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Report of the Dose Evaluation Review & Assessment (DERA) Advisory Panel

To the Idaho Department of Health and Welfare

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Review of INEL Dose Models and the INEL Historical Dose Evaluation

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Dose Assessment
Ground Water Models

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PREFACE

The Dose Evaluation Review & Assessment (DERA) Advisory Panel represented the first organized public involvement in health studies at the INEL. This has been a good preliminary model for communication between a panel, representing scientific expertise and citizens interests, and state and federal agencies. Many of our members represented large constituencies that depended on them to fully participate in and follow specific site activities.

We hope the constructive working relationship between the Idaho Department of Health and Welfare (IDHW) and the citizens it serves can be preserved in future models for public input to health-related studies.

The DERA panel wishes to thank the people who have contributed to their understanding of INEL activities and to their work. Pat McGavran, of the IDHW Division of Health, has provided valuable insights to and support of this panel.

We also are grateful to Kara Stevens, of the Division of Health staff, who worked with us in preparation of the several drafts of this report and for her help in the administrative details of the panel's work.

We also want to thank the technical presenters, state and federal officials, and members of the public who addressed the scientific issues and areas of concern related to our work.

ACRONYMS

AEC	Atomic Energy Commission
ANL-W	Argonne National Laboratory-West
ANP	Aircraft Nuclear Propulsion
ATSDR	Agency for Toxic Substances and Disease Registry
CDC	Centers for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CERT	Controlled Environmental Release Tests
CFA	Central Facilities Area
COCA	Compliance Order and Consent Agreement
CPP	Chemical Processing Plant
DEIS	Draft Environmental Impact Statement
DERA	Dose Evaluation Review & Assessment
DOE	Department of Energy
EBR-1&2	Experimental Breeder Reactor
EDMS	Environmental Data Management Systems
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ERDA	Energy Research and Development Administration
FAST	Flourinel & Fuel Storage Facility
FEIS	Final Environmental Impact Statement
HEDR	Hanford Environmental Dose Reconstruction
HEPA	High-Efficiency Particulate Air (Filter)
IAEA	International Atomic Energy Agency
ICPP	Idaho Chemical Processing Plant
ICRP	International Commission on Radiological Protection
IDHW	Idaho Department of Health and Welfare
IET	Initial Engine Test
IHDE	INEL Historical Dose Evaluation

INEL	Idaho National Engineering Laboratory
NAAQS	National Ambient Air Quality Standards
NCEH	National Center for Environmental Health
NCRP	National Committee on Radiation Protection and Measurements
NESHAP	National Emission Standards for Hazardous Air Pollutants (EPA Standards)
NIOSH	National Institute of Occupational Safety and Health
NOAA	National Oceanic and Atmospheric Administration
NPL	National Priorities List (of Superfund sites)
NRC	Nuclear Regulatory Commission
NRTS	National Reactor Testing Station
NTS	Nevada Test Site
QA/QC	Quality Assurance/Quality Control
RCRA	Resource Conservation and Recovery Act
RESL	Radiological and Environmental Sciences Laboratory
RWMC	Radioactive Waste Management Complex
RWMIS	Radioactive Waste Management Information System
SREL	Savannah River Environmental Laboratory
SRL	Savannah River Laboratory
SRP	Snake River Plain
SRPA	Snake River Plain Aquifer
TAN	Test Area North
TRA	Test Reactor Area
TRAC	Terrain Responsive Atmospheric Code
USGS	U.S. Geological Survey

MODELS:			PROJECTS:
	MESODIF	MESOILT 2	LIME II
	RACHET	TRAC	RALA
	PATHWAY	DAMBRK	
	ECOSYS	SEADEX	
	FOODMARC	MODFLOW	
	AIRDOS	MAGNUM 2D	
	AIRDOS-EPA	CHAINT	
	CAP88	TRACR 3D	
	MESOI 2.0		

MAJOR RADIONUCLIDES RELEASED:

^{125}Sb	Antimony-125	^{131}I	Iodine-131	^{90}Sr	Strontium-90
^{41}Ar	Argon-41	^{85}Kr	Krypton-85	^{133}Xe	Xenon-133
^{129}I	Iodine-129	^{137}Cs	Cesium-137		

1.0 EXECUTIVE SUMMARY

The Dose Evaluation Review and Assessment (DERA) Advisory Panel was formed by the Division of Health of the Idaho Department of Health and Welfare (IDHW) to review models commonly used to evaluate health risks for environmental contaminants produced by the Idaho National Engineering Laboratory (INEL) in Southeastern Idaho. We were also asked to review and evaluate the INEL Historical Dose Evaluation (IHDE) report, published by the U.S. Department of Energy (DOE) in 1991. The IHDE report describes, in detail, the atmospheric releases of radionuclides and resulting doses to offsite populations over the entire operating history of the INEL. We met seven times to review and discuss published documents and solicit public comments pertaining to its three objectives:

- Review atmospheric dispersion and dose assessment models
- Review water models
- Review the methodology and findings of the IHDE

It was not within our mission to confirm or refute the estimates provided in the IHDE, or in any of the other documents we reviewed. The purpose of these recommendations is to ensure that any future work is conducted in a public forum using sound and impartial scientific methods.

<u>Atmospheric Dispersion and Dose Assessment Models</u>

We reviewed documentation and evaluation of MESODIF (Mesoscale Diffusion), the computer model used to predict the air transport of radionuclides to offsite locations. When MESODIF was tested by the National Oceanic and Atmospheric Administration (NOAA) against a set of short-term data collected during summertime conditions at the INEL, there was no clear indication that it always produced conservative results.

However, an evaluation performed by the Nuclear Regulatory Commission (NRC) showed that MESODIF did not perform any better or worse than nine other models. We recommend that MESODIF be evaluated more extensively using both short-term and long-term data sets for both the INEL and non-INEL locations. Testing MESODIF with this type of data set will allow a formal comparison to be made against other models currently in use.

In order to interpret previous results obtained with MESODIF, it is important to provide complete documentation of past and current uses of MESODIF. It is also very important that any updated version of MESODIF (or its replacement) be fully documented and that the new model be made available to outside users for review.

We understand that NOAA is in the process of upgrading the MESODIF model and installing new meteorological measurement systems. The new version of MESODIF should be rigorously evaluated with the data sets described above. The evaluation should address both short- and long-term averages, and the analysis should follow current model validation protocols. The revised version of MESODIF should be evaluated against both observations and other models. The revised model should also incorporate analyses of uncertainty for its predictions.

The dose assessment models used at the INEL include the most common pathways of exposure to people but ignore the other pathways, such as inhalation of radionuclides resuspended from soil into the air, the ingestion of contaminated soil, and the ingestion of the meat from game and range animals that incorporate radionuclides on the site. Also, the doses resulting from ground contamination due to wet deposition (rain or snow) are not considered.

Traditionally, doses have been calculated for hypothetical individuals assumed to reside at the offsite location near the INEL site boundary, where the time-integrated

concentrations in air were highest. Doses received onsite by INEL workers, construction workers, security guards, field researchers, or ranchers herding stock have not been modeled and there are no alternate estimates for these.

In order to estimate doses from the pathways considered, the INEL made use of models that had been accepted by regulatory agencies, including the default parameter values for these models. No uncertainty analysis was performed and conservative assumptions were made in most cases in order to ensure that the calculated doses were overestimated. However, these dose estimates are based upon MESODIF air concentrations which are not necessarily conservative.

With respect to dose assessment models, the main recommendation for future studies is to use realistic models and to include rigorous analyses of uncertainty. These models should be based on site-specific data and make use of lifestyle and dietary habits that could be obtained through surveys. There should also be better documentation of the process by which predictions of the dose models were validated. Existing environmental monitoring data should be evaluated for use in model validation.

Water Models

The Snake River Plain Aquifer (SRPA) serves as the drinking water source for many residents of Southern Idaho and as the water supply for over one million acres of irrigated land and a large aquaculture industry. For these reasons, the public is concerned about potential contamination to the aquifer from operations at the INEL.

A comprehensive review of all water quality monitoring investigations including regional, local, and site-specific research should be conducted. The review should also summarize existing models and their applications. All existing water quality information should be centralized in a single database, which should also characterize

areas of contamination for type, extent, and source of contaminant plume for both chemicals and radionuclides.

In the future, water quality monitoring at regional, local, and site-specific levels should be continued and geologic, hydrologic, and geophysical studies should be conducted to further characterize the regional setting and to help define parameters for future modeling efforts. Data from all investigations should be added to a centralized database.

State-of-the-art groundwater and solute-transport models should be developed as predictive tools to simulate contaminant migration over time, both within and beyond the INEL boundaries.

INEL Historical Dose Evaluation

The IHDE is a substantial compilation of data describing the operating history of the INEL, and establishes a chronology for operational and episodic radioactive releases that have taken place at the INEL. It is a major step toward addressing public concerns on the health risks posed by activities at the INEL. The following specific recommendations, though critical, are not based on evidence that doses were substantially different than those reported in the IHDE.

We recommend that more work be done on reconstructing doses from toxic exposures to workers and members of the public potentially affected by the INEL operations. Future work should include independent collection and verification of data, comparisons between modeled and monitored data, rigorous uncertainty analyses, and a quality assurance program for all data collection and analysis. Doses should be reconstructed for hazardous chemicals and all potential exposure pathways, including groundwater and soil ingestion. Radiation and chemical exposure to INEL and contract workers from outdoor activities and ingestion of contaminated drinking water should be evaluated. We recommend a phased approach with careful planning to avoid

unnecessary duplication. The dose reconstruction project at the INEL should be similar in scope to the dose reconstructions at Hanford, Fernald, and Rocky Flats.

The lack of public involvement was a major shortcoming in the IHDE report. We recommend that future studies involve full public participation. We are concerned that Centers for Disease Control and Prevention (CDC) is proceeding with its dose reconstruction without a mechanism for adequate public participation and oversight. We urge the State of Idaho and its congressional delegation to assure the establishment of an advisory group composed of representatives of the public and independent technical experts. Substantive work on the dose reconstruction should not begin before a mechanism is established for public participation and oversight.

We recommend an independent evaluation of the health risks from exposure to chemicals and ionizing radiation to all persons who have worked at the INEL.

Radiation exposure from outdoor activities and from contaminated drinking water should be quantified in the CDC dose reconstruction.

Because of the number of federal and state health studies, there should be a single state agency that acts as a public and technical point of contact for information about all health and risk studies at the INEL.

The public needs to have access to all data and results. We recommend that all relevant classified documents be declassified, and that all documents used in the CDC dose reconstruction be available for public review.

2.0 INTRODUCTION

This report summarizes the findings and recommendations of the Dose Evaluation Review and Assessment (DERA) Advisory Panel to the Idaho Department of Health and Welfare (IDHW). The panel was formed by the Division of Health of the IDHW to review dose models commonly used to evaluate health risks for environmental contaminants produced by the Idaho National Engineering Laboratory (INEL) in Idaho Falls, Idaho. We were also asked to review and evaluate the INEL Historical Dose Evaluation (IHDE), published by the U.S. Department of Energy (DOE) in 1991, for the purpose of describing, in detail, the offsite releases of radionuclides from the INEL over its entire operating history. We are hopeful that its findings will be used by the various federal, state, and local agencies involved in assessing the public health risks from the INEL.

2.1 The DERA Advisory Panel

In June 1990, a Health Agreement signed by the U.S. DOE and the IDHW provided for the creation of a panel to:

1) Review current models used by the INEL for assessing radiation doses to the public for their accuracy and adequacy and recommend appropriate follow-up actions to the state; and
2) Review the IHDE and the report of the Peer Review Panel established by the U.S. DOE to evaluate the IHDE report and provide the state with recommendations regarding the need for modifications, more comprehensive studies, or both.

Richard Donovan, former director of the IDHW, appointed 14 individuals to serve on the DERA Advisory Panel in April 1991, after soliciting and receiving nominations for potential members from concerned citizens throughout the state.

The members, the groups they represent, and their areas of technical expertise are:

- Duane Allen, Oil Chemical & Atomic Workers International Union, Labor Groups
- André Bouville, Ph.D., National Cancer Institute, Environmental Pathways
- Beatrice Brailsford, Snake River Alliance, Environmental Groups
- Charles Brockway, Ph.D., University of Idaho Water Resources Research Institute, Hydrogeology
- Barbara Brooks*, U.S. Department of Energy, Office of Health
- Suzanne Budge, Idaho Council on Industry and the Environment, Commerce Groups
- Bernard Graham, Ph.D., Idaho State University, Health Physics
- Bradley Jahn, Idaho Falls, Public
- Brian Lamb, Ph.D., Washington State University, Meteorology
- Jerry Leitch*, U.S. Environmental Protection Agency
- Carl Pendleton, Shoshone, Public
- James Ruttenber, Ph.D., M.D., University of Colorado, Epidemiology
- Margrit von Braun, Ph.D., University of Idaho, Risk Assessment
- Mary Washakie, Fort Hall Business Council, Shoshone-Bannock Tribe

* ex officio (non-voting) members

Some panel members were selected for their expertise in the scientific disciplines required for dose reconstruction and environmental modeling which include meteorology, risk assessment, hydrogeology, and environmental exposure assessment. Other panel members represented the general public, Native Americans, environmental groups, commerce, and labor. Four subcommittees were formed to: 1) review atmospheric models; 2) review water models; 3) review the IHDE report; and 4) help the panel communicate with the public. The DERA Advisory Panel held seven public meetings in various locations throughout the state. These meetings included working sessions for report review and writing, presentations by outside experts, and numerous public comment periods. Dates and locations were:

Idaho Falls	June 19-20, 1991
Twin Falls	October 1-2, 1991
Boise	January 22-23, 1992
Pocatello	April 13-14, 1992
Moscow	July 27-28, 1992
Boise	September 28-29, 1992
Boise	November 16-17, 1992

Each meeting was open to the public and most were advertised with press releases and paid advertisements. During the meetings, we encouraged public participation and sought written and verbal comments. The meetings were not conducted as hearings. Rather, we encouraged open discussion about issues of concern. We acknowledge our limitations in being able to formally respond to all comments, such as is done in a responsiveness summary required by numerous federal statutes. However, we made every effort to actively involve members of the public and to consider their concerns throughout development of this report. We sent a postcard describing the draft report to the 4,200 people currently on the INEL Oversight mailing list and provided copies to those who requested them. Written and oral comments were considered in producing the final report.

Appendix A contains the minutes of each of our meetings. Section 7.0 provides a listing of written comments from the public which is available as an addendum to this report. Copies of our correspondence, technical materials, and tapes of the meetings are available from the State Office of Environmental Health in Boise.

2.2 Description of the INEL Site

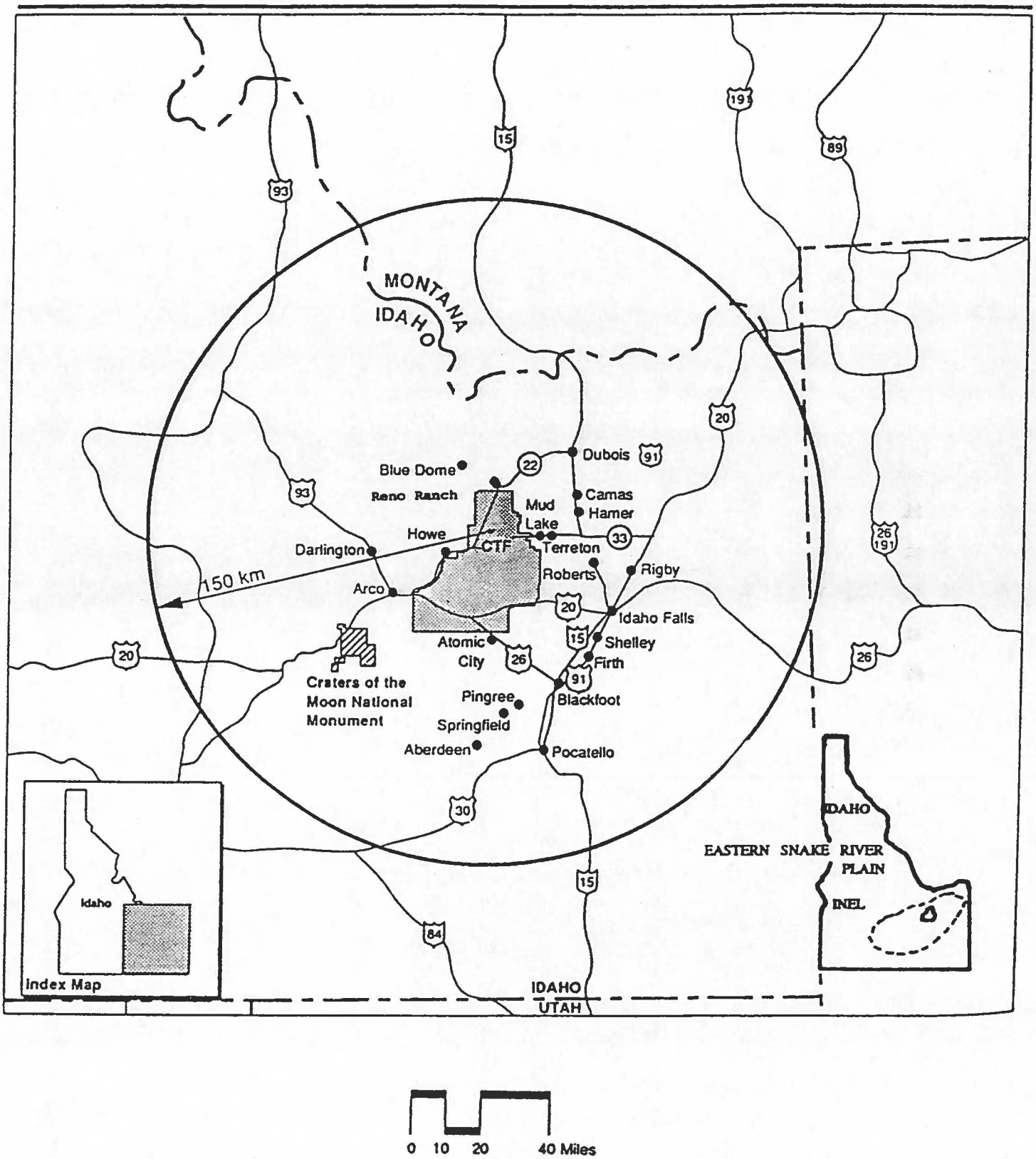
In 1949, the National Reactor Testing Station (NRTS) was established by the Federal Government to provide a site where various kinds of nuclear reactors and support facilities could be built and tested. The name was changed in August 1974 to the Idaho National Engineering Laboratory (INEL) to better reflect the broader mission of

the site. Over the years, the INEL site has been operated by the Atomic Energy Commission (AEC), the Energy Research and Development Administration (ERDA), and is currently operated by the U.S. DOE.

The INEL site is located on the Upper Snake River Plain (SRP) in Southeastern Idaho and includes an area of 890 square miles (2300 square km) (Figure 1). It is isolated from large population centers. Approximately 121,000 people reside within a 50 mile (80 km) radius of the site's geographic center, but none within 10 miles (16 km) of the center. Within a 94 mile (150 km) radius, there are about 272,000 residents. No appreciable amount of surface water flows from the INEL Site to offsite areas. The Big Lost River, Little Lost River, and Birch Creek are intermittent streams that flow onto the INEL site and sink into porous soils and fractured basalt, ultimately recharging the SRPA. The SRPA, underlying 9,600 square miles of the Eastern SRP, is composed of highly permeable basalt and interbed materials. Groundwater flow is generally from northeast to southwest with over 7 million acre-feet of water passing through the aquifer each year. It serves as the water supply for over one million acres of irrigated land. Springs issuing from the aquifer constitute the water supply for aquaculture facilities which raise over 70 percent of the nation's commercial rainbow trout. In addition, groundwater from the aquifer is the domestic supply for some 120,000 rural residents.

The INEL lies at the foot of the Lost River, Lemhi, and Bitterroot-Centennial Mountain Ranges which are generally oriented northeast to southwest and act to channel westerly prevailing winds into predominately southwesterly winds. Northeasterly winds occur as the second most common wind. Because of the surrounding mountain barriers, air masses entering the area are dry and the region has semi-desert characteristics. In terms of atmospheric diffusion conditions, this implies intense solar heating and vigorous vertical mixing during summer days and strong radiational cooling of the ground with suppression of vertical motion during clear nights. During

Figure 1



INEL Site vicinity map.

periods without strong weather systems in the area, northeasterly winds occur late at night and in the early morning due to cold air drainage down the valleys and across the INEL. During the day, winds shift to the southwest in an up-valley flow. Late morning and early evening flow patterns during the transition periods can be very complex. In the summer, temperature inversions corresponding to limited vertical mixing occur approximately 50 percent of the time. In the winter, the presence of a snow-covered surface causes more intense inversion formation and temperature inversions occur as much as 60 percent of the time. Overall, an inversion can be expected to form on almost every day of the year. (For more information see Clawson et al., 1989; Yanskey et al., 1966.)

The first nuclear reactor on the INEL Site was the Experimental Breeder Reactor No. 1 (EBR-1), which achieved initial criticality in 1951. Since the INEL Site was established, 53 reactors have been built and tested. In addition, the Idaho Chemical Processing Plant (ICPP) reprocessed spent fuel and recovered uranium from 1953 to 1989. The INEL is also a major nuclear waste storage and disposal site. Shallow land disposal has been used for over 5 million cubic feet of low-level waste. Over 2 million cubic feet of transuranic waste was buried at the INEL, and 1.3 million cubic feet of Transuranic waste are stored there. Nearly half a million cubic feet of high-level waste is stored as calcine and in liquid form, and 760 metric tons of spent fuel are stored in pools and in dry casks. The operation of those facilities has resulted in releases of radioactive materials into the environment.

Other releases occurred when planned experiments involving radioactive materials were conducted at the site; examples of such experiments are the Controlled Environmental Release Tests (CERT), designed for the purpose of studying the transfer of radioiodine from air to vegetation, cows' milk, and humans. Most of the environmental releases have been intentional, except for those from nuclear waste storage and disposal sites. A notable exception was the accident at the Stationary

Low Power No. 1 Reactor (SL-1) in 1961, which cost the lives of three workers and resulted in uncontrolled releases over a period of one month.

Numerous efforts have begun to address the environmental and health concerns related to the site. In 1987, the INEL and the Environmental Protection Agency (EPA) signed an agreement to bring the INEL into compliance with provisions of the Resource Conservation and Recovery Act (RCRA). In November 1989, the INEL was added to the National Priorities List (NPL) of Superfund sites. The 1987 RCRA Consent Order was superseded by the Federal Facilities Agreement signed in 1990 by the State, EPA, and the U.S. DOE to guide Superfund cleanup. 'Superfund' or Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) risk assessments have been initiated at some release sites. The Agency for Toxic Substances and Disease Registry (ATSDR) has conducted onsite visits as part of a public health assessment. The Centers for Disease Control and Prevention (CDC) plans to conduct a historical dose reconstruction at the INEL beginning in the Fall of 1992.

2.3 An Overview of Procedures Used in Making Dose Estimates

The purpose of making historical dose estimates is for assessing health risks associated with these doses, a process called risk assessment. The procedures used in estimating doses over the operational history of a nuclear facility vary considerably depending on the desired accuracy of the estimates. For instance, the IHDE made estimates for worst-case conditions, which required much less effort than more realistic ones with estimates of their uncertainty.

Often, estimates such as those made in the IHDE, are termed *dose evaluations* or *dose estimates*. These procedures are commonly used in risk assessments for compliance with RCRA and CERCLA. The term *dose reconstruction* is applied to the procedures that yield the most realistic estimates, accompanied by their uncertainties. Regardless

of the degree of accuracy in estimates of historical doses, the general methodologic approach is the same.

The first step in a dose reconstruction is a thorough review of production and environmental monitoring data to identify radionuclides and chemicals that may pose health risks. Environmental monitoring data, when appropriately collected and analyzed, are the best for reconstructing doses. Because such data are usually not available, particularly for early years of operation, dose reconstruction must rely heavily on models of radionuclide movement in the environment.

These models usually depend on a source term - the quantity of radioactive material released to the environment over a defined period of time. Source terms are estimated by extensively reviewing data in production records, recordings from stack monitoring, and from mass-balance analysis - a technique which compares quantities of starting material with the quantity of finished products.

The radionuclides and chemicals which may provide offsite exposures are then assessed with screening models that assume conditions that maximize doses and risk estimates to the public in order to select those that require more detailed modeling and uncertainty analysis. The screening process can involve different levels of effort, depending on the particular site and on the availability of funds.

The models used in dose reconstruction incorporate the latest advances in modeling techniques and rely on large data sets obtained by in-depth investigations. These models are designed to describe atmospheric dispersion of substances based on local and regional weather patterns, terrain, and the release characteristics of the facility. Models are also available for the surface, groundwater, and food chain transport of radionuclides and chemicals.

In order to be meaningful from a public health standpoint, estimated doses are converted to estimates of disease risk by multiplying them by estimates of disease risk per unit dose. These risk conversion factors are available in the scientific literature for cancer and genetic damage to offspring. When using results from an in-depth dose reconstruction, extensive analyses of the combined uncertainty from all variables is used to establish the upper and lower bounds for risk as well as to estimate the median risk for the exposed group.

2.4 Structure of the Report

Chapters 3 and 4 provide detailed reviews of the air and water models used at the INEL, and Chapter 5 is a critical review of the IHDE. We reviewed and discussed the many health-related studies planned by different governmental agencies and were concerned that efforts might be duplicative and confusing. Therefore, we included Chapter 6 in an attempt to describe our understanding of the current and planned health-related studies at the site. Chapter 7 summarizes the public comments we have received which are available as an addendum to this report. Chapter 8 is a listing of references for this report.

3.0 REVIEW OF AIR MODELS USED AT INEL

One of our goals is to assess the accuracy and appropriateness of models in general, and specifically the MESODIF (Mesoscale Diffusion) model, as tools for estimating air concentrations used to determine deposition and doses to the population within the region surrounding the INEL. Specific objectives of the review covered in this section include:

1) Completing a review of the field study and model evaluation exercises conducted at the INEL and summarizing this review with respect to the level of accuracy obtainable using mesoscale diffusion models; and
2) Completing a qualitative comparison of the modeling methods incorporated in MESODIF with methods used in similar models and/or generally representative of the state-of-the-art for modeling plume diffusion over the distances and terrain characteristic of the INEL.

The models used to estimate radiation doses resulting from airborne releases from the INEL site between 1952 and 1988 can be classified into two categories:

1) Atmospheric dispersion models, used to estimate ground-level air concentrations at offsite locations; and
2) Dose assessment models, used to calculate the radiation doses to hypothetical individuals from the estimated air concentrations.

3.1 Atmospheric Dispersion Models

Introduction

The potential release of airborne radionuclides has been of concern at the INEL since its inception. To address this concern, an atmospheric transport and dispersion model can be used. This type of model predicts air concentrations downwind of the release using information concerning the source and amount of material released in

conjunction with data describing atmospheric wind and temperature conditions. At the INEL, the primary model used to estimate air concentrations of radionuclides has been the MESODIF model developed specifically for use at the INEL. As a result of the previous and continuing use of MESODIF, our review of air modeling at the INEL focus on the performance of MESODIF.

Air concentrations predicted with MESODIF or with other dispersion models can be used in a dose assessment model to estimate the radiation doses to hypothetical individuals from a variety of pathways. At the INEL, dose estimates have been made using models based upon NRC guidelines. Our review of the INEL dose assessment calculations covered these models.

To evaluate MESODIF, the following tasks were completed: review of available field data, review of performance tests of MESODIF based upon these field data, and comparison of MESODIF to other available models. The latter task involved a review of previous model intercomparison studies and also a technical review of the structure and capabilities of MESODIF as compared with state-of-the-art methods for dispersion modeling. Our evaluation of the air dose models for the INEL focused primarily upon how these models compare to other possible methods. In part, this type of evaluation was necessary since there appeared to be little data available for direct evaluation of these models on a quantitative basis.

Description of the MESODIF Model

It is useful to give a brief description of the MESODIF model as a basis for comparison with other models and for understanding why the model may provide more accurate results in some situations than in others. A more complete technical description of MESODIF and details of its applications are available in Start et al. (1974) and Start et al. (1985).

MESODIF is a Gaussian puff trajectory model which means that emissions from a point source are modeled by releasing a series of puffs which grow as they are carried along by the wind. Each puff carries with it a certain mass of pollutant, and as the puff grows in time, the material in each puff is diluted with ambient air and the concentration (mass of pollutant per volume of air) decreases.

Within each puff, the concentration is at a maximum at the center of the puff and decreases with distance, measured from the center in a manner following a Gaussian or bell-shaped curve. The concentration of material at any downwind receptor is equal to the sum of the concentrations due to all of the puffs which pass over the receptor during the sampling interval. A schematic of this puff release and growth process is shown in Figure 2.

The path or trajectory of each individual puff is determined independently based upon wind observations within the region of interest. This trajectory calculation involves several steps. First, wind observations, recorded as six minute averages at as many as 25 measurement stations, were used to develop a gridded wind field for each time step during the modeling period. As illustrated in Figure 3, this means that wind directions and speeds measured at a relatively sparse number of points are used to estimate the wind direction and speed at a regular array of points covering the entire modeling area. These estimates for the dense array of points are repeated for each six minute period. Each puff is moved according to the wind direction and wind speed from the grid point(s) nearest the current location of the puff. This process is repeated every six minutes for every puff which remains within the modeling domain. Puffs which move out of the region of interest or have concentrations diluted to near zero are removed from the modeling domain. The MESODIF model addresses neither wet nor dry deposition.

Figure 2 Schematic of puff release and growth procedure used in MESODIF to simulate pollutant dispersion in the atmosphere. The horizontal and vertical concentration profiles show the pollutant distribution in a puff at some time t_1 and at a later time t_2. The size of the puff is measured in terms of σ_r which is the distance from the centerline to where one standard deviation of the distribution occurs.

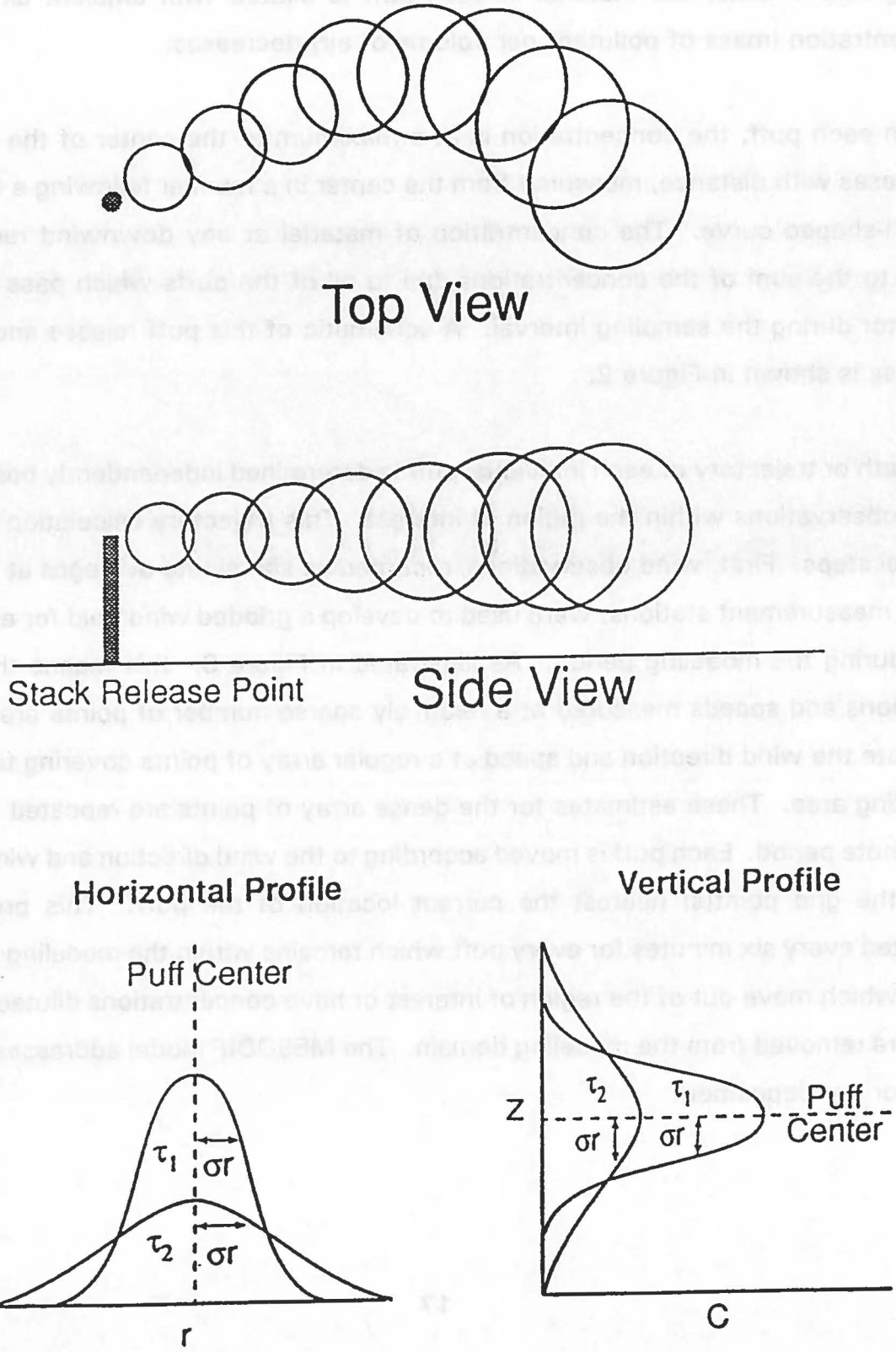
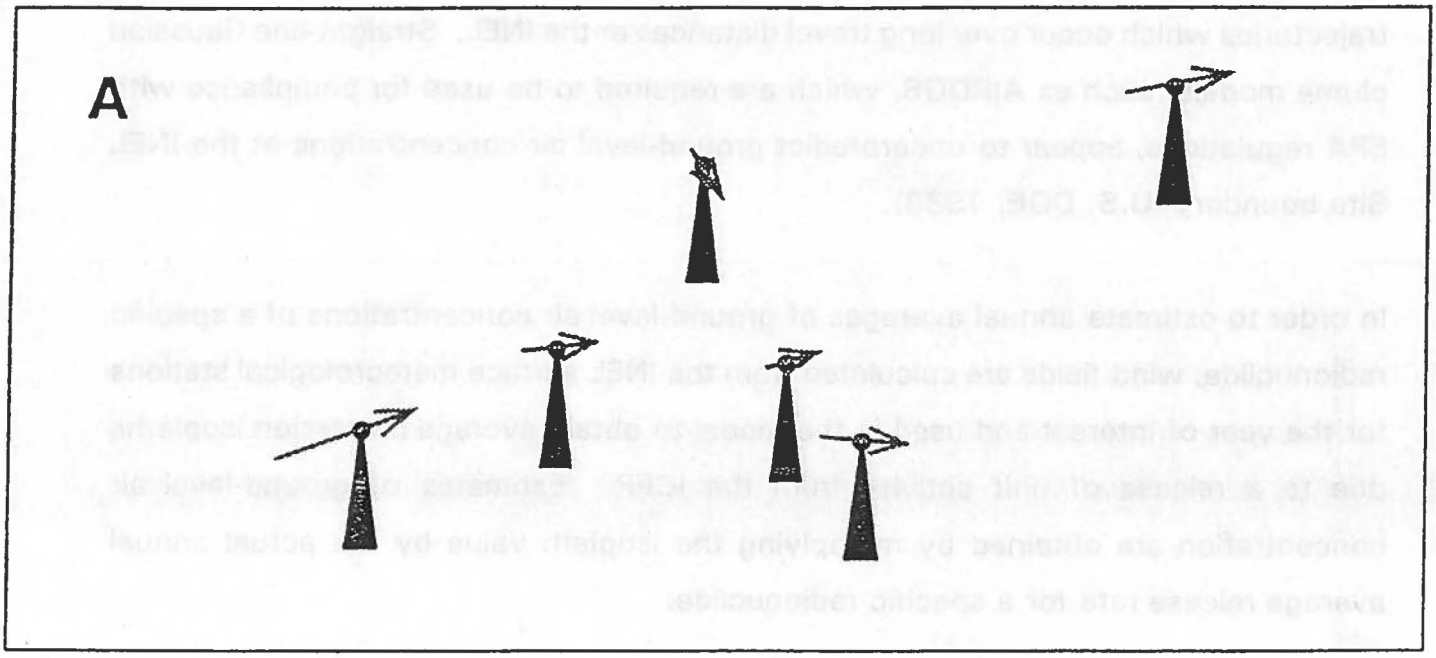
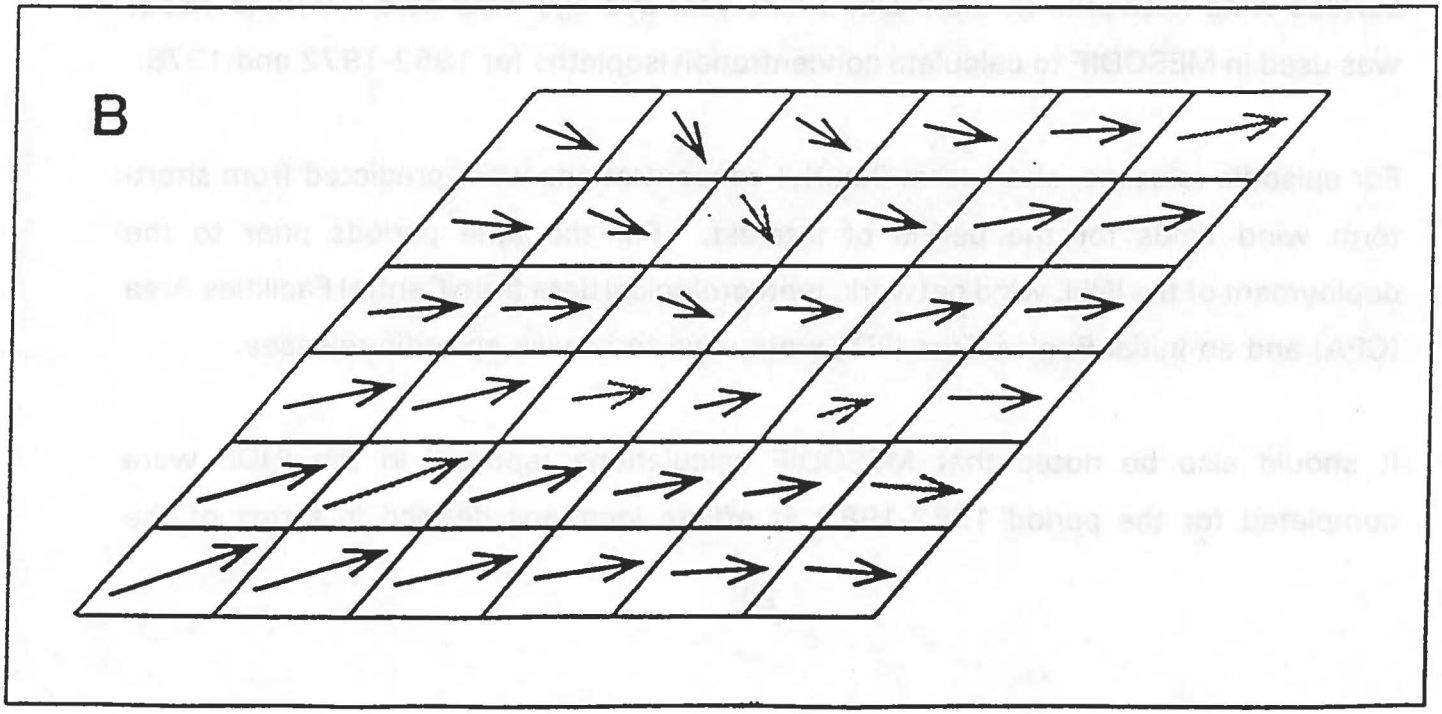


Figure 3. Development of a wind field for use in MESODIF: a) wind direction and wind speed are measured at a number of surface stations; the arrows represent the average wind direction and wind speed during a six minute period; and b) measured winds are interpolated to estimate wind direction and speed at each point in a grid for the averaging period. This gridded wind field is then used to calculate the puff transport for that time period.





The application of MESODIF is limited to the area where the INEL meteorological monitoring stations are located. This area extends in all directions to approximately 95 miles (150 km) from the center of the INEL.

Previous and Current Uses of MESODIF

MESODIF was chosen over other models used for these types of calculations because it was developed specifically for the INEL and it explicitly accounts for curved plume trajectories which occur over long travel distances at the INEL. Straight-line Gaussian plume models, such as AIRDOS, which are required to be used for compliance with EPA regulations, appear to underpredict ground-level air concentrations at the INEL Site boundary (U.S. DOE, 1988).

In order to estimate annual averages of ground-level air concentrations of a specific radionuclide, wind fields are calculated from the INEL surface meteorological stations for the year of interest and used in the model to obtain average dispersion isopleths due to a release of unit activity from the ICPP. Estimates of ground-level air concentration are obtained by multiplying the isopleth value by the actual annual average release rate for a specific radionuclide.

For the years 1952-1972 and 1978, wind data were not available from the INEL surface wind network. In the IHDE, a nine year average wind field (1974 to 1983) was used in MESODIF to calculate concentration isopleths for 1952-1972 and 1978.

For episodic releases, short-term (hourly) concentrations were predicted from short-term wind fields for the period of interest. For the time periods prior to the deployment of the INEL wind network, meteorological data from Central Facilities Area (CFA) and an Initial Engine Test (IET) were used to assess episodic releases.

It should also be noted that MESODIF calculations reported in the IHDE were completed for the period 1952-1987 at offsite locations defined in terms of the

current INEL boundaries. However, in 1959 the INEL area was enlarged. The IHDE results do not reflect this change prior to 1959.

MESODIF is used at the INEL as an emergency response tool. In this role, the NOAA Air Resources Laboratory runs the model and provides near real-time predictions and analyses to emergency personnel.

There is an extensive effort currently underway to update the meteorological and data acquisition system at the INEL and to revise or replace the MESODIF model (Ackerman and Johnson, 1989). The objectives of this upgrade are to improve the INEL emergency response capability and to improve estimates of the air transport of hazardous materials. After these changes are implemented, upper-level winds will be measured at one location on a continuous basis. The revised or new model will be a multiple-layer code which will use these data to account for the vertical structure of the atmosphere.

Uncertainties in MESODIF

The key aspects of the MESODIF modeling approach which are subject to uncertainties and which may produce errors in dose estimates can be categorized as follows:

1) Wind Field and Trajectory Calculations

   a. Errors in the surface wind measurements, sparseness of the measurement array, and lack of upper level wind measurements;

   b. Methods for interpolating of wind measurements to a gridded array, treating air motions at different heights, effects of terrain, and effects of atmospheric conditions on mean air motions;

   c. Methods for calculating puff trajectory, number of puffs released per hour, and treatment of vertical movements of puffs.

2) Puff Growth Rates and Concentration Calculations

a. Errors in the emission rate, material characteristics (gas, particle), and source properties (continuous stack release, instantaneous or short-term release);

b. Errors in the initial plume rise (specification of the starting height for each puff), initial puff size, and effects of buildings upon the initial dispersion of the plume;

c. Errors in the horizontal and vertical puff dimensions as a function of travel time, topography, atmospheric conditions, and vertical structure of the atmosphere;

d. Errors in the puff shape and concentration profile within each puff;

e. Assumption that there is no loss of material from each puff (dry and wet deposition) as a function of travel time, atmospheric conditions, and surface characteristics;

f. Absence of modeling of secondary exposure pathways such as resuspension of particles or revolatilization of gases deposited to surfaces.

These uncertainties are not addressed explicitly in MESODIF and estimates of modeling uncertainties do not accompany the IHDE estimates or the INEL annual dose estimates. However, without estimates of uncertainties in reported concentrations or doses, the model predictions cannot be used to judge the degree of impact for a given situation. For example, it is typical for atmospheric dispersion models to have uncertainties on the order of a factor of two. Given this degree of uncertainty, conclusions regarding predicted concentrations relative to air quality limits cannot be made unless the predictions are more than a factor of two below the air quality limit. This need for a clear indication of model uncertainty has been recognized in the current Hanford Environmental Dose Reconstruction (HEDR) project. In the dispersion model being formulated for HEDR, a formal uncertainty analysis is built into the model so that each model prediction will be accompanied by an uncertainty estimate. Future

modeling estimates made at the INEL should include a formal analysis of the uncertainty in the estimates.

Other Modeling Methods

Any modeling method used for this scale of problem will share a similar list of uncertainties and sources of error. This is true for other puff-trajectory models as well as for more complicated numerical models. Ramsdell (1991) has reviewed a variety of modeling methods as a basis for selecting a method for the HEDR project. These methods include straight-line Gaussian models, puff trajectory models, and gradient theory numerical models.

Straight-line Gaussian models (such as AIRDOS-EPA and CAP-88) represent the simplest approach to dispersion modeling. In this method, plumes are assumed to travel in a straight line along the mean wind direction (measured at the source), and there is no possibility to account for curvature in the plume transport path.

Gradient theory or grid models, which are more complex, use mathematical equations to describe atmospheric behavior and pollutant diffusion. In the most rigorous case, these solutions yield predictions of the wind speed, wind direction, temperature, and pollutant concentration at every point in a three dimensional grid extending horizontally over the modeling domain and vertically to at least the top of the atmospheric boundary layer (several kilometers in height). The size of the grids may be smaller than 2 kilometers horizontally and vary in vertical dimension from less than 100 meters at the surface to up to 1000 meters near the top of the modeled atmosphere. While these models can be formulated over a range of complexities, this type of numerical model generally requires much more detailed atmospheric measurements in order to initiate the model calculation, and the computer requirements are also much larger than for a puff trajectory model like MESODIF.

Evaluating MESODIF With INEL Field Data

In the development of models for use at nuclear facilities, the NRC supported efforts to obtain improved data bases for the evaluation of atmospheric dispersion models. The Idaho Field Study, conducted by the NOAA laboratory at the INEL, was one of these data collection efforts. During July 1981, nine separate tracer releases were conducted along with tetroon (neutrally weighted balloon) flights, and detailed meteorological measurements in order to evaluate MESODIF and other models with regard to use in emergency situations. These tests were generally conducted during high-pressure, clear-sky conditions. Each release period covered eight hours, and releases occurred during both daytime and nighttime conditions. Tracer was released from a height of 45 meters above the surface near the center of the INEL. Tetroons were released periodically during each test and tracked via radar to beyond the INEL boundaries. An extensive grid network of ground-level sampling points were used to obtain tracer concentrations throughout the INEL region.

Start et al. (1985) presented an evaluation of MESODIF in terms of the comparison of tracer, tetroon, and modeled trajectories and in terms of a comparison between predicted and observed tracer concentrations. In the comparison of transport paths, the test area was divided into six zones. For all of the zones, the transport path based upon the tracer was correctly predicted in 72 percent of the cases (54 observations). In 61 percent of the cases, the results from tetroon, tracer, and model transport paths were in agreement with one another. There was no apparent difference between daytime and nighttime test periods. In terms of the area where measurable tracer was observed (threshold set at 1 percent of maximum observed concentration), the impact locations were correctly predicted in 81 percent of the cases, but the size of the impact areas calculated with the model were less than half (42 percent) of the measured plume impact areas. In addition, the calculated degree of plume impact (sum of concentrations multiplied by plume impact area) was 66 percent of the observed plume impact. In terms of concentrations observed at

specific locations, the model systematically underestimated observed concentrations by a factor of about two to three.

To summarize these results, the MESODIF model was relatively successful at predicting the transport path, but the model underestimates the area of impact and the concentration in the zone of impact. Start et al. (1985) made two recommendations:

1) Further analyses of these data were needed to determine why the model underestimated observations; and
2) Further field measurements were needed to investigate the phenomena which contribute to model errors.

The MESODIF model can also be evaluated from a comparison of predicted and observed concentrations of radionuclides at offsite locations. In most cases, the offsite atmospheric concentrations of radionuclides released by INEL facilities usually have not been high enough to measure. There are, however, exceptions. Antimony-125 (^{125}Sb) is an effluent of the fuel-dissolution process at the Flourinel and Fuel Storage Facility that could be measured at a few off-site locations from 1986 to 1988. Annual, semi-annual, or quarterly concentrations of ^{125}Sb were also calculated using the MESODIF model at some of those locations. The results, as extracted from the INEL Site Environmental Reports for Calendar Years 1986, 1987, and 1988 (U.S. DOE 1987; U.S. DOE 1988; U.S. DOE 1989) are given in Table 1.

On the basis of this limited set of data, it does not appear that MESODIF consistently underestimated or overestimated the average concentrations at off-site locations due to atmospheric releases.

There are also other opportunities to compare MESODIF calculations with measured concentrations. For example, environmental monitoring data were used to estimate

Table 1. Comparison of Measured and MESODIF-Predicted ^{125}Sb Average Air Concentrations, 1986-1988

YEAR	LOCATION	MEASURED (fCi/m^3)	PREDICTED (fCi/m^3)	RATIO Predicted/ Measured
1986	Atomic City	12	6	0.5
1987	Atomic City	2.2	9	4
1987	Howe	4.8	6	1.3
1987	Arco	measurable	not measurable	
1987	average of all locations	2.2	4.5	2
1988	Atomic City	2.2	11	5
1988	Howe	2.9	3.6	1.3
1988	Reno Ranch	2.5	1.3	0.5
1988	Terreton	not measurable	8.4	

Data from U.S. DOE 1987; U.S. DOE 1988; U.S. DOE 1989

the dose from Iodine-131 (^{131}I) at Atomic City for the SL-1 accident in 1961 (Islitzer, 1961), but a comparison of the ^{131}I air concentrations, which were measured or derived from vegetation samples, with those predicted by MESODIF have not been made.

Also, the Aircraft Nuclear Propulsion (ANP) program, which was operated in the late 1950's and the early 1960's, was designed with field monitoring teams in place, including, in many cases, aerial monitoring. These data have not been used to validate the MESODIF model. We recognize that these releases occurred before the MESODIF model was developed, but suggest they may be useful for future evaluations.

We have found no evidence that additional work has been done to clarify the source of the aforementioned model errors or to improve the model through additional field work or through adaptation of recent scientific advances. The 1981 model evaluation study yielded a relatively comprehensive database for model evaluation, but the MESODIF performance was tested with only a limited analysis of these data and the model performance statistics are not adequate for comparisons between MESODIF and other models, such as those reviewed by Ramsdell (1991).

The questions which remain unanswered include:

1) How applicable are the results to other times of the year?
2) What is the model accuracy for long term releases and long term dose calculations?
3) Have the underestimates of the model in the INEL tracer study ever been addressed?

Comparison of MESODIF With Other Models

Since MESODIF is an early version of the puff trajectory models, it is worthwhile to describe the differences between it and the more recent trajectory models. Models which are currently being used at other U.S. DOE facilities include MESOI 2.0 (Ramsdell et al., 1983) and MESOILT2, a climatological version of MESOI 2.0 (Ramsdell and Burk, 1991) in use at Hanford and in the HEDR project, and the Terrain Responsive Atmospheric Code (TRAC) developed for use at Rocky Flats and under consideration for use in the Rocky Flats Dose Reconstruction project (Hodgin, 1986; 1991).

An extensive tracer and meteorological field study was conducted at Rocky Flats in January, 1991. Its purpose was to develop a database for model evaluation. The data are now being used to evaluate TRAC as well as other models used at U.S. DOE facilities. At the present time, MESODIF has not been included in this evaluation.

To compare MESODIF to MESOI 2.0 and TRAC, methods used to develop wind fields, trajectories and puff diffusion rates, and to treat other atmospheric effects are summarized in Table 2. Generally, MESODIF is a much simpler model than either MESOI or TRAC, and TRAC addresses a much wider range of atmospheric effects from a theoretical basis than either of the others. The main differences among the models are:

1) the use of a single layer of winds (MESODIF) versus multiple layers;
2) the use of Gaussian concentration distributions (MESODIF and MESOI 2.0) versus a non-Gaussian distribution;
3) specification of diffusion rates from local empirical curves (MESODIF and MESOI 2.0) or from turbulence parameters (MESOI 2.0 and TRAC); and
4) the lack of spatial details in stability and mixing height in MESODIF and MESOI 2.0.

Table 2. Comparison of MESODIF, MESOI 2.0, and TRAC Puff Trajectory Models

FEATURE	MESODIF	MESOI 2.0	TRAC
Wind Fields	1-minute average observations, 1 km & 6 km grids, 1 layer of winds, inverse interpolation from observations to obtain wind field, no explicit terrain treatment, no adjustment of winds for atmospheric conditions (stability)	Hourly wind fields 5 km grids, 3 vertical layers, inverse interpolation from observations to obtain wind field, optional terrain adjustment (ad hoc), interpolation of intermediate layer winds to match surface and upper layer winds from measurements or upper air charts	15-minute average, 4 vertical layers, surface layer winds obtained from mass conservation solution that includes thermal/terrain effects and predicts grid winds, temperature, and stability conditions, intermediate mixing layer wind speed constant interpolated from upper gradient layer
Stability Field	1 hourly stability class from single tower measurements	1 hourly stability class from cloud cover, wind speed, time of day	Different stability class for each grid calculated from surface scaling theory
Mixing Depth	1 hourly value based upon climatological means	1 hourly value based upon upper air sounding, follows terrain	Local grid values for each time step
Plume Rise	None	Briggs standard formulas	Yes, no details
Building Effects	None	None	Yes, no details
Puff Shape	Gaussian	Gaussian	6-particle ellipsoid
Puff Growth	Desert diffusion curves	4 options, terrain effects	Wind shear effects, local turbulence, calculated turbulence terms
Deposition	None	Dry deposition fixed, wet deposition empirical washout terms	Dry deposition function of time and grid position, wet deposition empirical washout terms, gravitational settling of large particles
Decay/Growth	None	Exponential	Yes
Resuspension	None	None	Yes, by grid

It is noteworthy that the HEDR project selected MESOILT2 (a climatological version of MESOI 2.0) for Phase I calculations and that a revised version of this model (RACHET, Ramsdell and Burk, 1992) is being developed for further calculations. MESOILT2 is a modified version of MESODIF and incorporates more details related to the vertical structure of winds, puff diffusion schemes, and deposition mechanisms.

Ramsdell and Burk (1991) have reported results from a test of MESOI 2.0 against some monthly average Krypton-85 (^{85}Kr) measurements. The model accounted for approximately 58 percent of the variation in the observations. The performance of this model was better than the weighted average performance of all models used to estimate monthly means in a model evaluation workshop using data from the Savannah River Environmental Laboratory (SREL) (Weber et al., 1982). On average, the model produced results about a factor of two higher than the measured values.

While it is clear that TRAC and numerical grid models are based on more realistic descriptions of the atmospheric physics than simple puff-trajectory models, it is not necessarily true that these numerical models are significantly more accurate. Ramsdell (1991) examined model performance results for a variety of methods and models and concluded that the puff model was the best approach for providing air concentrations and deposition required to perform dose estimates as part of the HEDR project.

Correlation coefficients between observed and predicted concentrations from the modeling workshop, using data from the Savannah River Laboratory (SRL) (Weber et al., 1982) for a variety of different models, exhibited surprisingly little difference among modeling methods (i.e. puff trajectory vs. numerical grid or gradient methods). Ramsdell summarized these and similar results (Lewellen et al., 1987; Carhart et al., 1989) by noting that "the standard puff models perform as well as the more complex models;" that "no one class of models performed significantly better than the others;" and that "differences in the performance of simple and complex dispersion models are smaller than would be expected." MESODIF was not included in these evaluations.

The INEL tracer field data were used by Lewellen et al. (1985) to test a number of different models, including MESODIF. These authors found that neither puff models nor the gradient theory models performed any better than the simple Gaussian straight-line models for near-field (less than 10 km) transport distances. For hourly average concentrations at near-field locations, the best model results showed agreement within a factor of two at about 40 percent of the receptor locations. One implication of this result is that predictions of worker exposure at outdoor locations within 10 km of a release cannot be accurately predicted with the models tested in this study. Improving the accuracy of these near-field predictions will probably require more detailed treatment of the effects of plume downwash and enhanced diffusion due to the presence of buildings near source points.

At longer distances, for 12 hour integrated doses, 60 percent of the predictions agreed with corresponding observations to within a factor of two. For the maximum observed values, the level of agreement within a factor of two decreased to approximately 40 percent. For these distances and integration periods, MESODIF performed as well as the other models. Two conclusions can be drawn from this model intercomparison. First, the accuracy of model predictions is limited to approximately a factor of two. Second, MESODIF is as good as other models developed for this type of application.

In a test of eight different models (which did not include MESODIF) with long-range tracer data, Carhart et al. (1989) concluded the following:

1) All of the models overestimated observed concentrations and underestimated plume spread;
2) Predicted plume arrival times at a receptor lagged behind plume arrival times; and
3) Use of multi-layer wind fields and an alternate plume diffusion scheme appeared to improve model performance.

Given the first result and the fact that MESODIF is quite similar to several of the models tested, it is perplexing why MESODIF underestimated concentrations in the 1981 INEL tracer study (Start et al. 1985). The second result has potential implications for the consideration of isotope half-lives in assessing air transport of radionuclides. In the IHDE, the amount of isotopic decay based upon the transport time to the site boundary was used to reduce the effective source strength used in the model calculations. To the extent that plume transport times are less than might be predicted with a model, the amount of isotope activity may be underestimated.

As indicated previously, more sophisticated models do not necessarily imply more accurate results. However, it can be expected that a sophisticated model will be better suited to a wide range of conditions than a simple model. To determine the accuracy of a model or whether one model is significantly better than another requires the use of detailed data collected during comprehensive field studies. These data are used as input to various models, and results are compared with observations and among models. This type of model evaluation should be required for all models used to predict environmental transport of hazardous materials. MESODIF has not been adequately evaluated in this manner.

3.2 Dose Assessment Models

Introduction

MESODIF is used at the INEL to calculate time-integrated concentrations of the radionuclides in the atmosphere at ground-level for points located beyond the site boundaries. Calculations are completed for both operational and episodic releases. Dose assessment models are then needed to estimate the radiation doses received by the members of the public as a result of identified routes of exposure.

The dose assessment models generally consist of three parts:

1) Evaluation of the environmental transfer, leading to estimates of the environmental concentrations of the radionuclides of interest in soil and in foodstuffs;
2) Determination of the lifestyles and dietary habits of the populations exposed, leading to estimates of intake for specific radionuclides; and
3) Determination of the dose per unit intake (dose coefficient) for specific radionuclides and calculation of the radiation doses received by the exposed population.

Description of the Models Used by INEL

In the IHDE report, doses were estimated for four routes of offsite exposure: 1) external exposure from immersion in contaminated air; 2) external exposure from radionuclides deposited on ground surfaces; 3) internal exposure from inhalation of contaminated air; and 4) internal exposure from ingestion of contaminated foodstuffs.

Other routes of exposure were not modeled in the IHDE report but are considered in the annual environmental reports (e.g., U.S. DOE 1991). For example: 1) inhalation of radioactive materials resuspended into the atmosphere from contaminated soil at the Radioactive Waste Management Complex (RWMC); 2) ingestion of meat from game animals such as ducks which reside briefly upon liquid waste ponds, sage grouse, and antelope that are contaminated onsite and killed for consumption offsite. A route of exposure that is not considered in the IHDE or in the annual environmental reports is the ingestion of contaminated soil.

The hypothetical individuals for whom the doses were calculated in the IHDE report (adults, 10 year-old children, and infants 1 year-old or less) were assumed to reside at the location near the INEL site boundary where the time-integrated concentrations in ground-level air were highest for the year considered.

The doses from environmental releases received onsite by INEL workers, construction workers, security guards, or ranchers herding livestock have not been included in the IHDE report.

In their estimates of the hypothetical doses received by offsite residents, the INEL uses models and default parameter values for these models that have been accepted by regulatory agencies. Uncertainty analysis is not performed. As shown later, assumptions are made in order to ensure that the doses calculated are overestimated for the routes of exposure that were considered.

Environmental Transfer Models Used by INEL

For the routes of exposure considered in the IHDE report and for INEL annual reports, estimates of environmental concentrations are based on models developed by the NRC and published as Regulatory Guide 1.109. Most of the parameter values in these models are default values that imply conservatism (or tend to overestimate doses). For example, in a comparison of the models used to calculate the contamination of milk resulting from the Chernobyl accident, it was found that the NRC models usually overestimated the measured concentrations in milk.

For external exposure from radionuclides deposited on ground surfaces and for internal exposure from ingestion, the environmental concentrations of interest are those in soil and in foodstuffs, respectively. In the case of external exposure from immersion in air and for internal exposure from inhalation, the environmental concentrations of interest are those in ground-level air, provided by the MESODIF model. Other routes of exposure were ignored in the IHDE report because the INEL estimated that they were less important than the ones that were considered (e.g., ingestion of meat from game and range animals). The ingestion of contaminated soil was also not considered.

Lifestyle and Dietary Habits Considered by INEL

For the IHDE, the hypothetical individuals for whom the doses were calculated in the IHDE were assumed to have: 1) resided at the same location for 50 years; 2) lived in dwellings that provide minimal shielding against external radiation and that do not provide any filtration of incoming air; and 3) consumed only agricultural products (milk, meat, and produce, for example) that have been grown at the same location. All of these assumptions are conservative.

Dose Coefficients Used by INEL

The internal dose coefficients used in the IHDE report are those recommended by the International Commission on Radiological Protection (ICRP) in its latest publications on this subject (ICRP 1978-1981; ICRP 1988). For many radionuclides, the internal dose coefficients depend on their chemical form. In the IHDE and in its annual monitoring reports, the INEL assumed that the radionuclides present in the environment were in the chemical forms that correspond to the highest dose factors. The external dose coefficients for immersion in contaminated air assumed no protection by buildings, and those for ground deposition assumed no vertical migration or wash-off from ground surfaces during the 50 years following deposition.

Description of Other Models

For estimating annual releases of radionuclides and for estimating releases in the IHDE, INEL used dose assessment models and parameter values that were deliberately conservative in order to provide overestimates of doses. This is perfectly acceptable in view of the purpose of the IHDE report. However, the tendency in dose assessment is to use realistic models and to associate the estimated doses with error estimates. Models for estimating radionuclides are also dynamic in character, i.e., the parameter values can change as a function of time. An example of such a model is PATHWAY, which was used by the U.S. DOE to estimate doses resulting from the atmospheric bomb tests that were carried out at the Nevada Test Site (NTS). Other realistic dose assessment models are FOODMARC, a model developed in the United

Kingdom, and ECOSYS, a model developed in Germany, both of which were used to estimate the doses resulting from the Chernobyl accident. Validation exercises of dose assessment models are now being carried out under the auspices of the International Atomic Energy Agency. Some of the characteristics of realistic dose assessment models, in comparison to those used by the INEL, are described below. All transfer processes are considered and then incorporated in dose assessment models for realistic conditions if they produce doses to humans. For example, a realistic dose assessment model for the INEL would include the contamination of ground surfaces through wet deposition, the resuspension of radionuclides from soil into the air, the contamination of game and domestic animals that incorporate radionuclides on the site, the contamination of groundwater consumed by workers, and the ingestion of soil by children.

It is clear, in particular, that wet deposition processes (scavenging of radioactive materials to the ground by rain or snow) deserve to be considered. Wet deposition was ignored in the models used by the INEL because of the low annual precipitation at the site. In its 1986 Environmental Monitoring Program Report (U.S. DOE 1987), however, the INEL reported that fallout from the Chernobyl accident was greater in southeastern Idaho than in most other parts of the continental United States because of the slow drizzle that occurred during the passage of the radioactive cloud. This fact alone justifies the inclusion of wet deposition processes in the INEL models.

The values for all model parameters were determined for the unique characteristics of the site. For example, the pasture intake by cows was varied throughout the year according to agricultural practices in the area, the interception factor took the standing crop biomass into account, and the vertical migration of radionuclides deposited on soil was considered as well.

The doses from external irradiation and from inhalation depend on the amount of time spent indoors because buildings filter incoming air and because they shield occupants from gamma radiation. Conservative models such as those used by the INEL lead to

doses that are overestimated by a factor of about two for inhalation and of about five for external irradiation.

The doses from ingestion can be very sensitive to the origin of the foodstuffs consumed. People consuming milk from their backyard cow and eating vegetables produced in their own garden are likely to receive higher doses than those who obtain milk and vegetables from a supermarket. The degree to which the INEL model is conservative can only be determined by surveying agricultural and commercial practices in the region.

Dose coefficients are used to convert estimates of exposure to estimates of dose. For external exposures, they depend on the morphology of the exposed person which is correlated with age. The variability of dose with age is often ignored in view of the much larger sources of uncertainty for other parameter values. The dose factors for internally deposited radionuclides also depend on the age of the exposed person and on the chemical form of the radionuclide. They are usually obtained from ICRP publications.

Validation of INEL Models With Field Data

Extensive environmental monitoring programs and experiments were carried out at the INEL. It seems that very little, if any, of the results have been used to determine parameter values for environmental pathway models. For example, the CERT experiments were conducted in the 1960's for the purpose of investigating, in depth, the deposition-cow-milk foodchain for ^{131}I. However, it is not clear whether any of the results that were obtained in the course of those experiments have been used in the models.

In the same way, after the Chernobyl accident radioactive contamination was measured in air, precipitation, milk (backyard cows and dairies), sheep, and game animals. Unfortunately, these measurements were not used to derive transfer factors

specific for the INEL Site. Appendix E of the IHDE report attempts to compare the calculated doses with those derived from measurements but fails to derive any conclusion with respect to the dose assessment models.

3.3 Observations

1) MESODIF has been tested against a set of short-term data collected during summertime conditions at the INEL. Generally, there is no clear indication that the MESODIF model always produces conservative results. While the model usually predicts the correct transport path (72 percent of the test cases were correctly predicted), it appears to underestimate the area and degree of plume impact (measured as the product of concentration and land area), and radionuclide concentrations. In a comparison of long-term average ^{125}Sb air concentrations measured offsite, MESODIF overestimated some, but not all, of the observed levels. The overestimation of the ^{125}Sb levels may be related to the lack of a deposition term (wet or dry) in the model.

2) An intercomparison between ten models, using the INEL tracer data, showed that MESODIF did not appear any better or worse than other models. All of the models agreed, within a factor of 2, with concentrations measured in the far field (greater than 10 km) for only 60 percent of the time. In the far field MESODIF did not appear any better or worse than other models.

3) The radiation doses reported in the IHDE report for the years prior to 1959 were calculated at the current site boundaries which were not established until after 1959. Prior to 1959, the site boundaries were smaller than they are now.

4) NOAA is in the process of upgrading MESODIF and is also installing new meteorological measurement systems. Upper-level winds will be measured on a continuous basis and the new model will incorporate more details of the vertical structure of the atmosphere in the calculations.

5) The dose assessment models include the most common pathways of exposure to man but ignore the inhalation of radionuclides resuspended from soil into the air, the ingestion of contaminated soil, and the ingestion of the meat from game and range animals that incorporate radionuclides onsite. Also, the ground contamination due to wet deposition (rain or snow) is not considered.

6) Traditionally, doses have been calculated for hypothetical individuals assumed to reside at the offsite location near the INEL site boundary where the time-integrated concentrations in air were highest. Doses received onsite by INEL workers, construction workers, security guards, field researchers, or ranchers herding cattle have not been modeled, and there are no alternate estimates for these.

7) To estimate doses from the pathways considered, the INEL used models that had been accepted by regulatory agencies, including the default parameter values for these models. No uncertainty analysis was performed and conservative assumptions were made in most cases in order to ensure that the calculated doses were overestimated. However, these dose estimates were based upon MESODIF air concentrations which were not necessarily conservative, given the degree of underestimation observed in the model evaluation study (see item 1 above).

3.4 Recommendations

1) MESODIF should be further evaluated using both short-term and long-term data sets for both the INEL and other facilities. The INEL data sets which should be considered include the ^{125}Sb and ^{85}Kr measurements, data from the SL-1 accident, and results from the ANP program. Non-INEL data such as the tracer study conducted during 1991 at Rocky Flats provide an alternative for model evaluation. Testing MESODIF with this type of data set will allow a formal comparison to be made against other models currently in use.

2) ***In order to interpret previous results obtained with MESODIF, it is important to provide complete documentation of past and current uses of MESODIF. It is also very important that the updated version of MESODIF (or its replacement) be fully documented and that the new model be made available to outside users for review.***

3) ***The new version of MESODIF should be rigorously evaluated with the data sets described above. The evaluation should address both short- and long-term averages, and the analysis should follow current model validation protocols. The revised version of MESODIF should be evaluated against both observations and other models. The revised model should also incorporate analyses of uncertainty for its predictions.***

4) ***With respect to dose assessment models, the main recommendation for future studies is to use realistic models and to include rigorous analyses of uncertainty. These models should be based on site-specific data and make use of lifestyle and dietary habits that could be obtained through surveys. There should also be better documentation of the process by which predictions of the dose models were validated. Existing environmental monitoring data should be evaluated for use in model validation.***

4.0 WATER MODELS USED AT INEL

4.1 Introduction

The INEL activities have impacted the aquifer through disposal of waste water by injecting it into wells and releasing it into percolation ponds. Chemicals and radionuclides have also leached into the aquifer from waste disposal sites. The SRPA, in the area impacted by releases from the INEL, has been studied continuously since the site was established in 1949. Because geologic and hydrologic characterization of the aquifer has been extensive and has involved hundreds of monitoring wells and the efforts of several agencies and research groups, a unique opportunity exists to investigate changes in the aquifer over time. There is an extensive database on the SRPA which helps define original baseline conditions, predicts contaminant migration through time, defines the current conditions, and contributes to local and regional modeling efforts.

The U.S. Geological Survey (USGS) has played the dominant role in research, monitoring, and documentation. Several other groups, including state and federal agencies and universities, have been involved in water quality research and monitoring. A large quantity of data exists on water quality monitoring of various contaminant plumes as well as the hydrologic, geologic, and geophysical nature of the aquifer that underlies the INEL site and surrounding region. Application of a regional transport model to the area of the SRPA underlying the INEL is complicated by the non-homogeneity and anisotropy of the basalt flows and interbed formations. Three dimensional modeling is a necessity to understand contaminant transport impacts, and calibration of a model requires a thorough knowledge of vertical gradients and hydraulic conductivities between flow systems. Although a significant amount of data are available, a thorough analysis of the data is required to define the hydrogeologic system.

4.2 Models Used at the INEL

Groundwater models have been used at the INEL since computer modeling came of age in the early 1970's. The purpose of this chapter is to review surface and groundwater models at the INEL, particularly as they relate to prediction of offsite contaminant levels and dose evaluation. In developing this report, the subcommittee reviewed available published reports, interviewed the USGS, the State of Idaho, the INEL Oversight Program, and the contractor personnel.

Surface Water Models

HEC 2, a stream water surface profile model, is utilized for flood runoff events to design dike and flood facilities. The DAMBRK model is used to analyze hydrological aspects of failure of Mackay dam and to assist in determining location and management of infiltration of recharge to the aquifer. These models deal with surface hydrology and hydraulics and do not relate to definition of the groundwater pathway for contaminant transport. Location of recharge from flood events and subsequent groundwater recharge need to be considered in evaluating historical groundwater response and future modeling efforts.

Groundwater Models

The use of groundwater models at the INEL began prior to 1974 when the USGS began using a two-dimensional transport and dispersion model to simulate the plume of inorganics and radionuclides beneath the site and offsite (Robertson, 1974; Lewis and Goldstein, 1982). This model is a two-dimensional finite difference model which assumed a uniform 250 foot aquifer thickness, negligible aerial recharge, and uniform transverse and longitudinal dispersivities. The model was used primarily to simulate chloride and tritium plumes from injection wells used for waste disposal, a practice which was assumed to have stopped in 1973. This model predicted that tritium would reach the south INEL boundary in 1980. Tritium was detected in monitoring wells at the south boundary in 1983. This model has not been updated, but the USGS plans to construct a new model utilizing the USGS MODFLOW code. A solute-

transport module for MODFLOW has been developed and is now in the testing and documentation phase. A well calibrated and verified contaminant transport model can be used to define areas of the aquifer where additional data are required, for estimating horizontal and vertical contaminant plume migration in areas where monitoring has not been conducted, and for predicting trends in contaminant levels based on future hydrologic and contaminant flux scenarios.

Computer models of regional flows within the SRPA, including the INEL, have been developed by the University of Idaho (de Sonniville, 1971; Newton, 1978) and the USGS (Garrabedian, 1986). These models are small-scale flow models that do not include transport routines and do not predict contaminant flow. They are useful, however, in defining the general flow paths beneath the INEL with respect to the Snake River and populated areas on the Eastern SRP.

Table 3 is a summary of groundwater flow and contaminant transport computer codes used at the INEL. This summary, prepared by the INEL Oversight Program (Barrash, December 1991, personal communication), follows this section. It outlines the various computer codes, documentation, and references for each model used at the INEL. Most of these models have been utilized by personnel at EG&G or by other contractors for evaluating multiphase fluid flow, heat transfer, and mass transport in both saturated and unsaturated porous and fractured media.

Much of the computer modeling has been performed in connection with evaluations of projects such as the New Production Reactor (NPR) project. Several models such as the Magnum-2D, CHAINT, TRACR3D, and others have been used at the INEL for simulating plumes in the SRPA. It appears that at least seven groundwater flow and transport models have been used or evaluated at the INEL for some purpose. Three or four unsaturated flow models have also been utilized. Generally, groundwater models have not been used at the INEL to evaluate the risk of offsite exposure to radionuclides. The Robertson Model was used to predict offsite contaminant

Table 3

STATE OF IDAHO INEL OVERSIGHT PROGRAM

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Ground Water Flow and Contaminant Transport Computer Codes used at INEL.

December 3, 1991

Agency	Code Name / Proprietor / Contact / Verification / Validation	Application / Prime User	Code Documentation / Description / Selection Justification / Computing Environment
EG&G	POREFLOW-3D, v. 2.36 Analytical and Computational Research, Inc. Akshai Runchal POREFLOW version 1.0 has been extensively verified and benchmark tested (Magnuson, et., al., 1990). POREFLOW version 2.36 is an updated, multifluid, multiphase version of the original POREFLOW computer code, Version 1.0.	FLUID FLOW, HEAT AND CONTAMINANT TRANSPORT Swen Magnuson, Subsurface and Environmental Modeling Unit.	Runchal, A.K., and B. Sagar, 1991, POREFLOW: A Model of Fluid Flow, Heat, and Mass Transport in Multifluid, Multiphase Fractured or Porous Media, User's Manual, Version 2.36, Analytic and Computational Research, Inc. Versions of POREFLOW prior to Version 2.0 were denoted POREFLO. POREFLOW is a computer code for solution of multiphase, fluid flow, heat transfer, and mass transport in variably saturated porous or fractured media. The code uses nodal point integration on a three-dimensional finite difference grid and employs several solution options such as ADI, conjugate gradient, etc. POREFLOW is written in FORTRAN 77, is hardware independent and uses FREEFORM command language input. The code has been used at other DOE sites in similar studies, and several users at INEL are very familiar with the code. Requires a workstation or mainframe computer. References: S.O. Magnuson, R.G. Baca, A.J. Sondrup, 1990, Independent Verification and Benchmark Testing of the POREFLOW-3 Computer Code, Version 1.0, EGG-BG-9175.
EG&G	MAGNUM-2D, ver.?: ____ Westinghouse Hanford Operations, Richland, WA (the INEL version of the code is significantly advanced and modified from the original base version). R.G. Baca, R.C. Arnett Validation and Verification?: _____	2D SATURATED GROUND WATER FLOW R.C. Arnett, Subsurface and Environmental Modeling Unit.	England, R.L., N.W. Kline, K.J. Ekblad, R.G. Baca, 1986, "MAGNUM-2D Computer Code: User's Guide," RHI-CR-143 P, Rockwell Hanford Operations, Richland, WA The MAGNUM-2D computer code was originally developed at the Hanford site for modelling ground water flow in the vicinity of a high-level waste repository. The MAGNUM-2D code is unique in that it can simulate ground water flow and/or heat transport in a two-dimensional domain, i.e., radial or Cartesian system. The MAGNUM-2D code uses a dual permeability approach to represent the hydraulic behavior of a fractured porous media. The porous zones in the domain are modeled using standard two- and three-dimensional isoparametric finite elements. Discrete fractures are modeled using line elements which are embedded along the sides of the continuum elements. The code can be used to produce transient and steady-state simulations of ground water flow. MAGNUM-2D is interfaced with support software that computes and plots: streamlines, pathlines, travel times, velocity vectors, contours, profiles, and time histories. MAGNUM-2D has been used in ground water modeling studies of plumes in the Snake River Plain aquifer. Reference?: _____ MAGNUM-2D is written in FORTRAN (F-90) standard. Practical application of MAGNUM-2D requires availability of a large mainframe or a high-end workstation.

Agency	Code Name / Proprietor / Contact / Verification / Validation	Application / Prime User	Code Documentation / Description / Selection Justification / Computing Environment
EG&G	CHAINT, ver.? ____ Westinghouse Hanford Operations, Richland, WA R.G. Baca, R.C. Arnett Validation and Verification?: _____	2D GROUND WATER CONTAMINANT TRANSPORT R.C. Arnett, Subsurface and Environmental Modeling Unit.	Kline, N.W., R.L. England, and R.G. Baca, 1986, CHAINT Computer Code: Users Guide, RHO-CR-144 P, Rockwell Hanford Operations, Richland, WA. CHAINT is a counterpart to the MAGNUM 2D computer code designed to simulate multicomponent contaminant transport in a ground water system. The code considers advection, diffusion and dispersion, sorption, decay chains, and time varying mass release. CHAINT is limited to 2D systems. CHAINT uses the Galerkin finite element method to solve the transient form of the governing equation. The CHAINT code utilizes a dual permeability approach to represent fractured porous medium. The code can handle heterogeneous, anisotropic systems with networks of discrete fractures. The porous zones in the domain are modeled using standard two-dimensional isoparametric finite elements, i.e., triangles and quadrilaterals. Discrete fractures are modeled using line elements which are embedded along sides of the continuum elements. In addition, the code can accommodate a variety of initial and boundary conditions. Primary outputs of the CHAINT code are contaminant concentrations and fluxes at specified locations. The CHAINT computer code has been recently used at INEL to model major contaminant plumes in the Snake River Plain aquifer (Baca, et. al., 1984); the code has also been applied to other DOE sites. CHAINT is written in FORTRAN (F-90) standard and is operational on the CRAY supercomputer. Practical applications of this code require availability of a large mainframe or a high-end workstation. Support software for this code requires DISSPLA and GKSS graphic kernals. A copy of the source code can be obtained directly from Westinghouse Hanford Operations in Richland WA. The INEL version is significantly advanced and modified from the original base version. This new version will be released after preparation and issuance of updated documentation. References: Baca, R.G., R.C. Arnett, and D.W. Langford, 1984, "Modeling Fluid Flow in Fractured Porous Rock Masses by Finite Element Techniques," International Journal of Numerical Methods in Fluids, Vol. 4, pp. 337-348.

Agency	Code Name / Proprietor / Contact / Verification / Validation	Application / Prime User	Code Documentation / Description / Selection Justification / Computing Environment
EG&G	MAGNUM-3D, v. 4.0 Westinghouse Hanford Operations, Richland, WA (the INEL code is significantly advanced and modified from the base version). R.C. Arnett MAGNUM-3D has undergone extensive verification and benchmarking.	SATURATED GROUND WATER FLOW R.C. Arnett, Subsurface and Environmental Modeling Unit.	Estey, S.A., R.C. Arnett, and D.B. Aichele, 1985, "User's Guide for MAGNUM-3D: A Three-Dimensional Ground Water Flow Numerical Model," RHO-BW-ST-67P, Rockwell Hanford Operations, Richland, WA. MAGNUM-3D is a finite element code designed to model saturated flow in fractured porous media in 2D or 3D. 2D sheet elements are used for discrete zones or for strictly 2D problems and isoparametric hexahedrons or triangular prisms for three dimensional zones. MAGNUM-3D is used in conjunction with FECTRA for contaminant transport problems. Compatibility with unsaturated codes, sheet elements for use with discrete zones in basalt, 2 & 3D, substantial set of pre- and post-processors, can adjust to situations when transmissivity anisotropy is not aligned with the coordinate system. Requires a workstation or mainframe computer. References: Arnett, R.C., S.A. Estey, and D.B. Aichele, 1986, "Verification and Benchmarking of the MAGNUM-3D Ground Water Flow Code", RHO-BW-ST-69P. Rockwell Hanford Operations, Richland, WA.
EG&G	FECTRA, v. 2.0 Westinghouse Hanford Operations, Richland, WA (the INEL version of this code is significantly advanced and modified from the base version). R.C. Arnett FECTRA has been verified and benchmarked to a limited degree. The FECTRA 3D code is still under development and will be available after completion of code verification, benchmarking, and documentation.	2 & 3D GROUND WATER CONTAMINANT TRANSPORT R.C. Arnett, Subsurface and Environmental Modeling Unit.	User's manual and code testing report is in preparation, scheduled for completion early in FY 1992. FECTRA is designed to simulate contaminant migration through saturated, fractured, porous medium. It simulates advection, dispersion, diffusion, decay, and retardation. Using a 2 & 3D, finite element solution method, FECTRA is designed to be used with MAGNUM-3D. MAGNUM-3D provides the advective flow field for FECTRA. This code was selected because of its compatibility with MAGNUM-3D, it handles 2 & 3D, it has sheet elements to handle discrete zones, is specifically applicable to INEL, it is efficient, and is being used for other projects at INEL. References?: _____ Requires a workstation or mainframe computer.

Agency	Code Name / Proprietor / Contact / Verification / Validation	Application / Prime User	Code Documentation / Description / Selection Justification / Computing Environment
EG&G	FLASH, v. 2.6 Proprietor?: _____ R.G. Baca The FLASH computer code has been extensively verified and benchmarked.	FLUID FLOW IN ARID SITE VADOSE ZONES R.G. Baca, Subsurface and Environmental Modeling Unit.	FLASH was used in the verification and benchmark testing of the UNSAT-H computer code (Baca and Magnuson, 1990). FLASH was used also in the verification and benchmark testing of the PORFLO-3 computer code (Magnuson, et., al., 1990). A technical report on the model theory, numerical technique, and code testing is in preparation and is expected to be issued in FY-92. The FLASH computer code is designed to model variably saturated flow in fractured porous media. The code uses a finite element technique to solve the governing equations for flow and/or heat transport. The code uses line elements for discrete conduits and isoparametric triangles and quadrilateral elements for porous zones. The FLASH code is used in conjunction with the FLAME code. Available codes were reviewed and found inadequate for use at INEL. Primary limitations of existing codes were (1) inadequate documentation, (2) unable to handle arid site conditions, and/or (3) not applicable to fractured-porous basalt geology. Being used for other projects at INEL. References?: _____ Requires a workstation or mainframe computer. References: Baca, R.G., and S.O. Magnuson, 1990, Independent Verification and Benchmark Testing of the UNSAT-H Computer Code, Version 2.0, EGG-BEG-8811. Magnuson, S.O., R.G. Baca, A.J. Sondrup, 1990, Independent Verification and Benchmark Testing of the POREFLO-3 Computer Code, Version 1.0, EGG-BG-9175.
EG&G	UNSAT-H, v. 2.0 Proprietor?: _____ R.G. Baca The UNSAT-H code has been verified using analytical solutions and benchmark tested against other independent codes. Some limited comparisons have been made against field data.	WATER BALANCE IN ARID SITE VADOSE ZONE R.G. Baca, Subsurface and Environmental Modeling Unit.	The model theory and user instructions are documented in Fayer and Jones (1990). Results of code verification and benchmarking are presented in Baca and Magnuson (1990). M.J. Fayer and T.L. Jones, 1990, UNSAT-H Version 2.0: Unsaturated Soil Water and Heat Flow Model, PNL-6779. R.G. Baca and S.O. Magnuson, 1990, Independent Verification and Benchmark Testing of the UNSAT-H Computer Code, Version 2.0, EGG-BEG-8811. The UNSAT-H code is designed to model soil-moisture dynamics in an arid site vadose zone. The code solves the one-dimensional Richard's equation. The code accounts for water flow by gravity, capillarity, evapotranspiration, and uptake by plants. The code is very useful for estimating the net infiltration rate into the soil. A review of water balance codes indicates that UNSAT-H is the only code available that models soil-water flow as a function of meteorological conditions, evapotranspiration, etc. The code is being used at other DOE sites. Requires a 80386 PC, 80486 PC, or workstation.

Agency	Code Name / Proprietor / Contact / Verification / Validation	Application / Prime User	Code Documentation / Description / Selection Justification / Computing Environment
EG&G	FLAME, v. 1.0 Proprietor?: _____ R.G. Baca The FLAME computer code has been verified and benchmarked to a limited degree.	CONTAMINANT TRANSPORT IN ARID SITE VADOSE ZONES R.G. Baca, Subsurface and Environmental Modeling Unit.	The FLAME computer code was only recently developed. A technical report for the code is planned for completion in FY-92. The FLAME computer code is designed to predict contaminant migration through a variably saturated vadose zone. The code simulates advection, dispersion, diffusion, decay and sorption. The code uses a finite element technique to solve the governing equation. The FLAME code is used in conjunction with the FLASH code. Available codes were reviewed and found to be lacking in various areas. The FLAME code was developed for specific application to the hydrogeology of the INEL site. The code is being used for other projects at INEL. References?: _____ Requires a workstation or mainframe computer.
EG&G	MINTEQ, v. A1 EPA-Athens Research Center. D.S. Brown MINTEQ was verified during development by comparison calculations with WATEQ4. Validation has only been conducted for aqueous systems containing Cu(II), Pu, and U.	EQUILIBRIUM OF ROCK/WATER SYSTEMS C.A. Dicke, Subsurface and Environmental Modeling Unit.	Brown, D.S., and J.D. Allison, 1987, MINTEQ A1, An Equilibrium Metal Speciation Model: User's Manual. EPA-600/3-87/012, U.S. EPA, Athens GA. Felmay, A.R., D.C. Garvin, and E.A. Jenne, 1984, MINTEQ: A Computer Program for Calculating Aqueous Geochemical Equilibria. (NTIS P884-157148) EPA-600/3-84-032, National Technical Information Service, Springfield, VA. Peterson, S.R., C.J. Hostetler, W.J. Deutsch, and C.E. Cowan, 1987, MINTEQ Users Manual. NUREG/CR-4804, PNL-6106, U.S. Nuclear Regulatory Commission, Washington, D.C. MINTEQ is a geochemical computer code for predicting and evaluating the equilibrium of inorganic pollutants in a variety of geochemical environments. The code can model the complex equilibrium relationships among aqueous species, solids, gases, and adsorbed species. The code can also be used to calculate the consequences of equilibrium mass transfer between aqueous and solid phases. The code is used at many DOE sites, is familiar to INEL users, and is capable of handling a wide variety of geochemical problems. Requires PC's with 286 processors or greater, workstations, or mainframes.

Agency	Code Name / Proprietor / Contact / Verification / Validation	Application / Prime User	Code Documentation / Description / Selection Justification / Computing Environment
EG&G	GRDFLX, ver.?: ____ U.S. Nuclear Regulatory Commission Contact?: _____ Verification and validation?: _____	GROUND WATER TRANSPORT AND RADIOACTIVE DECAY Art Rood, Subsurface and Environmental Modeling Unit.	Documentation?: _____ GRDFLX consists of two models whose computational mechanics are quite similar though they perform different tasks. Program GRND calculates the vertically averaged concentration at points in a uniform aquifer of finite thickness with constant physical transport properties. Program FLUX calculates the flux of radioactive liquid effluent passing a plane perpendicular to the ground water flow direction. Both models require most of the same input data and are for horizontal area sources. The models are formulated as analytical solutions to the equations of mass transfer for conservative substances in porous media. Radioactive decay is treated separately from the transport computations. Requires an IBM PC. Reference: Codell, R.B., K.T. Key, and G. Whelan, A Collection of Mathematical Models for Dispersion in Surface Water and Ground Water, NUREG-0868, 1982.
EG&G	Codell NRC Surface Water Codes U.S. Nuclear Regulatory Commission Contact?: _____ Verification and Validation?: _____	2D DISPERSION IN SURFACE WATER Art Rood, Subsurface and Environmental Modeling Unit.	Documentation?: _____ The codes STTUBE and TUBE are useful for two-dimensional dispersion of a continuous source into a river after steady state has been attained. These codes require actual river cross sections and roughness coefficients. RIVLAK code is also used for dispersion in a river, but the source may be either steady or unsteady. The river channel must be of constant width and depth. Requires and IBM PC. Reference: Codell, R.B., K.T. Key, and G. Whelan, A Collection of Mathematical Models for Dispersion in Surface Water and Ground Water, NUREG-0868, 1982.

Agency	Code Name / Proprietor / Contact / Verification / Validation	Application / Prime User	Code Documentation / Description / Selection Justification / Computing Environment
EG&G	Model Name?: _____ Version?: _____ Proprietor?: _____ Contact?: _____ Verification and Validation? _____	STOCHASTIC REPRESENTATION OF THE SUBSURFACE Christine Lee, Subsurface and Environmental Modeling Unit.	Documentation?: _____ A stochastic model has been built, based on currently available data, that provides: 1) a statistically inferred data set from which a 3-D realization, or other representation of parameter values, may be generated, 2) an estimate of the expected error in the model, 3) the minimal data set necessary to generate a stable model of the subsurface (i.e., how many wells are necessary to develop a stable view of the subsurface characteristics?), and 4) a sensitivity analysis (i.e., where should new wells be placed?). Based on data currently available, empirical statistical distributions have been generated for each of 12-15 parameter (i.e., conductivity, porosity, flow depth, etc.) associated with the subsurface. As a result, it is possible to statistically infer parameter values for any point in the basalt subsurface using well established statistical techniques. The model is essentially an expert system using empirical statistical distributions at key points in order to generate statistically sound parameter values. Computing Environment?: _____
EG&G	Model Name?: _____ Version?: _____ Proprietor?: _____ Contact?: _____ Verification and Validation? _____	FLOOD FLOW MODELING Rich Martineau, Subsurface and Environmental Modeling Unit.	Documentation?: _____ Developed own code for 1D flooding model, and developing own code for 2D flooding model. Description?: _____ Computing Environment?: _____
EG&G	Model Name?: _____ Version?: _____ Proprietor?: _____ Contact?: _____ Verification and Validation? _____	GROUND WATER SUSCEPTIBILITY AT COCA SITES Art Rood, Subsurface and Environmental Modeling Unit.	Documentation?: _____ In-house code being developed. 1D, steady state ground water flow and transient chemical transport. Description?: _____ Computing Environment?: _____

Agency	Code Name / Proprietor / Contact / Verification / Validation	Application / Prime User	Code Documentation / Description / Selection Justification / Computing Environment
EG&G	Model Name?: _____ Version?: _____ Proprietor?: _____ Contact?: _____ Verification and Validation? _____	FLUID FLOW FROM FAILED CONCRETE STRUCTURES John Walton, Subsurface and Environmental Modeling Unit.	Documentation?: _____ Developing own code. Description?: _____ Computing Environment?: _____
EG&G	Van der Camp Version?: _____ Proprietor?: _____ Contact?: _____ Verification and Validation? _____	SLUG TESTS Allan Wylie, Quantitative Hydrology Unit.	Documentation?: _____ Description?: _____ Computing Environment?: _____
EG&G	HEC I and HEC II (sp?) Version?: _____ Proprietor?: _____ Contact?: _____ Verification and Validation? _____	FLOOD FLOW MODELING Joe Zukauskas, Waste Management Unit	Documentation?: _____ Trying to define maximum flood wave for engineering aspects, r.e., RWMC. Description?: _____ Computing Environment?: _____
EG&G	TARGET 2D HORIZONTAL, ver. 4.0 (TARGET2DH) Dames and Moore, Inc., Denver, CO Joanna Moreno or Peter Sinton Verification and Validation?: _____	Ground Water Flow and Contaminant Transport Anticipated User?: _____	Dames and Moore, Inc., October, 1985, User's Guide to TARGET_2DH, 27 p. This TARGET code is for modeling two-dimensional, vertically integrated, confined/unconfined, ground water flow and contaminant transport. This code has been proposed for use in modeling ground water flow and contaminant transport in the perched water zone beneath TRA. The TARGET_2DH code is prepared for 80386- or 80486-based microcomputers using UNIX or extended-memory DOS operating systems.

Agency	Code Name / Proprietor / Contact / Verification / Validation	Application / Prime User	Code Documentation / Description / Selection Justification / Computing Environment
EG&G	TARGET 2D UNSATURATED, ver. 4.0 (TARGET2DU) Dames and Moore, Inc., Denver, CO Joanna Moreno or Peter Sinton Verification and Validation?: _____	Ground Water Flow and Density-Coupled Contaminant Transport Anticipated User?: _____	Dames and Moore, Inc., October, 1985, User's Guide to TARGET_2DU, 28 p. This TARGET code is for modeling two-dimensional, variably saturated, density coupled, ground water flow and contaminant transport. This code has been proposed for use in modeling ground water flow and contaminant transport in the perched water zone beneath the TRA. The TARGET_2DU code is prepared for 80386- or 80486-based microcomputers using UNIX or extended-memory DOS operating systems.
EG&G	PLOTAR2D, ver. 4.0 Dames and Moore, Inc., Denver, CO Joanna Moreno or Peter Sinton Verification and Validation?: _____	Plotting Programs for TARGET 2D Models Anticipated User?: _____	Dames and Moore, Inc., September, 1985, User's Guide to PLOTAR_2D PLOTAR2D is a plot programs which permits the graphical representation of results as generated by a 2-dimensional TARGET ground water code. Both contours of scaler variables and vector representations of velocity are possible. The PLOTAR2D code is prepared for 80386- or 80486-based microcomputers using UNIX or extended memory DOS operating systems.
EG&G	POSTAR2D, ver.?: _____ Dames and Moore, Denver Joanna Moreno or Peter Sinton Verification and Validation?: _____	Post Processors for TARGET 2D Models Anticipated User?: _____	Documentation?: _____ POSTAR is designed to assist in the analyses of results of TARGET ground water flow and solute or heat transport modeling studies. The capabilities of these post-processors are: - Calculation of time histories of flows of water, solute, or heat energy through individual nodes or lines of nodes. - Calculation of fluxes of water, solute, or heat energy through each model boundary. - Calculation of fluxes of water, solute, or heat energy through all model fixed head nodes. - Plots of time histories of water head, solute concentration, or temperature at model nodes. - Plots of fluxes of water, solute, or heat energy against distance along any chosen line of nodes. - Plots of time histories of fluxes of water, solute, or heat energy through nodes or lines of nodes. Computing Environment?: _____

Agency	Code Name / Proprietor / Contact / Verification / Validation	Application / Prime User	Code Documentation / Description / Selection Justification / Computing Environment
WINCO	TRACR3D, ver.?: _____ Los Alamos National Laboratory B.J. Travis Verification and Validation?: _____	GROUND WATER FLOW AND CONTAMINANT TRANSPORT (3D, finite difference, isothermal code) Tom Thomas, Technical Department	Used to model ground water flow and contaminant transport in the unsaturated vadose zone and saturated aquifer zone (Thomas, Chipman, and Berreth, 1986). Flooding was modeled to represent a transient water flow and rainfall over several thousand years, a steady-state water flow. Radionuclides which completely leach out in the first few years of rainfall represent a transient contaminant flow whereas the highly insoluble radionuclides represent a steady-state contaminant flow. The vadose zone was modeled as consisting of a top layer of alluvium, five interbeds, and six layers of basalt; the aquifer consisted of one layer of basalt. Radionuclides modeled were Se-79, Sr-90, Tc-99, Cs-135, and Am-241. It was assumed that the behavior of Cs-137 would be similar to Sr-90 and the behavior of Am-243, Pu-239, and Pu-240 would be similar to Am-241 based on solubilities, sorption coefficients, and half-lives. References: Robertson, J.B., May, 1974, Digital Modeling of Radioactive and Chemical Waste Transport in the Snake River Plain Aquifer at the National Reactor Testing Station, Idaho, U.S. Geological Survey National Reactor Testing Station Open-File Report, IDO-22054. Robertson, J.B., January, 1977, Numerical Modeling of Subsurface Radioactive Solute Transport from Waste - Seepage Ponds at the Idaho National Engineering Laboratory, IDO-22057. Travis, B.J., May, 1984, TRACR3D: A Model of Flow and Transport in Porous/Fractured Media, LA-9667-MS Thomas, T.R., Chipman, N.A., and Berreth, J.R., 1986, Impact of Rain, Flood, and River Water on Potential Near-Surface Disposal of High-Level Radioactive Waste at the Idaho Chemical Processing Plant; Westinghouse Idaho Nuclear Company, Inc., Idaho Falls, Idaho; WINCO-1042 Thomas, T.R., 1988, Modeling Hypothetical Ground Water Transport of NO_3Cr and Cd at the ICPP, WINCO report #1060. Thomas, T.R., 1991, Solute Transport Benchmark Studies for TRACR3D Code Verification, WINCO report #1083. Thomas, T.R., J.A. Del Debbio, 1988, Fitting the Corrective Dispersive Solute Transport Equation to Soil Column Effluent Data, WINCO report #1053. Thomas, T.R., J.A. Del Debbio, 1989, Transport Properties of Radionuclides and Hazardous Chemical Species in the Soils at ICPP, WINCO report #1068. Computing Environment?: _____

Agency	Code Name / Proprietor / Contact / Verification / Validation	Application / Prime User	Code Documentation / Description / Selection Justification / Computing Environment
WINCO	DAMBRK, ver.?: ____ National Weather Service D.L. Fread Verification and Validation?: _____	HYDRAULIC ROUTING MODEL Tom Thomas, Technical Department	Thomas, T.R., Chipman, N.A., and Berreth, J.R., 1986, Impact of Rain, Flood, and River Water on Potential Near-Surface Disposal of High-Level Radioactive Waste at the Idaho Chemical Processing Plant; Westinghouse Idaho Nuclear Company, Inc., Idaho Falls, Idaho; WINCO-1042 Used to model the combined consequences of maximum precipitation in the Big Lost River drainage area and a failure of the Mackay Dam located on the Big Lost River about 70 km northwest of ICPP. The flood wave from this scenario was calculated and routed through the downstream valley to determine the maximum flooding potential near ICPP. The DAMBRK code solves equations of continuity and momentum conservation in one dimension. References: Fread, D.L., July 18, 1984, DAMBRK: The NWS Dam-Break Flood Forecasting Model, Office of Hydrology, National Weather Service, Silver Spring, Maryland. Computing Environment?: _____
USGS	MODFLOW, ver.?: ____ Proprietor: Public Domain Contact: Brennon Orr Validation and Verification?: _____	GROUND WATER FLOW AND CONTAMINANT TRANSPORT Dan Ackerman and Brennon Orr	McDonald, M.G., A.W. Harbaugh, 1988, A Modular Three-Dimensional Finite Difference Ground Water Flow Model, in Techniques of Water Resources Investigations of the United State Geological Survey, Book 6, Modeling Techniques, Chapter A1. MODFLOW is a modular quasi-three-dimensional finite-difference model for solving the saturated ground water flow equation. Ground water flow is simulated using a block-centered finite difference approach. The equations can be solved using either the Strongly Implicit Procedure or the Slice Successive Overrelaxation method. The modular structure of the code consists of a number of independent packages that deal with the hydrologic system to be simulated such as wells, areal recharge, evapotranspiration, drains, and streams. Layers within the aquifer can be simulated as confined, unconfined, or a combination of the two. MODFLOW includes a variety of options for source terms, input/output, boundary conditions, and time dependent data. The code is also interfaced with pre- and post-processors to aid in the input and output. Dan Ackerman is looking at integrating the work that Steve Anderson has done on the volcanic/sedimentary sequence with his work on transmissivity and trying to develop a model based on MODFLOW that will simulate ground water flow and contaminant transport at INEL. Brennon Orr is working on building up input data and modifying MODFLOW to simulate ground water flow and contaminant transport in perched water systems at INEL. MODFLOW is written in FORTRAN 77 and will run without modification on most computer with a FORTRAN 77 compiler.

Agency	Code Name / Proprietor / Contact / Verification / Validation	Application / Prime User	Code Documentation / Description / Selection Justification / Computing Environment
USGS	VS2D, ver.?: ____ Proprietor?: _____ Contact?: _____ Validation and Verification?: _____	2D VARIABLY SATURATED GROUND WATER FLOW John Pittman	Documentation?: _____ Description?: _____ John Pittman is building up data from the USGS test trench near the RWMC to be used in a VS2D (Variably Saturated Two Dimensional) model simulating unsaturated zone transport. Computing Environment?: _____

concentrations for current and future and operating conditions of injection wells at the ICPP. A comparatively simple groundwater model was used at EG&G for the environmental assessment of fuel processing restoration at the INEL (EG&G-Idaho, 1987).

Groundwater Model Simulations

Groundwater flow and contaminant transport models are simulation tools that assist in evaluating and understanding flow systems. The use of groundwater models for offsite predictions of contaminant levels is not the most reliable procedure. Proper use of a model helps determine the validity of aquifer parameter values, points out anomalies in assumed or measured flux values, and provides estimates of projected values of flow or contaminant concentrations. They are most useful for filling in spatial gaps in monitoring data, bridging time gaps in observed data, and flagging inconsistent data. They can also be used, with caution, to extend estimates of contaminant levels beyond the boundaries of measured data.

Models are calibrated and verified using measurements made within the spatial and temporal boundaries of the model. The credibility of extrapolating beyond the measured boundaries depends on the degree to which modelers are certain about aquifer parameters and water level data beyond the boundary. At the INEL, the USGS aquifer model is based on 161 observation wells in the SRPA. While this is a dense network compared with the remainder of the SRPA, there are still spatial gaps in the network relative to specific sites and activities. An updated USGS groundwater model could assist in evaluating the need for new observation wells in the existing network.

Additional data and information necessary to develop a credible transport model include:

1) Better determination of the geologic system including classification of flow systems or similar groups of basalt flows;
2) Increased definition of the influence of depth on hydraulic head and basalt flows;
3) Definition of hydraulic conductivity and storativity among modeled zones, especially at large depths;
4) Definition of transverse and longitudinal dispersivities; and
5) Treatment of fracture flows.

The USGS, which is charged with the primary monitoring and evaluation of water quality in the aquifer, does not have an updated operational groundwater flow and contaminant-transport model. There are adequate computer codes available which could be applied to the geologic and water quality data that are now available. The solute transport model for MODFLOW is in the testing and documentation phase. It is estimated that this work will be completed in 1994. The additional geologic, hydrologic, and water quality data available will support the development of a new model and improve the confidence in predictive capabilities. Development of this model is in the current USGS five-year plan.

4.3 State Oversight Program Water Quality Model Evaluations

The State of Idaho INEL Oversight Program is conducting an evaluation of groundwater models used at the INEL by different agencies. The purpose is to gain familiarity with, and confidence in, operating groundwater models used for specific research or investigative purposes.

The INEL Oversight Program is not developing new groundwater transport models. Rather, the program is attempting to secure computer codes and computer capability to evaluate existing programs, reproduce results, and evaluate adequacy of data sets used for each model.

The INEL Oversight Program also conducts research on the unsaturated zone through programs and contracts with the University of Idaho. These projects will examine the interaction between surface water and groundwater on the INEL site and evaluate applicable vadose zone models.

4.4 Groundwater Data

Most of the groundwater data for the early years of operation at the INEL were obtained by the USGS. They compose the largest single groundwater data set in Idaho. Some of the data collected before 1987, although collected under established procedures for that time, lack documentation of Quality Assurance and Quality Control (QA/QC) procedures (L. Mann, W. Barrash, personal communication). Some of the early water quality data in the Atomic City and Mud Lake areas have specific anomalies which need further evaluation. More recent data have been collected under improved QA/QC procedures by USGS, contractors, research personnel, the Radiological and Environmental Sciences Laboratory (RESL), INEL Oversight personnel, and Idaho State University. Generally, these data are not easily accessible and some may not have been collected under rigid QA/QC procedures.

The technology for water quality data acquisition and analysis has vastly improved since its first use at the INEL. Analysis of temporal trends and health risks should benefit from these changes. The historical data should be scrutinized and the procedures for quality control, outlier identification, establishing minimum detection levels, and laboratory analyses should be documented and included in a central database. These data should be catalogued as to location, type, and magnitude; and exclusion criteria for new data should be developed. This database should be accessible to all users.

The cooperative Environmental Data Management Systems (EDMS), organized by the State of Idaho INEL Oversight Program and Groundwater Quality Program and managed by the Idaho Department of Water Resources, would be an appropriate

program for compiling the comprehensive database. The U.S. DOE is also pursuing a separate data consolidation program which could evolve into a site-wide data system. Both the State and the U.S. DOE data consolidation efforts should be coordinated and aggressively pursued.

4.5 Recommendations

Although the U.S. DOE does not consider ground and surface water pathways to be significant contributors to offsite radiation dose, longstanding public concern over the aquifer requires that this issue be explored thoroughly. Ample documentation on the condition and nature of the SRPA exists and should be treated comprehensively, both in summarizing current information and for developing future research needs. The panel found that existing water quality data, historical contamination sources, and data on aquifer characteristics exist in various agency or organizational files but not in any single accessible data base. A concerted effort should be made to enhance the water quality monitoring, hydrologic data base of contaminant transport modeling at the INEL.

The following recommendations apply to current and future data acquisition and analysis for assessing health risks at the INEL:

Existing Data

1) ***Develop a comprehensive review of all water quality monitoring investigations, including regional, local, and site-specific research. Continue to review and summarize existing models and their applications.***

2) ***Centralize all existing water quality information in a single database. Although the information will vary in character, quality, age, and origin, centralized information and access will benefit investigators as well as the general public. An assessment of the quality of these data will also be necessary.***

3) ***Characterize areas of contamination for type, extent, and source of contaminant plume. Include summary documentation on specific sites that have been contaminated, provide a listing of all known releases to the aquifer of chemicals and radionuclides, and review anomalous historical data for tritium concentrations such as at Mud Lake and Atomic City.***

<u>Future Investigations</u>

1) ***Continue water quality monitoring at regional, local, and site-specific levels. Data from all investigations should be added to a centralized database.***

2) ***Continue geologic, hydrologic, and geophysical studies to further characterize the regional setting and to help define parameters for future modeling efforts.***

3) ***State-of-the-art groundwater and solute transport models should be developed as predictive tools to simulate contaminant migration over time, both within and beyond the INEL boundaries. To date, groundwater modeling has not been used routinely to predict radiation doses to offsite individuals. Models have been applied either regionally in specific remediation situations or for prediction of impacts from potential future projects. Solute transport models may be useful as predictors of radiation exposure through the groundwater pathway.***

4) ***A comprehensive program of collecting all information related to the SRPA should be a primary goal. Given the variety of organizations participating in monitoring and research at the INEL, it seems most effective to centralize databases at a state agency and to share experience and information.***

5.0 TECHNICAL REVIEW OF THE INEL HISTORICAL DOSE EVALUATION

5.1 Background

In December 1988, the INEL Historical Dose Evaluation (IHDE) Task group was formed in response to public inquiries concerning possible radiological exposure to the public from past operations at the INEL. The U.S. DOE released a draft of the IHDE in March 1990, which estimated radiation doses potentially received by individuals who lived near the site boundary, for each year of INEL operations from 1952-1989.

The U.S. DOE established an independent Peer Review Panel to review the IHDE draft report. This panel consisted of nine members with technical expertise in radiological dose assessment. The Peer Review Panel made numerous recommendations for improvements in the draft report including a revision of the stated objectives, completeness of the data on radioactive releases, methodology in the dose evaluations, quality assurance, references to classified documents, treatment of the groundwater pathway, and validation of results. The Peer Review Panel also recommended a timely release of the revised document and pointed out that the lack of public participation was a major shortcoming in the report's development.

The U.S. DOE issued the final IHDE in August 1991 (the IHDE report Volume 1, may be obtained from the Office of Environmental Health in Boise). We made the IHDE available to the public for comment in October 1991. The public's comments on the IHDE are included in the Addendum to this report that is available from the Office of Environmental Health.

5.2 Introduction

This section summarizes our review of the IHDE and makes recommendations for additional work, which we recommend be performed during the CDC dose reconstruction project. ***Specific recommendations from the Panel are placed in boldface italics for emphasis***.

Estimating historic exposures to environmental contaminants involves several steps. The first is to identify and quantify the pollutants released to the environment. Scientists then study the ways these contaminants are distributed through different environmental pathways. The dispersion patterns and concentrations of the contaminants in the environment are then predicted with a variety of computer models. The quantities of these contaminants that are inhaled or ingested by humans and other organisms are estimated and the resulting doses computed, along with the doses from radiation that penetrate the body from contamination in the environment. Finally, the consequent health risks are estimated.

This is the way the IHDE progressed. The authors estimated the amount and kind of radionuclides released to the air by INEL activities. The U.S. DOE reviewed process records and emission reports covering the 1952-1989 period of INEL operation, and made estimates of releases where they were not actually measured. Specific weather records were used for short-term, episodic releases, and average conditions were used for longer periods to predict the direction and extent of travel in the air. A model called MESODIF predicted the spread of the radionuclides by the wind. The model assessed a number of ways for people to be exposed, including: 1) simply being immersed in the radioactive plumes; 2) breathing the radionuclides; 3) exposure to radiation from radionuclides deposited on the ground; and 4) ingesting food or water contaminated by radionuclides. The radiologic dose from the sum of all these routes of exposure was estimated for a hypothetical person who would have received the highest offsite dose.

In the IHDE report, radiation doses are evaluated for each year between 1952 and 1989 for members of the public residing offsite. Only doses resulting from atmospheric releases were assessed. According to the U.S. DOE, radioactive liquid effluent has contaminated the SRPA on the INEL site, but has not produced measurable radiation exposure beyond the INEL site boundaries.

In the IHDE, atmospheric releases were categorized as either *operational* or *episodic*. Operational releases were continuous, somewhat uniform releases occurring over a year or over a portion of the year that spanned a variety of meteorological conditions. Episodic releases took place over a short period of time, typically a few hours.

In the IHDE report, doses have been estimated for hypothetical individuals (adults, children, and infants) who may have resided at an offsite location with the highest concentration of airborne radionuclides near the INEL. Calculation of atmospheric transport to locations offsite was done using the MESODIF computer code. The location, lifestyle, and habits of these hypothetical individuals were chosen by the U.S. DOE to yield dose estimates that are likely to reflect the highest doses that could have been received. The U.S. DOE intended for these estimates to be "conservative but realistic." They are not, however, the doses which would have resulted from maximizing all the variables in the chain of dose calculations.

The IHDE computed effective doses, which represent the combined doses from all types of radiation exposure to each organ of the body, scaled by the combination of the following probabilities: 1) the probability the dose would result in a fatal cancer; 2) the weighted probability the dose would result in a non-fatal cancer; 3) the weighted probability the dose would produce severe hereditary effects; and 4) the relative length of life lost. In addition to the effective doses; doses to the skin, bone surfaces, red bone marrow, lungs, liver, and thyroid were calculated separately. The thyroid doses to infants are also important because the cancer risk per unit exposure is higher for infants than for any other age group; cancer of the thyroid, however, is rarely fatal.

5.3 Summary of IHDE Results

According to the IHDE, the amounts of radioactive materials in the operational releases varied from year to year according to the work conducted at the site and waste management practices. The bulk of the radioactive material released from the

INEL originated from the Test Reactor Area (TRA) or from the ICPP. Figure 4 shows the time variation of the total operational releases and the radionuclides that contributed the most to the total releases between 1952 and 1989.

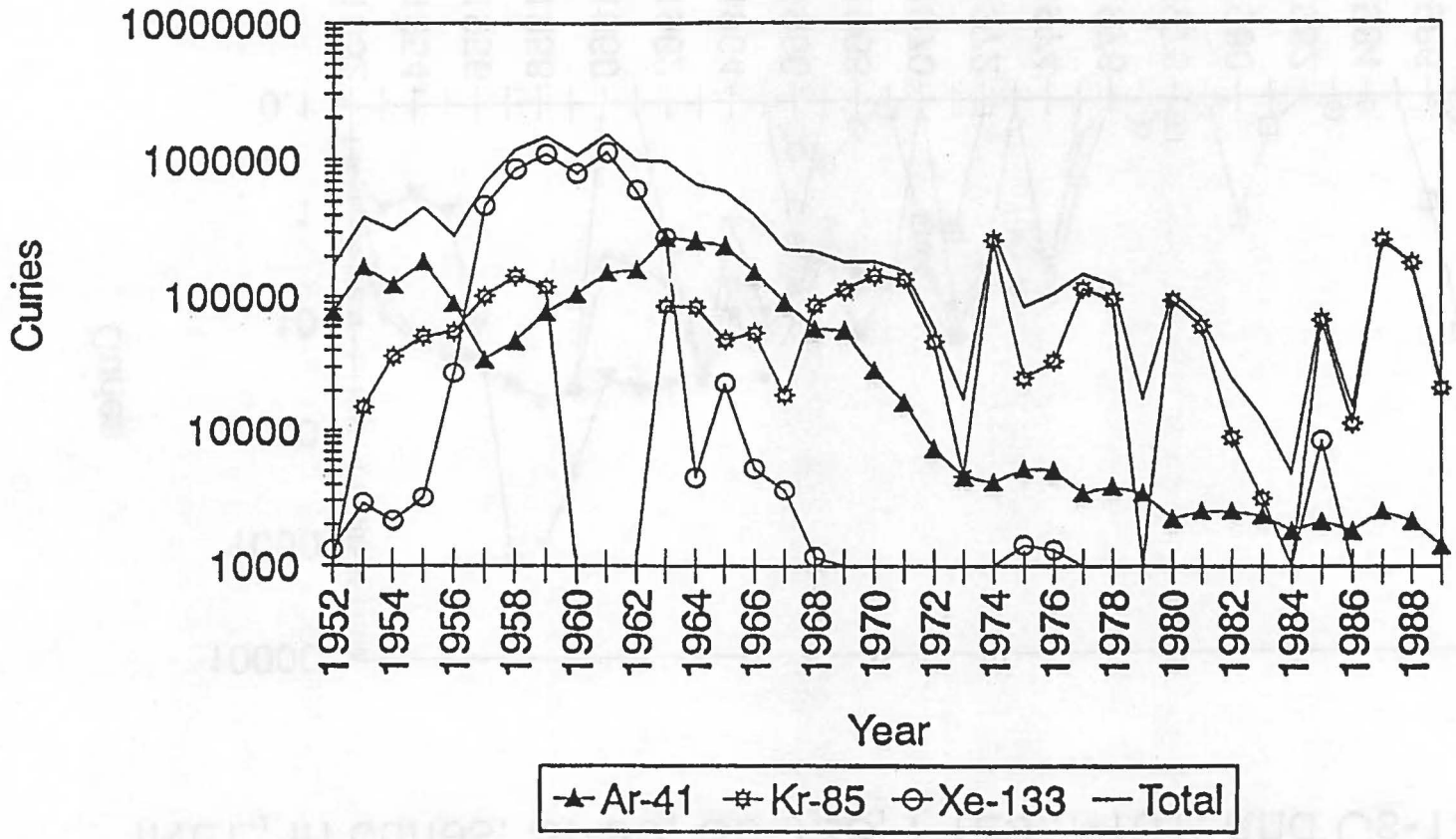
The three radionuclides that contributed the most to the total operational releases are isotopes of noble gases and include: ^{41}Ar, which was the isotope responsible for the largest amount of activity from 1952 to 1956 and from 1963 to 1967; ^{85}Kr, most of which was released from the ICPP, which has accounted for the majority of the operational releases since 1968; and ^{133}Xe, which dominated the operational releases from the RaLa process at the ICPP between 1957 and 1963.

It should be noted, however, that total activity is not a reliable indicator of the radiation doses received by members of the public, as the dose per unit activity delivered by the noble gases is relatively low. As will be seen later, the doses received by members of the public were mainly from other radionuclides (^{90}Sr, ^{125}Sb, ^{129}I, ^{131}I, and ^{137}Cs), which were emitted in much smaller amounts than the noble gases (Figure 5). During the 1950's, releases of ^{90}Sr, ^{131}I, and ^{137}Cs were relatively high; in recent years, releases of ^{125}Sb and ^{129}I have been more abundant than those of ^{90}Sr, ^{131}I, or ^{137}Cs.

Episodic releases have usually been much smaller in total radioactivity than the operational releases. They contributed to the doses received by members of the public only for a few years during the test programs of the 1950's and early 1960's.

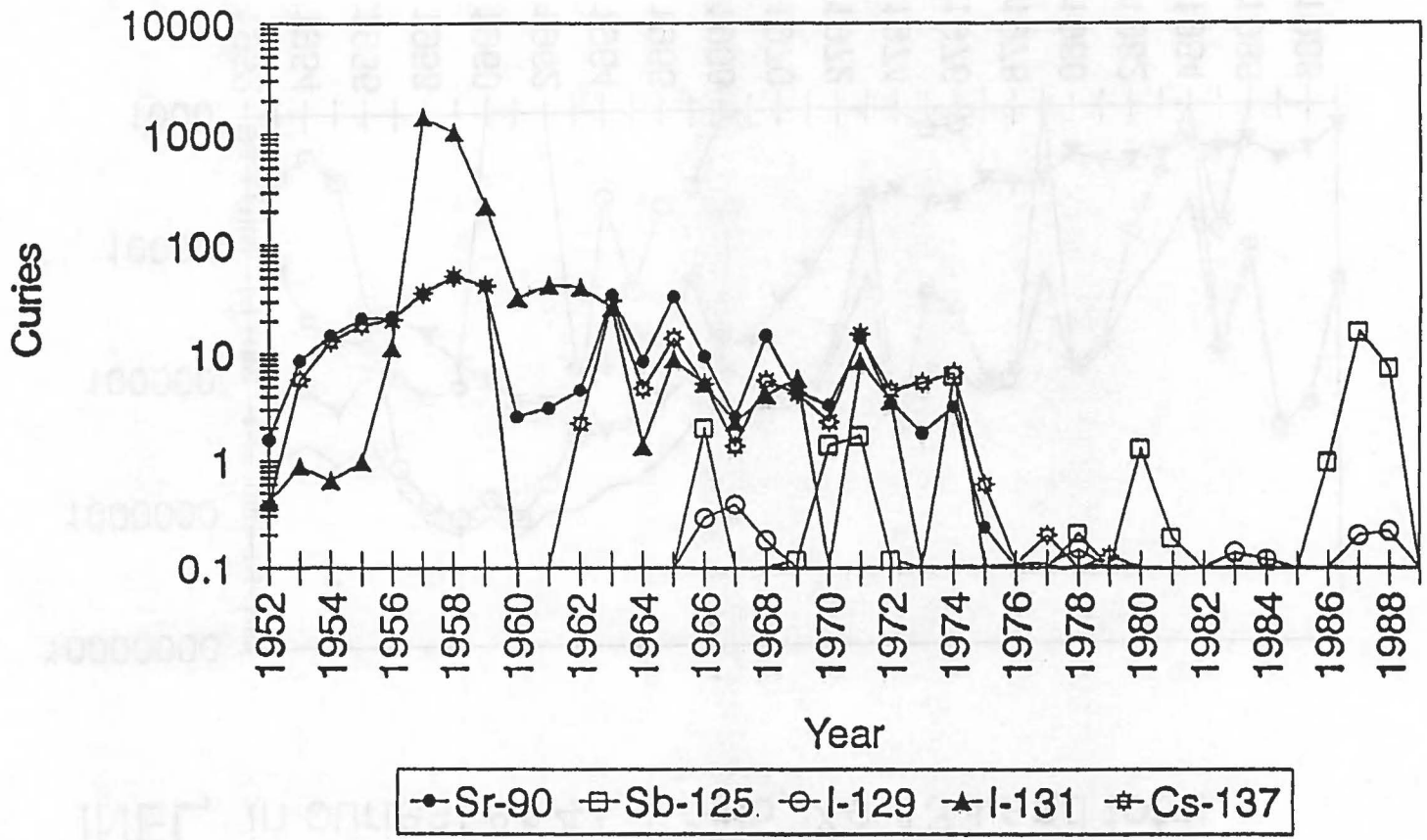
According to the IHDE, the effective doses to adults from the combination of all radionuclides from both operational and episodic releases reached a maximum of about 30 mrem (0.3 mSv) per year in 1956 and 1958. The adult doses decreased more or less steadily to values of about 0.1 mrem (1 μSv) per year in the late 1980's.

Figure 4. Annual operational releases into the atmosphere from INEL, in curies: Ar-41, Kr-85, Xe-133 and total.



Source: INEL Historical Dose Evaluation Report

Figure 5. Annual operational releases into the atmosphere from INEL, in curies: Sr-90, Sb-125, I-129, I-131, and Cs-137



Source: **INEL Historical Dose Evaluation Report**

With a few exceptions, the effective doses from operational releases were much smaller than those due to episodic releases.

The radionuclides and modes of exposure that contributed the most to the annual effective dose varied with time include: ingestion of agricultural products contaminated with ^{131}I in 1957, immersion in air contaminated with ^{41}Ar in 1960, external exposure to radioactivity from ^{137}Cs deposited on the ground in 1971, and external exposure to radioactivity from ^{125}Sb deposited on the ground in 1988.

The infant thyroid was the organ that received the highest organ doses. According to the IHDE, the thyroid dose to infants was highest in 1956, when the dose was estimated to be 1350 mrem (13.5 mSv), or 61 mrem (0.61 mSv) effective dose equivalent. Ingestion of milk contaminated with ^{131}I released by an IET for the ANP Program accounted for most of this dose. Infant thyroid doses have been low in recent years, averaging a fraction of a millirem per year.

The maximum doses reported in the IHDE are difficult to interpret by comparing them with radiation standards because both the standards and the methods of computing doses have changed over the years. The maximum effective dose equivalent in 1956 corresponds to about 2 percent of the applicable whole-body standard (1,500 mrem or 15 mSv) and the maximum effective dose equivalent for 1958 corresponds to 6 percent of the standard applicable in this year (500 mrem or 5 mSv whole body dose). Though similar, the effective dose equivalent and whole body dose are not the same measurements and, strictly speaking, should not be compared.

Until 1961, the radiation protection standard for the thyroid was 3,000 mrem/yr. Therefore, the thyroid doses computed for an infant in 1956 was about 45 percent of the standard in effect at the time. The dose limit currently recommended by the ICRP and NCRP is 330 mrem/yr, and the industry-based EPA standard for the thyroid is 33 mrem/yr.

The general radiation protection standard currently recommended by the ICRP and the National Committee on Radiation Protection and Measurements (NCRP) is 100 mrem /yr (1 mSv) effective dose equivalent. The EPA has established an industry-specific standard for atmospheric releases from operations considered to be in the nuclear fuel cycle. Currently, this standard is 10 mrem/yr (0.10 mSv/yr) effective dose equivalent for the entire body.

5.4 Source Term for Environmental Releases

Radiologic Emissions Monitoring

Sections A.2.2 and A.2.3 of the IHDE correctly point out that the methodology for effluent monitoring at the INEL has improved with time. The IHDE also describes the upgrading of the systems for monitoring releases to the atmosphere.

Currently, radiologic stack emissions are monitored if dose assessments indicate that it is required. The EPA's National Emission Standards for Hazardous Atmospheric Pollutants (NESHAP) regulations require continuous monitoring of sources of radionuclides that could lead to annual doses to the public of 0.1 mrem or greater. These regulations require that the monitoring be carried out in accordance with certain procedures. According to the Draft U.S. DOE Tiger Team Assessment, the INEL has not demonstrated that its current monitoring program meets all of these requirements.

The Radioactive Waste Management Information System (RWMIS) database contains the results from monitoring stack and pipe releases of radionuclides. It also identifies the release points at which monitoring equipment has been installed. Section A.2.2 of the IHDE describes *post facto* "adjustments" which have been made to the RWMIS data in order to better represent actual releases. Other sections describe monitoring that was judged to be of insufficient quality to justify inclusion in the RWMIS. Instead, these emissions were modeled or reconstructed with other techniques. As noted later in this report, various operational and episodic emissions of radionuclides

have not been monitored. Some of these were estimated and included; some are not addressed at all.

For future dose reconstruction efforts, we recommend a more thorough description of the effluent monitoring program for releases to the air, groundwater and soil, and its limitations. Where possible, the uncertainty in the reported emissions should be estimated. All emissions should be reported as best estimates and their uncertainty should be quantified.

The DERA Advisory Panel also recommends that components of the source term be carefully evaluated and compared with historical data on INEL operations. This procedure may identify other sources of chemicals and radionuclides that may contribute to offsite exposure.

Future dose reconstruction should clearly describe the process for selecting releases for inclusion in dose estimates as well as the rationale for modifying these estimates. Specific factors, such as release fractions, can have a powerful influence on these estimates and are subject to uncertainty which must be quantified.

Unmonitored Emissions

There are exposure pathways for radionuclides which are not monitored at the INEL. The U.S. DOE has criteria (U.S. DOE Order 5400.1) for determining whether a release point requires monitoring. This order applies to the monitoring required for compliance determinations, for identifying environmental problems, and for detecting unplanned releases. Many known points of release for radionuclides to the atmosphere do not require monitoring for compliance and are, therefore, not monitored. Under the rules for data entry in the RWMIS, unmonitored operational releases were treated as if they were zero and were not included in the source terms for the IHDE.

The Peer Review Panel organized by the U.S. DOE for the IHDE suggested that the possibility of chemical exposures to the public, via the atmosphere, should be investigated. The panel recommended a complete inventory and documentation of releases and monitoring data. Statements such as "exposure to offsite individuals to chemicals is considered insignificant due to the isolation of facilities at the INEL," made by the U.S. DOE in response to the Peer Review Panel report (Gesell, 1991), have not been sufficiently substantiated.

In particular, meeting the National Ambient Air Quality Standards (NAAQS) is not sufficient to conclude that all offsite exposures to all chemicals released at the INEL were insignificant. The NAAQS only address seven criteria pollutants: carbon monoxide, sulfur dioxide, nitrogen dioxides, hydrocarbons, ozone, lead, and particulate matter less than 10 μm diameter. According to the new Clean Air Act (Calabrese and Kenyon, 1991) there are more than 150 hazardous air pollutants which are generally classified as air toxics.

We recognize that there is a severe lack of data for ambient atmospheric monitoring, as well as for releases of toxic chemicals at the INEL. Reconstruction of past chemical releases will require examining records for receiving production and engineering records to develop an inventory of particular chemicals.

We believe that the IHDE excluded, without adequate justification, the potential for public exposure through groundwater contaminated by chemicals and radionuclides. In evaluating this route, scientists must identify the quantities and physical characteristics of the radionuclides and chemicals that contaminated the groundwater below the INEL site. All of the concerns about atmospheric source terms could apply to the materials that have reached groundwater by injection, leaching, and percolation.

Areas of radiologically contaminated soil have been identified at the INEL. They probably resulted from solid and liquid waste disposal from deposition of airborne

material. The Final Environmental Impact Statement (FEIS) on the Waste Management Operations, published in 1977, shows the results of aerial surveys and other methods used to evaluate the distribution of surface soil contamination. During the review of the Environmental Impact Statement (EIS), the U.S. DOE received and acknowledged comments which identified the potential for offsite dispersal of this contamination. However, this pathway was omitted from the IHDE.

The U.S. DOE Tiger Team Draft Report (U.S. DOE, 1991c), in Finding A/CF-10, noted the potential for fugitive emissions of radionuclides and chemicals. The U.S. DOE orders require that resuspension be considered for compliance monitoring. For example, recent public interest has focused on the RWMC, where soils have been contaminated with transuranic elements. Air samplers positioned around the complex have occasionally measured higher than ambient concentrations. The IHDE report dismissed, without sufficient justification, the existence of this pathway as a source of offsite exposure.

Unmonitored releases and diffuse sources for atmospheric dispersion present special problems for dose estimation. In the case of unmonitored release points few, if any, data exist for making quantitative estimates. The dispersal of diffuse sources, such as contaminated soil, is subject to large variation based on factors such as the physical and chemical states of specific radionuclides, the type of soil they were deposited in, and the local weather patterns. When large areas of soil are contaminated, the impact of these factors on specific receptor locations is subject to uncertainties not encountered with monitored point releases.

One approach to estimating the impact of these sources is to rely on the data from an environmental monitoring system to provide an upper limit or bound on releases. If utilized, the environmental monitoring system should be evaluated to ensure that it is sensitive enough to detect resuspended soil and that the data are complete and

representative. Sensitivity should be expressed as concentrations of specific radionuclides and converted to possible doses at the receptor.

In the same fashion, analysis of environmental samples serves as a check on source-term measurements or calculations, their dispersion, and predictions of their environmental fate. The U.S. DOE agreed with the Peer Review Panel that comparisons with environmental measurements would improve the report. The U.S. DOE correctly points out, in responding to the Peer Review Panel review of the draft IHDE, that environmental samples are subject to their own set of errors. This is the reason that both source-term-driven models and environmental results should be assembled and compared. The dose should be reconstructed or bounded several ways, the results compared, and the strengths and limitations of each method evaluated. This process helps develop confidence in the final estimates.

Appendix E of the IHDE provided examples of comparisons between analyses of environmental samples and effluent-driven model predictions that were made for situations where environmental measurements were readily available. Subsequent efforts should build on this work.

Security Classification of Source-Term Information

The Peer Review Panel, in its final report (Till 1990) stated:

> No reference was made to the use, existence, or exclusion of classified documents. This significantly impacts any independent review and the potential for public confidence....Confidence in the source term is established by comparing various process and stack monitoring results for consistency. Public credibility is strongly enhanced by the availability of these records to permit public repetition of that process....The Panel discovered apparent inconsistencies in noble gas source terms for operational releases as reported in the dose reconstruction and in referenced documents. Resolution of this minor (in dose consequence) inconsistency required dependence on classified information.

In order to improve the public confidence and acceptance, the results of any dose evaluation or reconstruction should be verifiable by independent researchers.

We believe that some source-term data at the ICPP *are* classified, or otherwise restricted in a way which prevents their use by independent scientists. This conclusion is based on the INEL Environmental Reports for Calendar Years 1987 through 1990 and on personal communications. The operational releases of ^{85}Kr for the ICPP, as reported in the IHDE, are traceable to the RWMIS database. Because the ^{85}Kr releases are classified (U.S. DOE, 1991a, p.B-13), they are reported in the RWMIS as being less than a number which was chosen to overestimate the size of the ^{85}Kr source term. As such, no independent review of open literature can verify the sampling and measurement of ^{85}Kr, the isotope with the largest activity emitted by the INEL. The U.S. DOE, in responding to the Peer Review Panel (Gesell, 1991), stated: "We did not need to reference classified data. No discrete projects or emissions were omitted for classification reasons." This statement may be literally true, but it does not accomplish the goal of verifiability. The category "unclassified controlled nuclear information" also precludes the use of some data. ***Any future dose reconstruction effort should remove these classification and restriction barriers to public acceptance.***

We have heard allegations of classified discrete projects which can not be identified in the IHDE, such as Operation Bluenose. We have no way to evaluate the contention that projects with environmental releases have been selectively omitted. Some documents support the contention that a project named "Bluenose" did exist. The allusions to Bluenose illustrate barriers to credibility which do exist, the difficulty in verifying their possible dose impacts, and the importance of dealing with this issue as openly as possible.

Uniformity of Operational Releases

Annual operational releases were totaled in the IHDE. These data were entered into the MESODIF atmospheric model to predict dispersion. The weather information used

to drive this model was a nine-year average for wind direction and velocity between 1965 and 1973, and annual averages for the years thereafter. The implication of this method is that operational releases happened relatively uniformly throughout the year, and that their dispersion in some years can be described in terms of the nine-year average for wind velocity and direction. For dose calculations, deposition is assumed to be uniform and dry, as MESODIF does not incorporate wet deposition. ***These assumptions should be examined in future reconstruction efforts.***

A significant portion of the operational atmospheric releases from the INEL originates from the ICPP and its calcining facility. This plant reprocesses irradiated nuclear fuel from several sources, mainly the U.S. Navy's nuclear propulsion program. Irradiated fuel was processed in campaigns, or batches, and the emissions occurred sporadically over the course of a year. Doses to residents offsite have resulted from the release of fission products during the dissolution of the irradiated fuel; these releases occurred over periods of a few days to a few weeks. Releases from the calcining facility are also episodic, but these occur over longer time periods (a few to many months) than those for the releases from fuel dissolution. Modeling these releases as continuous increases the uncertainty of the estimates of some offsite doses.

For example, in the IHDE the dispersion of episodic releases of short duration from ICPP was modeled using the wind information for the specific day and time of release. A review of the dispersion factors for the episodes in Appendix B shows large differences in the modeled dispersions between releases. ***The ICPP operational releases should be modeled as episodic releases using wind patterns measured at the time of the releases.***

Precipitation and Wet Deposition

The annual average precipitation at the INEL is low, about 20 centimeters (7.8 inches). However, the region occasionally has rain and snow, which is subject to large daily and seasonal variations. In most locations with temperate climates, the

predominant way radioactive materials present in the atmosphere reach the ground is in rain or snow, a process called wet deposition. This process is not included in the models used in the IHDE for either operational or episodic releases. In our opinion, it is important to include wet deposition in dose calculations. This process should be considered in episodic release models, as their time and duration are known with some precision. Precipitation records should be available for release times, and the importance of wet deposition can be determined.

5.5 Uncertainty Analysis

In the August 19, 1991 response to the Peer Review Panel Report, the U.S. DOE stated that analysis of model parameter sensitivity and the uncertainty of model predictions was beyond the scope of the IHDE. ***Though it may have been beyond the scope of the IHDE, we believe the analysis of the uncertainty in predicted doses is essential for the dose reconstruction planned by the CDC. We also recommend that the pathways resulting in the highest doses should be identified through sensitivity analysis, and receive additional assessment for data quality and uncertainty.***

Because members of the public have expressed concern over the possibility of inhaling or ingesting a few highly radioactive particles from the INEL, we suggest that uncertainty analysis also address particulate transport and the conversion of estimates this exposure to estimates of dose and risk.

The unattractive alternative to quantitative uncertainty analysis is to be completely conservative at every step in the chain of calculations used to estimate dose. The liability of such an approach is that the reported result tends to be an incredible overestimate of the real or likely dose. In the IHDE, the U.S. DOE chose not to maximize all parameters but rather estimated doses to hypothetical residents who were expected to have received the highest exposures. These doses were estimated using average values for most of the calculations.

In our opinion, this choice is not an adequate replacement for a formal uncertainty analysis. We agree with the U.S. DOE Peer Review Panel recommendation that future efforts include quantitative uncertainty analysis, particularly for those pathways that provide the greatest exposure to members of the public.

In the IHDE, doses were estimated for specific locations expected to receive the highest offsite exposure. Information about exposures in other areas was provided in figures with isopleths for radionuclide deposition. We suggest that future dose reconstruction efforts carefully review the best ways to present the geographic distribution of doses. Converting deposition isopleths to dose isopleths would make the report more easily understood by the public.

5.6 Quality Assurance

A quality assurance (QA) plan was used (IHDE, Vol. I-Section 5.0; Vol. II-Appendix G; Peer Review Panel Comment No. 4) for the IHDE to review basic elements of the report. The plan included: 1) documenting and assessing the adequacy of data; 2) determining the appropriateness of data; 3) transcribing data; and 4) verifying calculations. Although tasks were reviewed by individuals not responsible for performing them, the QA was not done by a group independent from the project. Moreover, much of the effort was apparently made after the first draft of the IHDE. These factors make unbiased or "fresh" analysis difficult. The QA cover sheets verify that QA was performed in terms of the methodology used (e.g., from QA File #112 "hand calculations were performed to check results calculated by Lotus 1-2-3"). Independent data verification, particularly for source terms, was not done in a comprehensive way.

We recommend that the QA plan for the future dose reconstruction incorporate thorough uncertainty and parameter sensitivity analyses. The uncertainty and sensitivity analyses will help identify the data that are relevant to the pathways resulting in the highest doses. These data should receive the closest attention and

be a major effort in the proposed dose reconstruction. An environmental monitoring program also serves as an external QA check and should be integrated into future studies.

Another important component of the QA process is a review of engineering, maintenance, and construction reports and the results of emissions monitoring for individual facilities. These data can be evaluated for quality, and compared with the values in the RWMIS and the IHDE.

The IHDE states on page A-12 that, because of the reliance on published historical data, "extensive interpretation and supplementary evaluation" of source terms has been necessary. ***We recommend oversight by the State of Idaho to assure that the CDC dose reconstruction and subsequent studies include extensive data verification.***

5.7 Water Models

There is a general misunderstanding of the role and use of groundwater models at the INEL. There is also confusion over the extent to which groundwater models have been used to predict offsite contaminant levels and radiation doses. The USGS Robertson model was used to predict the approximate time of arrival of the tritium plume and other chemicals and radionuclides at the south boundary. The extent of the tritium plume resulting from injection at the ICPP well was determined from monitoring data in the USGS well network. These data showed that the plume reached the south boundary of the INEL in 1983 as defined by tritium concentrations of .05 pCi/ml. By 1988 the concentrations had decreased as had the total number of curies of tritium in the aquifer. No model has been used for determining of contaminant concentrations for offsite dose evaluation except for a comparatively simple model used for the environmental assessment of fuel processing operations (EG&G-Idaho, 1987).

The IHDE conclusion stated that "...there has been no significant dose to an offsite member of the public through the Snake River Plain Aquifer pathway," has not been adequately substantiated. The discussion and explanation of the groundwater pathway, although expanded in the 1991 IHDE final report, does not adequately address the concerns of the public. Groundwater users down gradient from the INEL are entitled to a full review and explanation of the copious data and studies which justify the U.S. DOE conclusions. They also need documentation of future programs to assure adequate monitoring and evaluation of the aquifer system.

The USGS, as the primary groundwater monitoring and aquifer evaluation agency, should continue acquiring the data needed and develop a state-of-the-art groundwater flow and contaminant transport model to assist in system evaluation, network evaluation, and predictive capabilities. A program to evaluate historical groundwater quality data and contaminant sources and to develop a central database, accessible to all users, should be pursued.

Data indicate that there were exposures to workers onsite from drinking water obtained from the contaminated region of the aquifer. We recommend that such exposures be thoroughly investigated.

5.8 Doses to Workers Exposed Through Environmental Pathways

In their response to the Peer Review Panel report, the U.S. DOE stated that computing doses to workers exposed through environmental pathways was outside the scope of their study. Moreover, the U.S. DOE implied that such data would be covered in a separate report.

We are aware of no plan to provide such data, and believe that existing occupational dosimetry data (primarily data from film badges and urine sample analyses for radionuclides) may not be adequate for estimating exposure from tritium-contaminated drinking water and from radionuclides that could have been inhaled by workers while

working outdoors during some of the INEL releases. This is because film badges measure doses from external radiation and do not account for radionuclide exposure by inhalation or ingestion.

Urine sample analyses have been performed for INEL workers and can determine internal exposure from radionuclides. To our knowledge, these data have not been critically reviewed and systematically analyzed in order to determine this value for estimating environmental exposures to INEL workers for all years of operation.

Because the same models that will be used for the dose reconstruction can be used to estimate doses to workers, we strongly recommend that the proposed future dose reconstruction take advantage of this opportunity to clarify risks to all persons who have worked on the INEL site including military, research, and construction personnel. Omitting these dose estimates would provide an incomplete picture of health risks at the INEL. Such estimates would also be useful for quantifying risks to members of the public who may have been on INEL property during releases.

5.9 Public Acceptance of the INEL Historical Dose Evaluation

The U.S. DOE Peer Review Panel released its report on September 15, 1990. In the section on public acceptance of the IHDE, the report states:

> Reconstructing exposure and dose to persons who live near nuclear facilities is a public process. People who may have been exposed have an interest in the results and how they were obtained. A number of dose reconstruction projects for U.S. DOE facilities are underway. The ones for Fernald, Rocky Flats, Hanford, and the Nevada Test Site have active citizen participation in their planning and in review of results. It is inconsistent and not publicly responsible to solicit involvement from the public for one facility and not for another.

We concur that lack of public participation in the IHDE process has hindered its acceptance. Omissions, perceived inaccuracies, and inconsistencies have also contributed to negative public sentiment. For example, inconsistencies between the draft and final versions of the IHDE were not explained and serve as examples of the

kind of problem that detracts from public acceptance. On October 26, 1960, the LIME-II Test was conducted at the IET resulting in the release of 1,100,000 Ci of total activity (Draft IHDE, page 2-5). In the final IHDE, no reference is made in Volume I to the LIME-II Test (DOE 1991b). Volume II of the final IHDE refers to this test as IET-24 (DOE 1991b), but the total activity has been reduced to 4,800 Ci. Even though this change was attributed to a clerical error, it was not explained in the IHDE or in the QA files.

Public comments made to and discussed with the DERA Advisory Panel regarding the IHDE report and the future CDC dose reconstruction are summarized in Chapter 7.

5.10 Final Recommendations

It was not within our mission to confirm or refute the estimates provided in the IHDE. The following specific recommendations are not based on evidence that doses were substantially different than those reported in the IHDE. The IHDE is a substantial compilation of data describing the operating history of the INEL, and establishes a chronology for operational and episodic radioactive releases that have taken place at the INEL. It is a major step toward addressing public concerns on the health risks posed by activities at the INEL.

The purpose of these recommendations is to ensure that any future work is conducted in a public forum using the soundest and most impartial scientific methods.

1) ***We recommend that more work be done on reconstructing doses from toxic exposures to workers and members of the public potentially affected by INEL operations. Future work should include independent collection and verification of data, comparisons between modeled and monitored data, rigorous uncertainty analyses, and a quality assurance program for all data collection and analysis. All potential exposure pathways; including groundwater and soil ingestion, radiation and chemical exposure to INEL, contract workers from***

outdoor activities, and ingestion of contaminated drinking water should be evaluated. Doses should be reconstructed for hazardous chemicals. We recommend a phased approach with careful planning to avoid unnecessary duplication. The dose reconstruction project at the INEL should be similar in scope to the dose reconstructions at Hanford, Fernald, and Rocky Flats.

2) *We recommend that future studies involve full public participation. The Panel concludes that the lack of public participation in the IHDE is a major shortcoming. We are concerned that CDC is proceeding with its dose reconstruction without a mechanism for adequate public participation and oversight. We urge the State of Idaho and its congressional delegation to assure the establishment of an advisory group composed of representatives of the public and independent technical experts. Substantive work on the dose reconstruction should not begin before a mechanism is established for public participation and oversight.*

3) *We recommend an independent evaluation of the health risks from exposures to chemicals and ionizing radiation to all persons who have worked at the INEL. Radiation exposure from outdoor activities and from contaminated drinking water should be quantified in the CDC dose reconstruction.*

4) *The public needs to have access to all data and results. We recommend that all relevant classified documents be declassified, and that all documents used in the CDC dose reconstruction be available for public review.*

6.0 A SUMMARY OF ACTIVITIES AND PLANS OF GOVERNMENTAL AGENCIES EVALUATING HEALTH RISKS FROM INEL

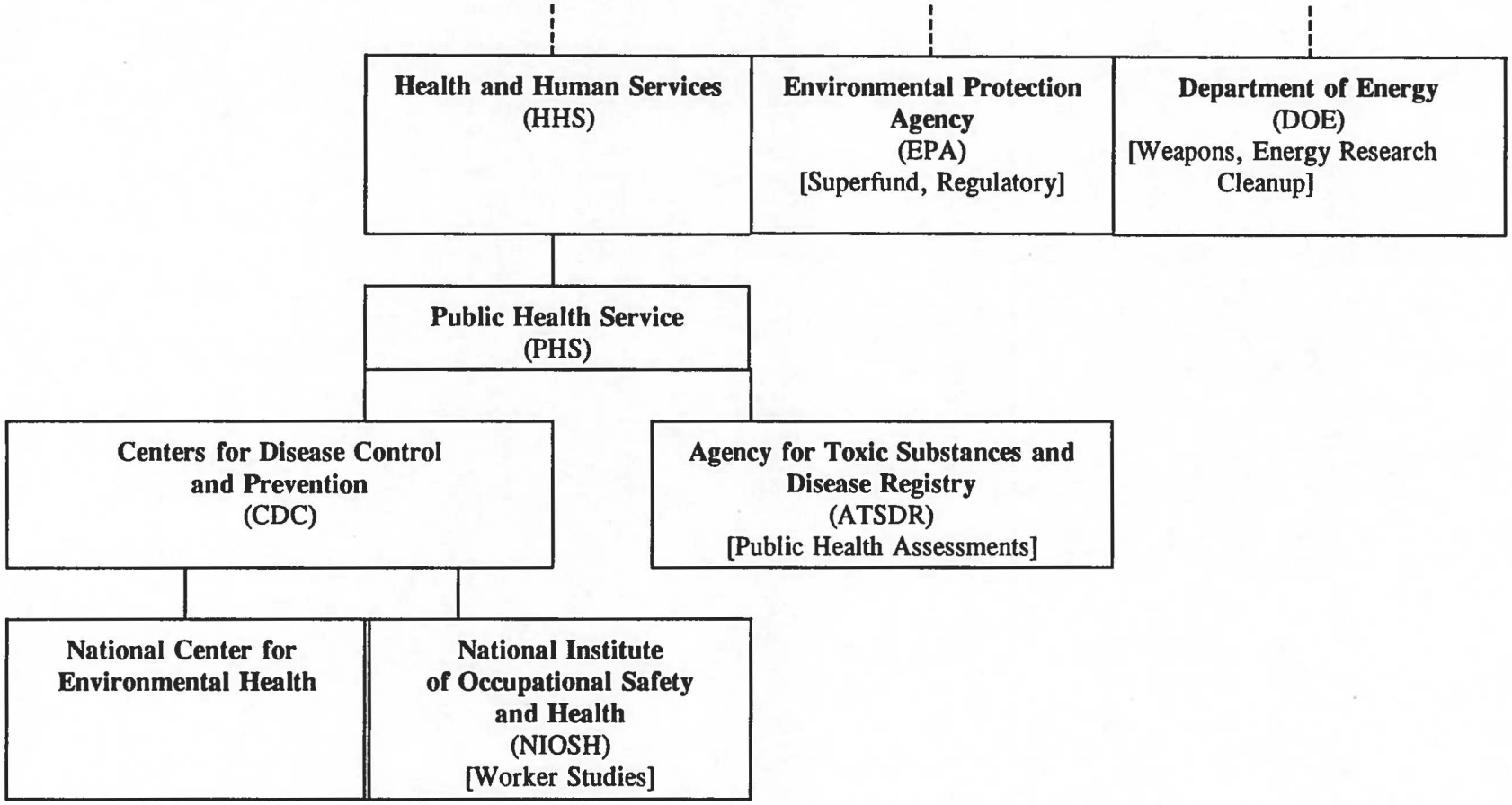
Since the creation of the DERA Advisory Panel, a number of governmental agencies (see charts on the following pages) have initiated or begun considering of projects related to assessment of health risks due to the operation of the INEL. Some of the major efforts are summarized below. ***In general, we are concerned that these efforts may overlap and will not build on work previously performed. The various governmental agencies should coordinate their efforts and clearly state the objectives of each effort in order to avoid confusing the public.***

6.1 Centers for Disease Control and Prevention Environmental Dose Reconstruction Project

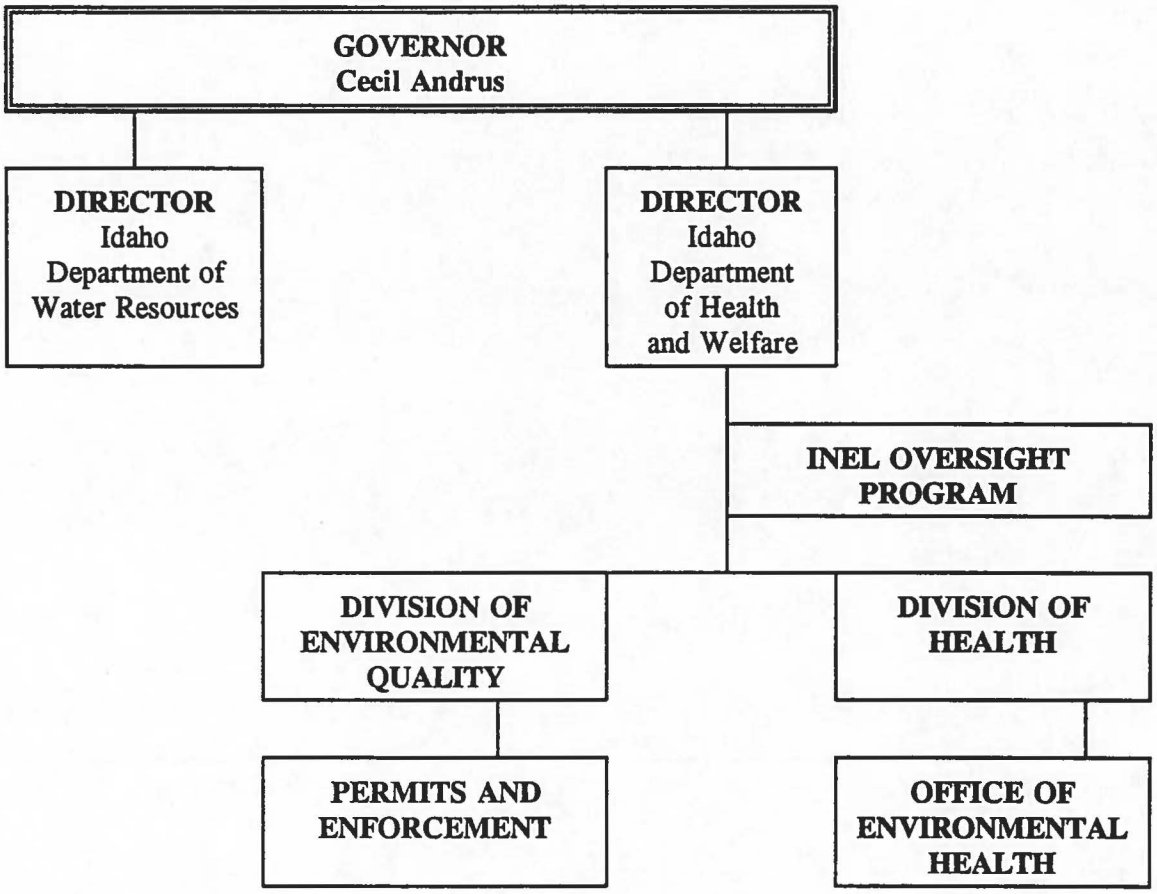
In December 1990, a Memorandum of Understanding (MOU) was signed by the Secretary of the U.S. DOE and the Secretary of the Department of Health and Human Services (HHS). This MOU transferred the management of dose reconstructions and epidemiologic studies from the U.S. DOE to HHS. The Centers for Disease Control and Prevention (CDC) was named the lead agency within HHS. Within CDC, the Center for Environmental Health was given the responsibility for designing and conducting dose reconstruction projects. The lead for worker health studies was given to the CDC's National Institute for Occupational Safety and Health (NIOSH).

In late 1991, the Governor of Idaho requested that CDC perform a dose reconstruction for the INEL and on October 1, 1992, the National Center for Environmental Health (NCEH), an agency within CDC, awarded a two-year contract for the first phase of an environmental dose reconstruction at the INEL. CDC's contractor will identify documents necessary to quantify all materials, both radioactive and chemical, released to the environment during past operations of the INEL. The contractor will also collect data on past environmental measurements which may be used in determining the transport of chemicals and radionuclides through environmental pathways. The contractor will evaluate the quality of all data, and develop a computerized listing of

AGENCIES OF THE FEDERAL GOVERNMENT



STATE OF IDAHO



all documents identified and examined. The contractor is also expected to develop and implement a plan for public involvement. This includes conducting public meetings where all plans and reports generated during the study will be presented for discussion and comment.

The CDC plans to use data from this first phase as the basis for subsequent work not within the scope of work of the current contract. Subsequent work, not necessarily performed by the same contractor, would encompass screening calculations, methodology development, and dose calculations.

The proposed CDC dose reconstruction will provide important improvements to the data and conclusions presented in the IHDE. Specifically, the environmental release of toxic chemicals will be addressed, and the groundwater exposure pathway will be evaluated further. ***We are pleased that the CDC proposal includes the examination of worker occupational dose and the collection of data that may be used to estimate doses to INEL workers exposed to atmospheric and groundwater pathways while onsite.***

While the technical approach appears to be comprehensive, the plan for public involvement will be difficult to implement. There are two major reasons: 1) public input was not sought during the development of the initial request for proposals by the CDC; and 2) the Community Panel specified in the contract as a point of interaction between the contractor and the citizenry has not yet been established. We believe that the CDC owes the public an explanation of exactly how such involvement can be achieved.

We understand that the CDC was under time constraints to award the contract before the end of the 1992 fiscal year and that the administration of CDC has been unable to establish a Community Panel for the INEL to ensure citizen involvement in the oversight of CDC's work. ***We are concerned that if the CDC does not move quickly***

to establish citizen involvement and oversight, its work will not be accepted by the residents of Idaho.

The CDC has communicated minimally with the DERA Advisory Panel and the INEL Oversight group in the IDHW. ***We urge the CDC to improve these relationships before the demise of our panel, so that its staff and contractors can benefit from our collective experience in reviewing past work at the INEL.***

6.2 National Institute For Occupational Safety and Health Worker Studies

In the winter of 1992, the National Institute for Occupational Safety and Health (NIOSH) visited the INEL site to evaluate records of worker exposure and to consider plans for an epidemiologic study of the workforce. An advisory panel, established by the Secretary of Health and Human Services, will review all plans related to epidemiologic or health assessments before NIOSH initiates further studies. ***While we recognize the problems involved in reorganization and the formation of an advisory committee to facilitate the development of a national strategy for NIOSH research, we hope that NIOSH will continue its discussions with INEL workers and concerned citizens. NIOSH should make every effort to keep them involved in decisions regarding studies of the INEL workforce. We also recommend that NIOSH coordinate with Center for Environmental Health staff on the issue of worker exposure at INEL from atmospheric releases and from contaminated groundwater pathways.***

6.3 Agency for Toxic Substances and Disease Registry Public Health Assessments

In 1992, the Agency for Toxic Substances and Disease Registry (ATSDR), another federal agency within HHS, began a preliminary public health assessment of the offsite releases from the INEL. Although a plan for this assessment has not been made public, representatives of ATSDR have begun reviewing environmental data and collecting data on the incidence of cancer from the State of Idaho Cancer Registry and data on birth defects from local hospitals.

We are also aware of studies performed by this agency in the past, which have usually been designed to screen for evidence of current health risks. It is not clear to the DERA Advisory Panel why an ATSDR health assessment is being considered at the same time CDC is performing a dose reconstruction, since the dose data provided by the CDC will be of far greater quality than the data which will be considered by the ATSDR. Furthermore, we question the point of collecting data on health effects without coordinating with the dose reconstruction effort. In the past, such assessments by ATSDR have not clarified relations between environmental exposure and health effects.

The ATSDR is also involved in assessing health risks from the various Superfund sites at the INEL. ***We recommend that these assessments be coordinated with CDC, because data from the CDC reconstruction will improve estimates of health risk from Superfund areas as well.***

6.4 Environmental Protection Agency Risk Assessments for Superfund Sites

The Environmental Protection Agency (EPA) performs risk assessments as part of the remedial action plans for all Superfund sites. The risk assessments usually focus on the risks for cancer and acute toxicity to members of the public most likely to be exposed to toxic materials from a site.

The EPA risk assessments usually apply to current and future conditions (rather than past operations) and evaluate risks from various remedial actions that are being considered for site cleanup. The ATSDR is also involved in the Superfund risk assessment process, usually for the purpose of identifying risks to public health that require emergency cleanup. The ATSDR also has responsibility for assessing historical risks at Superfund sites.

Because Superfund risk assessments are designed to assist in the selection of engineering alternatives, they do not overlap much with the work of historical dose

reconstruction. Periodic meetings between EPA and groups engaged in historical dose reconstruction could help facilitate information exchange.

6.5 State of Idaho INEL Oversight Program

The INEL Oversight Program was created by the state legislature as part of an Environmental Oversight and Monitoring Agreement between the state of Idaho and the U.S. DOE. Its purpose is to assure the citizens of Idaho that public health, safety, and the environment are being protected.

The Oversight Program analyzes historic and current INEL environmental monitoring and health data, conducts independent environmental monitoring on and offsite, reports findings to the public and the legislature, and makes recommendations to the U.S. DOE.

We recommend that future dose reconstruction activities sponsored by the CDC be coordinated with activities of the INEL Oversight Program.

7.0 SUMMARY OF PUBLIC COMMENTS

In June, 1991, the first meeting of the DERA Advisory Panel was convened in Idaho Falls. We were charged to review the IHDE compiled by the U.S. DOE for operations conducted at the INEL. As part of this review, we solicited public comment at all of our meetings. An addendum of this report contains all written material submitted to us by the public. We recommend that this information be reviewed in its entirety by the IDHW as an integral part of this report. The following section is a brief summary of the written and oral public comments received most often at our meetings.

1) Lack of meaningful public participation is seen as one of the major shortcomings of the IHDE. Public participation is essential to public acceptance of future dose reconstruction efforts. The public asserts that members of the public need to be involved in negotiations and oversight of the dose reconstruction project directed by CDC.

2) The public feels the dose reconstruction study should be done by an entity independent of the U.S. DOE.

3) The CDC dose reconstruction will only be viewed as a credible study if all source-term-related documents are declassified and made available for public review.

4) Omission of a review of groundwater contamination in the SRPA is, in the eyes of the public, a shortcoming of the IHDE report. The public questions the safety of the aquifer, which is its primary source of drinking and irrigation water.

5) Members of the public have questioned the benefit of an exhaustive dose reconstruction study. Concern was expressed over large expenditures of public resources on a study which does not appear to be warranted for public health or scientific reasons.

6) Chemical releases were not included in the IHDE. Many INEL operations involve toxic chemicals, and the public believes that the dose reconstruction study should include an assessment of chemical exposures.

7) Exposure to workers onsite was not specifically addressed in the IHDE report. The public regards worker studies as important and feels they should be conducted at the INEL, and that doses to workers should be a part of the CDC dose reconstruction.

7.1 CORRESPONDENCE AND COMMENTS RECEIVED BY THE DERA ADVISORY PANEL

Copies of these comments have been published as an addendum to this report, available from the Office of Environmental Health (208) 334-6584.

LETTERS AND WRITTEN COMMENTS

Phyllis Hand	10/25/92	Cancer rates in Eastern Idaho.
Leeann Sewell	10/22/92	Public meetings in Idaho.
Theresa Potts	10/21/92	Dr. Henry Royal's presentation at the Risk Assessment workshop.
Gertie Hanson	10/20/92	Dose Reconstruction at INEL.
Dr. John Tanner, Jr.	10/19/92	Are further studies needed?
Eddie Chew	10/16/92	INEL groundwater models.
Chris Johnson	10/06/92	Comments on air transport.
Chuck Broscious	09/28/92	Transcript of oral comments given at the Boise meeting.
Dr. André Bouville	09/28/92	Structure of the report and additional comments.
John Horan	09/26/92	Comments on the draft report.
Chuck Broscious	09/25/92	Comments on the draft report.
Eddie Chew & Larry Mann	09/18/92	Comments on the draft report.
Eddie Chew	07/28/92	Comments on July 28 draft report.
Chuck Broscious	07/27/92	Comments on the draft report.
Thomas Dechert	07/24/92	Water pathway and cleanup.
Gertie Hanson	07/23/92	INEL Risk Assessment Workshop.
Chuck Broscious	04/13/92	Transcript of oral comments made at the Pocatello meeting.
Daryl Kimball	04/03/92	Physician's for Social Responsibility comments on DOE.
C.R. Robertson, DOE	03/19/92	Chuck Broscious's FOIA request.
Dr. Arjun Makhijani	03/09/92	CDC Dose Reconstruction.
Gertie Hanson	02/19/92	DERA Panel.
Joan Drexler	01/23/92	Phosphate slag.
Kerry Cooke	01/22/92	Transcript of oral comments made at the Boise meeting in January.
Peter Rickards	01/22/92	Public comment questions.
John Horan	01/20/92	Comments on IHDE report.
Kent Liske	01/06/92	Concern for radiation exposure to onsite workers.
Sy Trout	12/15/91	Ore sampling.

Chuck Broscious	10/08/91	Transcript of oral comments at the Twin Falls meeting.
Peter Rickards	10/02/91	Questions presented to the panel at the Twin Falls meeting.
Brad Jahn	10/02/91	Concerns about inconsistencies in reports.
Peter Rickards	10/02/91	Written questions given to Margrit and Carl to be considered by the panel.
Chuck Broscious	09/25/91	Letter to Richland Information Officer.
Chuck Broscious	07/03/91	Letter to Richard Donovan re: using TSP as a model panel.
Denise Revis	06/22/91	Promoting services as a Biokinesiologist.

REPORTS/DOCUMENTS

Chuck Broscious	06/02/92	INEL Research Bureau recommendations to CDC on public involvement.
Chuck Broscious	05/19/92	Citizens Guide to the INEL.
Chuck Broscious	12/02/91	Case study of Fernald.
Eddie Chew	05/29/91	Description of MESODIF.
M.O. Huntington	(no date)	Cancer data in Eastern Idaho.

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APPENDIX A

MINUTES OF DERA ADVISORY PANEL MEETINGS

Dose Evaluation Review & Assessment (DERA) Advisory Panel
June 19-20, 1991
Idaho Falls, Idaho
Meeting Summary
(Revised October 1, 1991)

Wednesday, June 19

OPENING REMARKS:

The Administrator of the Division of Health, Mr. Richard Schultz, opened the Dose Evaluation Review & Assessment (DERA) Advisory Panel meeting and introduced state representatives and presenters to the panel. Mr. Richard Donovan, Director of the Idaho Department of Health and Welfare and Mr. David Humphrey, Deputy Director and the governor's coordinator for state oversight of the INEL welcomed the panel, provided a brief history of the State's INEL Oversight Program and reviewed the panel's purpose.

The panel is to examine the historical dose evaluation that DOE-INEL is currently revising to ascertain if the comments and recommendations made by the peer review panel (assembled by DOE to review the predecisional draft dose evaluation) have been addressed and/or met. The peer review panel recommended that the dose evaluation undergo extensive revision and that a dose reconstruction be done for the INEL. The Department of Energy (DOE) has agreed to fund a dose reconstruction for the INEL, which would be performed by the Centers for Disease Control (CDC).

The second assignment for the panel is to assess models that are used by the INEL to predict radiation exposures to offsite populations. The panel should evaluate the models for appropriateness, accuracy, adequacy, determine if the models are state-of-the-art for projecting offsite exposures and make recommendations to the Department on how the model(s) can be improved, if needed.

Jane Smith and Pat McGavran discussed honorariums, standard agreements, travel vouchers and the panel's procedures policy.

DISCUSSION:

The panel will provide the State of Idaho with advice and recommendations regarding the model(s) and the final dose evaluation document.

DOE plans to release the final version of the dose evaluation late this summer. Even though a dose reconstruction, when completed, would supersede the dose evaluation, it was recognized that the dose evaluation may be the only document on doses from the INEL available for several years. As such, this document should be reviewed by a credible body and comments as to its validity should be made public. It will be an important function of the panel to determine if shortcomings, gaps in information, inaccuracies and other problems identified by the peer review panel have been addressed so that limitations of the document are made known to the state and the public.

The panel was encouraged to communicate to the public through the newsletter published by the INEL Oversight Program. The state of Idaho can circulate news releases when needed.

The panel took a site-tour of the INEL. They were shown the ERB-1, ANP Engines, RWMC, SL-1, CFA, ICPP and were driven by the TRA, TAN and IET sites.

Thursday June 20, 1991

The panel elected Margrit von Braun as Chairperson and Carl Pendleton Vice-Chair of the panel. The Chair then formally called the meeting to order.

PRESENTATIONS:

Dr. Clay Nichols welcomed the panel on behalf of the INEL Operations Office. DOE and NOAA officials described some of the models that are currently used at the INEL.

Eddie Chew, DOE, presented an overview of atmospheric modeling and provided a handout, *Steps in INEL Dose Assessments*. Jerry Sagendorf, NOAA, provided *MESODIF: A Regional Atmospheric Transport and Diffusion Model*. MESODIF stands for MESO scale Diffusion. The model was described and questions from the panel answered. In some instances, the 1981 field test measured higher concentrations of SF_6 than MESODIF predicted. Eddie Chew said that the MESODIF model tends to predict higher than measured values, and predicts higher than the CAP-88 model by a factor of 2 to 10.

Steve Maheras of INEL's EG&G provided copies of *CAP-88 Computer Code*. It was noted that CAP-88 uses a 'standard man' so does not adjust for the gender and age of affected individuals. CAP-88 is a compliance code, which must be used by the INEL to comply with federal regulations.

D.R. Wenzel of INEL described and provided copies of *RSAC-4 Radiological Safety Analysis Computer Program, fourth revision)*.
Dr. Mark Otis of INEL's EG&G gave an overview of dose assessment methodology and provided copies of *Radiological Assessment (Radiation Dose Calculation)*.

DISCUSSION:

The panel's first 'formal' request for the State of Idaho was that they provide copies of DOE's pre-decisional draft historical dose evaluation report.

The Chair requested that panel members refer press questions for the panel to her or in her absence, to the Vice Chair. It was decided that although each panel member may speak to the press on behalf of themselves as individuals or as representatives of an interest group or a technical field, the Chair shall serve as the spokesperson for the panel. It was suggested that the Chair and Vice Chair may wish to talk with the press the evening before the panel meeting. The chair agreed to notify panel members 24 hours before press releases. The state will FAX copies of all releases to panel members.

Panel members were asked to submit written comments on the procedural policy to the Chair so that the policy can be modified and formally adopted at the next meeting.

André Bouville asked to have a formal presentation of the DOE pre-decisional dose evaluation document. The Chair proposed that the four peer review panel members on the advisory panel develop a presentation of the document and a description of the peer review panel's review and present this to the DERA Advisory Panel at the next meeting.

The next meeting was set for October 1 and 2 in Twin Falls.

Dose Evaluation Review & Assessment (DERA) Advisory Panel
October 1-2, 1991
Twin Falls, Idaho
Meeting Summary
(Revised January 22, 1992)

Tuesday, October 1

OPENING REMARKS:

Chairperson, Margrit von Braun, opened the Dose Evaluation Review & Assessment (DERA) Advisory Panel meeting by introducing members of the panel. Barbara Brooks was introduced as the new representative for DOE's Office of Epidemiology & Health Surveillance.

It was noted that in July, the panel should have received the Predecisional Draft Dose Evaluation Report and comments from the Peer Review Panel. In mid-September, the Final Historical Dose Evaluation Report was sent to all panel members.

Revisions to the minutes were made and approved. The panel discussed the Procedures Policy and agreed to change section IV, H5 to include a paragraph on receiving reimbursement for contractual work. The panel also agreed to change section IV, B3 which now specifies that meeting locations will be rotated among towns in Idaho. Beatrice Brailsford suggested having a consensus process rather than Roberts' Rules of order. The panel voted to adopt Roberts' Rules with consensus as a format for discussion. The panel voted unanimously to adopt the revised Procedures Policy.

PANEL COMMUNICATIONS:

The DERA Advisory Panel notebook was circulated among the panel members. The notebook consists of correspondence, newspaper clippings, and information regarding panel activities and will be available to the panel and the public at each meeting. A suggestion was made to also include a section on public comments and questions.

PRESENTATIONS:

Jim Smith, Chief of the Radiation Safety Program, and Mike Sage, Deputy Chief, representing the Centers for Disease Control (CDC) in Atlanta, gave a presentation on CDC's involvement with Dose Reconstructions and Health Studies at DOE Research and Production Facilities. A workshop will be held in Atlanta on December 3 & 4, to discuss CDC's research agenda and to allow scientists and others to express their views on research needs.

CDC's studies for fiscal year 1992 include the Hanford Environmental Dose Reconstruction (HEDR), Fernald Dose Reconstruction, Hanford Thyroid Disease Study (HTDS), National Institute of Occupational Safety & Health (NIOSH), and Rocky Flats Toxicological Review & Dose Reconstruction Study. CDC has also agreed to do a Dose Reconstruction for the INEL. CDC will determine the technical work to be done and the estimated cost for contractors. A Request for Proposal (RFP) may be written by next Spring and then a research contract may be awarded within six to eight months.

Mr. Richard Schultz, Administrator of the Division of Health, discussed the State role in Dose Reconstruction. The State Health Department requested a Dose Reconstruction be done at the INEL as the basis for health or risk assessment and epidemiologic studies which may be conducted in the future.

Mr. Schultz discussed with the panel their charge to review models that are currently used by the INEL to predict offsite doses to the population and make sure they are technically accurate. The panel can make recommendations to the State and the State can then make recommendations to DOE if current models do not meet the expectations or the current scientific standards for modeling offsite doses. Mr. Schultz presented a handout on the need for written workplans to accomplish DERA Panel Advisory objectives.

BUDGET:

Jane Smith, Chief of the Bureau of Preventive Medicine, presented the predicted grant award figures for the DERA Advisory Panel expenses for this year (October 1, 1991 - September 30, 1992). Travel and Honorarium totals for the four meetings are estimated at $47,840. Cost estimates breakdown as $5,500 for honorarium and $5,500 for hotel, per diem, and other meeting expenses, totalling $11,000 per meeting. Contractor services and travel total $15,000.

WORKPLAN FOR REVIEWING MODELS:

Because air models are currently used to predict offsite exposures, reviewing the air models is a higher priority than reviewing groundwater models. Jerry Leitch suggested having someone research and become familiar with the models. Brian Lamb suggested forming subcommittees to do the necessary homework.

DOSE EVALUATION:

Jim Ruttenber summarized the panel's objective, to review the dose evaluation document and make recommendations. He felt the document was inadequate and could be improved.

John Horan, a Radiation Protection Consultant, presented a brief history of the operations at the INEL. He discussed the building of the reactors, the release of iodine, and the number of releases which involved accidents.

Wednesday, October 2:

Eddie Chew, representing DOE-Idaho, presented a summary of the INEL Historical Dose Evaluation. The purpose of the Dose Evaluation was to estimate the radiation dose potentially received by a hypothetical maximally exposed individual who lived near the INEL site boundary for each year of INEL operation from 1952-89. Results indicated that estimated doses were within standards and guidelines applicable at the time of release. Mr. Chew also went over the approach and methods used to determine the quantity released.

WORKPLAN FOR REVIEWING MODELS:

The panel formed subcommittees for Dose Evaluation Review, Air Models, and Water Models. The Subcommittees agreed to do research before the next meeting.

DOSE EVALUATION REVIEW SUBCOMMITTEE:		
(Chair)	Jim Ruttenber	Suzanne Budge
	Brad Jahn	Margrit von Braun
	Duane Allen	Jerry Leitch
	André Bouville	

Brian Lamb discussed the workplan for reviewing dispersion models. He suggested having a subcommittee conduct an internal preliminary review of the dispersion models and then report to the panel. The panel may want to have an outside expert review the dispersion models as described in various documents, and report back to the panel with an independent assessment of the model. The panel can also ask a contractor to conduct some actual hands-on testing. Jim Ruttenber suggested co-sponsoring a workshop on air models.

André Bouville discussed the workplan for reviewing dose models. The tasks of the panel are to obtain documentation of the models, review the models, validate the models, check the results, compare with other models, make use of environmental monitoring data and site specific data, and consider all other possible pathways.

AIR MODELS SUBCOMMITTEE:		
(Chair)	Brian Lamb	Bernie Graham
	André Bouville	Barbara Brooks

Charles Brockway will be contacted by phone to help develop a workplan for reviewing groundwater models.

WATER MODELS SUBCOMMITTEE:		
(Chair)	Chuck Brockway	Mary Washakie
	Suzanne Budge	Beatrice Brailsford
	Carl Pendleton	

DISCUSSION:

The panel agreed public comments at panel meetings are important, but there should be a time limit. Jim Ruttenber agreed to draft a letter in response to public comments and questions and will bring the letter to the next meeting. The panel unanimously agreed to attach public documents as an appendix.

A Communications Subcommittee was formed to help the State with News Releases, Additions to the Monitor, and Community Involvement.

COMMUNICATIONS SUBCOMMITTEE:		
(Chair)	Brad Jahn	Beatrice Brailsford
	Bernie Graham	Carl Pendleton

The next meeting will be held on January 21-23 at the Department of Environmental Quality Building, 1410 N. Hilton, Boise. Plans for the next meeting's agenda consist of subcommittee reports, panel review, soliciting and reviewing written public comments, and drafting a letter to the public informing them the DOE Dose Evaluation document is available.

Panel members are encouraged to take News Releases about future DERA meetings to their individual radio stations and newspapers.

DOSE EVALUATION REVIEW & ASSESSMENT (DERA) ADVISORY PANEL
January 22-23, 1992
Boise, Idaho
Minutes Summary
(Revised April 13, 1992)

Subcommittees met the evening of January 21 to discuss objectives and work plans.

JANUARY 22, 1992

SUBCOMMITTEE REPORTS:

At the beginning of the meeting, the Chair of each subcommittee presented a report to the panel.

Jim Ruttenber, Chair for the Dose Evaluation Subcommittee, reported that they will use the Department of Energy's response to the Peer Review Panel's report on the Historical Dose Evaluation as guidance for their subcommittee work. The subcommittee will comment on the quality of the Historical Dose Evaluation and the extent that DOE responded to the comments of the Peer Review Panel. They will also make recommendations for doing future studies. A draft of the subcommittee report will be presented to the panel at the next (April) meeting. A final draft will be presented at the July meeting.

Brian Lamb, Chair for the Air Modeling Subcommittee, reported that the objective of this subcommittee is an assessment of the application and performance of the MESODIF model. They would like to review and summarize model validation results from the INEL field experiment conducted in 1981. They also want to look at other models, like the TRAC model used at Rocky Flats, Colorado, and compare the performance of TRAC and MESODIF. An internal review draft of the model review may be completed by the April meeting.

Members of the Water Modeling Subcommittee met in Kimberly, Idaho on December 19. Charles Brockway, Chair, invited Larry Mann from USGS-INEL, Jerry Lindholm from USGS-Boise, and Warren Barrash from the INEL Oversight Program in Boise, to speak about the Snake River Plain Aquifer and groundwater monitoring. The objective of the Water Modeling Subcommittee is to evaluate groundwater pathways to exposure for offsite persons. Dr. Brockway pointed out that the INEL has not used groundwater models for offsite exposure assessment since 1976. Since modeling is not being done, reviewing models may not be appropriate for this subcommittee. He suggested a flow transport model would be useful to fill gaps in the monitoring network and to extend prediction of contamination plumes past the site boundary. The subcommittee report will recommend this be considered in the CDC Dose Reconstruction. The Water subcommittee will have a report drafted for the April meeting.

DISCUSSION:

Carl Pendleton volunteered to keep track of the budget and give a budget status report at each meeting. Subcommittees that anticipate expenses due to additional meetings or guest speakers should have estimates out early so the panel can decide what can be covered for reimbursement.

Minutes to the second meeting were approved with minor changes.

The panel voted unanimously to allow substitutes for those who are absent on the panel. The panel member may use their own judgment in selecting substitutes. The substitutes should come with a letter signifying who they are representing.

Brad Jahn brought a report/presentation that was made to the Idaho Falls Chamber of Commerce by the American Cancer Society on cancer rates and types of cancer occurring in Eastern Idaho.

Brad Jahn was named Chair of the Communications Subcommittee. The Communication Subcommittee will draft a letter of clarification outlining the panel's understanding of responsibilities.

Chuck Broscious, Environmental Defense Institute, presented a handout to the panel regarding a review of the operations at the Feed Materials Production Center near Fernald, Ohio from 1951-1985. The handout described how the Department of Energy study was not thorough, accurate, or complete enough to record employee exposures precisely.

EVENING OF JANUARY 22:

PUBLIC COMMENTS

Margrit von Braun, Chair for the DERA Advisory Panel, welcomed the members of the public and gave a summary of the panel's background and objectives.

Kerry Cooke, Director of the Snake River Alliance, expressed how the Snake River Alliance is interested in what has been happening at the INEL and the impacts it may be having on the people of Idaho. Her views of the weaknesses of the Department of Energy's Historical Dose Evaluation is summarized as follows: the study of the groundwater should not have been left out, all radionuclides and hazardous chemicals and their effects should have been studied, the dose should have been measured onsite, and the public should have been involved in the study.

JANUARY 23, 1992

PRESENTATIONS:

Jerry Lindholm, from the United States Geological Survey (USGS) District Office in Boise, presented a slide show on the Snake River Plain Aquifer and the Snake River Plain Regional Aquifer Systems Analysis. The first models used were developed by the USGS and the Bureau of Reclamation. The model can be used to predict what groundwater levels might have been in the past when irrigation was first started, and in optimizing water use so that future generations can reap the benefits.

Larry Mann, from the United States Geological Survey (USGS) stationed at the INEL, gave a presentation on USGS involvement in monitoring groundwater and understanding of the hydrogeology at the INEL site. There are over 100 different basalt flows on the INEL site. Geochemical characteristics of the hydrologic environment dictate distribution of chemicals and radiochemical constituents, and the water/rock relationships. Mr. Mann showed overheads

listing the monitoring wells in the USGS INEL groundwater system. There has been no surface water flow onsite since April, 1987.

Warren Barrash from the INEL Oversight Program gave a presentation on how the Oversight Program operates and how their work has contributed to the understanding of the aquifer and verification of monitoring results. DOE funds the State Oversight Program. Mr. Barrash presented observations made on data that have implications for contaminant distributions onsite and offsite.

Steve Oberg from the INEL Oversight Program discussed the wide role of the State Oversight programs. He believes they are interested in getting better information on source terms, engineering controls, emission measurements, air dispersion, exposure pathway assessments, and interpretation of dose. Mr. Oberg invited panel members to register for a workshop on Risk Assessment, scheduled for May 27-28.

Chris Johnson, with the Permits and Enforcements section of the Department of Environmental Quality, discussed the methods of assessing the transport of radionuclides or other pollutants by air from INEL to surrounding areas. He gave panel members a

handout on air quality models and discussed the application, usefulness, and strengths and weaknesses of the models available.

DISCUSSION:

Brad Jahn suggested budgeting funds to pay for newspaper advertisements for the next meeting. The Communication Subcommittee will investigate cost and feasibility of this. Suzanne Budge reminded everyone that press releases should be faxed or sent to members of the panel before they are released.

The next meeting will be held in Pocatello on April 13 & 14 at the Idaho State University Student Union Building.

DOSE EVALUATION REVIEW & ASSESSMENT (DERA) ADVISORY PANEL
April 13-14, 1992
Pocatello, Idaho
Minutes Summary

April 13, 1992

DISCUSSION

The minutes for the January meeting were approved unanimously with minor changes.

Carl Pendleton provided a report on the DERA panel's budget.

Chuck Broscious presented a letter addressed to Pat McGavran from Arjun Makhijani, President of the Institute for Energy and Environmental Research (IEER). The letter was in regard to the INEL Dose Reconstruction project and was placed in the DERA notebook.

SUBCOMMITTEE REPORTS

Brian Lamb, Chair of the Air Subcommittee, stated that the subcommittee had drafted a preliminary report. They are comparing MESODIF with other air dispersion models. André Bouville is reviewing the dose calculations. Gene Start from NOAA met with the subcommittee to answer questions and discuss MESODIF documentation.

Chuck Brockway, Chair of the Water Subcommittee, announced that they had completed a draft report. The subcommittee reviewed groundwater models used at the site. They made some general findings regarding the nature of groundwater data sources and the fact that monitoring data is not readily available to all users. They found that there is a need for an updated groundwater flow and transport model.

Jim Ruttenber, Chair of Dose Evaluation Review Subcommittee, explained that they had also prepared a draft report. The report will focus on the subcommittees review of the Historical Dose Evaluation Report and their recommendations for future dose reconstruction. They will rely heavily on the groundwater and atmospheric modeling subcommittee reports. The report will also include a section of written and verbal comments from the public.

Russell Brown gave a presentation on cancer mortality. He supplied a handout to the panel comparing cancer mortality data in Idaho Counties with the National average.

April 14, 1992

The Chair welcomed Roger Turner who sat in for Mary Washakie on the 14th. He is a Water Quality expert with the Shoshone-Bannock Tribes.

PRESENTATION

Reed Hodgin, a Certified Consulting Meteorologist from AlphaTRAC Inc., provided information to the panel on atmospheric dispersion modeling as a tool for dose evaluation. Mr. Hodgin also described the Terrain-Responsive Atmospheric Code (TRAC) as a state-of-the-art atmospheric dispersion model. He furnished a handout to the panel outlining his presentation.

SUBCOMMITTEE REPORTS

Brian Lamb, Chair of the Air Subcommittee, stated there were no indications that MESODIF is a truly conservative model. According to NOAA, MESODIF doesn't do any better or any worse than other models available today. NOAA is in the process of upgrading monitoring equipment and plans to acquire new computers for running MESODIF. Brian would also like to see additional documentation for the MESODIF and recommended that the model be evaluated further.

Chuck Brockway, Chair of the Water Subcommittee, explained that no surface water models for contaminant transport or sediment have been utilized at the INEL. Groundwater flow models are used which do not predict transport of contaminants in the aquifer, however, INEL sits over the aquifer, so they are useful for identifying general flow directions and groundwater levels underneath the site. An early groundwater transport model has been used by the USGS for research but has not been used for prediction of offsite contaminant levels. Warren Barrash, of the INEL Oversight Program, conducted a review of groundwater models that have been used onsite. The subcommittee will utilize this information as part of their review. They feel that examining the exposure to workers onsite is warranted.

The subcommittees will prepare draft reports which can be merged and reviewed by the entire panel at the July meeting.

Jim Ruttenber suggested having money in the proposed budget to compensate two or three members of the panel who may be interested in editing the final report.

The panel expressed their appreciation to Brad Jahn, Chair of the Communications Subcommittee, for his excellent work in promoting the meeting. Brad described the release of the paid advertisements, letter to the editor, and press releases sent out for this meeting.

DISCUSSION

The location of the next meeting, July 27-28 to be held in Idaho Falls, was changed to Moscow. A public meeting will be held the evening of July 27. The sixth meeting, which will focus on the release of the panel's final review report, was scheduled for September 28-29 in Boise.

PUBLIC MEETING

Margrit von Braun, Chair of the DERA Advisory Panel introduced the members of the panel, and stated the two objectives of the panel: to review DOE's Historical Dose Evaluation Report and make recommendations about future studies, and to review computer models (groundwater and air dispersion) used at the INEL. She explained that the panel is preparing a report of these findings which should be completed this fall. Margrit explained that the purpose of the public meeting was to allow the members of the public to voice their concerns to the panel before their review work is finished.

Jim Ruttenber, Charles Brockway, and André Bouville gave a summary of subcommittee work that has been completed to date for each subcommittee's part of the report. They then answered questions from members of the public.

DOSE EVALUATION REVIEW & ASSESSMENT (DERA) ADVISORY PANEL
July 27-28, 1992
Moscow, Idaho
Minutes Summary

July 27, 1992

The minutes for the April meeting were approved unanimously.

Chuck Broscious, Environmental Defense Institute, filled in for Beatrice Brailsford as the environmental group's representative.

Carl Pendleton provided a report on the DERA panel's budget and gave a summary of meeting expenditures to date. The panel discussed using funds budgeted for meetings in 1993 (which we now know will not be held) for editing and publishing costs for the report.

Brad Jahn described the arrangements he made for display advertising in five North Idaho newspapers.

DISCUSSION

All subcommittees had a draft report presentable to the panel for comment.

The chair of each subcommittee will edit their section of the draft report. Jim was appointed as the overall editor. If possible, those who spend time editing and formatting the draft report will be compensated with honoraria.

Jim Ruttenber has asked that CDC be requested to send a representative to the September meeting. The panel is not aware of what CDC is planning to do as far as incorporating the findings of this panel into the workplan for Phase I (Document Retrieval) of the dose reconstruction. The DERA panel is not mentioned in CDC's public involvement plan or other documents. He also suggested having the contractor selected to do the Phase I work, meet with the DERA panel and discuss the panel's recommendations. Pat and Margrit agreed to each draft a letter to CDC explaining the importance of CDC's and the contractor's attendance at the panel's meeting. They will also request a written notice on how CDC is planning on involving the public in the design of the contractor's work. CDC's RFP stipulates that the contractor have a draft plan for Phase I work ready by October 15. The panel doesn't know how CDC plans to incorporate public input so that it can be utilized by the contractor to develop their workplan. In the RFP for Phase I, the contractor is asked to conduct public meetings to solicit public comments on their plans and work conducted. Everyone agrees that CDC must have community involvement throughout the entire dose reconstruction process. Chuck Brockway recommended adding a section to the report suggesting the possibility of having the DERA panel function as a liaison between CDC and the public.

Barbara Brooks supplied the panel with a copy of the 'Statement of Work' portion of the RFP.

CDC, ATSDR, EPA, and NIOSH are all conducting health-related studies at the INEL site. Jim suggested adding a section in the report explaining government responsibility for future activities and clarifying what each agency is doing. Barbara suggested writing a brief summary on each agency and how they interact with one another. Brian recommended having an annual symposium with each agency offering a series of presentations describing their role.

PUBLIC MEETING

Approximately five members of the public attended the evening public meeting. The panel discussed their draft report and answered questions from the public. Many of the questions and comments were concerned with community involvement in studies at the INEL.

JULY 28, 1992

DISCUSSION

All of the draft subcommittee reports and introductory comments were put together as a single draft report. The entire panel then went through the draft report providing suggestions and comments on format and content. Barbara explained the importance of having the lead paragraph describe the panel and what they are doing. Andre' suggested adding a brief history of the INEL in the first paragraph, and a summary of the Historical Dose Evaluation to make the report self standing.

The panel discussed the objective of the Boise meeting as having a final panel review and discussion of the entire draft document. Panel members were encouraged to make a list of public members who would be interested in receiving a copy of the draft report. A postcard will be sent out to all those on the INEL mailing list describing the report and how to obtain a copy. The draft report will be ready for public distribution by September 14. The public will then have until October 19 to respond to the draft. If the public has major corrections to the draft, a meeting may need to be scheduled in November. A schedule for submitting revisions and editing the draft report was agreed upon and is summarized on the following page.

Discussion of the letters and recommendations to go to CDC was resumed. CDC has said that they are committed to making all dose reconstruction information available to the public. It was suggested that the panel encourage CDC to clarify in writing their support of declassifying all relevant documents.

The next DERA Advisory Panel meeting will be held September 28-29 in Boise.

SCHEDULE FOR COMPLETING DRAFT REPORT

August 17	- Subcommitte chairs send changes to Jim
August 31	- Jim sends his editing to Kara for finalizing and formatting
September 14	- Circulate the draft to interested members of the public
October 19	- End of three week comment period
November 5-6	- Follow-up meeting of subcommittee chairs/editors or the entire panel, if necessary

DOSE EVALUATION REVIEW & ASSESSMENT (DERA) ADVISORY PANEL
September 28-29, 1992
Sixth Meeting
Boise, Idaho
Minutes Summary

SEPTEMBER 28, 1992

At the request of a member of the public, the minutes from the July meeting in Moscow will be amended to include a summary of Lynne Mineur's oral comments.

Carl Pendleton provided a budget summary. Extra honoraria was allotted for those panel members who have spent additional time editing the draft report.

Publicity for the meeting included radio interviews, paid advertisements with the Boise and Nampa papers, press releases, and a letter to the editor.

DISCUSSION

The DERA draft report was mailed to the panel and members of the public for review and recommendations. Written comments were received on the report from Chuck Broscious, Eddie Chew, Larry Mann, and André Bouville. These comments were considered and incorporated into the report.

Written or verbal comments from the public will be summarized and included as an appendix to the report. It was decided that a glossary will also be added as an appendix. A few panel members volunteered to go through the report and pick out key words and phrases for the glossary. It will be stated in the report that all meetings were recorded and where copies of the tapes can be obtained.

Using flip charts, the panel discussed and revised the recommendations section in Chapter 3 of the report.

PUBLIC MEETING

Members of the public included: Fritz Bjornsen, Kerry Cooke, Chuck Broscious, and Phyllis Hand.

Margrit explained the purpose of the DERA Advisory Panel and the draft report to those present at the public meeting.

Phyllis Hand, a member of the public, asked the panel about a cancer study by NCI on cancer deaths around nuclear facilities. Dr. Ruttenber stated that it was published in the Journal of the American Medical Association and that the researchers did not find elevated cancer rates around

nuclear facilities. But the study did not use adequate methodology for determining if there was an elevated cancer risk near nuclear facilities. Ms. Hand said that she lived near Idaho Falls and has family members with cancer and she knows that seven people in a 1977 high school graduating class in Idaho Falls are being treated for lymphoma. Jim explained that linking these cancer cases to the INEL is very difficult. Pat said the state looks at the Cancer Data Registry of Idaho. Counties surrounding the INEL have had some of the lowest average cancer rates in the state for the past several years.

Chuck Broscious read his written comments on the draft report. He criticized the panel for not implementing meaningful public involvement. He requested a more formal response mechanism from the panel to those who provide public comments. Panel members asserted that a less formal, more interactive exchange seemed to work better. Mr. Broscious made several other comments about the report including: provide definitions of important terms in the report, coordinate the various public health agencies into a single process, offer a more explicit recommendation on what the elements of a public participation vehicle should be, and other comments which were discussed by the panel.

Dr. Charles Miller, with CDC in Atlanta, stated that CDC has selected a contractor for Phase I of the dose reconstruction. The contractor is Sanford Cohen and Associates from Virginia. This will be a two year contract and their job is two fold: 1) To collect information on releases from the INEL and environmental monitoring data from INEL. This will include chemical and radiological data and; 2) To coordinate public involvement at the present time. Under their contract, they will be responsible for conducting public meetings throughout the state of Idaho, soliciting input, preparing news letters, fact sheets, and responding to public comments. The establishment of a community panel is being discussed within the Department of Human Health and Services (HHS) at CDC. The process is complicated because HHS has to follow laws and regulations concerning public panels. CDC is also concerned about other projects going on at the INEL including ATSDR (public health assessments and consultations) and NIOSH (worker studies, etc.) and want to ensure that the agencies are all working together. The contractor will be putting together work plans which will be presented at public meetings before work is started. CDC and the contractor are planning a trip to Idaho during the third week of November to hold meetings at: Boise, Idaho Falls, Twin Falls, and Coeur d'Alene. At the meetings, the contractor will be introduced and the plans discussed. CDC and their contractor believe it is important that the public is involved and that their comments are addressed.

Kerry Cooke, Snake River Alliance said she would like to have a citizens panel implemented that works with the contractor before things get started. She has seen citizens come to meetings to comment and that is the last that is ever heard of those comments. She stated that citizen involvement has to start at the very beginning with selecting the contractor and forming what will be done by the contractor.

Dr. Miller explained that no agency of the federal government can appoint any kind of an advisory committee without very explicit approval from the secretary of that agency. CDC is attempting to improve the conditions required for setting up panels. Fritz Bjornsen, Snake River Alliance, reminded everyone that there are members of the public who can be well enough informed about the entire situation to provide meaningful input. One of the things he sees is a feeling of "we as scientists" know best how to proceed.

Dr. Miller said that the contractor will not have finalized any plans when they meet with the citizens of Idaho in November. The Phase I plan deadline has been changed from the October 15 date in the RFP to sometime towards the end of December. He stated that anyone can request a copy of the signed contract from the contracts office at CDC. Margrit asked how CDC might incorporate the findings of this panel into the workplan. He said that the DERA panel did a good job on the report and CDC is looking forward to reviewing and responding to the recommendations. Margrit also asked if he had any idea on how long it will take for the public panel to be formed. Dr. Miller responded by explaining that CDC is discussing this right now on how to get something in place before two years.

Panel members discussed ways to put pressure on CDC to form a panel.

SEPTEMBER 29, 1992

DISCUSSION

The panel received written comments on the draft report from John Horan.

It was agreed that a chapter, rather than an appendix summarizing public comments be added to the report.

Several members of the panel suggested that a letter be written from the panel to CDC recommending that work not begin on the dose reconstruction until there is a citizens advisory panel in place. Dr. Miller stated they are working on implementing a citizens panel. There is not an advisory panel for all DOE facilities undergoing dose reconstruction studies, but they do have public meetings, and they do have good public participation without a panel. He will relay the concerns of the panel to the appropriate people at CDC, but doesn't know if increased pressure will hurry the process.

Mary Brissenden, a member of the public, expressed her concerns to the panel about the importance that the public be informed of what their hazards are at the INEL and that operations creating more hazards cease until it is discovered how much the hazard is and what our risks are from past tests.

A motion was made and passed to write letter to CDC with copies distributed to appropriate health officials including the Governor.

The panel briefly reviewed a letter from John Horan. He expressed his concerns surrounding the panel's ability to communicate information about health risks to the public and stated technical reasons for not conducting a dose reconstruction. He wrote that the panel should clarify the difference between what's in the dose evaluation and what's in a dose reconstruction. Mr. Horan suggested that the panel should state the people that have reported at the individual meetings, their organizations, and the number of people they represent.

The next meeting will be held November 16-17 in Boise.

DOSE EVALUATION REVIEW & ASSESSMENT (DERA) ADVISORY PANEL
November 16-17, 1992
Boise, Idaho
Minutes Summary

November 16, 1992

Charlie Bidondo, Water Quality Specialist for the Shoshone Bannock Tribes, substituted for Mary Washakie.

The minutes were approved for the Moscow meeting in July and the Boise meeting in September.

Carl Pendleton reported on a meeting of himself, Suzanne Budge, Pat McGavran and Kara Stevens held in Boise on October 21 to discuss and summarize the public comments section in chapter 3 of the DERA report.

It was decided that public comments received by the panel will be listed as an addendum to the report and will be available upon request from the Office of Environmental Health in Boise.

The panel reviewed the draft report and made minor changes and additions.

Public Meeting

Margrit von Braun welcomed members of the public and explained the purpose of the DERA Advisory Panel and the report. Members of the public included Eddie Chew, Joe Henscheid, and William Otting. Concerns were expressed about the public's lack of awareness on what is going on at the INEL and how releases are being measured.

November 17, 1992

Margrit drafted an Executive Summary and a Preface for the panel to review. Beatrice Brailsford drafted the panel's press release. These were discussed and revisions made.

Richard Schultz, Administrator for the Division of Health, presented plaques to the panel members in appreciation for their representation on the panel and hard work.

Agenda for finalizing the report:

Send revised report to panel on December 14
Receive final comments from panel by the first of January
Release final report the first or second week of January

APPENDIX B

GLOSSARY OF TERMS

GLOSSARY

AERIAL RECHARGE	Recharge from precipitation.
ANOMALIES	Abnormalities, unusual occurrences.
BACKGROUND RADIATION	The radiation occurring in man's natural environment, including cosmic rays and radiation from naturally radioactive elements such as potassium.
BECQUEREL (Bq)	A unit of the activity of radioactive material where 1 becquerel is equal to 1 disintegration per second; 37 billion Bq are equal to 1 curie.
CHERNOBYL ACCIDENT	A reactor accident that occurred at Chernobyl, USSR, in 1986, which resulted in the release of radioactive materials to the environment.
CLASSIFIED	Documents and information that are designated by the government as top secret, secret, or confidential in order to protect the information from unauthorized users.
CURIE (Ci)	A unit of measure used to describe the amount of radioactivity in a sample of material. 37 billion disintegrations (or Bq) is equal to 1 Ci.
DEFAULT PARAMETER	A value to be used as various models or equations when an actual value is unknown.
DISPERSIVITY	Aquifer property which governs dispersion of contaminants in the ground water.
DOSE	A general term for the measurement of energy or damage imparted to tissue by ionizing radiation. In this report, it is often used interchangeably with dose equivalent.
DOSE EQUIVALENT	A measure of dose that accounts for the different damage potential to tissue from various types of ionizing radiation. The unit of measure is the rem.

DOSE DETERMINATION The calculatiion of radiation doses to the whole body or various organs and tissues using information about the amount of radioactive material present in air, water, and food sources and the biological fate of these materials in the human body.

DOSE RECONSTRUCTION A study process in which historical information is used to estimate the doses that may have been received by population groups. Dose reconstruction involves identifying the types and sources of toxic or radioactive materials used at and released from a facility; how the materials could have moved off the site; historical land use, population patterns and lifestyles; and by what means, how often and for how long a person could gave come into contact with a substance.

ENVIRONMENTAL DOSE RECONSTRUCTION A complex process of quantifying past releases of potentially hazardous materials released to the environment, evaluating the pathways by which the materials reach humans, and estimating the resultant doses to affected populations.

ENVIRONMENTAL TRANSPORT How substances are moved from their point of release through the environment to areas where people could have been exposed.

EPIDEMIOLOGY The study of specific health effects or diseases that occur in a given population group. An epidemiologic study compares rates of particular diseases in a study population with those for an unexposed control group or the general population.

EPISODIC Noncontinuous, short-time or one-time occurrences. Accidents or emissions from experiments conducted at the INEL may have resulted in episodic releases of contaminants.

EXPOSURE PATHWAYS Pathways or routes by which exposure to environmental contaminants can produce a dose to people. Examples are inhalation, ingestion, and absorption.

EXTERNAL EXPOSURE	Exposure that occurs as a result of radiation outside the body from plumes or clouds carrying radioactive material or from radionuclides deposited on the ground, vegetation, buildings or other objects.
GROUND WATER	Water under the ground that can collect in a well. The water bearing zone underground is called an aquifer.
HEALTH PHYSICS	The discipline or study concerned with the evaluation and limitation of human exposure to ionizing radiation.
INEL HISTORICAL DOSE EVALUATION	A study completed by DOE-INEL in 1991 which estimated radiation doses that individuals who lived near the INEL site boundary could have received for each year of INEL operations from 1952-1989. The acronym is IHDE.
INEL OVERSIGHT PROGRAM	State program which analyzes INEL monitoring data, conducts environmental monitoring, and makes recommendations to State and DOE officials.
INGESTION	Eating or drinking a substance.
INTERNAL EXPOSURE	Exposure resulting from the inhalation or ingestion of substances containing radioactive materials (breathing, eating or drinking contaminated air, food, or water).
ISOPLETH	Lines on a map connecting points of equal value (like contour lines for elevation).
MODEL	Computer program for mathematical simulation of water and contaminant movement.
MONITORING	Determining the amount of ionizing radiation or radioactive contamination present. Also referred to as surveying.
MORPHOLOGY	Shape, gross appearance, size.

MREM	One one-thousand of a REM.
NOAA	National Oceanic and Atmospheric Administration - Responsible for monitoring meteorological data storage and much of the atmospheric dispersion modeling (MESODIF) at the INEL.
OCCUPATIONAL DOSIMETRY	Measuring devices and systems to determine radiation doses incurred by workers during the course of their employment.
OPERATION RELEASE	Releases of materials to the environment during routine operations of a facility.
PERCOLATION PONDS	Storage ponds for evaporation and percolation of liquid waste.
PLUME	A contaminated amount of water or air.
RECEPTOR	The person, place or object receiving a radiation dose.
RELEASE FRACTION	A percentage or fraction which represents how much of the radioactive iodine present in fuel is released to the environment.
REM	A measure of radiation dose related to biological effect; 100 rem = 1 sievert.
RESUSPENSION	Deposited particles becoming suspended in the air by wind or other forces.
REVOLATILIZATION	Re-evaporation.
SATURATED ZONE	Below the ground water table.
SENSITIVITY ANALYSIS	Involves determining input parameters to which the results of computer modeling are sensitive, determining to what extent the accuracy of an input parameter influences the accuracy of the result.
SIEVERT	The SI unit of dose equivalent; 1 sievert = 100 rem.

SOURCE TERM	The chemical form, amount, type, and time during which radioactive materials were released to the environment.
TETROON	Neutrally weighted balloon which can be used to indicate wind direction and speed.
TIGER TEAM ASSESSMENT	A multidisciplinary team from DOE Headquarters that performs an in-depth examination of DOE site operations.
TRAC	Atmospheric Dispersion computer model used at Rocky Flats in Colorado.
TRACER STUDY	Study tracing the movement of compounds through the environment.
TRANSPORT	How radioactive substances move in the environment.
UNCERTAINTY ANALYSIS	Determination of the uncertainty associated with values expressed in ranges of possible values.
UNSATURATED ZONE	Above the ground water table.
USGS	U. S. Geological Survey - Responsible for much of the ground water monitoring at the INEL.
VADOSE ZONE	Zone below the surface but above the ground water table.
WET DEPOSITION	Deposition of airborne substances by rainfall or snowfall.

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