Residual Contamination Level (ARCL) method, recently documented by Bruce Napier of Battelle (Slide 15). (The document number is PNL-3852.) The calculations are performed with two boundary conditions or performance objectives, shown in Slide 16. These same performance objectives have been mentioned in most of the papers presented at this meeting. The first objective is to be in accordance with the Environmental Protection Agency (EPA) requirements: at the site boundary, 25-millirem per year whole-body, 75-millirem thyroid, and 25-millirem for other organs. The second objective is for doses

Slide 13


IN SITU WASTE VITRIFICATION
POWER CONTROL EQUIPMENT
OFF-GAS TREATMENT EQUIPMENT
VITRIFIED AREA
OFF-GAS COVER
ELECTRODE SUPPORT FRAME
ELECTRODE
BURIAL TRENCH
1
OFF-GAS COVER
SUPPORT
STARTER
ELECTRODE
2
MELTING ZONE
WASTE BURIAL TRENCH
3
4
BACKFILL
VITRIFIED SOIL/WASTE
SLIDE 13

Slide 14

COST INFORMATION SUMMARY:

METHOD	UNIT COST (1980 $)
2m SOIL (NRC)	1.40/m^2
3m ADDITIONAL (NRC)	15.50/m^2
5m INTRUDER (MEANS)	80/m^2
15m INTRUDER (MEANS)	200/m^2
SOIL (MEANS)	12/m^3
RIPRAP (MEANS)	26/m^3
BOULDERS (MEANS)	42/m^3
CEMENT-BENTONITE (ORNL)	113/m^3
IN-SITU VITRIFICATION (PNL)	600/m^3

Slide 15

SYSTEMS ANALYSIS: EXAMPLE CALCULATIONS

^{239}Pu DISPOSAL CRITERIA USING THE "ALLOWABLE RESIDUAL CONTAMINATION LEVEL" (ARCL) METHOD (NAPIER, PNL-3852)

Slide 16

PERFORMANCE OBJECTIVES:

1) SITE BOUNDARY ANNUAL DOSE:
   $\leq$ 25 mrem/yr WHOLE-BODY
   $\leq$ 75 mrem/yr THYROID
   $\leq$ 25 mrem/yr OTHER ORGANS

2) INADVERTENT INTRUDER
   $\leq$ 500 mrem/yr

to inadvertent intruders to be less than or equal to 500 millirem per year.

To determine compliance with these annual dose limits, as shown in Slide 17, Hanford-specific exposure scenarios were developed, using a 10,000 year performance period. We looked at four basic scenarios. The first three, examined for comparison with the 25-millirem/year limit, were first groundwater migration of the radionuclides. However, because the soil in these three scenarios is in the unsaturated zone, no clear direct groundwater movement occurs except through the unsaturated zone. Our projections estimate very long times for movement of plutonium and TRU radionuclides through the unsaturated zone and the soils at Hanford. If radionuclides did in fact reach the groundwater, dilution must also be considered. We also examined overburden erosion, and estimates of this erosion vary widely. We concerned ourselves with this question: could we construct barriers that would help reduce or eliminate the erosion? We believe we can do this and eliminate erosion to about 1 m over the 10,000 year period, but this projection will have to be verified with further work.

Finally, we also considered biotic transport; however, as other papers presented during this meeting have mentioned, modeling efforts on biotic transport are now insufficient. We do have a program with the NRC and are developing biotic transport models examining gophers and ants and deep-rooted sagebrush and tumbleweeds. Eventually we will examine similar parameters for eastern sites. However, we can now only report on farm crop root penetration. If farm crops are involved, we felt a human intrusion scenario resulted, which is the fourth category of scenarios that we considered. To set up the human intrusion scenarios (Slide 18), we needed to know some specific conditions about the location of the wastes. We examined three specific scenarios.

First, we looked at potential contamination in the top meter of soil. We set up a scenario with an intruder that would inhale dust at 10^{-4} g/m^3 and ingest 230 kg/year of produce raised on the site. Second, for wastes 5 m deep, the human intrusion scenario centered on root penetration, resulting in an agricultural scenario. A small fraction of the root crops, about 1%, penetrate the waste zone. (Again, 230 kg/year were assumed to be ingested.)

The third scenario for human intrusion (Slide 19) involved two individuals. First, we looked at the drill rig worker, who could be exposed to airborne dust as the drill core penetrates the waste zone. We assumed he would breathe air with 10^{-4} g/m^3 dust concentration for a period of 1 h during the drilling activity. Next, we looked at an individual who could move onto the site contaminated from the drill core. The drill core was assumed to be mixed in the plow way or the top 15 cm of a rather small piece of land (we assumed 2500 m^2). This individual inhales the dust with a concentration of 2×10^{-6}

Slide 17

RADIATION EXPOSURE SCENARIOS OVER 10,000 YEARS:

- UNSATURATED ZONE TRANSPORT (10^4 - 10^5 YEARS PLUS DILUTION)
- OVERBURDEN EROSION (WIND) (1m OVER 10,000 YEARS)
- BIOTIC TRANSPORT (FARM CROP ROOTS ONLY)

Slide 18

HUMAN INTRUSION:

- SURFACE TO 1m - INHALATION 10^{-4}g/m^3, INGESTION OF 230 kg/yr PRODUCE
- 5m - ROOT PENETRATION OF 1%, 230 kg/yr PRODUCT INGESTED
- 10m - WELL DRILLING

Slide 19

WELL DRILLING:

- RIG WORKER - INHALATION FOR 1 hr WITH 10^{-4} g/m^3 OF DUST IN AIR
- INDIVIDUAL ONSITE:
  - -DRILL CORE MIXED IN 15 cm OVER 2500 m^2 OF LAND
  - -INHALES DUST 2×10^{-6} g/m^3 (4hr/d)
  - -INGESTS 60 kg/yr PRODUCE

g/m^3 for 4 h a day and ingests 60 kg/year of produce. The smaller air concentration for this individual was determined because of the finite size of the contaminated area and because he could not raise his entire diet on such a small site.

As Slide 20 indicates, we applied the ARCL method, which uses the MAXI-computer program, to calculate the maximum annual dose received by an individual exposed to these scenarios. Then we compared this dose to our annual dose limit of 500 millirem/year for these scenarios. We did not develop scenarios to equate to the 25 millirem condition established in EPA's site boundary limits.

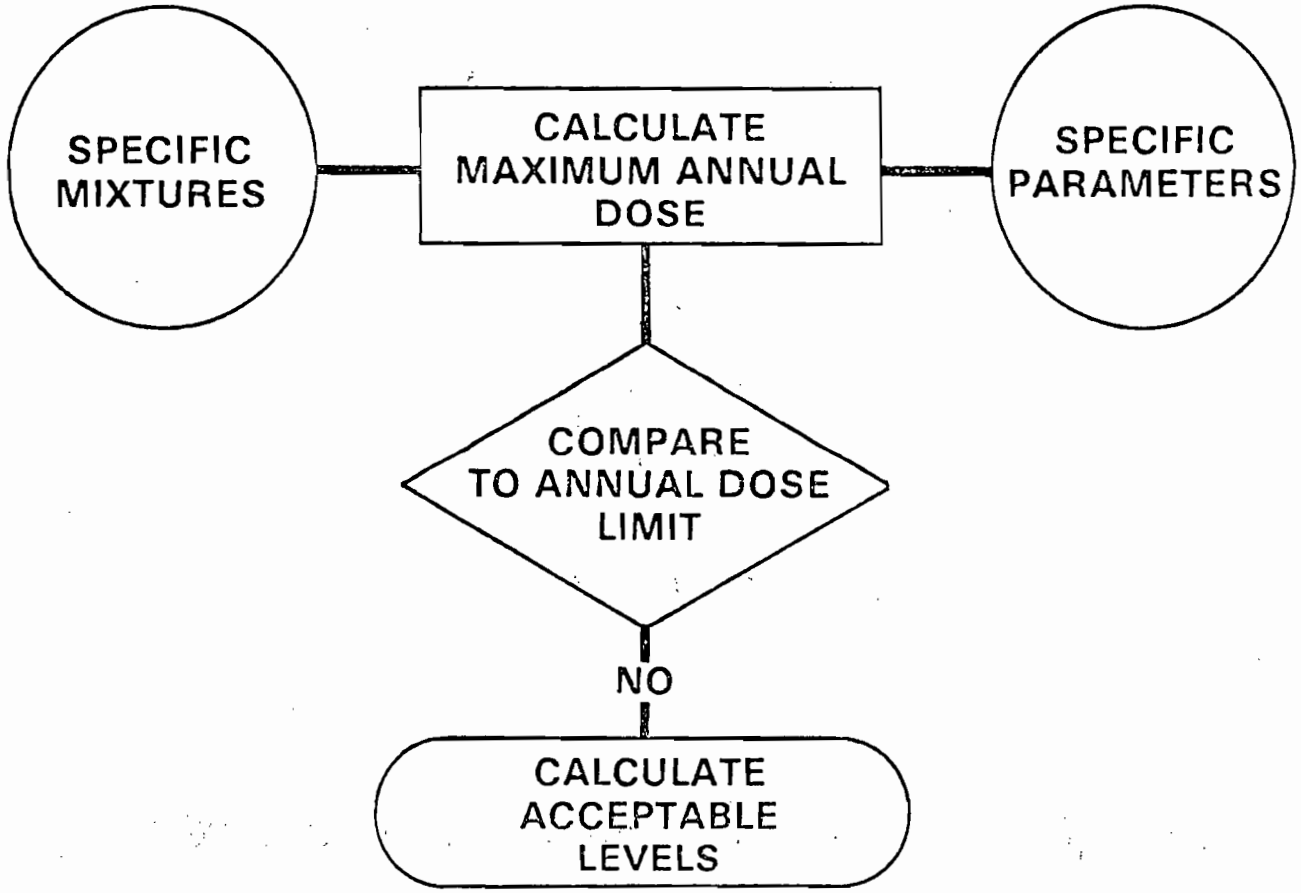
From the comparison and the maximum annual dose calculation, we calculated the allowable residual contamination level in nanocuries of plutonium-239 per gram of soil in the soil/waste mixture. We can extend this method to do site-specific applications by altering the input to look at the specific mixtures of radionuclides present and at other site-specific parameters, like rainfall, the environment, or the waste form, that may influence the calculation.

The maximum annual dose was calculated by the MAXI-computer program, a bookkeeping routine that uses dose factors from the DACRIN and the FOOD computer codes. This program tracks the exposure to the internal organs during continual exposure over 50 years. If we look at it a year at a time, as in Slide 21, the dose in the first year to an internal organ is shown in box D1,1. During continual exposure in the second year, as Slide 22 shows, the dose has two components that must be accounted for: the dose delivered in the second year from the first year's exposure (D2,2) and the dose delivered in the second year from the first year's exposure (D1,2). In the third year (Slide 23), we see three boxes, to account for a dose delivered to the organ in the third year from the third year's exposure, in the third year from the second year's exposure, and in the third year from the first year's exposure.

The relative magnitude of the boxes decreases as radionuclides are eliminated from the body. Slide 24 shows the process continuing. As continual exposure progresses, the dose is an increasing function to these internal organs, and I have shown it in this slide as a simple slope. The organ dose rate from continual internal exposure and residual contamination levels varies. The source that the individual is exposed to during the continual exposure decays. The organ dose rate peaks as a function of biological elimination and the half-life of the materials the individual is exposed to. For plutonium-239, a straight line could represent the 50-year exposure period because no decay would occur, and an increasing slope could represent an increasing function of the long biological retention of plutonium in the body, which would peak in the fiftieth year of continual exposure.

We used the ARCL method, as Slide 25 shows, to identify our preliminary plutonium-239 waste disposal criteria for Hanford. These

Slide 20


SPECIFIC MIXTURES
CALCULATE MAXIMUM ANNUAL DOSE
SPECIFIC PARAMETERS
COMPARE TO ANNUAL DOSE LIMIT
NO
CALCULATE ACCEPTABLE LEVELS

Slide 21

ANNUAL DOSE DURING CONTINUOUS EXPOSURE

FIRST YEAR:

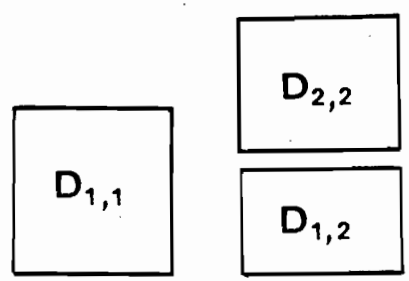
$$\boxed{D_{1,1}}$$

D • INTERNAL DOSE

Slide 22

ANNUAL DOSE DURING CONTINUOUS EXPOSURE

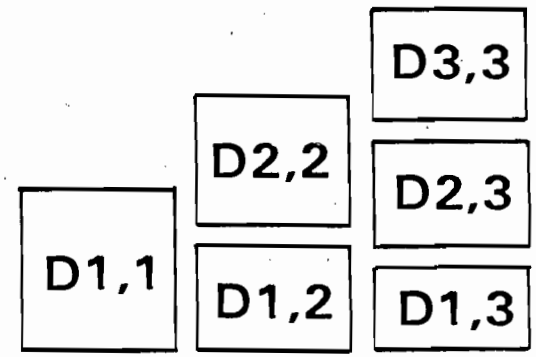
SECOND YEAR:



D • INTERNAL DOSE

Slide 23

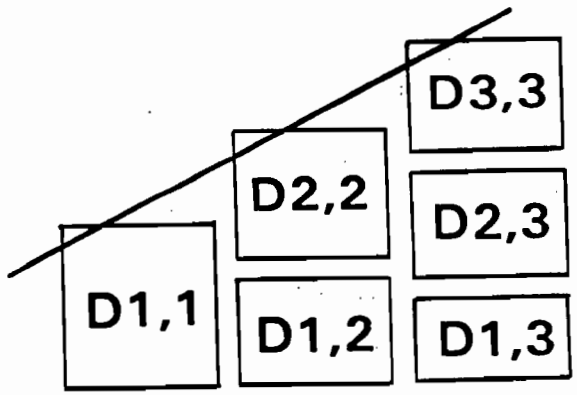
ANNUAL DOSE DURING CONTINUOUS EXPOSURE



D • INTERNAL DOSE

Slide 24

ANNUAL DOSE DURING CONTINUOUS EXPOSURE



D • INTERNAL DOSE

Slide 25

PRELIMINARY ^{239}Pu DISPOSAL CRITERIA:

DEPTH (m)	CRITERION (nCi Pu/g SOIL)	EXPOSURE SCENARIO
0-1 m	0.5	INHALATION 10^{-4} g/m^3 INGESTION 230 kg/yr
5 m	2200	ROOT PENETRATION 1% INGESTION OF 230 kg/yr
$\geq$ 10 m	10,000	WELL DRILLING: INHALATION 2×10^{-6} g/m^3 INGESTION 60 kg/yr

criteria are summarized in this slide. At a surface contamination depth between 0 and 1 m, we have 0.5 nCi plutonium per gram of soil, with the driving scenario being inhalation and ingestion of farm crops. (Compared with Jack Healy's 200 pCi in the surface soil as a contamination limit, our figure becomes 500 pCi.) At a depth of 5 m, where root penetration is the exposure scenario, the calculated value is 2200 nCi of plutonium-239 per gram of soil. Again, 1% root penetration and 230 kg/year of ingestion occur. In the final scenario, at 10 m or greater depth, based on the well-drilling scenario, the criterion was 10,000 nCi/g. The individual farming the site was used as the control. Again, these results indicate comparative magnitudes.

As Slide 26 shows, we extended these preliminary disposal criteria to an example site at Hanford, the 216-Z-142 cribs and associated tile field. This site, constructed in 1949, consists of two 60-m^3 cribs with a distributor tile field consisting of an 80-m central field tile with seven 20-m laterals that go off to the side of the central distribution pipe. The pile consists of a 0.2-m diameter clay field tile pipe. A plan view of this site is shown in Slide 27. The square boxes at the right represent the cribs (wooden structures below the ground surface filled with aggregate), and the herringbone layout of the field tiles is shown to the left.

The site, as indicated in Slide 28, has been characterized over the years in data by Rockwell Hanford Operations and by Price. They have done a series of well drillings through this site to determine the soil profiles and concentrations of TRU materials below the surface. At this site, the well with the peak concentration shows a concentration of 3.8×10^4 nCi of plutonium per gram of soil. The maximum depth at which the contamination was found at a concentration greater than 10^{-2} nCi/g was 30 m. This is 25 m above the saturated goundwater zone at this site. Plutonium was found in concentrations greater than 1000 nCi/g in soil lenses 2 m below the depth of the crib and at 100 nCi/g in soil lenses in isolated spots 15 m below the depth of the crib.

For the example well shown in Slide 29, I plotted the data to show the plutonium-239 concentration in nanocuries per gram of soil versus depth. Starting at the base of the crib, the concentration decreases with depth. The peak value is the first value shown, 38,000 nCi/g.

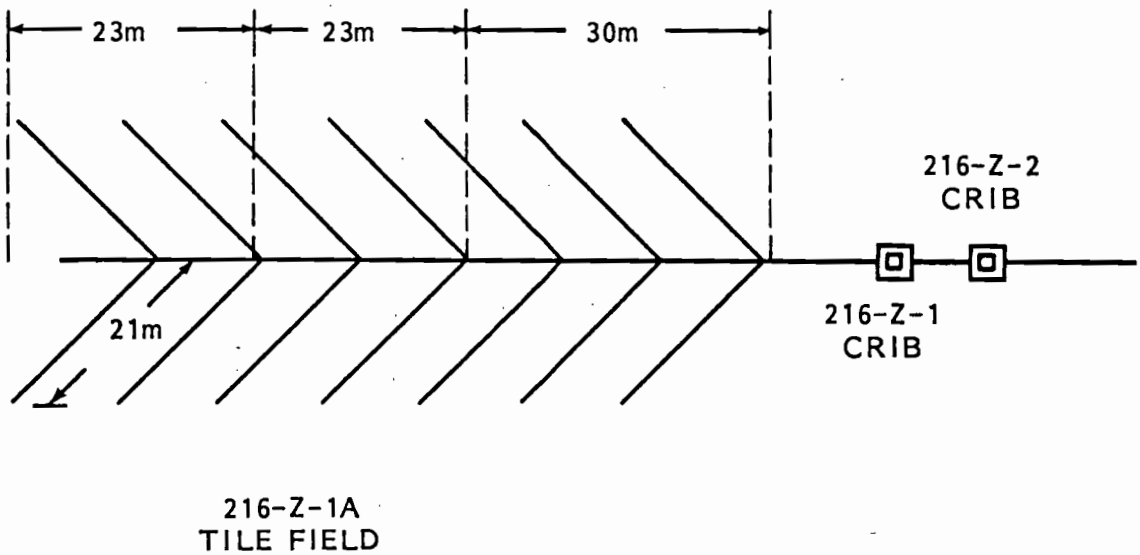
If we compare the information from this graph with the disposal criteria that I've derived, as Slide 30 does, and if we assume that this well characterizes the site (which is an oversimplification because this is the worst soil profile and most of the soil profiles associated with that crib and tile field have lower concentrations than 38,000 nCi/g), we can do the analysis. The concentration of 38,000 nCi/g could not be left in the top meter of the soil; however, because the crib depth started 3.4 m from the surface, we must examine the next criterion of depth. For wastes greater than 5 m

Slide 26

SYSTEMS ANALYSIS REFERENCE SITE: 216-Z-1&2 CRIBS AND TILE FIELD

- TWO $60m^3$ CRIBS WITH AN 80m CENTRAL TILE: 7-20m LATERALS
- 0.2m VITREOUS CLAY PIPE
- CONSTRUCTED IN 1949

Slide 27



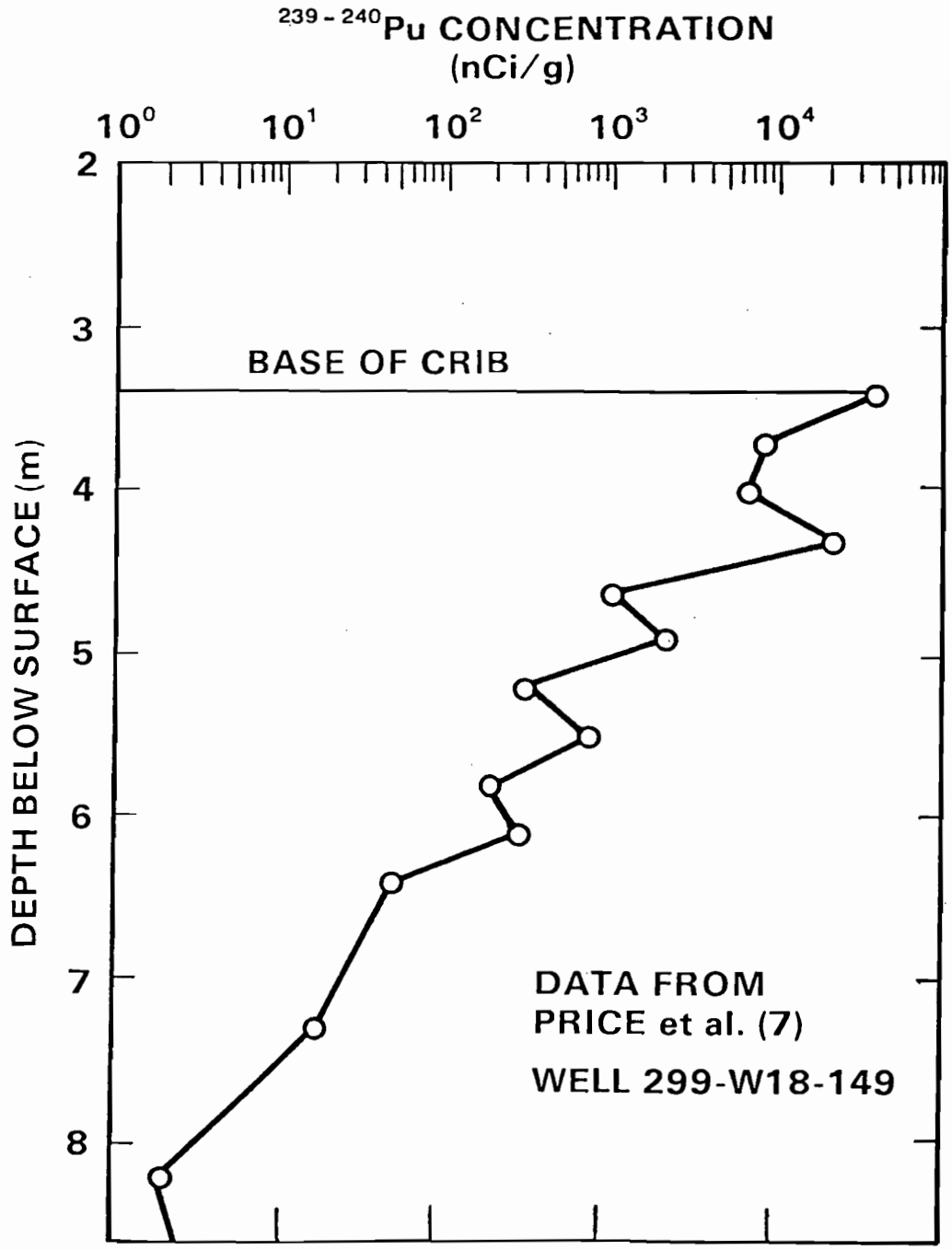
Slide 28

216-Z-1&2 CRIB SITE:

299-W18-149 WELL DATA (PRICE)

- PEAK CONCENTRATION 3.8×10^4 nCi/g
- MAX. DEPTH ($\geq 10^{-2}$ nCi/g) = 30m
  (STILL 25m ABOVE GROUNDWATER)
- Pu $> 10^3$ nCi/g EXTEND 2m
- Pu $> 10^2$ nCi/g EXTEND 15m

Slide 29


239 - 240Pu CONCENTRATION
(nCi/g)
10^0
10^1
10^2
10^3
10^4
DEPTH BELOW SURFACE (m)
2
3
4
5
6
7
8
BASE OF CRIB
DATA FROM
PRICE et al. (7)
WELL 299-W18-149

Slide 30

COMPARISON OF 216-Z-1&2 CRIBS WITH DISPOSAL CRITERIA:

- 299-W18-149 WELL DATA
- PEAK CONCENTRATION 3.8×10^4 nCi/g
- GREATER THAN 0-1 m CRITERION
- GREATER THAN 5m CRITERION (REQUIRES AT LEAST 5m COVER)

the criterion was 2200 nCi/g. The peak concentration, then, does not compare and, according to this analysis, at least 5 m of cover material is required. The site already has 3.4 m of cover, so an additional 1.6 m of cover is required.

Next, I compared the criterion at 10 m or more with the well drilling scenario (Slide 31). The drill core of the well penetrated the waste zone. To calculate the base case, the volume of the waste zone was assumed to be 0.5 m^3, distributed in the top 15 cm. At 10,000 nCi/g, this drill core would contain 8.5 Ci of plutonium-239. If we drilled a similar well through the soil profile shown for this example site, we would recover about 5.6 Ci of plutonium to a depth of 7 m. Below that depth, this well has a much smaller distribution, between 0 and 10 nCi/g of soil. Thus, we could conclude that a total cover depth of 10 m would not be required for this example site.

I would like to stress, as Slide 32 does, that this is only an example of applying the conditions to our criteria; exact cover requirements will have to be determined as work proceeds on site characterization, developing the radiation exposure scenarios and testing their plausibility and looking at barrier performance. Can we in fact construct barriers that will mitigate erosion and biotic and human intrusion?

The systems analysis results shown in Slide 33 indicate that the waste from this example calculation is 3.4 m deep. It requires at least 1.6 m of additional cover, but does not require 6.6 m to get to the 10-m depth, so we assumed that 5 m of cover could be added to this site, a total area of 3600 m^2. We determined cost on the basis of excavation, hauling, and spreading costs only; we also examined two composite cover cases and some simple cases.

The first composite cover case (Slide 34) assumes 1 m of boulders covered by 2 m of riprap and 2 m of soil. The second composite cover case assumes isolating the hot spots by using in-situ vitrification with a total volume of 180 m^3 of soil that would be turned to glass. (This would be the volume of the material in the two cribs and extra volume along the central distribution tile field.) Along with the in-situ vitrification, we would still add 2 m of cover, 1 m riprap and 1 m of soil. The results, shown for comparative magnitudes in Slide 35, indicate that covering this site with 5 m of pure soil with a unit cost of \$12/m^3 would cost \$220,000; 5 m of riprap would cost \$470,000; and 5 m of boulders would cost \$760,000. For the first composite case, 5 m of cover (1 m of boulders, 2 m of riprap, and 2 m of soil) would cost \$420,000. For the composite case using in-situ vitrification, the cost was \$250,000.

I would like to point out that these costs are not real applications. We are not now proposing that any of these methods be used to adapt this site for disposal. However, the systems analysis technique

Slide 31

$\geq$ 10m CRITERION:

- BASE CASE $0.5m^3$ DRILL CORE AT 10,000 nCi/g CONTAINS ABOUT 8.5 Ci OF ^{239}Pu; 299-W18-149 WELL CORE CONTAINS:
- ABOUT 5.6 Ci OF ^{239}Pu TO A DEPTH OF 7m (10m NOT REQUIRED)

Slide 32

EXACT COVER REQUIREMENTS WILL BE DETERMINED AS FUTURE WORK PROCEEDS ON:

- SITE CHARACTERIZATION
- EXPOSURE SCENARIOS
- BARRIER PERFORMANCE

Slide 33

SYSTEMS ANALYSIS: COSTS

- IF WASTE IS 3.4m DEEP, AT LEAST 1.6m MORE COVER NEEDED - BUT 6.6 IS NOT NECESSARY
- ASSUME 5m COVER ADDED
- EXCAVATION, HAULING, SPREADING
- ASSUME 2 COMPOSITE CASES

Slide 34

COMPOSITE COVER CASES:

CASE 1: 1m BOULDERS
2m RIPRAP
2m SOIL

CASE 2: 180 m^3 IN-SITU VIT.
(2 CRIBS PLUS SOIL)
1m RIPRAP
1m SOIL

Slide 35

SYSTEMS ANALYSIS: COST RESULTS:

5m ADDITIONAL COVER

METHOD	UNIT COST (1980 $)	APPLICATION (1980 $)
5m SOIL	$12/m^3$	2.2×10^5
5m RIPRAP	$26/m^3$	4.7×10^5
5m BOULDERS	$42/m^3$	7.6×10^5
COMPOSITE 5m	$24/m^3$	4.2×10^5
COMPOSITE 2m (IN-SITU VIT.)	$19/m^3$	2.5×10^5

can be conducted to determine barrier requirements and disposal requirements.

In summary (Slide 36), during this fiscal year we have attempted to begin our evaluation of the feasibility of TRU advanced disposal systems; they are a common sense approach to dealing with the soil contamination limits and conditions of Hanford. We have performed our evaluation using a systems analysis approach, and we have developed our preliminary disposal criteria using the ARCL method. In the future, we plan to review the parameters, assumptions, and scenarios that go into such calculations, examining efforts to calibrate the models over the time periods of interest and conducting barrier studies to determine (1) if our preliminary assumptions about the performance of these barriers are correct and (2) the exact tradeoffs between various barrier systems.

We will also examine the impact of waste form analysis. Does vitrifying the soil waste column actually reduce effects to human and biotic intrusion? Finally, we will have to examine the impact of other TRU radionuclides on the calculations.

Bill Lawless, Savannah River Laboratory: What is the cost of going from 10 to 100 nCi/g?

Kennedy: We have not yet looked at that case. Our disposal limits were site applications. As Jack Healy said, the 10 or the 100 nCi/g limit is a fine low-level waste or general trash limit, but specific cases must be examined on a case-by-case basis, and that's what we're looking at with a specific contaminated soil column at Hanford.

Lawless: Do you have a small animal transport problem at Hanford also? And can you characterize it?

Kennedy: Some of the wastes are disposed of at different depths. I think on the site that we showed, the crib was 3.4 m from the surface, but the tile field is about 1 m from the surface. At a meter, you can predict and in fact collect field samples that transport radionuclides. We're trying to quantify the magnitude of this problem and determine models, if we can, to help us better understand conditions and to help design experiments on barrier performance to determine how to mitigate this effect.

Lawless: Instead of the scenario of the intruder or the human intruder, or instead of the scenario of farm roots (I'm not sure that you'll have too many farmers out there, even in 10,000 years), could it possibly be that the gopher intruder or the small animal intruder is a limiting factor?

Kennedy: I have only preliminary information on that, and I don't think I'm ready to report that at this time. As I say, the modeling efforts are under way and we are attempting to publish a

Slide 36

SUMMARY:

- EVALUATE FEASIBILITY OF ADVANCED DISPOSAL SYSTEMS
- SYSTEMS ANALYSIS
- DISPOSAL CRITERIA BASED ON THE ARCL METHOD

preliminary statement in the next couple of months on the impacts of the biotransport for an arid site. For now, we're looking at a low-level waste burial ground rather than one for TRU.

Paul Dejonghe, CEN/SCK Boeretang 200, Belgium: What is the state of development of in-situ vitrification? Can you already measure intrusion by availability of the material for contamination of the environment?

Kennedy: Studies at Battelle have been conducted on the leach properties of the glass waste form. I think two demonstrations have been completed. One was a 10-ton demonstration and recently a 27-ton waste demonstration was conducted. It had some nonradioactive traces. The exact properties of glass as a waste form are still being analyzed, and cost and potential applications are being determined. I know Battelle is looking at different electrodes and different procedures for starting the in-situ vitrification technique. The technique does have potential for stabilizing hot spots where they can be quantified. How best to characterize sites, to know where the concentrations are and which techniques to apply to those concentrations, is the major question. So, I'm giving you a round-about answer, but the effort is under way and Battelle is getting some interesting test results. I think I might add that those were nonradioactive demonstrations. I want to reinforce that.

Jerry Cohen, Science Applications, Inc.: No one would argue with your initial objectives like minimizing the health impact, but do you have a firm definition or are those maximum dose levels you gave, like 25 millirem at the site boundary? Are those the actual objectives you're trying to achieve?

Kennedy: That's what we're trying to achieve--the performance objective.

Cohen: Are you sure that if you didn't do anything they would in fact be exceeded?

Kennedy: That would have to be determined, I think, on a site-by-site basis. All the TRU sites at Hanford have different properties, from near-surface to distributed-soil column. There is no simple answer to that question. Some of the sites with contamination nearer the surface would have to be studied carefully before one could determine what best to do with those sites.

Cohen: You haven't looked into that yet?

Kennedy: Not in enough detail to make a firm statement about it.

Cohen: How much work would it take before you could answer a question like that?

Kennedy: Over 200 TRU-contaminated sites at Hanford would have to be considered in a systematic approach with a similar technique so the results could be compared. We have not attempted to march through all the sites because we're really on the first step of the process--determining a good method of approach, determining the performance of barriers that one might use as alternatives, and characterizing the sites in enough detail that we can make reasonable choices about how to handle the sites.

Charles King, Savannah River: What is the curie content of all this contaminated soil?

Kennedy: I didn't bring that information with me. I know the references list the estimates of the kilograms of plutonium and the activity associated with that particular site. Although I don't have that information, I do think it is quantified.

King: Are MAXI and DACRIN documented?

Kennedy: Yes, DACRIN and FOOD are documented, and we have documentation on MAXI, a bookkeeping routine, also.

Bill Lennemann: This question is probably addressed to you as well as to the Savannah River Plant people. At Richland you have a lot of plutonium-contaminated equipment in the tunnel. Savannah River also had plutonium-contaminated equipment that is generally stored somewhere, just like yours. Where does this plutonium-contaminated equipment fit in to all of this? Is that all going to be shipped to WIPP? I haven't heard the equipment considered at all in these various site proposals.

Mel Shupe, DOE: It depends on the location of the contaminated equipment. The equipment is still in place, like at the tunnel in the Purex building that was mentioned in one of the previous papers. That equipment would be considered part of the facility, and we would look at that equipment when the facility becomes D&D'd. The deposition of the burial will govern the equipment that has been already cut up and put into burial grounds.

RISK AND SAFETY ANALYSIS FOR DISPOSAL OF ALPHA-CONTAMINATED WASTE IN WIPP

Steven Woolfolk, Westinghouse/WIPP

I'm Steven Woolfolk with the Westinghouse Electric Corporation, which is the technical support contractor to the Department of Energy (DOE) at the Waste Isolation Final Project. I'd like to discuss the safety analyses completed for the Waste Isolation Pilot Plant (WIPP), which was discussed by Mr. Sadler yesterday.

WIPP is a demonstration project and will be used to dispose of defense transuranic (TRU) waste (Slide 1). As a DOE TRU waste disposal demonstration facility, it is regulated by DOE. As directed by Congress in the authorizing legislation, it is exempt from regulation by the Nuclear Regulatory Commission (NRC). For those who may not be acquainted with DOE's procedures when a new facility is constructed, DOE follows a need-to-compliance procedure, which includes public comment and public hearing on DOE environmental impact statements. DOE also requires that a safety analysis report (SAR), similar in content to the NRC's, be prepared. The SAR for WIPP is a living document, which is revised periodically to reflect changes in the facility design and the impact of such changes on the public health and safety.

During the SAR process at WIPP, various release scenarios have been analyzed to assess their impacts on the public health and safety. At the start of the project, it was determined that probabilistic risk assessment would not be used. Instead, consequence analyses assuming the probability of an event were performed. The decision to eliminate probabilistic risk assessment was based on (1) the public controversy in New Mexico about the construction of WIPP, (2) the lack of public understanding of probabilistic risk assessment, and (3) the lack of an adequate data base to support the probabilities in an unambiguous manner that would not be subject to continuing peer review or criticism from the public sector. To clarify the importance of these factors, I'd like to summarize the present situation at WIPP.

WIPP is authorized by PL 96-164, which directed the Secretary of Energy to enter into a consultation and cooperation agreement with the State of New Mexico by September 1980. However, no agreement could be reached between DOE and the State of New Mexico by 1980. An agreement was adopted in July 1981 as a part of a stipulated agreement to resolve litigation filed by the State of New Mexico, which was seeking a preliminary injunction to halt construction at WIPP. The focal point of this agreement is the New Mexico Environmental Evaluation Group, which is funded by DOE but controlled by the state. This group uses the SAR, primarily, to review aspects of WIPP that affect the environment and public health and safety.

Slide 1

CONSULTATION AND COOPERATION

- PUBLIC LAW 96-164
- ENVIRONMENTAL EVALUATION GROUP (EEG)
- DEPARTMENT OF ENERGY/STATE OF NEW MEXICO NEGOTIATIONS
- DRAFT AGREEMENT—SEPT 1980
- FINAL AGREEMENT—JULY 1981

To understand the situation at WIPP, it is necessary to recognize that we now have three ongoing suits (Slide 2). These suits are contentions filed on the basis of alleged failure to follow the National Environmental Policy Act (NEPA) process or the Bureau of Land Management Land Withdrawal requirements. Two of these suits were filed by intervenor groups, and the third suit was filed by the State of New Mexico. All three requested preliminary injunctions to stop work. None of these suits has received a hearing on the merits, although in all cases the preliminary injunction was denied. New Mexico's suit was resolved by the signing of a stipulated agreement between the state and DOE. This agreement requires the state and DOE to report periodically to the federal courts on the resolutions of remaining disagreements.

In addition to the consultation and cooperation agreement, the stipulated agreement has provisions that require DOE to prepare additional reports on issues raised by the state and to conduct additional field investigations at or near the WIPP site (Slide 3). To resolve some of the state's concerns, several additional geological characterization projects have been conducted. The consultation and cooperation agreement itself also contains a procedure for resolving disagreements between the state and DOE, which requires a final decision by the Secretary of Energy. If the state is dissatisfied, it still has legal recourse in the federal court systems. Finally, the agreement provides for state review of project status before key events in the construction and operation of the facility are initiated. This agreement lists activities that must be addressed and resolved with the state before initiating key events. For instance, before the exhaust shaft at WIPP is constructed, a preliminary transport analysis must be completed. This example indicates the type of concerns that the State of New Mexico now has.

Slide 4 is a summary of the WIPP schedule, which shows the scheduling of key events for the projected completion date of April 1989. If probabilistic risk assessment had been used in the SAR instead of consequence analysis, our experience indicates that we would have been unable to resolve many contentions with the state. We would still be justifying the probability of various accidents. This concludes the overview of the controversy surrounding WIPP and our reasons for the consequence analysis. I would now like to present our methods used in these analyses.

Slide 5 shows the waste forms that will be received at WIPP. As you know, there is still a question about whether the limit is 10 or 100 nCi/g. We will be receiving contact-handled (CH), remote-handled (RH), and experimental waste. As Mr. Sadler pointed out, the experimental waste will be removed before closure of the facility. Most of our waste will initially be received in 55-gal drums with a 200-g plutonium limit for each drum. This turns out to be of major significance in our intrusion scenarios. We will also be receiving

Slide 2

KEY EVENTS
IN SUITS AGAINST DOE (WIPP)

CARD SUIT

• CARD FILED SUIT	3/18/81
• CARD AND STATE SUIT COMBINED	5/28/81
• COURT'S FINDINGS ISSUED—PI DENIED	8/28/81

NM SUIT

• ATTORNEY GENERAL FILED SUIT	5/14/81
• STIPULATED AGREEMENT SIGNED	7/1/81
• NM ISSUED STATUS REPORT TO COURT	2/5/82

SWRIC SUIT

• SWRIC FILED SUIT	7/10/81
• PRELIMINARY INJUNCTION DENIED	12/3/81
• CONTINUING SWRIC INTERROGATORIES	Ongoing

Slide 3

KEY EVENTS UNDER CONSULTATION AND COOPERATION

- o DRAFT ENVIRONMENTAL EVALUATION
- o PRELIMINARY ENGINEERING - TITLE 1
- o FINAL ENVIRONMENTAL EVALUATION
- o COMMENCEMENT OF (SPDV) CONSTRUCTION
- o COMMENCEMENT OF DETAILED DESIGN - TITLE II
- o COMMENCMENT OF CONSTRUCTION OF CONSTRUCTION EXHAUST AND SALT-HANDLING SHAFT
- o COMMENCEMENT OF CONSTRUCTION OF VENTILATION SUPPLY AND SERVICE SHAFT
- o COMMENCEMENT OF CONSTRUCTION OF WASTE-HANDLING BUILDING

Slide 4

MAJOR MILESTONES OF PROJECT SCHEDULE

• START OF TITLE II DETAILED DESIGN	FEBRUARY 1981
• START OF SITE & PRELIMINARY DESIGN VALIDATION PHASE	APRIL 1981
• START OF PERMANENT WIPP SURFACE FACILITIES (SITE DEVELOPMENT AND ACCESS ROADS)	FEBRUARY 1983
• START OF WIPP UNDERGROUND CONSTRUCTION (CE AND SH SHAFT)	SEPTEMBER 1983
• RECEIPT OF FIRST TRU WASTE	APRIL 1989

Slide 5

WIPP WASTE FORMS

TRU WASTE

- PU > 10 n Ci/g?

CONTACT HANDLED

- 210 LITER DRUM < 200 GRAMS OF Pu
- 0.04 WATT/DRUM
- SDR < 200 mrem/hr

REMOTE HANDLED

- 4 WATTS/(30 cubic feet)
- SDR < 100 rem/hr
- CONTAINER SRP CANISTER

EXPERIMENTAL WASTE FORMS

- DEFENSE HIGH LEVEL WASTE FORM
- ENHANCED FORMS

RH waste, which is similar to our CH waste except that it has a higher fission product inventory and therefore a higher dose rate.

WIPP is located in southeastern New Mexico, about 26 miles from Carlsbad. Our primary long-term release point is Malaga Bend, on the Pecos River about 20 miles from the site. Slide 6 is a stratigraphy, as shown by Mr. Sadler yesterday. As you will note, the horizon is located about in the middle of the Salado formation, which is in hydrite salt with about 800 additional ft of overburden and is about 800 ft from the bottom of the Salado. Also notice the Rustler formation, where the release mechanism to primary aquifers occurs, and the Bell Canyon formation, a second aquifer that acts as a driving force for some of our long-term release scenarios. The WIPP site has an arid climate and low population density (Slide 7). There are only 96,000 people within the entire 50-mile radius around the site. The only major agricultural activity is grazing beef cattle and sheep; feed crops are raised to support this activity.

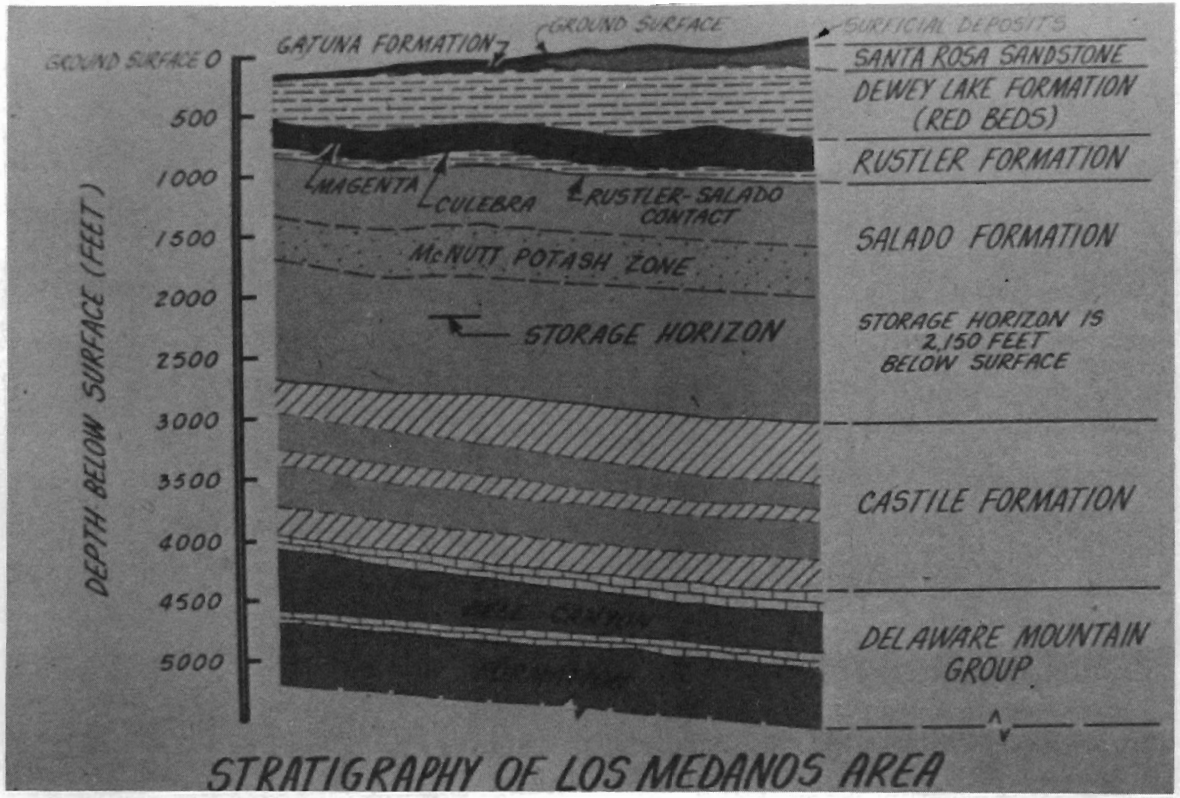
We have three categories of analysis in preparing the WIPP SAR: normal operating releases, accident releases, and long-term releases (Slide 8). These first two types are normally done for any nuclear facility. The long-term releases obviously are only applicable to disposal sites.

The isotopic distribution of waste used in the SAR was based on the work by Shefelbine for INEL's waste that is now in storage. Our project doesn't consider most of the other DOE facilities.

Slide 9 shows a sample of the inputs used in our models. The doses are all 50-year dose commitments. We do not attempt to assess first year or largest year doses.

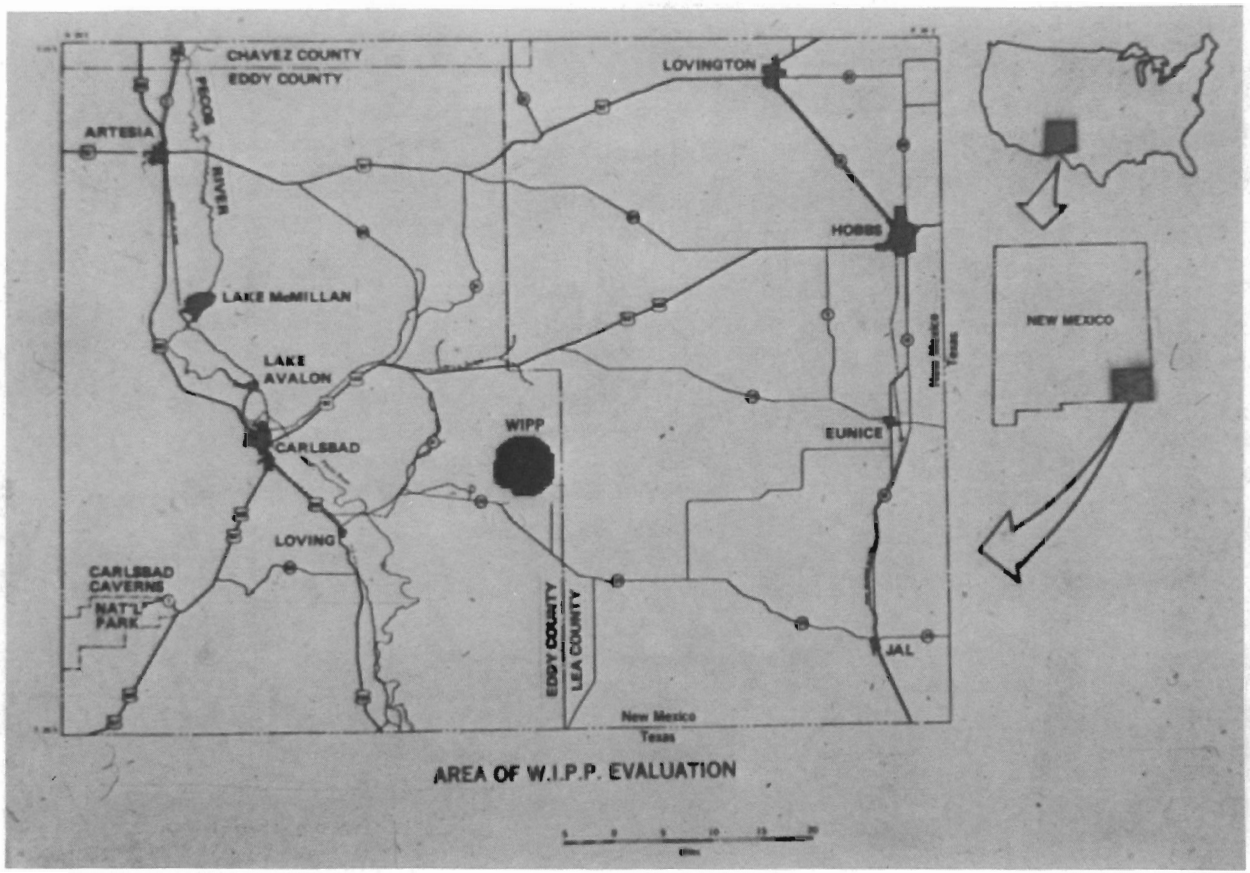
The computer program used to evaluate the release scenario for normal operating releases was AIRDOS-EPSA (Slide 10). We considered inhalation, immersion, direct exposure, and ingestion doses. The only significant dose was the inhalation exposure, as we expected. We also considered the impact of the deposition on the various water surfaces in the area and put this data back into the appropriate sections of AIRDOS-EPA to assess the dose. In the input to AIRDOS-EPA, we made a number of conservative, simplifying assumptions. We initially assumed we were dealing only with 0.3 micron particles. This assumption is conservative, but unfortunately no data are now available on the particle size distribution for salt in the vicinity of WIPP. We also assumed zero settling velocity, which is not a bad assumption for 0.3 micron particles. We would clearly be incorrect for larger particles. The dose conversion factors we used were those generated by Oak Ridge National Laboratory (ORNL) for NRC. These factors consider the task group lung model and even look at organ crossfire. Our source terms for all of our normal releases are based on the contamination levels of incoming shipments. WIPP will be operated as a clean facility. Incoming shipments will be the only

Slide 6



STRATIGRAPHY OF LOS MEDANOS AREA

Slide 7


CHAVEZ COUNTY
EDDY COUNTY
PECOS
RIVER
ARTESIA
LAKE McMILLAN
LAKE AVALON
CARLSBAD
LOVING
CARLSBAD CAVERNS NAT'L PARK
WIPP
EDDY COUNTY
LEA COUNTY
LOVINGTON
HOBBS
EUNICE
JAL
New Mexico
Texas
NEW MEXICO
AREA OF W.I.P.P. EVALUATION

Slide 8

CATEGORIES OF ANALYSES:

NORMAL OPERATING RELEASES

ACCIDENTAL RELEASES

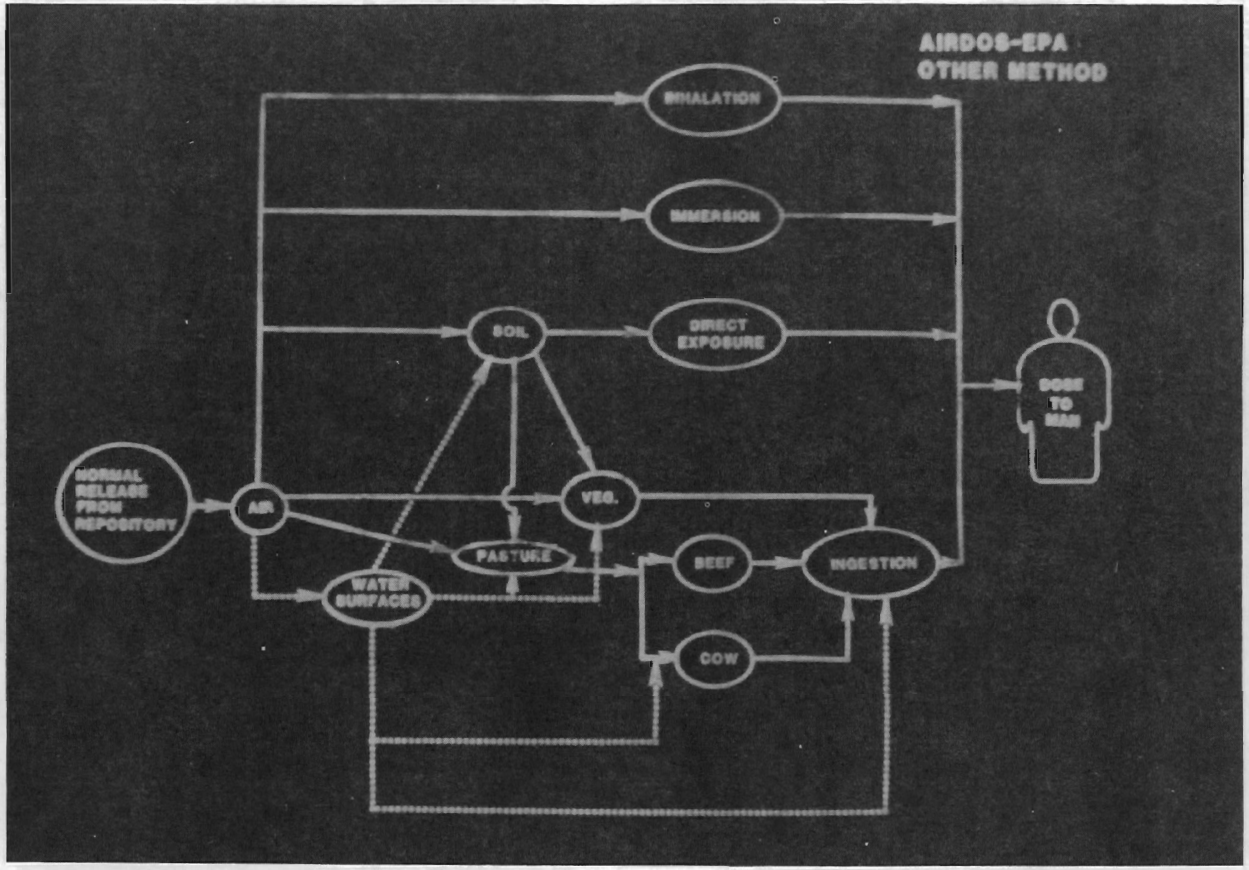
LONG TERM RELEASES

Slide 9

ASSESSMENT AREA ENVIRONMENTAL DATA:

POPULATION	96,000
MEAT ANIMALS	197,000
MILK ANIMALS	1750
CROP AREA, m^2	6.0 E + 8

Slide 10


AIRDOS-EPA
OTHER METHOD
INHALATION
IMMERSION
SOIL
DIRECT EXPOSURE
DOSE TO MAN
NORMAL RELEASE FROM REPOSITORY
AIR
VEG.
PASTURE
BEEF
INGESTION
WATER SURFACES
COW

source of uncontrolled radioactive material unless an accident occurs (Slide 11). Another unique characteristic of the analysis is that we used a weighted meteorology. Rather than choosing a single chi, we used a chi multiplied by the probability of occurrence of that chi for any long-term occurrence, which is typical for normal releases. All these data are based on site-specific meteorological data that have been collected by Sandia National Laboratories. Slide 12 summarizes the results of our normal operating releases. They are trivial, as you would expect, clearly below any of the existing exposure limits.

Slides 13 and 14 illustrate the basic analytical method we used for evaluating accident releases. Basically, we calculated the air concentrations with AIRDOS-EPA, the inhalation dose with DACRIN, and the immersion dose with SUBDOSA. We also looked at the impact of a release followed by a grass fire. These data were used as input for DACRIN. We used DACRIN instead of AIRDOS-EPA to calculate the inhalation dose to (1) simplify the input (AIRDOS-EPA requires a much more complicated input deck) and (2) allow us to enter comparison of the dose predictions of the two programs for assurance that AIRDOS-EPA, although validated, is producing comparable results with DACRIN. Both are commonly accepted programs. The immersion dose was calculated by SUBDOSA because it is a more sophisticated model. AIRDOS-EPA uses a simplified model. Again, the only significant exposure is by the inhalation pathway.

The table in Slide 15 summarizes our accident doses. Let me point out that DOE facilities have no accident dose release limits, particularly none that are applicable to plutonium facilities like WIPP. WIPP developed its own accident dose limits that were accepted by our field office. For accidents, we use a 25-rem limit for whole-body and 75-rem for other organs. No projected accident exposures for WIPP approach these values. We have analyzed the potential limiting case accidents, and the most significant are summarized in this slide. These accidents are (1) a fire in the CH waste underground, (2) a hoist failure involving an RH waste shipment, and (3) a hoist failure involving a high-level experimental waste package (Slide 16). We also considered worker doses. This method considered depletion of the inhaled activity. These are all done-by-hand calculations. Zero depletion was assumed for workers at the accident site. We also assumed that the deposition and dilution of the activity in a room was exactly equal to the resuspension of the released activity so that the air concentration didn't change with time. Thus the dose was determined by how long the worker was in the area.

Slide 17 summarizes the projected worker doses. Immediate area worker doses are subjective because of the difficulty in determining the exact circumstances of an accident. As you can see these doses do not even a approach the existing routine radiation exposure limits for workers, let alone for accident doses.

Slide 11

WEIGHTED METEOROLOGY

$$\overline{\chi} = \sum_{i=A}^{F} \chi_i * P_i$$

i	IS THE APPLICABLE PASCAL METEOROLOGY
χ_i	WORST CASE CONCENTRATION FOR THE APPLICABLE PASCAL METEOROLOGY, AND
P_i	IS THE PROBABILITY OF OCCURENCE OF THE PASCAL METEOROLOGY

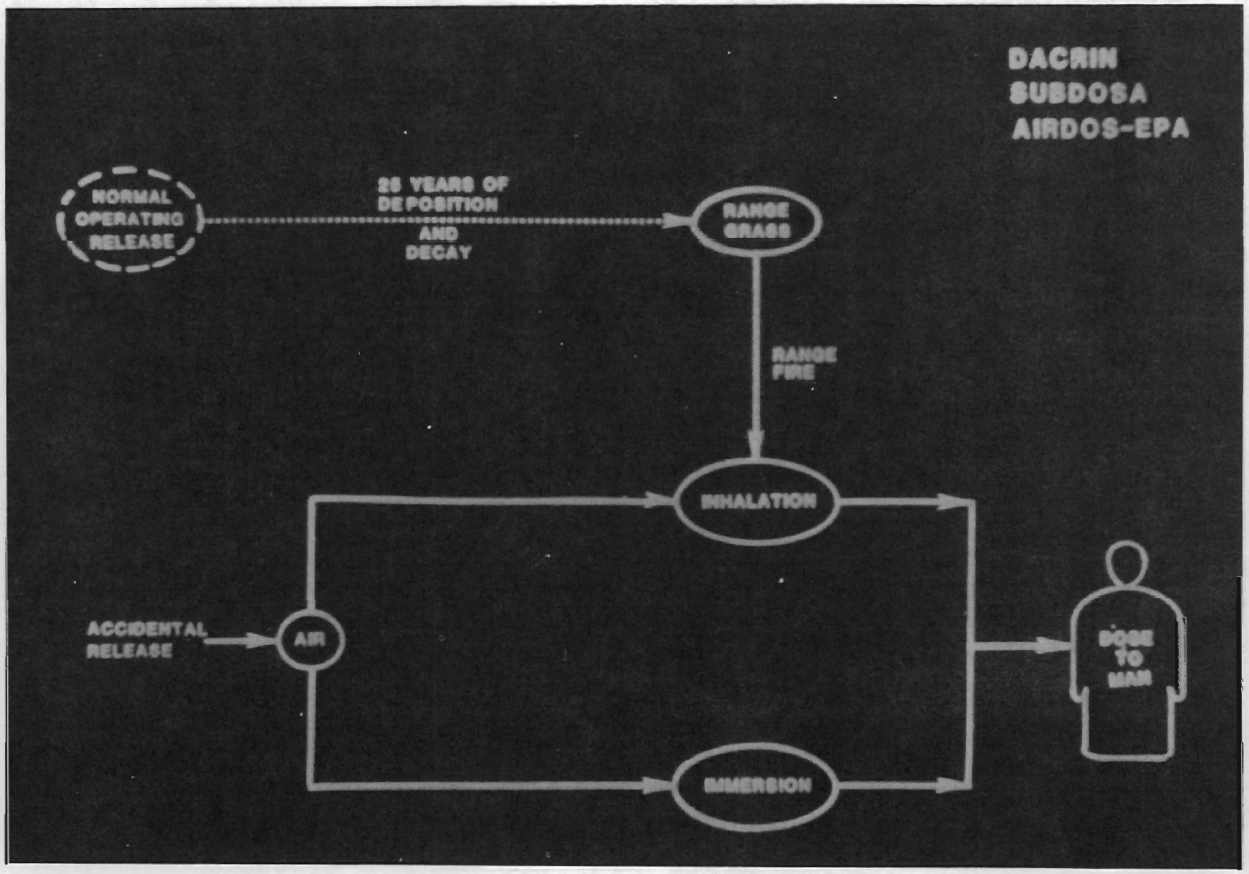
BASED ON SITE SPECIFIC DATA

Slide 12

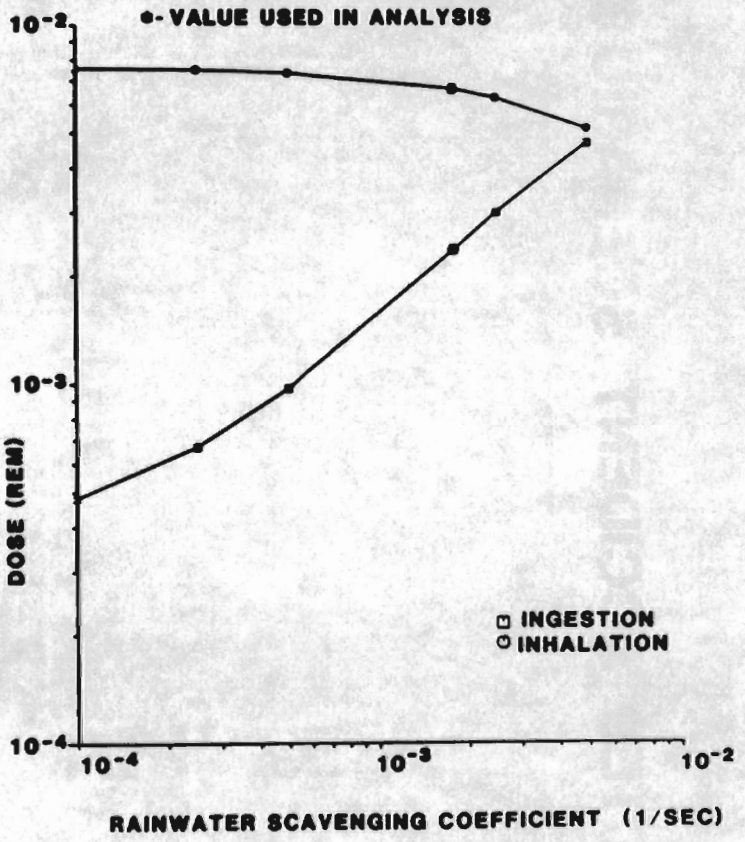
NORMAL OPERATIONS ALL PATHWAYS, REM

ORGAN	MAX INDIVIDUAL, REM	POPULATION, MAN-REM
TOTAL BODY	1.6 E-7	2.2 E-4
LUNG	3.0 E-7	4.0 E-4
BONE	6.5 E-6	8.8 E-3

Slide 13


DACRIN
SUBDOSA
AIRDOS-EPA
NORMAL OPERATING RELEASE
25 YEARS OF DEPOSITION AND DECAY
RANGE GRASS
RANGE FIRE
INHALATION
ACCIDENTAL RELEASE
AIR
DOSE TO MAN
IMMERSION

IMPACT OF SCAVENGING COEFFICIENT ON 50 YEAR DOSE COMMITMENT



Slide 14

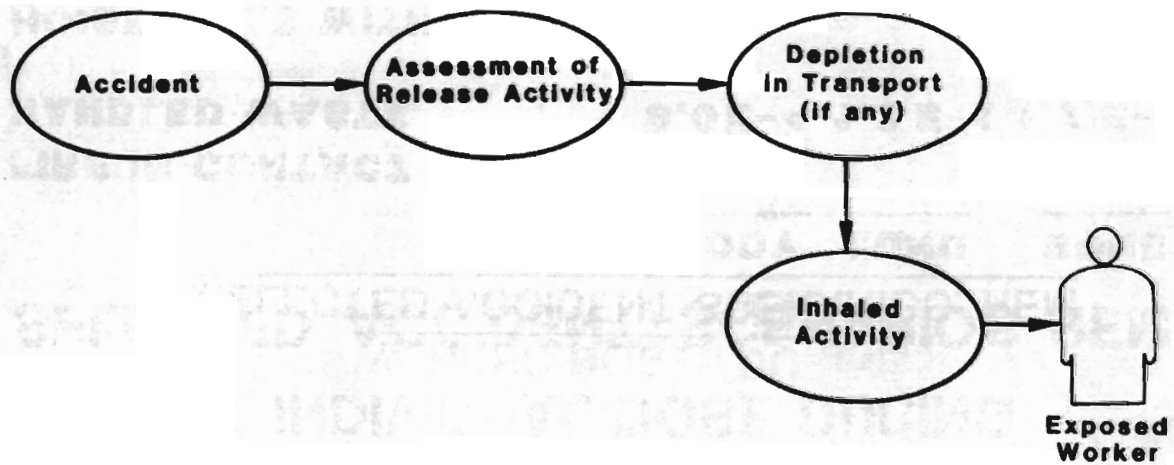
Slide 15

MAX INDIVIDUAL DOSE DURING SELECTED ACCIDENT SCENARIOS, REM

	TOTAL BODY	LUNG	BONE
FIRE IN CONTACT HANDLED WASTE	8.0 E-4	1.3 E-1	1.7 E-1
HOIST FAILS WITH REMOTE HANDLED WASTE	5.2 E-3	2.6 E-2	2.4 E-2
HOIST FAILS WITH HLW	4.8 E-3	1.2 E-1	4.9 E-2

Slide 16

Worker Exposure



Slide 17

WORKER DOSES DURING SELECTED ACCIDENT SCENARIOS, REM

	GENERAL WORKER			WORKER AT ACCIDENT SITE		
	Total Body	Lung	Bone	Total Body	Lung	Bone
TRANSPORTER HITS PALLET UNDERGROUND	1.5E-4	2.5E-3	3.2E-3	3.2E-1	5.4	7.0
HOIST FAILURE (CH—Waste)	1.3E-2	2.2E-1	2.8E-1	—	—	—
FIRE IN CH-WASTE UNDERGROUND	1.1E-1	1.8	2.3	1.5	2.6E+1	3.3E+1

Now I will discuss the long-term release limits, which are of interest to this group (Slide 18). Basically, when we looked at long-term releases, we looked at two types of events, naturally occurring and human intrusion events. We did not look at any population doses because we were not able to devise an adequate method for projecting future populations. Each one of these scenarios is totally scenario- and site-specific. There is no generic analysis for a long-term release. Most of our long-term release scenarios involved the water pathway (Slide 19). This slide illustrates the basic analysis we used. In the analysis we developed a hydrological model, looked at the communication event, looked at nuclide transport, and finally looked at a release to the Pecos River. All of these analyses, except the release to the Pecos River, were done by Interra and based on the SWIFT code. The release to the Pecos River was completed by Westinghouse using LADTAP. One of the problems we recognize is that most of the communication events are artificially constructed because there is no projected mechanism for creating this communication.

The first naturally occurring event we looked at was the establishment of a pathway between the Bell Canyon aquifer and the Rustler aquifer that passes through the storage area (Slide 20). This is our limiting case event because of the higher flow rates in the Bell Canyon. However, newer data indicate this probably is an ultra-conservative scenario; it appears that there isn't enough hydrological head in the Bell Canyon to produce this scenario. The scenario assumes complete dissolution of the waste. The projected doses are summarized in the slide. The exposures occur about 400,000 years after the communication event. The releases are delayed by the material in the Rustler aquifer and the slow transmission times through the aquifer (Slide 21).

The second event that we looked at was the communication from the Rustler to the repository and back to the Rustler. This one produces similar results to the Bell Canyon communication event. Again, the primary problem is how these communications occur. As illustrated in Slide 22, the doses again are relatively small. The final event that was analyzed is the naturally occurring diffusion of the radioactive material through the Salado to the Rustler aquifer. However, this event would require the intrusion of a brine pocket into the storage area after closure because without water there is no mechanism to move the radioactive material up to the Rustler aquifer. As you can see, these numbers are very small. This is not considered a particularly credible or useful case to analyze; however, it was of interest to the state consultation and cooperation review organization.

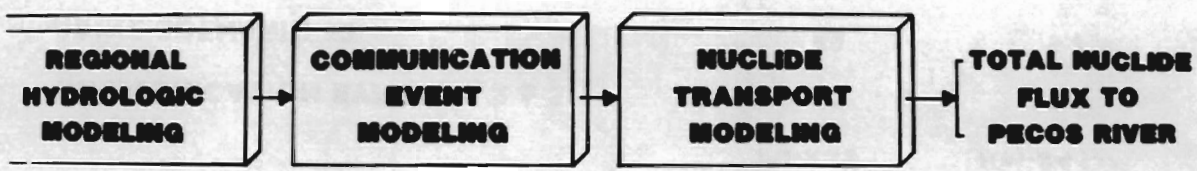
We looked at doses for several age groups, not just adults (Slide 23). As you can see, depending on what organ you are evaluating, various groups can be the limiting case. We looked at the releases at the Pecos River and at the releases from a well drilled about 3 km from the site and about 4500 ft off the center of the release plume. This location was chosen because the salt content of the water in the area

Slide 18

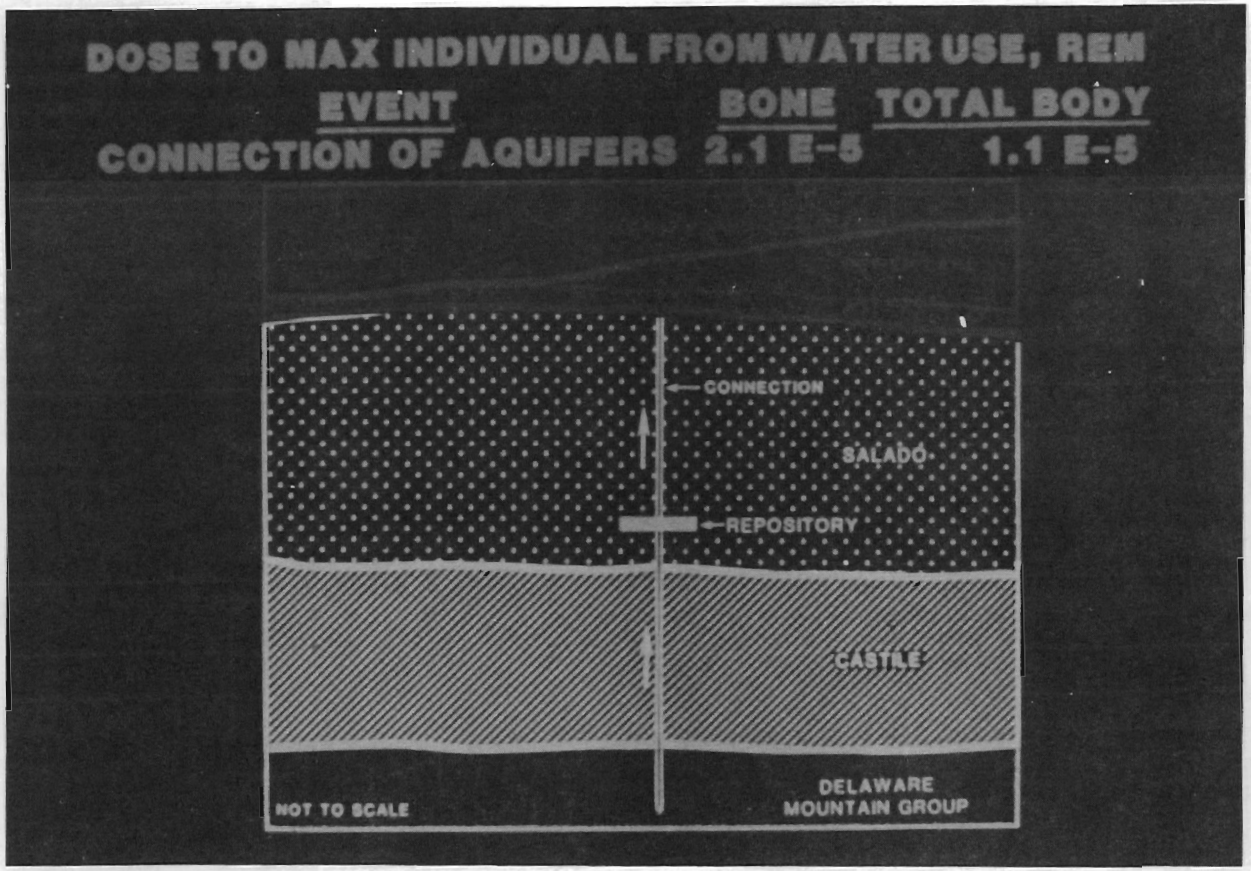
ACTIVITY RELEASE TO THE ACCESSIBLE ENVIRONMENT IN FIRST 10,000 YEARS (Ci)

	Pu-239	Am-241
COMMUNICATION EVENTS 1, 2 & 3	0	0
BRINE SCENARIO #2	49	5.7
APPLICABLE 40CFR191 LIMIT (Draft 20)		
REASONABLY FORESEEABLE RELEASES	100	11
VERY UNLIKELY RELEASES	1100	110

Slide 19


REGIONAL HYDROLOGIC MODELING
COMMUNICATION EVENT MODELING
NUCLIDE TRANSPORT MODELING
TOTAL NUCLIDE FLUX TO PECOS RIVER

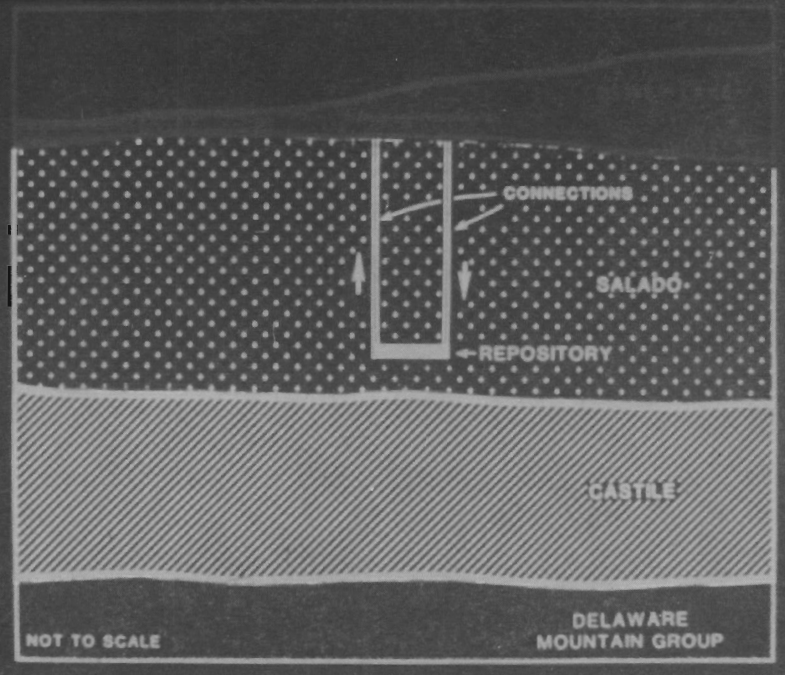
Slide 20


DOSE TO MAX INDIVIDUAL FROM WATER USE, REM
EVENT
BONE
TOTAL BODY
CONNECTION OF AQUIFERS
2.1 E-5
1.1 E-5
CONNECTION
SALADO
REPOSITORY
CASTILE
NOT TO SCALE
DELAWARE
MOUNTAIN GROUP

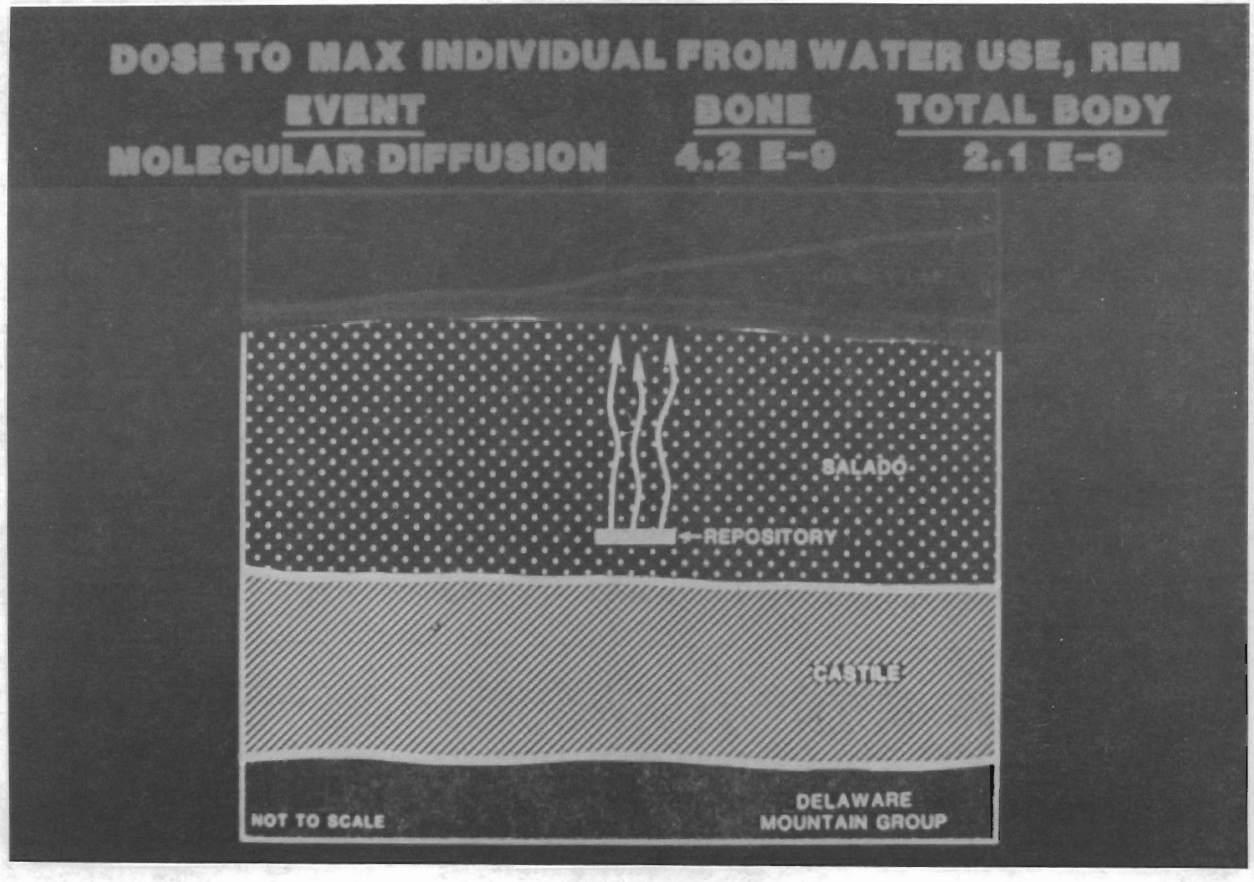
Slide 21

DOSE TO MAX INDIVIDUAL FROM WATER USE, REM

EVENT	BONE	TOTAL BODY
U-TUBE BETWEEN AQUIFERS	1.6 E-5	8.3 E-6



Slide 22


DOSE TO MAX INDIVIDUAL FROM WATER USE, REM
EVENT
BONE
TOTAL BODY
MOLECULAR DIFFUSION
4.2 E-9
2.1 E-9
SALADO
REPOSITORY
CASTILE
NOT TO SCALE
DELAWARE
MOUNTAIN GROUP

Slide 23

MAXIMUM INDIVIDUAL ORGAN DOSE COMMITMENT, mrem*

Individual	Skin	Bone	Liver	Total Body	Kidney	Scenario
ADULT	5.6E-6	1.6E-2	4.8E-6	9.5E-3	7.1E-4	1***
TEENAGER	3.1E-5	1.4E-2	2.5E-5	7.9E-3	5.6E-4	
CHILD	6.5E-6	2.1E-2	5.7E-7	1.1E-2	5.0E-4	
INFANT	____**	1.9E-2	6.7E-7	7.6E-3	4.2E-4	
ADULT	____	1.3	2.7E-5	0.90	5.4E-3	Well outlet 4500 ft off plume centerline (TDS#20,000 mg/l)
TEENAGER	____	1.2	3.3E-5	0.88	4.5E-3	
CHILD	____	1.7	5.5E-5	1.30	3.8E-3	
INFANT	____	1.3	9.4E-5	1.00	2.3E-3	

*50 year dose commitment resulting from a one-year intake.
**Pathway leading to skin dose not present.
***Geosphere outlet at Malaga Bend on Pecos River.

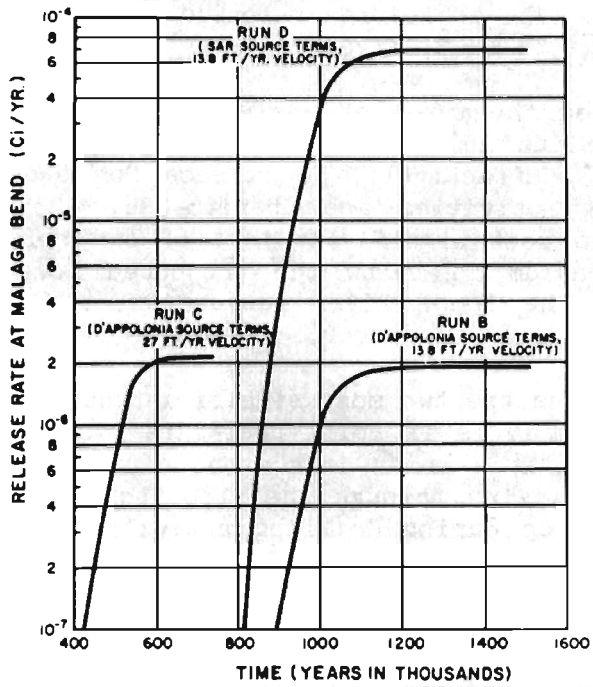
is so high that it would require desalination. Desalinating the water reduces the plutonium concentration. The local well 3 km away is our limiting case scenario. You can drill a well on the site, but by the time you desalinate the water so that you can use it, you've removed all the plutonium and other heavy metals.

We also looked at the effect of the permeability of the Rustler aquifer on the projected releases. Slide 24 summarizes how the releases depend on the flow rate. The SAR assumes a flow rate of about 13.8 ft/year. We evaluated a 27 ft/year flow rate, which only slightly decreased the length of time releases would need to reach the Pecos River. The activities released are relatively small in both cases, about 10^{-4} to 10^{-5} Ci/year.

We also evaluated the types of activities we were actually releasing to the Pecos (Slide 25). We are talking about extremely long time scales. We get, effectively, no release for about 10^5 years. The primary release activities are uranium-236, -235, -233, -238, and radium-226. The most significant part of our release is radium-226, and even the radium is below the projected level of detectability for release to the Pecos River because of the naturally occurring radium-226 activity in the river.

Slide 26 summarizes the two most significant human intrusion scenarios at WIPP. This analysis is still preliminary and may be revised. We looked originally at a human intrusion scenario that only dealt with a drill string passing through the repository and the impact of the material brought up during drilling activities. We are now looking at how this scenario changes when a brine pocket is located beneath the site. The analyses considered scenarios occurring 250 years after closure, the earliest credible time.

The first scenario assumes a 15-in. drill hole through the disposal site into a brine pocket, which is allowed to flow for 24 h. The material is collected in a mud pit. As it turns out, based on the geotechnical analysis of what happens, the only material removed in this process is the material through which the drill string passes, and this turns out to be the same as the original scenario that was analyzed. We also looked at a second scenario that assumes the drill hole passes through the repository into a brine pocket and then is plugged. When this brine comes to equilibrium with the plutonium present in the disposal area, which is constantly saturated with pressurized brine during this period, then a second hole is drilled into the storage area. This establishes a flow through the disposal site. In this case, the limiting concern turns out to be the radioactive material or waste that is washed out of the site and brought to the surface. Our initial geological modeling indicated that we probably would wash out very little activity, but we increased the conservatism of the assumption and ended up with about 350 ft^3 of waste reaching the surface. Thus, a significant amount of material ended up in the brine pond. With the brine pond, these two



TOTAL RELEASE RATES AT MALAGA BEND
COMMUNICATION EVENT I

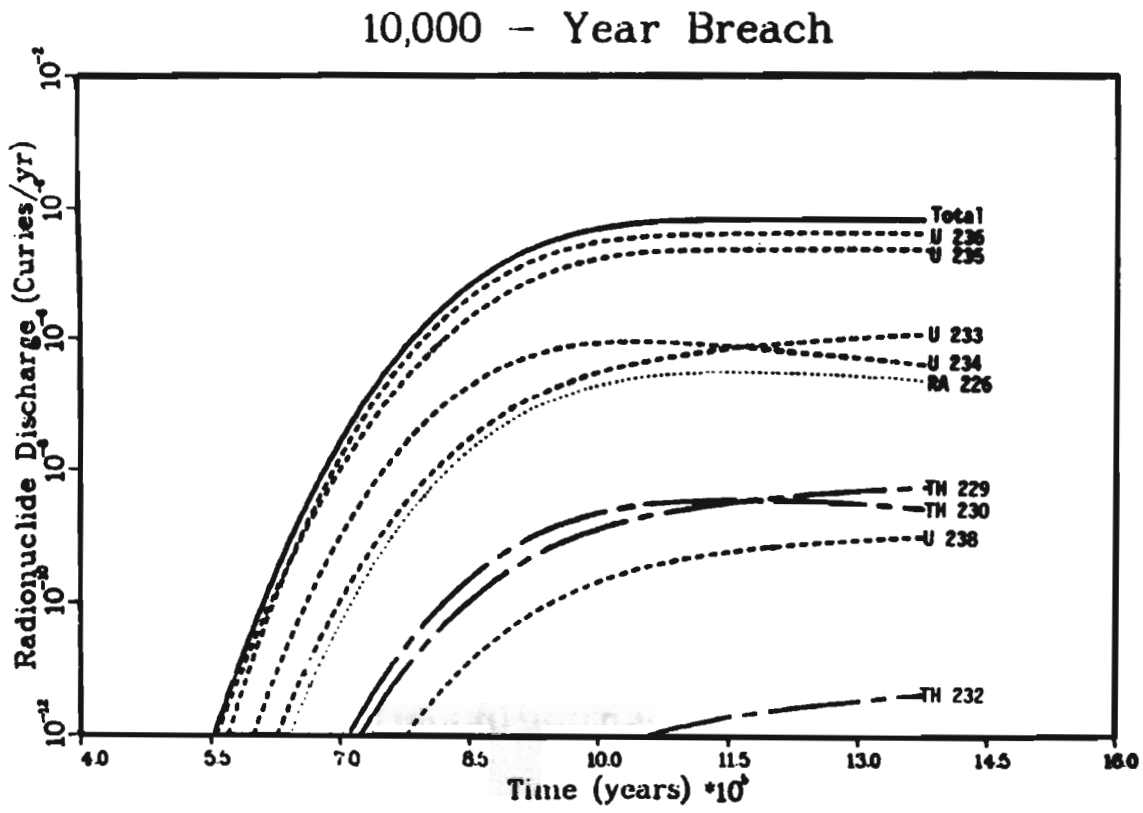
PREPARED FOR

WESTINGHOUSE ELECTRIC CORPORATION
ALBUQUERQUE, NEW MEXICO

D'APPOLONIA

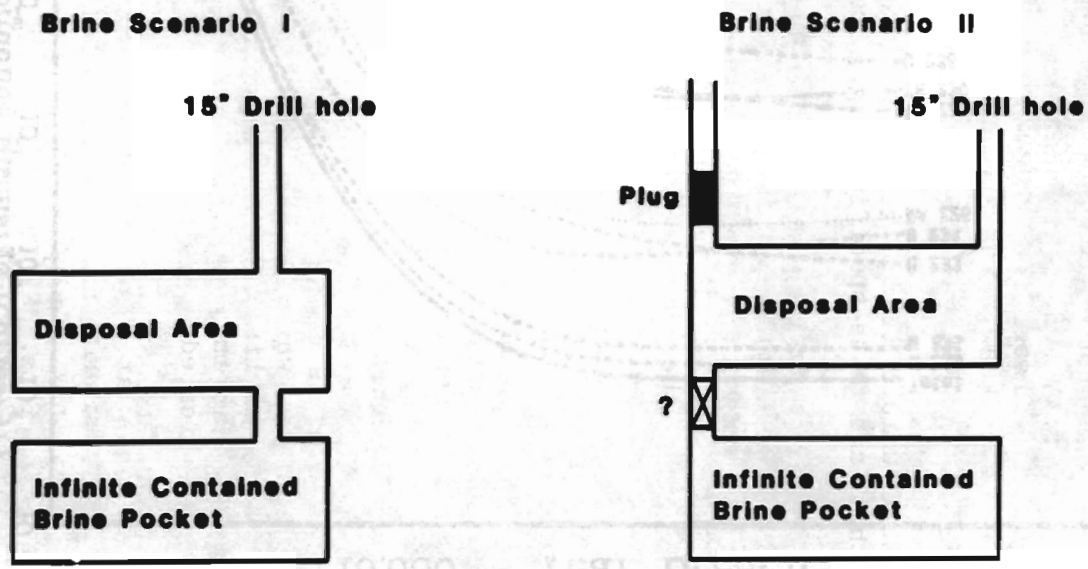
Slide 24

Slide 25


10,000 - Year Breach
Radionuclide Discharge (Curies/yr)
Time (years) *10^5
Total
U 236
U 235
U 233
U 234
RA 226
TH 229
TH 230
U 238
TH 232
4.0
5.5
7.0
8.5
10.0
11.5
13.0
14.5
16.0

Slide 26

Limiting Human Intrusion Scenarios



analyses are identical except that different quantities of material are available for release.

AIRDOS-EPA was the primary analytical tool in the analyses (Slide 27). We looked at inhalation, ingestion, and immersion doses, and again the inhalation dose was the only one of any significance. The domination of the inhalation dose occurs because at the end of 1 or 2 years the brine pond would normally be covered, using heavy equipment. If heavy equipment were not used, the doses would go down because no resuspension caused by the equipment would occur. To assure that we were obtaining a reasonable evaluation for maximum dose to the intruder, we also looked at the impact of taking a core through the disposal site and having that core inspected by workers.

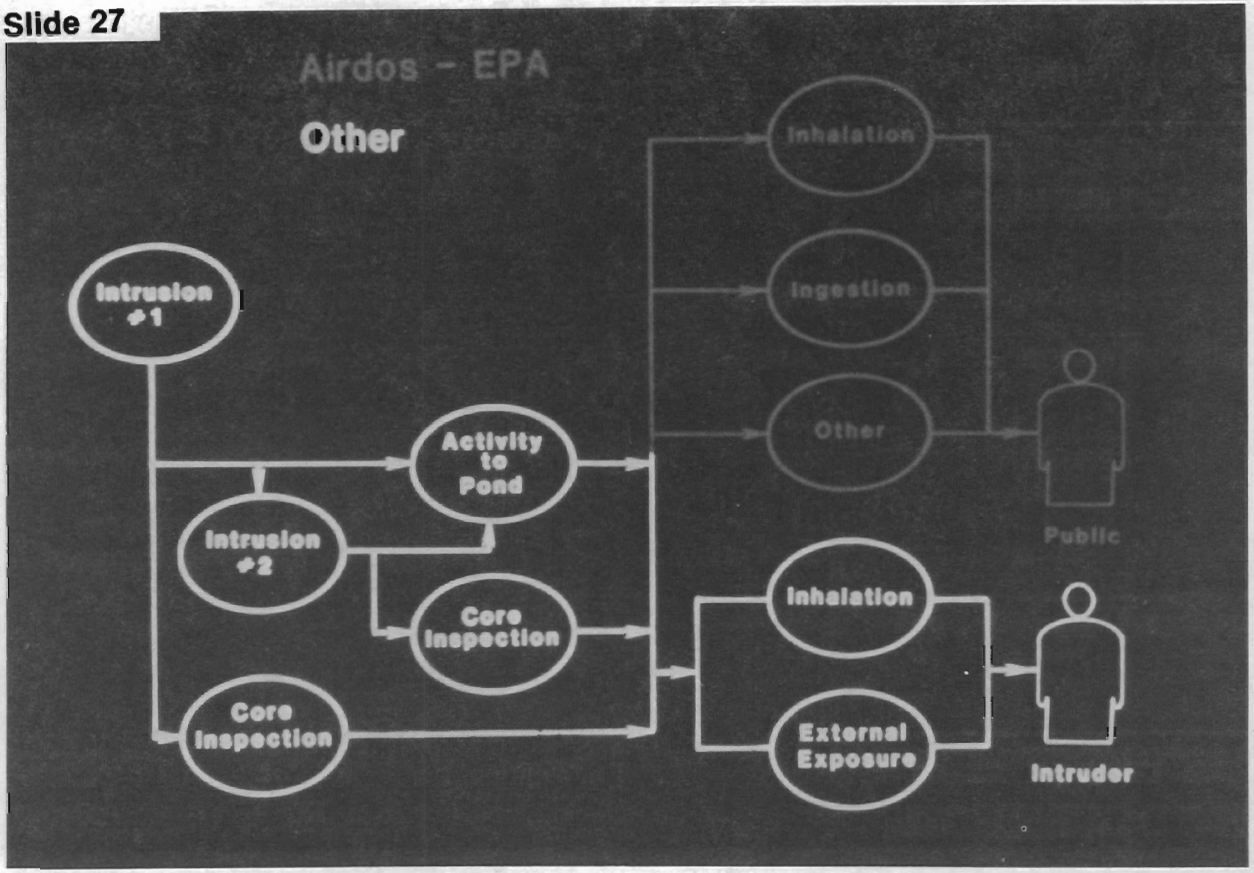
Because we were unable to establish solid numbers for many of the parameters that are site-specific (e.g., particle size), we also evaluated the impact of various parameters. Many of them did not produce a significant impact on inhalation dose, and it is useful to know they have little impact on our results. Knowing this allows us to evaluate results only for those parameters that did have an impact.

Slide 28 summarizes the results of the analyses. The communication event doses are all relatively small. Even the communication event that involves local well water produced small doses. The brine scenarios occur about 250 years after closure; we predicted doses of about 92 millirem for scenario 1 and of about 520 millirem for scenario 2. This is also the intruder dose for scenario 2. I have a little difficulty defining the term intruder for scenario 2 because if someone lives within 500 m of the site, which is the worst-case location, he gets as large a dose as the worker. In fact, the projected dose for this "intruder" is slightly larger than the one for the worker because the intruder has a longer residency time and is there as the pond is drying out, after the workers have left. The core inspection dose, which is the limiting dose to the intruder in scenario 1, is 520 millirem, which does exceed the 500 millirem that has been discussed at this meeting. All the doses could be reduced by making a sophisticated assumption on particle size.

I believe our doses at WIPP should be treated like accident doses instead of special situations. Maximum individual doses at a reactor facility are certainly higher in an accident than those occurring during normal situations.

Finally, we looked at and evaluated our releases as they relate to the new 40 CFR 191. Whether the limit is 10 nCi/g or 100 nCi/g makes little difference to WIPP. The effects of the maximum loaded containers, not those of the average loading of the containers, dominate our analyses and our results. The only effect that changing the limit might have on us would be decreasing the doses we are subjected to by decreasing the content of the facility. The interaction between the two limits may cause us a problem, and we have

Slide 27


Airdos - EPA
Other
Intrusion #1
Activity to Pond
Intrusion #2
Core Inspection
Core Inspection
Inhalation
Ingestion
Other
Public
Inhalation
External Exposure
Intruder

Slide 28

MAXIMUM INDIVIDUAL DOSE FROM SELECTED LONG RELEASE, REM

	Time of Occurrences (Years)	Total Body	Lung	Bone
COMMUNICATION EVENT #1 (River Outlet)	1E+6	9.5E-6	——	1.6E-8
COMMUNICATION EVENT #1 (Local Well)	4E+5	9.0E-4	——	1.2E-3
BRINE SCENARIO #1	2.5E+2	9.2E-2	3.4E-1	1.7E-1
BRINE SCENARIO #2	2.5E+2	5.2E-1	2.3E+0	1.2E+0

MAXIMUM WORKER DOSE FROM INTRUSION SCENARIOS, REM

BRINE SCENARIOS #1	2.5E+2	1.2E-1	4.5E-1

considered it in our evaluations of scenario 2. Scenario 2 produces significant releases of americium and plutonium, and the outside group that evaluates our analyses believes that scenario 2 is a potential release. If the total activity basis for the limits is reduced by a factor of 3, that would help. For intrusion scenario 1, our projected release is about 13% of the limit. In intrusion scenario 2, assuming that it is an unlikely release, our projected release is about 10% of the limit.

In conclusion, I would like to say that this type of facility appears to be one of the safer types in the nuclear industry. I am not sure I understand, and I cannot justify, the public concern over it. We receive many times more comment and recognition in the press than other facilities do. Thank you, and if you have any questions about any of the analyses, I do have some references that specifically clarify and summarize them.

Jack Healy, Los Alamos National Laboratory: I have a comment rather than a question. First, you said the 3 to 10 micron particles do not deposit well. This not true because the main mechanism for deposition of particles in that size range is aerodynamic and not velocity. They actually have a pretty good settling velocity. Second, you indicated that you should be able to use accident numbers as the NRC does. I do not believe that the NRC has a number for accidents. It does have a number that it has given for site selection purposes only, and that number is not to be interpreted as meaning "acceptable."

Preston Hunter, Ford, Bacon, and Davis, Utah: The last speaker brought up my question on decontamination and decommissioning, and I don't know if you are the person to ask. Have you anticipated the quantities of waste and the types of waste containers and materials that might be generated by decontaminating and decommissioning? If so, how much of an impact will that have on TRU burial at WIPP? Assuming that these types of waste might be in the form of bulk materials, contaminated equipment, cores, etc., what is your opinion on the relative impacts of trying to cut that waste up to fit it into a 10-m diameter hole in WIPP versus leaving it in place and covering it up?

Woolfolk: To answer your first question, one decommissioning concern is designing TRU waste packages. If they are large enough to hold such things as glove boxes, I don't think they will have much impact on WIPP. The materials most difficult for us to dispose of are plastics and paper covered with plutonium dust. My personal opinion is that we sometimes go beyond reason when we start cutting things up that are plutonium- contaminated. We take more risk cutting them up and preparing them for storage in a geological repository than is justified. We would not be subjecting future generations to significant risks if we dispose of them in a more reasonable manner.

Bill Lennemann: I missed something in your reasoning. You've done an excellent job, but in your brine scenario 1, you said that the geologist indicated that there wouldn't be enough brine under pressure to force its way to the surface when you hit it. Did I understand that right?

Woolfolk: I may have stated that incorrectly. There is sufficient pressure to force the brine to the surface. In fact, it is assumed to flow for 24 h. However, the disposal area has been closed with enough backfill to have enough integrity to resist the movement of the radioactive material brought up the shaft by the brine, and effectively no waste is removed from that shaft. The natural preference is for the brine to go straight up the shaft--that is the easy pathway. That movement actually appears to force the material away from the hole. Let me add a couple of comments. All of the brine scenarios are probably incredible. During normal drilling activities when you hit soft material, as you would at this site, you do things that effectively isolate the soft material because it interferes with your drilling process. You dump in mud, you case the hole, or you do something to get that stuff sealed up because it takes away the drilling fluid that you have to have to drill with. An occurrence like the brine scenarios would be artificial.

Don Box, Oak Ridge National Laboratory: Three or four years ago I read that some transport studies had been made on how products traveled from the OKLO natural reactor in Africa. Have any of your scenarios been compared with those?

Woolfolk: I don't know. Most of the transport scenarios were done by Interra with Sandia National Laboratories. I think SWIFT code was used. The analysis was done before I got to WIPP. But a comparison like you suggest might be valid.

COST-BENEFIT ANALYSIS OF ALTERNATIVES FOR DISPOSAL OF ALPHA-CONTAMINATED SOLID WASTE

Jerry Cohen, Science Applications, Inc.

The title of this paper is "Cost-Benefit Analysis of Alternatives for Disposal of Alpha-Contaminated Solid Waste." That title may be misleading. It might read better, "Cost-Benefit Analysis on Concentration Limits for Near-Surface Disposal of Transuranic (TRU) Waste." The discussion will first include a primer on cost-benefit (C/B) analysis. To those of you that are already familiar with the subject, I apologize. However, it has been my experience that cost-benefit analysis has been subject to much misunderstanding and misapplication so it may be well to review the general philosophy and approach.

Cost-benefit analysis is really not a very complex or mysterious subject. The object of cost-benefit analysis is simply to determine whether you get your money's worth. Cost-benefit analysis has an interesting history. It was developed in the Soviet Union during the 1930's. In a communist society, it is difficult to determine the effectiveness of programs. In a capitalistic society at the end of a fiscal year, a company like General Motors knows exactly how well they are doing. They can look on the ledger books and measure their performance in terms of dollars and profit. But in a communist society, it is more difficult. Therefore, a need existed, and C/B analysis was developed to assess fiscal effectiveness. In the years following World War II, cost-benefit analysis was adapted for application in many government programs in this country.

I became interested in the subject after witnessing several very costly health and safety programs that seemed to produce minimal benefits in terms of hazard reduction. I could not help but wonder whether the money might not be better spent in other areas. A longstanding problem in the field of public health is determination of how limited financial resources can be optimally applied. Cost-benefit analysis is intended to assist in the solution of such problems.

Cost-benefit analysis has been widely misunderstood. I will give you some examples. First, NEPA legislation specifies that cost-benefit is to be considered. Typically, in an environmental impact statement, you will see a section entitled "Cost-Benefit Analysis," which proceeds not to analyze a cost benefit. What they do is itemize all of the benefits, all of the costs, and make a subjective assertion that the activity is justified. Implicit in cost-benefit analysis is the premise that you can place a price on anything. I won't get into the complexities of it, but it may involve shadow costs, surrogate costs, discounting methodology, and hierarchy of objectives; however, values can usually be ascribed. To perform C/B analysis, you must

also definitively state the objectives that you are trying to achieve. This requires a certain amount of discipline.

A typical misapplication of C/B analysis may, for example, be found in the Environmental Protection Agency's (EPA's) approach to economic assessments. In evaluating the impact of a proposed policy or regulation, an assessment is made to determine whether a significant economic disruption to the affected industry or to the national or local economies would occur. The more rational question to resolve would be whether the cost of implementing a health or environmental policy would achieve a commensurate improvement in the state of health or in the environment.

Cost-benefit says, if you are going to spend money to get a gain in health and environmental quality, then you have to determine whether that gain in environmental quality justifies the expense. Therefore, you must find out what you are going to spend and what you get in return for that expenditure.

Appendix I of 10 CFR 50 could also be considered a misapplication in that it specifies $1000 per man-rem averted. Then it goes on to say it applies specifically to light-water reactor effluent. You are spending $1000 and what you are getting is the aversion of 1 man-rem. The misapplication is that it's restricted in application to light-water reactors only. If there is any validity to the cost-effectiveness of this guideline, it ought to apply "across the board" unless one could make a case that a health detriment of 1 man-rem varies as a function of the source of that man-rem.

Finally, the environmental impact statement in support of 10 CFR 61, portrays another misapplication. Let me read it verbatim. "In the spirit of ALARA, the lower value of 10 nCi/g has been demonstrated as an achievable concentration to control the disposal of TRU nuclides. This value has been imposed by DOE for some 11 years and by most of the commercial disposal site operators for nearly that long. The commercial site imposed the 10 nCi/g restriction in 1979, thus there is no need to increase the limit." Translated, I get the impression that means if you can afford to do it without going broke, you must do it. Again, in the spirit of ALARA and rational cost-benefit analysis, one would have to ask the question, "Would the economic cost of restricting the limit justify whatever additional health detriment might be avoided?" This question has not been addressed by NRC.

Application of cost-benefit analysis to health and safety programs is not immoral or unethical. However, some people seem to feel that it is repugnant to trade off dollars or money against human health and safety. In fact, it is not. We do it all the time. Cost-benefit analysis provides a means for doing it effectively. Cost-benefit analysis is consistent with ALARA guidelines, which specify that risk should be as low as is reasonably achievable taking into account social and economic considerations. Finally, cost-benefit

analysis is simply a way to get the most for your money in terms of health and safety.

A precept in the application of cost-benefit analysis to health and safety programs is that zero risk is unattainable. Regardless of how safe it is, any activity can be made safer yet by spending more money. You can and should place a monetary value on life and health. We do it all the time when we budget health and safety money into different programs. What we are suggesting is that it should be done efficiently. The problem is that we do it all the time, but we do not talk about it, which condemns us to doing it inefficiently.

Safety is a value judgement, and can be too safe. When you commit limited resources to a single area of health and safety where they do not achieve a great marginal return, you are necessarily leaving those resources unavailable to be spent in any other area of health and safety, where they might have been more beneficially applied.

The steps to determine cost-effectiveness in compliance with the law and with cost-benefit analysis, particularly with waste management alternatives, is as follows. First, you identify what it is you want to achieve (e.g., bury radioactive waste, etc.). Second, and you line them all up, then you determine if each alternative meets individual dose standards. You reject those that don't. In cost-benefit analysis, or in systems analysis, this is known as a constraint. The law of the land is that you shall not do anything that gives any member of the public greater than 500 millirem/year. That represents a constraint. It really does not matter what else you do in that alternative. Unless you can bring that alternative below that constraint, you must reject it. Assuming that there are several successful alternatives that meet that constraint, you then determine the cost of each alternative. In this case, you determine the collective or population dose on each alternative. Then you eliminate inefficient alternatives. In other words, if there is one method that is less costly and results in a lower collective dose than another alternative, you accept the first and the second. You then order the alternatives by increasing costs or decreasing dose. You determine the differential cost and differential dose, and then you finally select your optimum alternative according to some predetermined cost-effectiveness guideline. This guideline is set on a larger societal basis. The $1000/man-rem figure could be considered a cost-effectiveness guideline.

Unless you have an infinite number of alternatives you do not get a smooth curve. Normally it is a step function, and you compare the differential in risks with the differential in cost.

Let's assume that you have four waste management systems or alternatives that meet your maximum-dose criteria. We'll just call them A,B,C, and D. Second, we'll assume that an acceptable cost-effectiveness guideline is $1000 man-rem. Alternative A is $150,000,

B is $200,000, C is $400,000, and D is $1,000,000 per unit of waste, which could be per cubic meter, per metric ton, or per gigawatt electric hour--whatever unit you want to base it on. Let's assume that the decreasing dose is 1000, 800, 700, 650. You determine the differential. The differential dose between B and A would be $50,000. The differential in dose would be 200 man-rem. Now, you calculate the differential cost. If I selected alternative B instead of alternative A, I would be spending $250/man-rem. Therefore, B is a bargain. If I select C over B, I would be spending $2000/man-rem. If my guideline is valid, then I am saying that C is not worth it. Selecting D over C would result in $12,000/man-rem. In this case, I would select alternative B as being cost effective. We are going to use this approach to determine reasonable TRU waste limits. To do that, we are going to make the following simplifying assumption. What we are going to do is a generic determination. I realize this could also be done on a site-specific basis, but it is easier not to and we do not have site-specific data. For the alternatives we consider, we first assume that the maximum dose limits have been complied with. Other discussions have been presented today on modeling the predictive calculations required to determine compliance with maximum dose, and there are some serious problems with that modeling. I think we characterized it before. If you want to find out if a given scenario will exceed the maximum dose, you can do so by simply selecting the right parametric values. If you wanted to meet the maximum dose, you can do the same thing. There is much subjectivity in this modeling. I am not dealing with this subjectivity, but we will just assume that the maximum dose limits have been complied with. In the areas about which we are going to talk, these limits have been mostly complied with. However, that is little more than an opinion.

We are only going to consider two alternatives for this analysis. One is near-surface disposal, which used to be called shallow land burial. the other we will call geologic isolation, which would include all other alternatives (deep geologic disposal, greater confinement, ocean disposal, or any other alternatives more restrictive than shallow land burial). Here is a conservative assumption: we are going to assume that which ever of these alternatives you use, geologic isolation is perfect. In other words, no dose will result from geologic isolation. Therefore, the dose differential will be the dose you calculate for near-surface disposal minus zero, which is the collective dose you calculate for shallow land burial. Finally, we will use the simplifying assumption that we discussed this morning: all alpha emissions stem from plutonium-239.

I don't know if we are going to have enough time to go into detail on this, but for this calculation, we will use an analog approach. An analog approach is based on the assumption that any radionuclide will move through the biosphere at about the same rate as does its naturally occurring stable-element analog. Craig Smith discussed this a little bit this morning, and this is true for stable elements. This assumption circumvents the detailed-pathway analysis. It is

based on observation. We know, for example, the average geochemical concentration of stradium in the surficial environment with a fair degree of accuracy. If you study nutritional tables, we also know the quantity inhaled for all the given elements. From these data, we do not know the mechanism and there are probably many different mechanisms. We also know that the average would vary considerably for specific individuals; however, the average will be maintained from year to year, and there is a relationship between geologic concentration and biological concentrations. We see this relationship manifested in actual diseased status. That is how we found out that fluoride was good for the teeth. There was an area in Texas where kids never got cavities, and researchers found an increased level of fluoride in the environment. This is true of most trace elements.

Knowing the average quantity ingested and inhaled and knowing the average geological concentration for each element, for natural analogs, we can calculate the probability per year that a given atom of any given element will be ingested or inhaled by a human being. We will assume that collective dose in man-rem is simply the sum of the collective dose via inhalation pathways plus collective dose via ingestion pathways. Collective dose via ingestion can be calculated as follows: it is the probability over all time for ingestion. For plutonium-239 this is 3.2×10^{-5}. There is no natural analog for plutonium, but we can derive it from similarity studies because chemically similar elements behave similarly.

The annual probability of ingesting an atom of plutonium in the surficial environment is about 9.3×10^{-10}; however, because of the long half life associated with plutonium, we integrate the probability to infinity. This means that the average main life will be 24,000 years divided by the natural $\log_e$ of 2, or about 35,000 years. Therefore, we multiply the 9×10^{-10} by 35,000 years, and the result is a total probability over all time, given that a plutonium atom in the surficial environment has a collective dose of 3.2×10^{-5}.

The FC is the biggest fudge factor in the whole calculation. It represents a containment factor similar to the one that previous speakers have used; however, we have defined it as the ratio of the biological availability of the material in your shallow land burial and its natural analog. I am guessing at this definition for purposes of this analysis. This is perhaps an educated guess; we are going to call it 0.1. Conservatively speaking, the efforts we take in shallow land burial, judicial site selection, and waste-form development will help us engineer our shallow land burial materials so that the material we bury is about 0.1 as available as a natural analog of all the materials. That is a very conservative estimate, but it may be accurate if we dig random holes and bury the waste with no concern for population distribution, remoteness, or humidity. We must be better than a factor of 10, or we are wasting a lot of money.

The next item is curies per cubic meter, which is $1.6 \times 10^{-3} \times c$. The c represents nanocuries per gram. I used a density of 1.6 in deference to Bill Kennedy. I would rather use 1 because it makes the arithmetic easier. All we did is convert curies to nanocuries and grams and incorporate the density.

We took the ingestion dose conversion factor from ICRP 30, which states that dose is less than 5 man-rem/year. If you ingest an annual dose limit, you are going to get 5 man-rem, regardless of whether that is ingested by one person or a million people. In other words, the distribution of the material does not make any difference. For plutonium-239 ingested by a population, you will enter the stochastic range. You will get 3×10^{5} man-rem/Ci ingested. If you multiply that out, this is dimensionless, and you get an answer in terms of man-rem per cubic meter. This equals $1.5 \times 10^{-3} \times c$, which is concentration, nanocuries per gram, and man-rem per cubic meter. If you bury 1 m^3 of waste in a typical shallow land burial containing 1 nCi/g and integrate it over all time, you will get 1.5×10^{-3} man-rem.

We can calculate the collective dose via inhalation similarly. The procedure is similar. There is much less probability that the atom will be inhaled than ingested. In this case, the probability is 6.3×10^{-9}, or roughly 4 orders of magnitude less than the ingestion probability. Again, we will assume that our containment factor is 0.1 and that our density conversion is also 1.6×10^{-3}. From the inhalation material, we determine that one would get 2×10^{8} man-rem/Ci inhaled. We had always suspected that is far more dangerous, curie per curie, to inhale plutonium than it is to ingest it. If you multiply that, you get the collective dose via inhalation of 2×10^{-4} man-rem/m^3. If you have 10 nCi/g waste and you bury it in a shallow burial setting, you will average about 1.7×10^{-2} man-rem.

We are now getting into the cost-benefit part of this discussion. We will assume (I think this is reasonably consistent with much of the previous discussion) that the cost of geological isolation is \$5000/m^3 more than the cost for shallow land burial. I think Dixie Lee Ray used a figure of about \$12,000, but for GCDF, the number is not nearly that big. You can scale it for whatever cost differential you like. The arithmetic is relatively easy.

You plot these results in the form of collective dose versus the TRU concentration limit. This is the result based on the formula that we just derived by analog analysis. If you have a cubic meter of waste whose concentration of waste is 100 nCi/g, you will get about 0.16 man-rem over all time. We can only find one other citation in the literature that attempted to determine population or collective dose from waste in shallow land burial. That reference is NUREG 0456, for which Vern Rogers is responsible. We derived a collective dose figure from that and we plotted a curve. There is pretty good agreement for this sort of thing. Keep in mind that there are wide error bands of about 2 orders of magnitude.

Let's talk about some of the assumptions involved. Keep in mind our SC factor of 0.1, which I think is quite conservative. Were we to use perhaps a more reasonable factor of 10^{-4} or 10^{-5}, that would bring this curve down closer to the NUREG 0456 curve. This will give you a feel for the difference.

Again, given the $5000/m^3 differential in cost, if you have 100 nCi/g waste and you use the analog analysis, the marginal cost of putting it in geologic isolation as opposed to shallow land burial is about $2900/man-rem. If you use NUREG 0456, it is hard to justify anything more restrictive on any assumptions because now you reach $\$10^9$ or $\$10^{10}$/man-rem, which is unjustifiable. Keep one other thing in mind. There was another kind of conservatism in our analysis. We integrated to infinity, and we assumed that it is as justifiable to spend $1000 to avoid a man-rem 10,000 years from now as it is to avoid a man-rem next year. If this counting has any validity, that is an absurd assumption. Let's assume we have a choice. We could spend the $1000 to avoid 1 man-rem 10,000 years from now, or we could invest it. We could invest it so that it gains an interest of 1% greater than inflation. That should not be too hard to do. The value of that money after 10,000 years, would be about $21 million. Is it worth $21 million in 1982 dollars? I don't have an answer to that, but my intuition tells me that our calculations are fairly conservative. Cost-effectiveness is hard to justify under most circumstances on a cost-benefit basis. Let's take the 10 nCi/g level, which is what we are now using. We are retrievably storing wastes of about 10 nCi/g, with the idea of perhaps committing it to something more restrictive. Let's assume that whatever we restrict it to is perfect in every way and that we would get zero dose from it. What we are avoiding? What are we going to get for our money? Based on analog analysis at a 10 nCi/g, we would be spending at the rate of $250,000 per man-rem averted. It's hard to justify. This tells me that, although, there are error bands here, you ought to be able to justify elevating that limit.

From data we got out of the Oak Ridge 0017 Report, we now have 2.6×10^5 m^3 stored or buried, 6.1×10^4 m^3 retrievably stored, and a project producing TRU waste at about 4.5×10^3 m^3/year. Using Shefelbind's data, we estimated that this is about the breakdown of the stuff retrievably-stored. We are also going to assume that the projected waste has about the same concentration distribution as does the retrievably-stored waste which is about 20% below 10 nCi/g, about 37% between the 10 and 100 nCi/g, and 38% between 100 and 1000 nCi/g. This is roughly the breakdown. In other words, were we to raise the limit from 10 to 1000 nCi/g, this increment of waste could be put in shallow land burial at a cost of $5000/m^3 less than in more restrictive isolation scenarios. If we raise it to 1000/nCi/g, we could include this increment.

The economic impact of raising the TRU waste concentration for near surface disposal to 100 nCi/g would result in an annual cost savings

of about $18.6 million. If we raise the limit to 1000 nCi/g, we could save $39 million. If you raise the limit to 10,000, the savings would be $42.7 million. We assume that the currently stored waste will all be buried uniformly over a 10-year period and that the waste projected would be produced during that time. Again, the differential cost is $5000/m^3. Transportation costs, which were discussed earlier, have not been included in this analysis, and the cost of exhuming the already buried waste and doing something with it has also not been included. However, by our estimates, the cost would be large.

Denis Thackrah, Nuclear Installation Inspectorate, United Kingdom: First, I'd like to make a comment, and then, if I may, I'd like to ask a question. The containment factor you have conservatively chosen as 0.1.

Cohen: I hope it's conservative.

Thackrah: Why do you hope it's conservative? If you are doing a proper cost and benefit analysis, you ought to choose a realistic number rather than a conservative one.

Cohen: You are absolutely right. I agree that there is no such thing as conservativism in cost-benefit analysis. In this case, the most conservative figure I could have used would be the one that happens to be most realistic. Because we have no "realistic" values, I picked a pessimistic value (0.1).

Thackrah: Thank you. The question I'd like to ask you is one relating to cost-benefit analyses in general. How do you introduce the cost of an accident when you don't know the extent of an accident?

Cohen: Probabilistically.

Thackrah: Probabilistically?

Cohen: It can be done. In other words, you determine the expected value, which is the product of the probability and the consequences. The desirability of avoiding a given risk would be a function of the product of the magnitude of the consequences times the probability of their occurrence. Then you place a price on that. Obviously, society would be better off spending money to avoid the more probable accidents than those that are less probable.

Charles King, Savannah River Laboratory: Having spent 2 years as a senior financial analyst for DuPont, I compliment you in your understanding of the subject and your ability to explain it. Is the economic impact that you show a per year dollar value?

Cohen: Yes, for the first 10 years, until you get all the retrievably-stored stuff buried. After that, it would go down because

then all you must worry about is the material being produced each year.

King: That is for the whole DOE complex?

Cohen: Yes.

King: That would be about a half a dozen sites?

Cohen: I think it's actually more than that.

King: You could break it down by cost incentive by site.

Cohen: I specifically excluded transportation costs in the analysis. I think it might double the cost savings if we were to do that based on the figures that we saw this morning.

Preston Hunter, Ford, Bacon & Davis: How do you persuade either our governmental system or the public to accept cost-benefit analysis and justification that we can afford to do it? Does the benefit derived justify the cost?

Cohen: I don't know. In fact, there is an OMB directive right now on the books directing cost-benefit analysis. Cost-benefit analysis is often ignored.

Hunter: I guess the thing that is not in your calculations for cost-derived factors, or whatever you want to call that CD factor, is the perceived public risk.

Cohen: That's not included at all. But on the other hand, I would question whether very restrictive controls have any ameliorative effect on public perception. As a matter of fact, I think it's quite the opposite. The greater length to which we go to control a given risk, the more concerned the public will be about it. Because they actually think we are rational in our decisions.

GENERAL DISCUSSION

Martin Steindler, Moderator, Argonne National Laboratory

Steindler: The program committee will attempt to resolve the question of what can we get out of all this discussion and will present some conclusions later. We will now address questions that you didn't get a chance to discuss when we were in the regular sessions.

I have a few comments, however. The issue of de minimi concentrations of alpha contamination in wastes has not been mentioned. On the other hand, the back-of-the-envelope calculation of the amount of alpha activity in a smoke detector indicates that the concentration may be significantly higher than 10 nCi/g. Those smoke detectors are routinely destroyed and discarded in sanitary landfills. We are concerned here about reasonably well controlled alpha activity being discarded, but we throw away smoke detectors in an uncontrolled way.

Also, a significant number of speakers have talked about K_d values as part of their accident and risk analyses. Most of those K_d values, especially for geologic domains, were taken from either laboratory studies or a very small number of experiments in actual geologic formations. Most of those data are probably inapplicable to the conditions under which shallow land burial is practiced. Specifically, enormous differences in behavior of elements, particularly actinides. are encountered when variations in the E_h, valence states, and even more important, the high level of organic complexing agents that are found close to the surface are factored into predictions of actinide migration. Experiments done with groundwater for deep geologic disposal may not produce data useful for shallow land burial.

Another issue in some accident scenarios that determine risk values is the one of leach rates. I think very few people have discussed the kind of chemistry of the waste that is pertinent. There is an enormous difference in the leach rate of high-fired PuO_2 compared to a soluble plutonium salt.

Question: Marty, the question is to you. Do you intend to disseminate a compilation of all these papers that have been presented here, including the discussions, which I think are quite important?

Steindler: My personal interest is to try and put the entire proceedings between two covers and issue them. I also think that a peer group review of the papers will be useful. Because some of the papers will be slow in coming because it's an enormous amount of work to put them together and because some of the papers are review papers that may not fit into the same kind of journal that accepts original contributions, I would think a combination of both proceedings and subsequent publication of some of the papers in a refereed journal might be best.

Alan Moghissi, EPA: The Journal of Nuclear and Chemical Waste Management originally made the offer to publish the information generated in this workshop. That information falls into three categories: original contributions, review papers, and policy statements or expressions of opinion. Every learned journal has a place for all of these categories. Most learned journals these days publish reviews (we certainly do), and most learned journals publish original papers. Statements like the one by Dr. Ray are welcome contributions as editorials in most journals. Let me for a moment play the environmental game. I hate to see more pollution done by generating useless papers. Expression of opinion is exactly that, expression of opinion. For the purpose of using it to promote a thought, promote science, or promote disseminating information, it is nothing more than an ego trip for the one who made the statement. Most learned journals also have a category called "Letters to the Editor"; that category is also open to anyone who feels like making a statement on views that were not given in the papers. The reason I'm so vehement is this. This was a nice meeting and I certainly learned a lot, but a great deal of what we heard can be eliminated without losing anything. I would personally discourage a word for word, cover to cover publication of the material.

Jerry Cohen, Science Applications, Inc.: I'll throw out a provocative question, just wondering if somebody will argue with me. For purposes of controlling transuranic (TRU) waste, the so-called intruder scenario is irrational. Let me present my thinking on it and then maybe someone will have some counter arguments. We've been involved in a study for the last year on the toxic hazards of underground excavation, which are not generally known. Quite frequently in this country people dig a hole in the ground and die. In Michigan some people hit H_2S pockets. Three kids just died near us in California. They went into an abandoned cave and died of oxygen deficiency. Society is a little bit concerned about it, but I notice that cave isn't sealed up yet. But we're now advocating spending what could literally be hundreds of millions of dollars to prevent some individual 10,000 years from now getting a dose of 500 millirem. The idea bothers me. If I'm all wet, please straighten me out.

Steindler: Is somebody prepared to straighten him out? Let me at least comment that it is too late for you to consider that. The intruder scenario is now essentially a part of the licensing domain. You should have complained a lot earlier. You can try and determine for the Nuclear Regulatory Commission (NRC) that the intruder scenario is nonsense.

Steven Woolfolk, Westinghouse/WIPP: I'm sort of supporting Mr. Cohen's data. Two of the scenarios I discussed involved brine pockets and drilling into brine pockets. Generally, if you drill into an uncontained brine pocket in the WIPP area, you get a release of H_2S gas and that routinely kills people at the drilling rig. In comparison to the risk associated with hitting a brine pocket,

the risk associated with hitting a waste disposal site is trivial, something that nobody seems interested in, but that is a fact.

Paul Dejonghe, CEN/SCK Boeretang 200, Belgium: I agree with you gentlemen. However, when we decide to transfer more waste from shallow land burial to deep geological formations, I think we expose more people, more miners, more workers to such immediate dangers. Is that not a fact to consider? I'm convinced that this is true because if we build an underground mine with galleries and more, I would be extremely astonished if we would not have little accidents. That keeps me awake at night when I think of it. This is to protect people, exactly like was said, within 10,000 years from 500 millirem. I think it is something very serious.

Preston Hunter, Ford, Bacon, and Davis: Concerning the question of technical versus political considerations for the intruder calculation, I think, from a practical sense, it is clear to many people that we in the technical community do a lot to mitigate the public perception of risk, sometimes at great cost and sometimes at perhaps unreasonable cost, considering the limited economic resources we have available. On the other hand, we as technical people need to try to walk the line between increasing the public's perception of risk and mitigating the risk. I can see the practicality from an NRC or Environmental Protection Agency (EPA) legal point of view of evaluating a limit such as 10 or 100 nCi/g for near-surface disposal where intrusion may sometime be likely to occur. And the public perception of that occurrence may be enough to justify a reasonably low number. But we should also consider that world in between near surface and geologic isolation where in fact we may be able to go to reduce cost on greater confinement disposal with additional covers, engineered barriers, deeper burial, what have you, for TRU waste.

Vern Rogers, RAE Corporation: I can't resist also responding to some of Jerry Cohen's thoughts. Perhaps behind his concern are the numbers that come up and how an intrusion scenario was treated. Certainly, considering the protection of some maximally exposed individual is a basic characteristic of health physics. The step from considering the maximally exposed individual to considering conditions that can occur and the time periods isn't very long. I'd like to suggest, and see what others say, that the concept of the intrusion scenario isn't necessarily disturbing, but the manner in which we now treat it (i.e., the numbers, the time period we must consider, the way we consider it) basically is a consequence analysis. The limits we give might still be inconsistent with our other evaluations and perhaps that should be looked at more closely rather than whether or not the concept of intrusion is acceptable.

Bill Kennedy, Battelle-Pacific Northwest Laboratories: I have a philosophical statement here that underlines much of the difficulty that we seem to see here. In managing or attempting to model or predict the behavior of the TRU radionuclides in shallow land burial

and other disposal techniques, we're confronted with the uncertainties associated with all of the techniques; which parameters to use and how to do performance calculations are decided, in the final analysis, by the judgment of the scientists involved. Judgment is involved in selecting the parameters and doing the calculations and determining if an intruder is or is not a valid scenario. Any regulatory decisions about the waste forms will implicitly also be based on judgment. As a scientific community, that's why we're here, to review each other's work and try to gain a consensus of opinion on that judgment. We may never know all of the facts and we may never know all of the uncertainties, but as a scientific community if we can arrive at a consensus of opinion and a consensus of the basis upon which to make those judgments, then I think we've done our best job.

Steindler: I would like to obtain some expression of what the participants believe to be the major issues that are unresolved when we address a change from the current 10 nCi/g limit to 100, 150, 500, 1000, or whatever number you care to pick. Have you seen any technical impediments that have not been brought up throughout the course of the discussions that would challenge a statement such as: there is no reason why the value of 100 nCi/g, which we see in the proposed 10 CFR 61 for class C, should not be a perfectly acceptable value.

Bill Ellis, Savannah River Laboratory: I felt there was a lack of rigor in some of the papers presented, especially in Sessions 1 and 2. Much of the information presented was qualitative and not quantitative. It was even opinionated in some cases. I felt many of the papers were conclusive on relative hazard comparisons, but inconclusive on source term hazard impacts, and thus of doubtful value for this workshop on source term limits. Specifically addressing rigor, I think instead of tilting at windmills, we need cost benefits, based on experience, on environmental and operational impacts in general, but also specific to 10 and 100 nCi/g. Why is the 100 nCi/g number important? If it is specific to solving a problem at Hanford, would not an Environmental Impact Statement (EIS) be a more prudent and even necessary choice instead of solving the problem by raising the standard?

Denis Thackrah, Nuclear Installation Inspectorate, England: Why do you have to pick a magic number in the United States? Why do you say below 10 or below 100 nCi/g, dig a trench, and throw it in, or send it all the way to New Mexico and put it in a repository? Why not have some intermediate levels where you can say an engineered trench with concrete is needed for this because it's not worth the expense of putting it in New Mexico, but it's a bit too hazardous to put in a trench? Why don't you have a cheaper repository somewhere that's not quite as complex and not quite as secure as WIPP in New Mexico, but is still adequate for the sort of wastes that are going into it?

Steindler: I certainly don't want to have to defend the position that we've gotten into in the last 30 years to respond to those questions. I think they are excellent questions. I would like to have someone else respond to them.

Rogers: I might be a little optimistic, but I agree we should be heading in the direction of other concepts, such as intermediate disposal techniques that will allow intermediate levels. The NRC in its work seems to have opened the door in written material, and reconfirmed it in talk, that going in this direction is a possibility. Why one number? I'm in favor of trying to establish numerical limits as guidelines, even if the underlying philosophy is not strictly numerical. When ALAP and ALARA were applied in the reactor business, they were moving targets. What would apply one year was no longer acceptable a year or two later; it became extremely difficult to design and get licensing moving along when a non-numerical, non-quantifiable limit was raised. It was little more than a general evaluation on a case-by-case basis, and it became frustrating for reactor vendors, the utilities, and construction people.

Mike Barainca, DOE: I would also like to comment to the gentleman from England. We have had, as part of our low-level waste program, an evaluation of other confinement options. That is the reason that we are doing the study in Nevada. One of the difficulties that I found, and one of the questions that I've asked the people in Nevada, is how do you quantify risk? The assessment I get in the program is that if you go deeper, there is less risk from intrusion. But how do you quantify that in depth? You can look at sociological development and technology and find out how drilling technology has developed through time. The EPA has gone through that type of review, looking at the intruder, before it came up with this 100-year consideration, the loss of institutional memory. I think DOE, both in 10 CFR 61 and 10 CFR 60, has commented on "the 100-year period." There is a general consensus that you have to evaluate the intruder. Now, if you take a look at your position and say you give the guy some type of performance objectives and let him evaluate the site equated with those objectives, fine. I think that is essentially the approach the NRC has taken in 10 CFR 61 and that is the approach that we've been trying to take for the DOE sites. I was hoping to get information on four issues from the papers today, and I think the people who structured the meeting were looking for them also because that's the way the various sessions were structured. One was the hazard considerations, the type of paper that was presented by Rogers. Second was a comparison of accepted risks, the comparison of the ore body, the Oaklo phenomena, background, etc. Third was a summary of waste inventories and what the impacts of the changes will be. How well do we really know what we can expect from the D&D wastes? Fourth, how do you deal philosophically or technically with the intruder? I thought John Rodgers' paper was one of the key papers. I would like to ask John if he could tell us where Los Alamos stands on that paper. They've subjected the paper to broad review.

It was sent to all the agencies. It is in the process of being revised. Different numbers were put in that paper for health effects for various levels of nuclides. What did the technical community give Rodgers as feedback to his paper? I would also like to ask if the TRU program will follow up with the waste inventories and try to do a more rigorous analysis of the volumes they would expect to see changed before they formalize some position on 100 nCi or whatever number that seems to be.

John Rodgers, Los Alamos National Laboratory: Mike, the document that Jack and I wrote was circulated among the committee members who appear on the cover of the document. It wasn't published in open literature, and we've just recently gotten headquarter's approval to get it published and circulated. The answer, in part, is we don't really have the kind of feedback I think you are looking for. I hope that when we do get it published people in the technical community will respond and send us their comments.

I would like to raise one technical issue that I think ought to be raised and hasn't been. What is the effect of changing the limit from 10 to 100 nCi/g on the peak to average and what is the consequence for the intruder?

The idea of burying radioactive waste with some average of 10 nCi/g constitutes a significant departure from the kind of natural analog that Jerry Cohen is talking about. If you do want to contemplate intrusion, it seems to me that you have raised the possibility for contact with artifacts containing high concentrations. I have some misgivings about raising that limit without, at the same time, imposing some technology on the burial process that will lower the probability for intrusion into the waste.

Question: Would you not expect the peak average to drop?

Rodgers: Not necessarily.

Cohen: I have to take exception to what John said. If you're going to pursue that line of logic, I could develop a case that would show that even 1 nCi/g is too much because, if I'm not restricted in probability, I could dream up a scenario where some individual under the right set of circumstances could get quite a significant dose from that. What is your threshold of reasonability? We have to recognize that the decision is largely subjective.

Anibal L. Taboas, DOE: It's always easier to ask questions than to answer them. We can dig a hole to 3000 ft like we have in the WIPP site neighborhood, and we can create intermediate categories of waste at some other depth. It appears to be an accepted rationale that depth provides protection. Actually, we can dig a hole down to 3000 ft, put materials at different depths, and fill the hole all the way up to the surface according to different levels. We'll

have an infinite number of categories of waste. However, there are some practical considerations. When we generate waste, we treat it as waste. That's what we're talking about, waste, not the primary product. We don't have the resources to have an infinite number of categories of waste. What is being attempted is a rule of thumb that will allow for site-specific adjustment. We could study the problem forever. We could say that the volumes going into a repository might be decreased and some of them might go to a greater confinement facility. Actually, that would be assuming that, for example, a greater confinement facility would have higher numbers -- much higher numbers -- than 100 nCi/g. But in fact, there isn't that big cost differential. If you're going to do the job, you do it right and have the one limit. That provides a step function once waste gets past that limit. Adding additional step functions doesn't make the integral under the curve, the number of dollars, any lower.

There are places where the greater confinement, and that's somewhat undefined, would be quite valuable. It's been referred to at Hanford as In-Situ Mobilization. There are others, possibly at the Nevada test site, possibly at Oak Ridge, possibly at other sites that we haven't discussed. We continue to generate this waste, and looking the other way by not starting on the problem doesn't stop the generating. My last comment is this: there is talk of changing the limit of TRU from 10 to 100 nCi/g, but there is no such limit of 10 nCi/g for TRU waste. Some people will say that that exists in DOE Manual Chapter 511, or should I say AEC Chapter 511, which is not adopted by the DOE. We continue by tradition. Some people might say that NRC 10 CFR 61 Class A has 10 nCi/g, which is not finally promulgated. We don't have a guidance now. It's not that we're changing something, it's that we're establishing something in the first place.

Moghissi: I'd like also to thank Anibal Taboas for making one more third of what I was going to say, but let me get the last third of it. The EPA has no legal limit for TRU waste. DOE, Department of Defense, Department of Agriculture, or for that matter anyone in the business is more than welcome to set up internal limits for their own use. In fact, they should do so and, hopefully, the limits they set are more stringent than the legal limits set to protect the public and the workers. That does not stop anyone, certainly not the legally established agencies, from developing legal limits. But EPA does not have a limit; we are evaluating a limit. As Marty said, it's unfortunately a patch-up job, which is not a very nice way of doing business.

Craig Smith, Science Applications, Inc.: The model uncertainties for the intruder scenario that we've been talking about relate to hydrologic considerations, Kds, and such. I don't think you have those types of site-specific and model problems when the intruder scenario is driving the whole show, and I have to agree with Alan Moghissi's assessment of the relative importance of that scenario.

An agency like EPA needs to come up with some kind of philosophical position on what level of protection one should offer for inadvertent intruders sometime in the future. It almost goes without saying that the criteria established ought to apply to nonradioactive as well as radioactive activities of man.

Cohen: Am I to believe that that's not already been done? Let me address the question somewhat differently then, to the EPA. How does EPA treat the disposal of nonradioactive chemical waste and intruders?

Moghissi: Nonradioactive waste is treated much differently than radioactive waste. There are two laws, the Resource Conservation Recovery Act and the Super Fund and Hazard Obligation Surclause Comprehensive Environmental, etc., Act. Neither one says if you cannot establish risks with a chemical and if it is Class 1 and you have 1 lb of it, you do this; if it's Class 2, 10 lb of it, you do this; if it's Class 3, and so on. Not only that, but the presence of 1 lb of the first chemical does not prohibit you from having another pound of the second chemical, although the individual chemicals may have an additive effect (for example, carcinogens). There is a great deal of inconsistency. I was involved in looking at the radioactive side of the super fund regulations, which are still in progress. If we had treated radioactivity like we treated the other chemicals, in effect, you could have so much strontium-90 and, if you add plutonium to it, the limit for plutonium would be given, but the presence of plutonium would be independent of the presence of strontium-90 and so on.

Joe Lieberman, Nuclear Safety Associates: I think Craig is right. I think the intruder scenario is a major driving force, and it does need some rationality associated with it. In the proposed standard for high-level waste, as far as I can tell, about 90% of the health effects are associated with intrusion scenario. On the other hand, the NRC initially, at least, wrote off the intrusion scenario for high-level waste in the repository. Dan indicated that as a result of discussion, NRC and EPA are now much closer together. I don't know quite what that means, whether indeed some rationale has been developed that puts that intrusion scenario in a framework that is defensible, supportable, and rational. I would venture to say that if that's the case, it's gratuitous. Regarding the question about chemical waste, I think Alan said what has occurred to me, that if we were handling the radioactive waste like we are handling the chemical waste now, we'd be in a lot worse shape than we are. The way the whole subject of managing radioactive waste has been handled, in my view, is way ahead of the chemical waste. Generally, it seems to me that the question we are asking ourselves about managing of all these wastes, whether they be TRU or low-level or high-level waste, is, "How safe is safe enough and how much money are we willing to spend, can we afford to spend to achieve that objective?" Some people argue that the reason we're going to a repository for high-level waste is that the industry can afford it, and I think there's a measure of truth to

that. The analyses that have been done seem to show that the intruder is one of the driving forces. I have to agree with a point that Alan made, that we seem to be setting limits for very small populations. If that's the case, it seems to me that it is important to spend more time developing the rationale for intruder scenarios and deciding how we propose to handle them. Otherwise, it seems to me that we will continue to be in a position in which our resources for managing these wastes are allocated in an ineffective way. You mentioned, Marty, that it's part of the system now, and we won't be able to get around it. Well, there are a couple of us who say maybe in our old age we're going to institute some taxpayer suits. I'm referring specifically, for example, to the amount of money that is being spent to move the waste out of West Valley. This might affect the bread and butter of some of the people here, but I just don't see how we as a society can condone spending so much money to do something that really isn't improving the public safety at all. That kind of issue, admittedly, is not resolved by technical considerations. Our society passes a law, and we spend the money to do it. You're saying, as Jimmy Durante would say, "Them's the conditions that prevail." I can't argue with you, but it's not going to make it right.

Steindler: I want to clarify that I didn't say it was right. All I said was, "Them's the conditions that prevail."

Lieberman: I didn't quite get that impression from the way you responded to Jerry's comment. I think our work as scientists and engineers is to do a job that others have said we're never going to have all the information for.

Steindler: In that context I certainly think it's up to us to provide the regulators some alternative that both we and they can live with. We can't just continue to complain that the intruder scenario is costing a leg and an arm and runs the whole show. We've got to provide them something that we can buy, but they can buy as well.

Lieberman: That's the point I was making. With respect to that intruder scenario, I don't think we can kick it under the rug. We have to establish, to the best of our scientific and technical capability, what constitutes a defensible and supportable rationale for that kind of approach. How hard should the intruder scenario drive the system?

Barainca: I'm just going to respond to your question about models. I think the question asking how many models you need has been looked at some and we're still working on it. At a workshop in Denver about a year and a half ago, four hundred and some odd models were involved. We've agreed to get together and resolve what models we need. We've met with the NRC, EPA, and U.S. Geological Service (USGS) and their stance in the program is that you can't have just one model. Different models are required for different needs. You need different types of models for screening that have the flexibility to look at a

lot of parameters quickly, and you need more detailed models for more detailed site qualification. The EPA has a need for its own model as well. The one thing that is really evident, though, is that virtually none of the models is completely validated. What we're trying to do is get a data base for people to use to validate their models. The only agency we had that was neutral was the USGS. I have a task with the USGS in 1983 to put together that data base.

I'd like to ask a question to the group as a whole and maybe get a show of hands regarding the intruder. How many people think that we should consider the intruder when looking at shallow land burial?

Steindler: The record will have to show that a significant number of hands went up.

Barainca: The second question was, how credible is that event? I don't know how you can get that by a show of hands though, so just let everyone consider it.

David Gregg, Lawrence Livermore Laboratory: Everybody seems to be worried about the intrusion scenario, and we don't seem to be getting anywhere. I'd like to suggest a possible way to set bounds on it. If you think that you might dispose of nuclear waste, one fundamental principle is that if you've been there someone else can get there. So if you think about the future, what is the most likely situation that will happen? It's likely that with increased use of nuclear energy some future generation will be looking around to dispose of their nuclear waste. No matter what site you choose, or how you bury it, it's going to have an equal probability of an intrusion. So all sites start to look the same. Now this would be a base probability of intrusion, and then you can say any intrusion scenario that is less probable than this can be rejected.

Steindler: You've got to be careful with that argument because it drives you to the most unsuitable site to dispose your wastes because you know nobody else will ever in the future go out looking for that poor site.

Rogers: Making model calculations with the various intrusion scenarios and offsite transport scenarios, I feel more comfortable about the values assigned to many of the critical parameters in evaluating an intrusion scenario than I do about predicting what a radionuclide concentration in a well some distance away will be 10,000 years from now and what the consumption will be. We have a long way to go in evaluating and putting an intruder into context. But just because traditionally we've spent more time and money working on groundwater contamination, we don't need to feel uncomfortable just because different factors now appear to drive the limits of the system. I hear people concerned that the uncertainty of the intruder scenario (will the intruder occur or not) should be approached more probabilistically. Right now some consideration is given for

probability. The NRC in its proposed limits has given a factor of 20 to 75 millirem a year to 500 millirem a year, and that helps accommodate some of that. A factor of 20 may not be nearly enough, and I tend to think that extra credit could be given. What I'm saying is that many people feel uncomfortable about intrusion scenarios that might have the same degree of uncertainty or greater uncertainty than is associated with offsite transport scenarios. Yet many people here would feel comfortable in using the offsite transport scenarios to set a limit.

SUMMARY OF SESSION I

Joe Lieberman, Nuclear Safety Associates

This is a summary of Session I on source terms. The first paper by Rich Jensen from Rocky Flats covered the description and quantification of alpha waste from defense sources. These wastes were in three categories: wastes now generated and projected, wastes generated and stored in the early 1970s, and buried wastes. The largest sources of government waste are defense-related plants, particularly Rocky Flats and Hanford. Rich noted that the contact-handled (CH) waste exceeds the remote-handled (RH) waste by a ratio of about 30 to 1. The most diverse waste comes from the eastern sites, particularly Oak Ridge. I won't repeat any of the specific numerical data that were presented. Presumably, to the extent you were interested, you took notes on that and the data will be available. However, I would make the observation that while these inventory data are subject to error, they are probably the best available.

The second paper, by John Umbarger of Los Alamos National Laboratory, concerned the detection and determination of the alpha content of waste. New technology in the form of pulsed neutron interrogation coupled with passive radiation detection detected alpha contamination down to less than 10 nCi/g on single drums and to less than 100 nCi/g on multidrum crates in R&D situations. This is certainly in the range of interest in the alpha-waste management situations. This system is now being reduced to practice and certainly holds high promise for the application of separating alpha and non-alpha waste. The technique can be compromised by a number of factors, including unknown waste matrixes, unknown nuclide mixes, a wide mix of nuclides, a gamma background greater than 1000 r/h, and the presence of neutron poisons. However, John indicated that the system can generally indicate when there are problems with the waste being assayed. The accuracy of the method was indicated to be in the range of 30 to 50%. One item of interest was that the installed cost of the system is about $750,000 for a drum system and about $1.3 million for the multidrum crate system.

The third paper, by John Rogers of Los Alamos National Laboratory, involved a presentation of background information concerning the radiation hazards from alpha waste. John indicated that there is good agreement, plus or minus a factor of about 2, between experiment and calculation concerning plutonium inhalation hazards. There are wide error bands on calculated hazards from alpha emitters because of uncertainties in uptake rates, biological half-lives, the chemical form of the elements, and other factors. However, these uncertainties notwithstanding, most alpha emitters have roughly equivalent, plus or minus a factor of 10, doses per curie.

The last paper in this session, by Wally Sumner of Allied General Nuclear Services, discussed anticipated alpha-waste production rates

from a fuel reprocessing facility, specifically the Barnwell Nuclear Fuel Reprocessing Plant. The estimated alpha-waste production rate from the 1500 metric ton/year plant was indicated to about 85,000 ft^3/year at the 10 nCi/g limit. Most of this waste is estimated to come from the separations facility, and the major waste sources were cladding, which was 27%, and low-level CH general process trash, which was estimated at 32% of the total. It was estimated that 45% of the waste was combustible and 72% of the waste was compactible. These characteristics could have a significant impact on the final volumes as disposed. Changing the alpha-waste limit from 10 nCi/g to 100 nCi/g was estimated to reduce the amount of alpha waste produced by about 20%. Again, the uncertainty in this value obviously has to be substantial. One has to recognize that these estimates were just that; they were not based on any operating experience. The total plutonium losses to waste, including the high-level waste, was estimated to be 1.5%. The cladding waste was estimated to be contaminated with alpha emitters to the extent of 10^4 to 10^5 nCi/g.

John Sadler, Westinghouse/WIPP: I would like to make a correction in the ratio of CH to RH waste. That's probably more in the order of 100 to 1, not 30 to 1.

Lieberman: I don't know whether Rich is here or not to comment. Well, why don't we record that? Are you talking now about from fuel reprocessing plants or just general?

Sadler: Primarily based on defense waste.

Lieberman: Does anybody else have any comment on that particular point? I think that's a fairly significant point.

Well, I guess the point that's being made here is that the 30 to 1 ratio of CH to RH alpha waste is, at least in the experience of some people, too low.

SUMMARY OF SESSION II

Ed Albenesius, Savannah River Laboratory

Session II was planned to offer in some detail a review of disposal technology and practices for alpha-contaminated waste in the United States and a brief overview of similar technology and practices in Europe. Through the graciousness of our European visitors, a detailed picture of the state of the art in Europe was made available. We appreciate the fine effort of our attendees from Belgium, France, Sweden, and the United Kingdom in sharing their experience on this impromptu basis.

The presentations from the United States included one that addressed the present practice of near-surface disposal of low-level waste, as widely practiced within the Department of Energy (DOE) community, and a second paper that reviewed the status of work at the Nevada test site on the use of boreholes for deeper burial as an example of greater confinement disposal. These two papers addressed the issue of low-level waste management, and only qualitative inferences could be drawn on the issue at hand: what should be the limit defining transuranic (TRU) waste? In sum, from the viewpoint of these speakers, the impact of 10 nCi/g or 100 nCi/g or some other limit on low-level waste disposal was peripheral and not a real component of this issue. One striking conclusion of the work at Nevada on greater confinement disposal is that the long-term cost of such disposal in a dry site with alluvial deposits and a deep water table may be comparable to the cost of near-surface disposal.

The presentations on the Waste Isolation Pilot Plant (WIPP) and on the transportation of alpha-contaminated waste were both well done and enlightening. The operational emphasis of the first presentation makes the WIPP project come alive. To hear the speaker talk about reducing time on the construction schedule is a convincing argument indicating that we will soon have a real demonstration becoming a repository for the DOE plutonium waste now being held in interim storage. The presentation on transportation showed that the upgraded systems needed to get the waste to WIPP will be there on time with adequate capacity.

The European presentations provided some useful comparisons with the situation in the United States regarding the TRU limit. First, in Europe, there appears to be a more moderate view on intrusion compared to the preoccupation in United States with this issue. Second, and superficially, in the United Kingdom and France, the working limit for near-surface disposal is greater than 10 nCi/g and more like 100 nCi/g. Looking beneath the superficial, however, the important difference is that their limits are working limits; they are not cast in bronze like the 10 nCi/g U.S. value is now perceived to be. Europeans seem to have a more flexible and practical view of the issue and have reserved for its solution a rather large middle ground that

appears to be lacking in the U.S. position. For example, the United Kingdom is moving actively toward a version of greater confinement disposal or engineered disposal at a greater depth (with plutonium numbers like 10^4 nCi/g projected) and then moving on to the modified mine with limits like 10^5 nCi/g. From the French presentations, limits like 10^3 nCi/g were discussed.

As we debate the TRU limit issue, what we seem to hear is an argument between the advocates of a generic limit of perhaps 100 nCi/g and the arguments for site-specific limits. This debate clouds perhaps the more basic issue of the need for a middle ground disposal approach between the extremes of a room trash limit and geologic disposal.

John Sadler, Westinghouse WIPP: Ed, when you were talking about the cast-in-bronze 10 nCi/g, I thought that limit really should fall into a working limit as opposed to a legal or regulatory limit, but you phrased it that the Europeans had a working limit, but we had one cast in bronze.

Albenesius: What I meant to say is that our number has become a perceived limit that is somewhat tougher than a working limit.

Sadler: The wording seemed to say something otherwise.

SUMMARY OF SESSION III

Jerry Cohen, Science Applications, Inc.

To begin with, I would like to present some general insights from the session then review each author's presentation. Session three presented several generic and site-specific risk analyses of the radiological impacts of transuranic (TRU) waste disposal. Useful insights were also brought out regarding the modeling and calculational process. I derived five salient conclusions from the material presented in this session.

First, no fundamental characteristic or combination of characteristics of TRU radionuclides in waste were identified which could technically, logically, justify their management as a separate waste category. Second, several approaches to the calculational process have been designed, using a variety of assumptions for determining the consequences of management of TRU waste. Third, predicting maximum dose consequences involves a significant degree of subjectivity. Fourth, despite the various approaches and parametric assumptions, most of the results of the risk analyses presented indicate that raising the TRU concentration limit for near-surface disposal from 10 to 100 nCi/g would be a reasonable policy, consistent with sound health and safety practice. Fifth, at specific sites and under certain disposal conditions, even concentrations higher than 100 nCi/g may be safely disposed of by near-surface burial.

Those are the general conclusions. What I would like to do now is summarize the most important points each author made. If the author is here, he might add anything that he feels is important. I'll stop at the end of each one for questions or comments.

Our first was Vern Rogers. One, apparently no special characteristics of TRU waste justify its being a special category. Two, model calculations are largely subjective and can be influenced by the bias of the modeler. Finally, ingrowth and concentration of TRU daughter products could be an important consideration in risk assessment.

Paul Lohaus, the next author, reviewed the rationale behind the proposed 10 CFR 61 and discussed public comments on the draft. The limits for class-C waste are being raised to 100 nCi/cm^3, although higher levels may be considered on a site-specific basis. Paul, I think you are here. Could you add something to that?

<u>Paul Lohaus</u>: The limits for class-C waste are being raised to 100 nCi/g, not cubic centimeter. The calculated limits were expressed in nanocuries per cubic centimeter but the actual values in a rule were nanocuries per gram. Also, the class A limits would be retained at 10 nCi/g.

Cohen: Jack Healy, the next author, brought out that there could be a factor of 10 on certainty in just the dose conversion factors. Generally, he concluded, the results of model calculations are suspect.

Craig Smith, the fourth author, reviewed several risk assessments on TRU limits. The results indicate an emerging consensus within the technical community that TRU limits should be raised to at least 100 nCi/g. Parametric assumptions predicting maximum dose can be largely arbitrary. Finally, a wide range of results can be derived from reasonable assumptions.

Craig Smith: One other point ought to be included, the importance of the intruder scenario across the board.

Cohen: Author Joe Leiberman also found that the 100 nCi/g TRU dose limit is justifiable and supportable.

Charles King, in his presentation, reviewed risk assessment of the Savannah River project TRU waste disposal, which indicates that the 100 nCi/g limit is reasonable and would provide a wide safety margin. Raising the limit to 100 nCi/g would, at that site, allow 10 to 30% of the stored waste to be diverted to near-surface disposal. King also noted that model complexity does not equal credibility. Model results must be considered relative rather than absolute.

Author Tom Smith reviewed risk assessment of TRU waste at the INEL site and considered alternative methods for its handling. One of his conclusions was that a 10 nCi/g limit would provide adequate safety margins. Raising the limit to 100 nCi/g would allow about 20% of the stored waste to be diverted to near-surface disposal. He added that analyzing waste packages at 10 nCi/g is not now practical.

Martin Steindler, Argonne National Laboratory: You said that Tom said that 10 nCi would provide an adequate safety margin.

Cohen: Did I say that? I meant 100, I'm sorry.

Wayne Hansen reviewed risk assessment of TRU wastes at Los Alamos. In that assessment, vertical erosion appeared to be a critical scenario. However, burying the waste at least 72 m from the cliff or the edge of the mesa would provide an adequate safety margin. I believe Wayne said that a generic or allowable limit could not be derived from that assessment, but I may be wrong.

Steindler: You said 72 m. That was 72 ft. It was 22 m from the edge of the mesa. And wastes had to be buried 16 ft deep, or with a 5 m cover.

Cohen: Seventy-two ft, I'm sorry. A factor of 35 would be close enough.

Bill Kennedy, the next author, reviewed the TRU disposal practices at the Hanford site. At that site, contaminated earth is a major problem. One solution he discussed, which is being seriously considered, was in situ glassification, and he also discussed other alternatives. Bill, did you derive a safe limit from your analysis?

Bill Kennedy, Battelle-Pacific Northwest Laboratories: We looked at various barrier concepts, but we did present the number of 5 m depth. I think that number compares to the Nuclear Regulatory Commission number for class C waste disposal at 5 m of 220 nCi/g.

Cohen: Let me see if I got that right. From the risk assessment it was determined that concentrations in the range of 2200 nCi/g could be safely disposed of at a 5-m depth.

Last is mine (Jerry Cohen). I discussed cost-benefit methodology, based on an analog approach, for comparing the cost effectiveness of near-surface disposal and restrictive geologic isolation. Cost-benefit could be determined simply by dividing $3 million by the buried waste concentration (in nanocuries per gram). That calculation yields a value in dollars per man rem averted. Based on this, the TRU waste limit could easily be raised to 100 nCi/g. Assuming that $1000 per man rem averted is a reasonable cost in this guideline citing Appendix I, 1000 nCi/g could be justified.

SUMMARY STATEMENT OF THE PROGRAM COMMITTEE REGARDING THE MINIMUM ALPHA CONTENT OF WASTE IN SURFACE DISPOSAL

Martin Steindler, Argonne National Laboratory

For the final portion of the summary I'm going to read the summary statement from the program committee.

"The AEC Manual Chapter 0511 of 1973 states that solid wastes contaminated with certain alpha-emitting radionuclides to greater than 10 nCi/g shall be stored such that the packages can readily be retrieved. In the course of the application of this directive, the 10 nCi/g limit gradually became a concentration limit that defined the distinction between low-level waste destined for shallow burial or near-surface disposal and for retention as waste to be disposed by a more secure mode such as deep geologic disposal. As an increasing amount of waste was designated as alpha-contaminated wastes requiring interim retrievable storage in order to be ultimately transferred to a geological disposal facility, and as additional material was identified as potentially requiring such segregation, the technical community concerned with such matters intensified its efforts to examine the rationale and the supporting data that lead to the specific concentration limit used in this distinction. The present workshop included technical papers and discussions aimed at the question of whether the presently used limit is founded on sufficiently compelling information to allow no change in magnitude without significant and detrimental impact on the health and safety of the public.

"The program committee has carefully examined the technical presentations of the workshop, including the presented papers, the accompanying discussion, and the answers to questions. On this basis, the committee concludes that a level of 100 nCi of alpha contamination per gram of waste, averaged over the contents of a waste package, can be designated as an average concentration of alpha-emitting radionuclides in low-level wastes destined for a near-surface disposal. The committee concludes that such a designation is a reasonable basis for a safe disposal of low-level waste and that this disposal is unlikely to result in the transgression of present dose limits.

"In addition, the committee concludes that it is probable that concentration levels of alpha-emitting radionuclides in excess of 100 nCi/g of waste may be employed in the disposal of low-level waste in a manner that will not exceed the present dose limits. In order to determine the magnitude of the concentration limits for such situations, the committee concludes that site-specific or case-by-case analyses would be required, taking into account the particular attributes and circumstances of the waste and the proposed disposal system.

"The committee provides a section of commentary, which includes its judgment as well as an interpretation of what it heard. While the committee is able to reach its conclusions on the basis of the record of the workshop and ancillary discussions, the members of the committee provide additional comments based on their experience and extensive interactions with technical personnel and experts in disciplines related to the topics of the workshop. The committee noted that the workshop papers generally equated alpha contamination with transuranic elements, particularly plutonium. Nevertheless, the committee notes that other sources of alpha contamination not considered in the workshop papers should be included in the concentration designation. The committee also notes that the concentrations designated by site-specific analyses or by the 100 nCi/g level may be useful as a guide or a rule of thumb, but agrees with the workshop discussions that recommend waste disposal criteria that are based on estimates of dose and comparison of cost.

"The committee observes that the workshop made clear the need to rationalize the application of scenarios, for example, intrusion scenarios, used in risk analyses. This need, endorsed by the committee, appears to be significant and timely in light of the apparently great influence on the criteria for waste system attributes that is exercised by certain of the scenarios commonly used in such analyses. Finally, the committee noted that the workshop papers represent only a limited window to the available information that bears on the concentration limit and the associated topics. It appears clear from the view through that window that any analysis on the hazard or consequences of disposal of radioactive waste must take into account the quality of the algorithms and especially the quality of the underlying data. Continued effort to improve both of these facets of the analyses appears necessary and should be maintained."

That is the statement that we put together. Let me entertain whatever discussion or comments that anyone might have on it.

Ray Walton, DOE: When the limit of 10 nCi/g was established, the intent was that anything at that level or below could be disposed of by burial. Things above that were to be stored retrievably and at a later time we were to determine what would be done with them. A great error came about because people assumed that rather than just being retrievably stored, that waste was required to go to a geologic disposal repository. Now, as I understand what you have said, at 100 nCi waste can go to normal burial ground disposal and in specific cases up to maybe 1000 nCi can go. But you are not making any determination of what should go to geologic disposal; is that correct?

Steindler: That's correct.

Alan Moghissi, EPA: I have to confess that I left before this was put together because I live at the other end of the town, but let

me publicly endorse what has been written. I think it is an excellent job. However, a statement must be added that views expressed by the members of the program committee are their views and do not necessarily reflect the views of their affiliation.

Steindler: We will take note of the need for this disclaimer.

Chuck Gilbert, DOE: I want to comment on one facet of Ray Walton's statement. Wastes that were not necessarily designated for burial in some fashion are also not necessarily designated to go to something like the Waste Isolation Pilot Plant (WIPP) repository or geological disposal. We hope that same confusion won't exist again in future interpretations.

Joe Lieberman, Nuclear Safety Associates: Just a point of clarification; you mentioned that 100 nCi would be averaged over the contents of the drum, and then you made a statement that an average of 100 nCi/g would be averaged over all the waste. Could that be interpreted as meaning that if you've got one that's 110 and another that's 90, you could average the two drums?

Steindler: I don't think so, but let me take that into consideration when I read this again.

Bill Lennemann: I suggest you change the drum as a specific thing to package or container.

Ray Lambert, EPRI: Given the background that the regulations appear to differentiate among the A, B, and C for the 10 versus 100 nCi, was your statement deliberately avoiding that issue or was it to be inferred that you were suggesting all land burial? Should we clarify that we endorse either the total A, B, and C or have some depth implication (like 5 m) in the committee's position?

Steindler: This is not a licensing statement nor should it be a licensing statement. Division into classes on the basis of what we heard in the workshop seemed inappropriate. I think we should remain silent on that subject.

Lennemann: Again, I go back to this averaging business to a package. You may want to put in a volume consideration rather than a package because you have sizes of packages so package could be rather indefinite. We have been through this before, or I have on several occasions, and we generally end up with a designated volumetric average that seems to be more specific.

Steindler: Let me then close this meeting. The process is to take the tape of the comments we just had, make appropriate revisions, and then let the committee have one more shot at it. We will ultimately forward what we've written into the proceedings. In closing let me

say that this has been a most worthwhile exercise. I hope a year from now we can look back and agree that it has been useful.

Paul Dejonghe, CEN/SCK Boeretang 200, Belgium: Will these comments that you have just read be sent separately to participants or do we have to wait for them until you have the full compilation of papers? I would appreciate very much to receive them in a reasonable time because I think they are very important.

Steindler: We certainly will make an effort to get them out. If there is general interest in having at least a copy of the statement once we clean it up, we can easily mail it out.

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Telephone 312/972-4383

September 10, 1982

TO: Attendees of the Alpha-Contaminated Workshop, Gaithersburg, MD, August 10, 1982

FROM: Martin J. Steindler Program Chairman

SUBJECT: Transmittal of the Program Committee's Summary Statement

Attached please find the final version of the Summary Statement, prepared by the Program Committee of the Workshop on the Management of Alpha-Contaminated Waste.

The Committee extends its appreciation to all those whose efforts on behalf of the Workshop made possible an outstanding program. Preparations are continuing to publish the Workshop proceedings and to publish the technical papers in the refereed journal, Nuclear and Chemical Waste Management.

Finally, the Committee is grateful to each of the attendees whose interest and participation were the necessary ingredients for success.

Martin J. Steindler
Program Chairman

MJS:lj

Attachment: Summary Statement

Summary Statement from the Workshop on the Management of Alpha-Contaminated Waste

1. Introduction

The AEC Manual Chapter 0511 of 1973 states that solid wastes contaminated with certain alpha-emitting radionuclides to greater than 10 n Ci/g shall be stored such that the packages can be readily retrieved. In the course of the application of this directive, the 10 n Ci/g limit gradually was construed as a concentration limit that defined the distinction between low level waste (LLW) destined for shallow burial (i.e., near surface disposal) and material retained as waste to be disposed of by a more secure mode (e.g., deep geologic disposal).

An increasing amount of waste is being designated as alpha-contaminated waste requiring interim, retrievable storage and ultimate transfer to a geologic disposal facility. Additional material has also been identified as potentially requiring such segregation. The technical community concerned with such matters intensified its efforts to examine the rationale and supporting data that led to the specific concentration limit used in this designation. The present Workshop was convened to address these matters and included technical papers and discussions aimed at the question of whether the presently-used limit is founded on sufficiently compelling information to allow no change in magnitude without significant and detrimental impact on the health and safety of the public.

2. Conclusions

The Program Committee has carefully noted the technical presentations of the Workshop, including the presented papers, the accompanying discussion, and the answers to questions. On this basis, the Committee concludes that a level of 100 n Ci of long-lived alpha contamination per gram of waste, averaged over the contents of a waste package, can be designated as a concentration of long-lived alpha-emitting radionuclides in low level waste destined for near surface disposal that is unlikely to result in exceeding present dose limits.

In addition, the Committee concludes that it is probable that in some cases concentration levels of long-lived alpha-emitting radionuclides in excess of 100 n Ci per gram of waste may be employed in near surface land disposal of low level waste under conditions that will not exceed the present dose limits. In order to determine the magnitude of the concentration limits for such situations, the Committee concludes that site-specific or case-by-case analyses would be required that take into account the particular attributes and circumstances of the waste and the proposed disposal systems.

3. Commentary

While the Committee is able to reach its conclusions on the basis of the record of the Workshop and ancillary discussions, the members of the Committee provide additional comments based on their experience and extensive interactions with technical personnel expert in disciplines related to the topics of the Workshop. The Committee notes that the Workshop papers generally equated alpha contamination with transuranic (TRU) elements, particularly plutonium. Nevertheless, the Committee believes that waste contaminated by other sources of long-lived alpha contamination, some of which were not considered in the Workshop papers, should be managed by procedures similar to those used for transuranic wastes.

The Committee also notes that the concentrations obtained from site-specific analyses or the 100 n Ci/g level may be useful as a guide or "rule-of-thumb", but agrees with the Workshop discussions which recommend use of waste disposal criteria that are based on estimates of dose and comparison of costs.

The Committee observes that the Workshop made clear the need to reexamine the application of scenarios (e.g., intrusion) used for risk analyses. This need, endorsed by the Committee, appears to be significant and timely, in light of the apparently great influence on the criteria for waste system attributes that is exerted by certain of the scenarios commonly used in such analyses.

Finally, the Committee acknowledges that the Workshop papers represent only a limited window to the available information that bears on the concentration limit and associated topics. It appeared clear from the view through that window that any conclusions from analyses on the hazards or consequences of disposal of radioactive waste must take into account the quality of the algorithms and, especially, the quality of the underlying data. Continued effort to improve both of these facets of the analyses appears desirable and should be maintained.

The conclusions of the Committee represent the opinions of the individual members and not necessarily those of the organizations with which the members are affiliated.

PROGRAM COMMITTEE

Martin J. Steindler, Chairman, Argonne National Laboratory

E. L. Albenesius, Savannah River Laboratory
J. J. Cohen, Science Applications, Incorporated
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August 13, 1982

AGENDA

ALPHA-CONTAMINATED WASTE MANAGEMENT WORKSHOP

Tuesday, August 10, 1982

9:00 AM	Introduction	Mike McFadden Department of Energy/Albuquerque
	Opening remarks	Martin Steindler Argonne National Laboratory
	Welcome	Goetz Oertel Department of Energy/Headquarters

PLENARY SESSION

Chairman: Goetz Oertel, Department of Energy/Headquarters

Vice-Chairman: Martin Steindler, Argonne National Laboratory

Time	Title	Author(s)
9:30 AM	Keynote address	Dixy Lee Ray Consultant
10:30	BREAK	
11:00	Historical overview	Alex Perge Department of Energy/Headquarters
12:00	LUNCH	
1:00 PM	Legislative and Political Aspects of Waste Disposal	Ed Davis American Nuclear Energy Council Joyce Freiwald Committee on Science and Technology Tom Pestorius Office of Science and Technology Policy
2:00	Regulatory Policy of the EPA Related to Alpha-Contaminated Waste	Gordon Burley Environmental Protection Agency
3:00	BREAK	

TECHNICAL SESSIONS

Session I

SOURCE TERMS

Chairman: Joe Lieberman, Nuclear Safety Associates

Vice-Chairman: Allen Croff, Oak Ridge National Laboratory

3:30 PM	Physical Description and Quantities of Alpha-Contaminated Waste from Defense Sources	Rich Jensen and Larry Smith Rockwell International/Rocky Flats Plant — TWSO
4:15	Detection and Determination of Alpha Content of Waste	John Umbarger Los Alamos National Laboratory
6:30-8:30	RECEPTION	

Wednesday, August 11, 1982

Session I (continued)

8:30 AM	Radiological Hazards from Alpha-Contaminated Waste	John Rodgers Los Alamos National Laboratory
9:15	Alpha-Contaminated Waste from Reprocessing of Nuclear Fuel	Wally Sumner Allied General Nuclear Services
10:00	BREAK	

Session II

DISPOSAL TECHNOLOGY AND PRACTICES FOR ALPHA-CONTAMINATED WASTE

Chairman: Ed Albenesius, Savannah River Laboratory

Vice-Chairman: Bob Lowrie, Oak Ridge National Laboratory

10:30	Near Surface Disposal of Alpha-Contaminated Waste	George Levin EG&G Idaho
11:15	Deep Geologic Disposal of Alpha-Contaminated Waste in WIPP	John Sadler Westinghouse/WIPP
12:00	LUNCH	

Session II (continued)

1:00 PM	Greater Confinement Disposal Methods for Alpha-Contaminated Waste	Paul Dickman REECO
1:45	Transportation of Alpha-Contaminated Waste	Ron Pope Transportation Technology Center/ Sandia National Laboratory
2:30	Foreign Experience in Alpha-Contaminated Waste Disposal	Pete Lakey Battelle-Pacific Northwest Laboratory
3:30	BREAK	

Session III

RISK ANALYSES AND SAFETY ASSESSMENTS

Chairman: Jerry Cohen, Science Applications, Inc.

Vice-Chairman: Mel Shupe, Department of Energy/Richland

4:00	Risks from Principal Components and Their Daughter Products in Alpha-Contaminated Waste	Vern Rogers Rogers and Associates Engineering Corp.
4:45	Overview of 10 CFR 61 Licensing Requirements for Land Disposal of Alpha-Contaminated Waste	Paul Lohaus U.S. Nuclear Regulatory Commission

Thursday, August 12, 1982

Session III (continued)

8:30	Application of Models for Disposal of Alpha-Contaminated Waste	Jack Healy Los Alamos National Laboratory
9:15	A Review of Risk Assessments for Defining the Alpha-Contamination Solid Waste	Craig Smith Science Applications, Inc.
10:00	Critical Evaluation of the Limits of Alpha-Contamination in Low-Level Waste	Walt Rodger Nuclear Safety Associates
10:45	BREAK	

Session III (continued)

11:15 AM	Risk and Safety Analyses for Disposal of Alpha-Contaminated Waste at INEL	Tom Smith EG&G Idaho
12:00	LUNCH	
1:00 PM	Risk and Safety Analyses for Disposal of Alpha-Contaminated Waste at LANL	Wayne Hansen Los Alamos National Laboratory
1:45	Analyses of the Disposal of Alpha-Contaminated Waste at Hanford	Bill Kennedy Battelle-Pacific Northwest Laboratory
2:30	Risk and Safety Analyses for Disposal of Alpha-Contaminated Waste in WIPP	Steve Woolfolk Westinghouse/WIPP
3:15	BREAK	
3:45	Cost Benefit Analyses on Alternatives for Disposal of Alpha-Contaminated Waste	Jerry Cohen Science Applications, Inc.
4:30	General Discussion	Martin Steindler, Moderator Argonne National Laboratory

Friday, August 13, 1982

Session IV

SUMMARY AND CONCLUSIONS

Chairman: Martin Steindler, Argonne National Laboratory

9:00 AM	Summary of Session I	Joe Lieberman Nuclear Safety Associates
9:30	Summary of Session II	Ed Albenesius Savannah River Laboratory
10:00	Summary of Session III	Jerry Cohen Science Applications, Inc.
10:30	BREAK	
11:00	Summary Statement of the Program Committee Regarding the Minimum Alpha Content of Waste in Surface Disposal	Martin Steindler Argonne National Laboratory

ALPHA-CONTAMINATED WASTE MANAGEMENT WORKSHOP

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Keith Gilbert, Rockwell International/Rocky Flats Plant-TWSO

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Ray Lambert, Electric Power Research Institute

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