Appendix A
Nuclear Waste Technical Review Board Members: Curricula Vitae

Dr. Don U. Deere

Chairman

President Reagan appointed Dr. Deere to serve as chairman of the Nuclear Waste Technical Review Board on January 18, 1989. His term of office expires April 19, 1992.

Dr. Deere has more than 45 years' experience as an international consultant in the planning, designing, and construction of shafts, tunnels, dams, underground mines, and storage projects, primarily in the fields of engineering geology and rock mechanics. With more than 35 years of university teaching experience and approximately 50 professional papers, he is presently an adjunct full professor in the Department of Civil Engineering and the Department of Geology at the University of Florida.

Dr. Deere consults extensively, both in the United States and overseas, for private and governmental organizations on civilian and defense projects. In the past, he provided services to Fenix and Scisson and the U.S. Atomic Energy Commission on the design of underground openings for nuclear tests at the Nevada Test Site. He also has worked on numerous nuclear power plant projects. Currently, Dr. Deere advises the U.S. Bureau of Reclamation on aspects of the New Waddel Dam near Phoenix, Arizona, and serves as consultant on the design and construction of the Washington, D.C., metro system, a position he has occupied for the past 23 years.

He also has consulted on various aspects of several dozen hydroelectric engineering projects in many foreign countries including Argentina, Brazil, Canada, Chile, Colombia, Costa Rica, the Dominican Republic, Ecuador, Egypt, Greece, the British Colony of Hong Kong, Israel, Mexico, Panama, Peru, Rhodesia, Turkey, Venezuela, and New Zealand. He currently consults on the channel undersea tunnels for the chief executive of TRANS-MANCHE LINK, the consortium of five British and five French contractors who are constructing the tunnels.

Dr. Deere received the BEAVER Award in January 1990 and the MOLES Award in 1983 for Outstanding Achievement in Construction. In March 1990 he received the Rock Mechanics Award of the Society of Mining Engineers. In 1987, he participated in a National Academy of Sciences committee, which evaluated and proposed the final list of possible locations for the Superconducting Super Collider. He was elected to the National Academy of Engineering (1966), the National Academy of Sciences (1971), the National Academy of Sciences of Argentina (1987), and is a member of numerous professional societies.

He received a B.S. in mining engineering from Iowa State College (1943), an M.S. in geology from the University of Colorado (1949), and a Ph.D. in civil engineering from the University of Illinois (1955).

He resides in Gainesville, Florida.

Dr. Clarence R. Allen

President Reagan appointed Dr. Allen to serve on the Nuclear Waste Technical Review Board on January 18, 1989. His term expires April 19, 1992.

Dr. Allen is professor of geology and geophysics emeritus at the California Institute of Technology, where he has served as director of the Seismological Laboratory, chairman of the Division of Geological Sciences, and chairman of the faculty. He has more than 40 years' teaching experience and is the author of more than 120 professional publications.

Over the last 25 years, Dr. Allen has served in a variety of capacities on almost 30 advisory committees and professional boards including the National Academy of Sciences' Board on Radioactive Waste Management, Panel on Earthquake Prediction, Geology Section and Commission on Physical Sciences, Mathematics, and Resources; as chairman of the National Earthquake Prediction Evaluation Council; chairman of the National Science Foundation's Earth Science Advisory Panel; and chairman of the California State Mining and Geology Board.

He also has been a consultant on major dams and nuclear power plants located throughout the world including Argentina, Brazil, Canada, Chile, Costa Rica, Egypt, Haiti, Iran, Iraq, Pakistan, Paraguay, Peru, the Philippines, Tunisia, the United States, and Venezuela. Dr. Allen has conducted field research in Chile, China, Indonesia, Japan, Mexico, New Zealand, the Philippines, Taiwan, Tibet, Turkey, the United States, and Venezuela.

Dr. Allen received the first G.K. Gilbert Award in Seismic Geology from the Carnegie Institution of Washington. He has served as president of both the Geological Society of America and the Seismological Society of America and was elected to the American Academy of Arts and Sciences (1974), the National Academy of Engineering (1976), and the National Academy of Sciences (1976).

He is a fellow of the Geological Society of America and the American Geophysical Union and a member of six other professional societies. His wide-ranging research interests include seismicity, tectonics of fault systems, geologic hazards, earthquake prediction, siting of critical facilities, and geophysical studies of glaciers.

Dr. Allen is a Phi Beta Kappa graduate from Reed College (1949), where he received a B.A. in physics. He subsequently received an M.S. in geophysics (1951) and a Ph.D. in structural geology and geophysics (1954) from the California Institute of Technology.

Dr. Allen divides his time between Pasadena, California, and Copalis Beach, Washington.

Dr. John E. Cantlon

President Reagan appointed Dr. Cantlon to serve on the Nuclear Waste Technical Review Board on January 18, 1989. His term expires April 19, 1992.

As vice president for Research and Graduate Studies emeritus and former dean of the Graduate School at Michigan State University, Dr. Cantlon brings to the Board more than 20 years of academic and administrative experience at Michigan State University. After serving six years as academic vice president and provost, he was appointed to his present position. He retired from Michigan State University on September 1, 1990. Dr. Cantlon also has served as director of the Environmental Biology Program at the National Science Foundation.

Over the last 30 years, Dr. Cantlon has served on almost two dozen advisory committees with various academic, government, and private organizations including the White House, Department of Energy, National Academy of Sciences, Environmental Protection Agency, National Science Foundation, Oak Ridge National Laboratory, World Resources Institute, and the Boyce Thompson Institute. Most recently he participated in a National Academy of Sciences' committee, which evaluated and proposed the final list of possible locations for the Superconducting Super Collider.

Dr. Cantlon is a member of more than a dozen professional organizations and societies. In particular, he has served as president of the Ecological Society of America; president of the Michigan Academy of Science, Arts, and Letters; and chairman of the board of the Michigan Energy and Resources Research Association.

With more than 40 years' teaching and research experience at four universities and the publication of three dozen professional publications, Dr. Cantlon also is a professor emeritus of botany at Michigan State University. His diverse research interests include physiological ecology, micro-environments, Alaska tundra vegetation, and academic administration and research related to economic development.

Throughout his career, Dr. Cantlon has received numerous awards including the Distinguished Faculty Award and Centennial Review Distinguished Lecturer at Michigan State University. In 1986, he was awarded the Distinguished Faculty Award by the Michigan Council of Governing Boards.

He received a B.S. in biology and chemistry from the University of Nevada (1947) and a Ph.D. in plant ecology from Rutgers University (1950).

Dr. Cantlon resides in East Lansing, Michigan.

Dr. Melvin W. Carter

President Reagan appointed Dr. Carter to serve on the Nuclear Waste Technical Review Board on January 18, 1989. His term expires April 19, 1992.

As Neely Professor Emeritus in Nuclear Engineering and Health Physics, Georgia Institute of Technology and an international consultant on radiation protection, Dr. Carter has expertise in a broad range of issues related to radioactive waste management. He serves as a consultant to the Nuclear Regulatory Commission's Advisory Committee on Nuclear Waste and its Advisory Committee for Reactor Safeguards and has been on hearing boards for both the NRC and the Department of Energy (DOE).

Dr. Carter also has been a consultant to almost two dozen federal and state government agencies and private companies including the DOE, UNC Nuclear Industries, NUS Corporation, Westinghouse Electric, Roy F. Weston Inc., Battelle Pacific Northwest Laboratories, EG&G Idaho, Los Alamos National Laboratory, Coca-Cola, Homestake Mining Company, and the Georgia Department of Human Resources.

Among his many administrative posts, Dr. Carter has served as director of the Office of Interdisciplinary Programs and the Bioengineering Center at the Georgia Institute of Technology, and director of the Environmental Protection Agency's National Environmental Research Center in Las Vegas, Nevada, and the Public Health Service's Southeastern Radiological Health Laboratory in Montgomery, Alabama. In addition, he has been elected president of both the International Radiation Protection Association and the Health Physics Society, was on the board of directors of the National Council on Radiation Protection and Measurements, and has been chairman or a member of several of the Council's scientific and administrative committees.

In addition to developing and teaching a large number of graduate and undergraduate courses at the Georgia Institute of Technology over the last two decades, Dr. Carter has organized five major conferences on different types of radioactive material and has developed a dozen technical short courses on a variety of topics including radioactive waste management, radiological health and safety, toxic substances in the environment, and environmental protection.

Dr. Carter has testified before the Committee on Labor and Human Relations, U.S. Senate, and the Committee on Armed Services, U.S. House of Representatives. With nearly 100 major reports and publications to his credit, he also is editor of *Environment International*, a monthly scientific journal published by Pergamon Press.

He received a B.S. in civil engineering (1949) and an M.S. in public health engineering (1951) from the Georgia Institute of Technology and a Ph.D. in radiological and environmental engineering (1960) from the University of Florida.

Dr. Carter resides in Atlanta, Georgia.

Dr. Patrick A. Domenico

President Bush appointed Dr. Domenico to serve on the Nuclear Waste Technical Review Board on May 31, 1990. His term expires April 19, 1994.

Dr. Domenico is currently the David B. Harris Professor of Geology at Texas A&M University's College Station Campus, where he teaches and conducts research in his area of expertise, groundwater hydrology. He has more than 25 years' teaching experience and has authored more than 40 professional publications, including a textbook on groundwater hydrology. Over the past 10 years, Dr. Domenico's research and consulting activities have focused on hazardous and nuclear waste transport in the subsurface.

In the area of nuclear waste disposal, Dr. Domenico has served the Department of Energy as an advisor to the scientific program at the Basalt Waste Isolation Project and acted as a consultant to Argonne National Laboratory on the Deaf Smith and Nevada Test Site projects. Additionally, he served on the Performance Assessment Board for the Waste Isolation Pilot Plant as consultant to the Sandia National Laboratories.

Dr. Domenico has acted as a consultant for many private and governmental organizations including the International Bank for Reconstruction and Development, DuPont Chemical Company, and the Edison Electric Institute. In these positions, he has worked on projects dealing with hydrologic, groundwater supply, geothermal, and environmental issues.

Dr. Domenico has served on several expert panels, including the Panel on Groundwater Modeling of the Scientific Community on Problems of the Environment and the National Science Foundation Uranium Mill Tailings Study Panel. He also was a participant in the planning workshops for the *Hydrogeology* volume of the *Geology of North America.* He is a registered engineer with the State of Nevada.

Through the course of his career, Dr. Domenico has received many prestigious awards including the Birdsall Distinguished Lecturer in Hydrogeology (1981-1982), the Distinguished Teaching Award from the College of Geoscience (1986), and the Distinguished Teaching Award from Texas A&M University (1989).

Dr. Domenico is a cum laude graduate from Syracuse University (1959), where he received a B.S. in geology. He later received an M.S. in engineering geology from Syracuse (1963) and a Ph.D. in hydrology from the University of Nevada (1967).

He presently resides in College Station, Texas.

Dr. Donald Langmuir

President Reagan appointed Dr. Langmuir to serve on the Nuclear Waste Technical Review Board on January 18, 1989. His term expires April 19, 1992.

Dr. Langmuir brings to the Board an extensive background in groundwater geochemistry. He is presently a professor of geochemistry at the Colorado School of Mines, Golden, Colorado. During his career, Dr. Langmuir has accumulated more than 25 years' teaching experience at Rutgers University, Pennsylvania State University, the University of Nevada, the University of Sydney in Australia, and the Colorado School of Mines. He also has worked in the Water Resources Division of the U.S. Geological Survey.

His research interests include uranium, thorium, and radium geochemistry as it relates to radioactive waste disposal; groundwater prospecting for and in-situ leaching of ore deposits; mechanisms and modeling of metal and ligand sorption and solution-mineral equilibria in the saturated and unsaturated zones; thermodynamic and kinetic properties of water-rock systems; acid-rain weathering of building materials; and groundwater pollution.

Over the last 10 years, Dr. Langmuir has served on or been chairman of almost a dozen expert panels on various research programs sponsored by the Department of Energy, Nuclear Regulatory Commission, Environmental Protection Agency, and Lawrence Berkeley Laboratory. He is currently president of the 7,500-member Colorado Mountain Club.

With memberships in nearly a dozen professional societies, Dr. Langmuir has served as chairman of numerous society committees and sessions of national meetings related to hydrology and geochemistry and prepared several symposia and short courses. He is a fellow of the Mineralogical Society of America and the American Association for the Advancement of Science. Dr. Langmuir also has been associate editor of *Geochimica et Cosmochimica Acta*, the journal of the Geochemical Society, and served on the editorial board of *Interface*, the journal of the Society of Environmental Geochemistry and Health.

Over the last 25 years, Dr. Langmuir has published nearly 85 professional papers and articles and been awarded 23 grants and contracts supporting $1.8 million worth of research. He has consulted for clients in 16 U.S. states and in Australia, Canada, France, and Sweden.

He is a cum laude graduate of Harvard University (1956), where he received an A.B. in geological sciences. After serving as a naval officer, he subsequently received an M.A. (1961) and a Ph.D. (1965) in geology from Harvard University.

Dr. Langmuir resides in Golden, Colorado.

Dr. D. Warner North

President Reagan appointed Dr. North to serve on the Nuclear Waste Technical Review Board on January 18, 1989. His term expired on April 19, 1990. On August 7, 1990, President Bush reappointed Dr. North to a four-year term, which will expire on April 19, 1994.

Dr. North is a consulting professor in the Department of Engineering-Economic Systems at Stanford University, associate director of the Stanford Center for Risk Analysis, and a principal with Decision Focus Inc., Los Altos, California. In his work for the firm, Dr. North has performed risk assessments and other related activities for the Electric Power Research Institute and numerous electric utilities, energy companies, chemical companies, industry associations, the Department of Energy (DOE), and the Environmental Protection Agency (EPA). Prior to his employment with Decision Focus, he spent 10 years with SRI International in Menlo Park, California.

Dr. North's areas of expertise are risk analysis and decision analysis. He has worked on a wide variety of public policy issues, including weather modification, wildland fire protection, biological quarantine for the U.S. space program, disposal of chemical munitions and agents, planning of energy systems and energy research and development, and risk assessment and management of toxic chemicals. Dr. North serves on the editorial boards for *Risk Analysis, Risk Abstracts*, and *Management Science.* He is president-elect of the Society for Risk Analysis.

Dr. North served as a consultant on decision analysis to the National Academy of Sciences (NAS) for its review in 1986 of the DOE methodology used to select prospective sites for the nation's first geologic repository for high-level radioactive waste. Dr. North has participated in six other NAS studies on environmental risk issues, including those resulting in the reports *Risk Assessment in the Federal Government: Managing the Process* (1983) and *Improving Risk Communication* (1989). Dr. North currently serves on the NAS Committee on Risk Assessment Methodology.

Dr. North has served on committees of the Science Advisory Board (SAB) of the EPA continuously over the past 10 years. He currently is vice chair of the Environmental Health Committee. During 1988-89 he was the chair of the Global Climate Change Subcommittee for the SAB review of two EPA reports to Congress on climate alteration from carbon dioxide and other radiatively active gases in the atmosphere. Dr. North also has been a reviewer of the carcinogen risk assessment guidelines, chair of the subcommittee that reviewed EPA's risk assessment research, and vice chair of the subcommittee that advised EPA on the congressionally mandated revision of the Hazard Ranking System used to select Superfund sites. From March 1987 to June 1989, Dr. North was a member of the California Governor's Scientific Advisory Panel for the Proposition 65 Toxics Initiative, passed in 1986.

Dr. North received a B.S. in physics from Yale University (1962); an M.S. in physics (1963), an M.S. in mathematics (1966), and a Ph.D. in operations research (1970) from Stanford University.

He resides in Woodside, California.

Dr. Dennis L. Price

President Reagan appointed Dr. Price to serve on the Nuclear Waste Technical Review Board on January 18, 1989. His term expired April 19, 1990. On July 23, 1990, President Bush reappointed Dr. Price to a four-year term, ending on April 19, 1994.

Dr. Price is now professor of industrial and systems engineering, director of the Safety Projects Office, and coordinator of the Human Factors Engineering Center at Virginia Polytechnic Institute and State University. With more than 20 years' teaching experience at three institutions and eight years of industrial experience with two corporations, his present interests include transportation of hazardous materials, human factors research, engineering psychology, industrial hazard control, design and evaluation of person-machine systems, and system safety analysis.

Since 1977, Dr. Price has been a human factors / safety engineering consultant for a variety of clients including Florida Power and Light, U.S. Navy, IBM, Union Camp, Mountain West Research in Nevada, Aetna Life and Casualty, Liberty Mutual, Sears, and product liability attorneys in 10 states. He also is certified as a hazard control manager and a product safety manager.

As a member of the National Academy of Sciences' (NAS) Transportation Research Board Dr. Price has served as chairman or been a member of six committees or subcommittees, including the chairman of the A3C10 Committee on the Transportation of Hazardous Materials. In addition, he was chairman of NAS' Task Force on Pipeline Safety and a member of its Committee on Demilitarization of Chemical Weapons. For his NAS service, Dr. Price received the Distinguished Service Award (1987) and the Outstanding Service Commendation (1981).

Dr. Price's publications include more than 30 papers in the open literature, 1 book, 7 chapters in various books, and more than 160 technical reports for private industry, clients, or government agencies. Some of these studies were the subjects of public hearings and radio and television programs with nationwide coverage. He is also on the editorial board of *Human Factors*, the journal of the Human Factors Society, and serves as a professional reviewer for seven different organizations. Dr. Price is a member of six professional organizations and has served on numerous university committees.

Dr. Price has a very diverse educational background with a B.A. from Bob Jones University (1952), an M.A. in psychology from California State University at Long Beach (1967), and a Ph.D. in industrial engineering from Texas A&M University (1974). He also received an M.A. and B.D. from the American Baptist Seminary of the West (1955).

He presently resides in Blacksburg, Virginia.

Dr. Ellis D. Verink, Jr.

President Reagan appointed Dr. Verink to serve on the Nuclear Waste Technical Review Board from January 18, 1989 to April 19, 1990.

Dr. Verink brings to the Board nearly 50 years' experience in materials selection and corrosion. He is a Distinguished Service Professor of Metallurgy, former chairman of the Materials Science and Engineering Department at the University of Florida, and president of Materials Consultants, Inc. He was elected a fellow of the Metallurgical Society (1988) and the American Society for Metals (1978).

In addition to his election to president of the Metallurgical Society, Dr. Verink has served on the executive committee, board of directors, and board of trustees of the American Institute of Mining, Metallurgical and Petroleum Engineers. He was a three-term national director of the National Association of Corrosion Engineers and served on five National Academy of Sciences committees, including two that reviewed the conceptual geologic repository designed by Swedish engineers. Dr. Verink also has been chairman or a member of more than 20 other national committees or advisory groups.

With more than 25 years of academic experience, Dr. Verink has served as chairman of nine committees, including the Search Committee for the President of the University of Florida, and has been a member of eight other university committees. For his contributions to material sciences and university teaching, Dr. Verink was elected a fellow of the Metallurgical Society and has received nearly a dozen other awards including the Willis Rodney Whitney Award, Florida Blue Key Distinguished Faculty Award, Educator Award of the Metallurgical Society, and University of Florida Teacher-Scholar of the Year Award.

As a registered professional engineer with special accreditation in corrosion engineering, Dr. Verink has been a consultant on numerous projects for private clients such as the Aluminum Association, Copper Development Association, Sandia Corporation, and the Lockheed-Georgia Co. He has been a member of American delegations to both China and the Soviet Union and has lectured in five foreign countries.

Dr. Verink has written more than 75 technical papers, edited 2 books and 9 chapters in other books, and served as corrosion editor for the *Journal of the Electrochemical Society* and on the editorial board of *Surface Technology Magazine* and *Journal of Materials Education*.

Dr. Verink has three educational degrees in metallurgical engineering: a B.S. from Purdue University (1941) and an M.S. (1963) and a Ph.D. (1965) from Ohio State University.

He resides in Gainesville, Florida, where he has served in the past as president of both the Kiwanis Club and the YMCA.

Appendix B
Panel Organization

1. Structural Geology & Geoengineering

Chair:	Dr. Clarence R. Allen	Staff:	Mr. R.K. McFarland
Member:	Dr. Don U. Deere		Dr. Leon Reiter
Ad Hoc:	Dr. Patrick A. Domenico		

2. Hydrogeology & Geochemistry

Co-Chair:	Dr. Donald Langmuir	Staff:	Dr. Leon Reiter
Co-Chair:	Dr. Patrick A. Domenico		
Ad Hoc:	Dr. Clarence R. Allen		
Ex Officio:	Dr. Don U. Deere		

3. Engineered Barrier System

Chair:	Dr. Ellis D. Verink	Staff:	Dr. Sidney J.S. Parry
Members:	Dr. Dennis L. Price		
	Dr. Donald Langmuir		
Ex Officio:	Dr. Don U. Deere		

4. Transportation & Systems

Chair:	Dr. Dennis L. Price	Staff:	Dr. Sherwood C. Chu
Members:	Dr. Melvin W. Carter		
	Dr. Ellis D. Verink		
Ex Officio:	Dr. Don U. Deere		

5. Environment & Public Health

Chair:	Dr. Melvin W. Carter	Staff:	Dr. Sidney J.S. Parry
Members:	Dr. John E. Cantlon		
Ad Hoc:	Dr. D. Warner North		
Ex Officio:	Dr. Don U. Deere		

6. Risk & Performance Analysis

Chair:	Dr. D. Warner North	Staff:	Dr. Leon Reiter
Ad Hoc:	Dr. John E. Cantlon		
	Dr. Patrick A. Domenico		
	Dr. Dennis L. Price		
	Dr. Ellis D. Verink		
Ex Officio:	Dr. Don U. Deere		

7. Quality Assurance

Chair:	Dr. John E. Cantlon	Staff:	Dr. Sherwood C. Chu
Members:	Dr. Clarence R. Allen		
	Dr. Melvin W. Carter		
Ad Hoc:	Dr. Donald Langmuir		
Ex Officio:	Dr. Don U. Deere		

Appendix C
Meeting List for 1990

January 18-19, 1990

Containers & Transportation Panel Meeting
Pleasanton, California
Topic: DOE briefing on the engineered barrier system (EBS).
Transcripts available

January 31 - Feb.1, 1990

NWTRB/DOE Technical Exchange
Denver, Colorado
Topic: DOE presentation on the exploratory shaft facilities (ESF) alternatives.

February 6, 1990

DOE/NRC Technical Exchange
Las Vegas, Nevada

March 2-3, 1990

Full Board Meeting (closed, minutes available)
Tucson, Arizona

March 19-20, 1990

Joint Panel Meeting (Risk & Performance Analysis/Structural Geology & Geoengineering)
Denver, Colorado
Topic: Repository system design requirements.
Transcripts available

March 22, 1990

Full Board Meeting (closed, minutes available)
Washington, D.C.
*Release of *First Annual Report to the U.S. Congress and the U.S. Secretary of Energy*

April 7, 1990

Structural Geology & Geoengineering/DOE Technical Exchange (a.m.)
Las Vegas, Nevada
Topic: ESF alternatives.

April 7-8, 1990

Full Board Meeting (April 7, p.m.; April 8, a.m.; closed, minutes available)
Las Vegas, Nevada

April 12, 1990

Structural Geology & Geoengineering/ DOE Technical Exchange
Las Vegas, Nevada
Topic: Seismic hazards.

April 24-26, 1990

Environment & Public Health Panel Meeting
Las Vegas, Nevada
Topic: Presentations by the State of Nevada, the Western Shoshone National Council, and the DOE and its contractors.
Transcripts available

May 18, 1990

Transportation Panel/NRC Technical Exchange
Washington, D.C.
Topic: Transportation issues.

May 22, 1990

Engineered Barrier System Panel/DOE Briefing
Atlanta, Georgia
Topic: Waste package plan.

May 26 - June 2, 1990

Board visits Sweden and the Federal Republic of Germany

July 23, 1990

Full Board Meeting
Atlanta, Georgia
Topic: NRC briefing and presentation of panel reports.
Transcripts available for open portion
Minutes available for closed portion

July 24-25, 1990

Joint Structural Geology & Geoengineering and Hydrogeology & Geochemistry Panels Meeting
Atlanta, Georgia
Topic: ESF alternatives.
Transcripts available

July 26, 1990

Full Board Meeting (closed, minutes available)
Atlanta, Georgia

August 17, 1990

Public Hearing: Transportation & Systems Panel
Amargosa Valley, Nevada
Topic: Transportation issues.
Transcripts available

August 28-29, 1990

Engineered Barrier System Panel Meeting
Pleasanton, California
Topic: Engineered barrier systems.
Transcripts available

October 10, 1990

Full Board Meeting
Arlington, Virginia
Topic: NRC / EPRI presentations on performance assessment.
Transcripts available for open portion
Minutes available for closed portion

October 11, 1990

Structural Geology & Geoengineering Technical Exchange
Arlington, Virginia
Topic: Surface-based testing prioritization and Calico Hills risk / benefit analysis.

October 15, 1990

Public Hearing: Environment & Public Health Panel
Reno, Nevada
Topic: Environment and public health issues.
Transcripts available

October 16, 1990

Environment & Public Health Panel Meeting
Reno, Nevada
Topic: Socioeconomic issues.
Transcripts available

October 22, 1990

Transportation & Systems Panel Meeting
Washington, D.C.
Topic: Transportation operational and safeguards activities.
Transcripts available

November 1-2, 1990

Quality Assurance Panel Meeting
Arlington, Virginia
Topic: NRC / DOE quality assurance requirements and implementation process.

Transcripts available

November 19, 1990

Public Hearing: Transportation & Systems Panel
Reno, Nevada
Topic: Transportation issues.
Transcripts available

November 19-20, 1990

Structural Geology & Geoengineering Panel Meeting
Denver, Colorado
Topic: ESF alternatives.
Transcripts available

Appendix D
Presenters List

The following people made formal presentations to the Board or panel(s) from January 1, 1990 through July 31, 1990. This list is arranged alphabetically by organization.

Applied Decision Analysis, Inc.
3000 Sand Hill Road, Building Four
Suite 255
Menlo Park, CA 94025
(415) 854-7101

Hollis Call
Lee Merkhofer

Bechtel Corporation
12440 E. Imperial Highway
Norwalk, CA 90650
(213) 807-2000

Asadour Hadjian

Decision Analysis Company
23 Valley Oak
Portola Valley, CA 94028
(415) 851-3007

Bruce Judd

EG&G Energy Measurements, Inc.
P.O. Box 1912
Las Vegas, NV 89125
(702) 295-0029

Ted Doerr
Thomas O'Farrell
W. Kent Ostler

Electric Power Research Institute
P.O. Box 10412
Palo Alto, CA 94303
(415) 855-2000

Robert Shaw

Lawrence Livermore National Laboratory
P.O. Box 808
Livermore, CA 94551
(415) 422-1100

Lynden Ballou
Stephen Blair
Thomas Buscheck
Willis Clarke
Joseph Farmer
William Glassley
William Halsey
Leslie Jardine
Gary Johnson
R. Daniel McCright
John Nitao
Aberlardo Ramirez
Richard VanKonynenburg
Dale Wilder

RE/SPEC
4775 Indian School Road, Northeast
Suite 300
Albuquerque, NM 87110
(505) 268-2661

Paul Gnirk

Science Applications International Corporation (SAIC)

101 Convention Center Drive
Las Vegas, NV 89109
(702) 794-7000

Timothy Barbour
Monica Dussman
Jerry Frazier
Terry Grant
Thomas Greider
Ernest Hardin
Richard Lee
Steve Mattson
Grover Prowell
Michael Voegele
Stephen Woolfolk
Jean Younker

State of Nevada, Agency for Nuclear Projects

Capitol Complex
Carson City, NV 89710
(702) 885-3744

Steve Frishman
Carl Johnson

U.S. Department of Energy, Oak Ridge National Laboratory

P.O. Box 2008
Oak Ridge, TN 37831
(615) 576-5454

Karl Knotz

U.S. Department of Energy, Office of Civilian Radioactive Waste Management

1000 Independence Avenue, SW
Washington, DC 20585
(202) 586-5000

Richard Blaney
Stephen Brocoum
H. Jackson Hale
Thomas Isaacs
Jeffrey Kimball*
Gerald Parker
Franklin Peters

**Currently employed at*
U.S. Department of Energy, Office of Defense Programs
19901 Germantown Road
Germantown, MD 20585
(202) 586-5000

U.S. Department of Energy, Sandia National Laboratories

P.O. Box 5800
Albuquerque, NM 87185
(505) 844-5678

Thomas Blejwas
Larry Costin
Albert Dennis
Thomas Hunter
Eric Ryder
Al Stevens

U.S. Department of Energy, Yucca Mountain Project Office

P.O. Box 98608
Las Vegas, NV 89193-8608
(702) 794-7920

Maxwell Blanchard
Jerry Boak
Michael Cloninger
Wendy Dixon
David Dobson
J. Russell Dyer
Carl Gertz
Leo Little
Edgar Petrie

U.S. Geological Survey

705 North Plaza Street
Federal Building, Room 224
Carson City, NV 89701
(702) 887-7600

Otto Moosburner

U.S. Nuclear Regulatory Commission
11555 White Flint North
Rockville, MD 20852
(301) 492-3404

Francis X. Cameron
Seth Coplan
Lloyd Donnelly
John Jankovich
Philip Justus
Charles MacDonald
John Roberts
Dennis Serig

University of Nevada
Desert Research Institute
P.O. Box 60220
Reno, NV 89506
(702) 673-7306

Lonnie Pippin

University of Nevada
Nevada Bureau of Mines & Geology
Mailstop - 178
Reno, NV 89557-0088
(702) 784-6691

John Bell

Western Shoshone National Council
P.O. Box 140068
Duckwater, NV 89314-0068
(702) 863-0227

Ian Zabarte

Appendix E

OCRWM Responses to the NWTRB *First Report* Recommendations

As part of its effort to keep the Nuclear Waste Technical Review Board informed of its progress, the Department of Energy submitted to the Board on September 26, 1990, a summary of initial responses to the Board's recommendations in it's *First Report*. The Board has included those responses along with the transmittal letter in this report.

Department of Energy
Washington, DC 20585

SEP 25 1990

Dr. Don U. Deere
Chairman, Nuclear Waste Technical
Review Board
1100 Wilson Boulevard
Arlington, Virginia 22209

Dear Dr. Deere:

On behalf of the Department of Energy (DOE) and the Office of Civilian Radioactive Waste Management, I would like to thank the Board for its thoughtful and effective reviews of our site evaluation, waste packaging, and transportation activities over the past year.

Enclosed are DOE's initial responses to the Board's recommendations in its First Report to Congress and the Secretary of Energy. You will note a number of the responses refer to ongoing analyses that we are conducting, most notably with regard to the design and construction of the exploratory shaft facility. The final decisions that DOE will make in these areas obviously depend on the results of the analyses. As we wanted to keep the Board informed of our progress in conducting the analyses, several meetings to discuss the ongoing analyses have already been held and others are scheduled. The initial responses that are enclosed will, therefore, be updated as appropriate to reflect the results of DOE's analyses and subsequent discussions with the Board.

As the new Director of a complex scientific program with national impact, I look forward to our future interactions and want to assure you of the Department's desire to cooperate fully with the Board.

Sincerely,

John W. Bartlett

John W. Bartlett, Director
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Enclosure

OCRWM Responses to the NWTRB Recommendations in its *First Report to the U.S. Congress and the U.S. Secretary of Energy*, March 22, 1990

INTRODUCTION

The Nuclear Waste Policy Act of 1982 (NWPA) established the Office of Civilian Radioactive Waste Management (OCRWM) and assigned to its Director the responsibility for carrying out the functions of the U.S. Secretary of Energy (the Secretary) under the NWPA. The Nuclear Waste Policy Amendments Act of 1987 (NWPAA) established the Nuclear Waste Technical Review Board (the Board or the NWTRB) to evaluate the technical and scientific validity of activities undertaken by the Secretary after the date of the enactment of the NWPAA, including site characterization activities and activities relating to the packaging or transportation of high-level radioactive waste or spent nuclear fuel.

The Department of Energy (DOE) and the Board interactions occur in a variety of formats. These interactions have included Technical Presentations and Technical Information Exchange meetings to convey technical and scientific information to the full Board or NWTRB Panels and to provide a forum for interaction between the Board and DOE and its contractors. To the extent possible, representatives of State and local governments, Indian Tribes, and utilities, as well as members of the public have been provided opportunities, by the Board, to observe and / or participate in technical meetings between the Board and DOE.

The Board is mandated to report, not less than two times per year, to the Congress and the Secretary its findings, conclusions, and recommendations. The Board's report, issued on March 22, 1990, represents the *First Report to the U.S. Congress and the U.S. Secretary of Energy*. In the first NWTRB report, "the Board's objective has been to identify the most important technical and scientific issues that the DOE should analyze further and to specify a possible course of action." This document, "OCRWM Responses to the NWTRB Recommendations ...", contains the OCRWM responses to the Board's 17 technical and scientific recommendations along with responses to other recommendations of the Board.

DOE is committed to developing a geologic repository for spent fuel and high-level waste through a scientifically based, technically sound, and cost-effective program, and the development of the repository remains the focus of the OCRWM program. The difficulties facing the repository program, therefore, received particular attention during the Secretary's comprehensive program review, *Report to Congress on Reassessment of the Civilian Radioactive Waste Management Program*, November 1989.The Secretary's review focused on management readiness to proceed with scientific investigations at the Yucca Mountain candidate site, including the implementation of a quality-assurance program that has been reviewed and accepted by the Nuclear Regulatory Commission (NRC); OCRWM's understanding of the magnitude of the effort to be undertaken; and the views of the State of Nevada (the State). This review led to the development of a revised schedule, including near-term decision milestones, and significant changes in the focus of the near-term program. The new focus on surface-based testing is not meant to suggest that underground testing at the proposed repository horizon is now deemed less important. On the contrary, the Secretary's evaluation has led to an extension of the schedule for in situ testing, in accordance with the commitment to conduct a scientifically based and

technically sound program . The Secretary believes that conducting both surface-based and underground tests, combined with continuing evaluation of the data as they are obtained, will allow a cost-effective and timely assessment of the proposed site.

Currently, none of the required State of Nevada permits which allow technical and scientific investigations to proceed—the permit for underground injection, the air registration certificate, and the ground-water appropriation permit—has been obtained. The State has refused to issue these permits on the grounds that State law prohibits the disposal of spent fuel and high-level waste in Nevada. Although this matter is being litigated, DOE will continue its efforts to obtain the permits and is willing to work with the State to resolve specific permit issues.

To the extent that it can, DOE is collecting relevant data in strict accordance with the requirements of applicable Nevada statutes. DOE is continuing ongoing activities at, and near, Yucca Mountain to monitor transient events (e.g., seismicity, meteorology, stream drainage and runoff). These activities do not require air quality or other permits. Continuation of these monitoring activities is necessary to avoid loss of irretrievable information that is essential for assessing the magnitude and recurrence interval of potentially disruptive events and processes that could affect waste isolation.

As soon as the permits necessary for surface-based testing are issued, DOE will begin onsite testing to collect scientific information on the unsaturated zone. DOE will also collect information on zones of recent faulting to better understand the potential for surface offsets in the vicinity of the waste-handling building and the potential of major earthquakes. Also planned are investigations aimed at better understanding the origin of the calcite-silica deposits that have been identified by some program critics as indicators of saturated conditions in the proposed repository horizon. All these scientific investigations will provide early information about the suitability of the proposed site. This approach is in concert with a number of suggestions, particularly from the State, the Edison Electric Institute (EEI), and NRC, that scientific investigation activities focus on potentially adverse conditions and that efforts be made to evaluate key suitability issues early in the process.

TECHNICAL AND SCIENTIFIC RECOMMENDATIONS

The Board has recommended that the DOE take action on 17 issues. These issues are discussed below in the following format. Each issue is quoted from the Board's March 22, 1990, report and is followed by an appropriate response by OCRWM to the NWTRB recommendations.

A. Mechanical Excavation

"Maximize the use of the most modern mechanical excavation techniques in the recently initiated studies of alternative shaft and tunnel construction methods."

Response:

The Department of Energy (DOE) is committed to determining which method of mining will be most efficient for the exploratory shaft facility (ESF), with respect to collection of needed data, potential impacts on the waste isolation capabilities of the site, time, and cost. The choice between mechanical excavation and drill-and-blast techniques involves consideration of numerous factors, including (from a scientific perspective) the types and amounts of data needed on the characteristics of fractures within the geologic units above and at the repository horizon, and the best method for gathering that data.

A major effort is under way to reexamine the current design of the ESF, and to evaluate alternatives to that design. Thirty-four major options are being considered, including twenty-eight with some component of mechanical mining techniques. In July, DOE met with the NWTRB to discuss the progress of work addressing this topic. Studies of these alternatives will be completed in early 1991. The Department will continue to update the Board on the status of the ESF alternatives evaluation.

B. Ghost Dance Fault

"Intersect the Ghost Dance Fault with an exploratory drift at more than one location."

Response:

DOE has provided the Board with a report that describes an evaluation conducted by DOE. On the basis of this evaluation, DOE plans to intersect the Ghost Dance Fault, in at least one more location in the Topopah Spring Member, in addition to the intersection previously planned. DOE expects the second intersection to be located where the fault offset may be greater. Preliminary recommendations for investigation of the Calico Hills unit would also provide at least two more intersections with the Ghost Dance Fault at a lower horizon. The layout of the ESF is being evaluated by the ESF Alternatives Task Group, which will recommend the actual number and subsequent location of penetrations of the Ghost Dance fault. Progress on this topic was discussed in the July 25, 1990, NWTRB technical exchange panel meeting.

In addition, studies of the hydrologic properties of the Ghost Dance Fault and other faults fall under Site Characterization Plan (SCP) Activity 8.3.1.2.2.4.10: "Hydrologic properties of major faults encountered in the main test level of the exploratory shaft." SCP Activity 8.3.1.2.2.3.2: "Site vertical borehole studies," provides for a pair of boreholes (USW UZ-7 and USW UZ-8) to straddle and test the hydraulic and geologic properties of the Ghost Dance Fault, and also considers geophysical studies in the boreholes to investigate the repository block.

C. Early Exploratory Drifting

"Plan an exploratory drift in an east-west direction across the Yucca Mountain geologic block."

Response:

DOE is evaluating additional exploratory drifting through the ESF Alternatives Task Group and the Calico Hills Risk Benefit Analysis (CHRBA) which are planned for completion in early 1991. The ESF Alternatives Task Group and CHRBA are also examining alternative configurations for exploratory drifting in the Topopah Spring Member and the Calico Hills unit. Sufficiently flexible ESF layouts are currently being considered, such that additional exploratory east-west drifting may be incorporated in the future when the results of surface-based testing become available. The additional exploratory drifting proposed would add to the understanding of the host rock, although current data and the proposed program of exploratory drilling and drifting are expected to reduce the likelihood of encountering unrecognized, pre-Tiva Canyon Member faults cutting the Topopah Spring Member. DOE intends to construct additional exploratory drifts, where prudent. The technical justification and location of additional exploratory drifts will be determined when the ESF Alternatives Study is completed and will be reassessed as the results of scientific information, obtained from the proposed Yucca Mountain site, become available.

D. Exploratory Ramp

"Continue studies for incorporating an exploratory ramp entering the Yucca Mountain geologic block from the east."

Response:

DOE recognizes that there may be some advantages associated with the substitution of an exploratory ramp for one of the shafts. A ramp was considered previously, but the evaluations of possible configurations conducted at that time resulted in adoption of the current conceptual design. Among the benefits that might accrue through incorporation of an exploratory ramp is an improved ability to evaluate the degree to which surface-based testing of fault and fracture densities may indicate rock characteristics in the subsurface. The ESF Alternatives Task Group is presently evaluating the use of an exploratory ramp for access to the ESF. Twenty-eight different options include one or more ramps. Progress on this topic was discussed in the July 25, 1990, NWTRB technical exchange panel meeting. The studies evaluating these alternatives will be completed in early 1991, and DOE intends to continue its interactions with the Board on this subject.

E. Non-Welded Tuff

"Include in the exploratory program ample penetration of softer, less permeable tuff units by borings, shafts, ramps, or tunnels."

Response:

DOE is reexamining its current plans to expand the characterization of the non-welded tuff units both above and below the repository horizon through in situ exploration. Specifically, the risk-benefit analysis of the Calico Hills unit reexamines the methods of characterization of the Calico Hills unit. DOE believes the testing program is flexible and can be modified if additional information needs are identified, or if the current ESF design or construction method is revised. Progress on this topic was discussed in the July 25, 1990, NWTRB technical exchange panel meeting.

Several studies, which are described in the SCP, outline DOE's current plans for non-welded tuff characterization. Study 8.3.1.4.2.1: "Surface and subsurface stratigraphic studies of the host rock and surrounding units," is intended to gather data to describe units surrounding the host rock. Study 8.3.1.2.2.3: "Characterization of percolation in the unsaturated zone - surface based study," will provide extensive data on the matrix hydraulic properties of these tuffs. Data pertaining to water occurrence and flow at the upper and lower boundaries will be obtained from radial borehole studies described in Study 8.3.1.2.2.4: "Characterization of Yucca Mountain percolation in the unsaturated zone - exploratory shaft study."

F. Excavation-Testing Sequence

"Develop innovative ways of coordinating and sequencing excavation and scientific testing."

Response:

Results of a comprehensive reevaluation of the testing program, both with respect to inclusion and ordering of tests will depend upon the final outcome of the ESF Alternatives, CHRBA, and the Surface-Based Testing Priorities tasks. Coordination and sequencing of scientific and excavation testing ac-

tivities will also be addressed in prerequisites planning for new field activities. In the past, the coordination of excavation and testing sequences was considered in the Design Acceptability Analysis, in Chapter 8 of the SCP, and in the report "Evaluation of Alternative ESF Shaft Construction Methods and Test Sequences for Yucca Mountain Project Office". DOE has recently committed to place high priority on tests that could provide early indications of site unsuitability. This test strategy is being incorporated into the ESF Alternatives Study.

G. Unsaturated Zone Recharge

"Expand and accelerate the studies of snowmelt and rainfall infiltration into alluvium and near-surface fractures."

Response:

DOE is not in a position to expand or accelerate studies until the current impasse with the State of Nevada is resolved. DOE is currently monitoring infiltration in existing boreholes as part of ongoing studies, and as soon as new drilling can begin, additional holes will be added to the current network. Study 8.3.1.2.1.1: "Characterization of the meteorology for regional hydrology," and Study 8.3.1.12.2.1: "Meteorological data collection at the Yucca Mountain site," directly relate to surface infiltration and recharge of the unsaturated-zone and include the following activities whose priority is being evaluated by the Surface-Based Testing Priorities Task Group:

8.3.1.2.2.1.1: "Characterization of hydrologic properties of surficial materials"

8.3.1.2.2.1.2: "Evaluation of natural infiltration"

8.3.1.2.2.1.3: "Evaluation of artificial infiltration"

8.3.1.12.2.1.1: "Site meteorological monitoring program"

Study plans for the infiltration studies are in the final phases of DOE review, and initiation of the comprehensive drilling program associated with these studies is among the highest priorities for DOE when permits are granted for work at the site.

H. Fracture Flow

"Continue the sampling analysis of ^{3}H and $^{36}C1$ isotopes to gain a better understanding of the surface features that control the deep penetration of recharge."

Response:

DOE is aware of the importance of isotope geochemistry to the understanding of ground-water recharge at Yucca Mountain. Priorities for the following studies addressing this issue are being evaluated by the Surface-Based Testing Priorities Task Group:

8.3.1.2.2.2: "Water movement tracer tests using chloride and chlorine-36 measurements of percolation at Yucca Mountain"

8.3.1.2.2.3: "Surface-based unsaturated-zone percolation"

8.3.1.2.2.7: "Unsaturated-zone hydrochemical characterization (unsaturated- zone ^{3}H sampling)"

8.3.1.2.2.8: "Fluid flow in unsaturated, fractured rock (modeling studies using site data)"

8.3.1.2.2.9: "Site unsaturated-zone modeling and synthesis (modeling studies using site data)"

8.3.1.2.2.1: "Characterization of unsaturated-zone infiltration (^{3}H neutron holes)"

In addition, Study 8.3.1.2.2.4: "ESF unsaturated-zone percolation," also addresses this issue.

I. Hydrogeologic Modeling

"Approach hydrogeologic modeling in the program in a more systematic fashion, and validate models when new pertinent field data are made available."

Response:

DOE intends to approach the overall modeling of hydrogeologic processes in a systematic manner. Model validation is a continuing task in the performance assessment program and a number of activities are either underway or planned.

A general methodology for validating performance assessment models, including those for hydrogeologic processes, is being developed for DOE by its Validation Oversight Group. DOE has participated in relevant portions of international model validation exercises such as INTRAVAL and in field, laboratory and mathematical-modeling studies at various research facilities in other nations (e.g., the Organization for Economic Cooperation and Development, including its Nuclear Energy Agency Stripa Iron Mine Project, Sweden, and the Pocos de Caldas Natural Analog Project, Brazil) that are relevant to model validation.

Performance assessment calculational exercises in progress this year have pointed to critical data needed for model validation. The Surface-Based Testing Priorities Task Group is currently evaluating performance assessment needs in relation to critical data required.

Since validation is to a large extent application-dependent, detailed plans for validation of specific models will be presented in study plans dealing with application of the models. Hydrogeologic modeling of Yucca Mountain and the vicinity is planned for four separate SCP investigations. Models of portions of the site system will be developed and validated in the following investigations, by means of iterative refinement as site data become available:

8.3.1.2.1: "Regional hydrologic system"

8.3.1.2.2: "Unsaturated-zone hydrologic system at the site"

8.3.1.2.3: "Saturated zone hydrologic system at the site"

8.3.1.5.2: "Potential effects of future climatic conditions on hydrologic characteristics"

Section 8.3.5.20 of the SCP discusses analytical techniques requiring significant development.

J. Calico Hills Hydrogeologic Properties

"Explore the Calico Hills tuff unit with surface borings and with the exploratory shaft facility."

Response:

NRC raised an objection to the consultation draft of the SCP and required that DOE demonstrate that the penetration of the Calico Hills unit by a shaft and/or exploratory drifts would not compromise the waste isolation capabilities of the site. DOE is currently conducting a risk/benefit analysis of options for exploration of the Calico Hills unit in concert with the ESF Alternatives Study. A preliminary recommendation for providing early access to and capability for extensive exploratory drifting in the Calico Hills unit was presented to the NWTRB in the technical exchange panel meeting on July 24-25, 1990. This recommendation has been incorporated into the ESF Alternatives Study and resulted in the addition of 17 options to provide early access to the Calico Hills unit. Documentation of the results of the CHRBA is expected to be available early in 1991.

K. Adsorption in Unsaturated Tuffs

"Study radionuclide adsorption in unsaturated tuffs over the range of temperatures and variable conditions of pH, ionic strength and competing and complexing aqueous ionic species concentrations expected at the site."

Response:

The geochemistry program, as described in the SCP, is designed to study radionuclide adsorption in unsaturated tuffs over a conservative range of conditions expected at the site. Activities which address unsaturated-zone experiments include:

8.3.1.3.6.1.3: "Unsaturated tuff columns"

8.3.1.3.6.2.3: "Diffusion in unsaturated tuff columns"

The relevance of data from these activities to potential transport from the repository will be addressed by Study 8.3.1.3.7.2: "Demonstration of applicability of laboratory data to repository transport calculations."

L. Radionuclide Adsorption Workshop

"Organize a radionuclide adsorption workshop to determine the applicability of available radionuclide adsorption data on tuff and to establish additional research and model development needs."

Response:

A workshop was held on September 11 and 12, 1990, for DOE and its contractors, as well as for outside researchers in the forefront of this field. The purpose of the workshop was two-fold: 1) the applicability of available radionuclide adsorption data on tuff and models for predicting adsorption under existing conditions at Yucca Mountain, and 2) additional radionuclide adsorption research and model development needed to demonstrate that quantitative, scientifically defensible predictions of radionuclide adsorption are possible and how such measured and predicted adsorption relates to compliance with the radionuclide release rate criteria set forth in 40 CFR 191. A report is being prepared that analyzes the results of the workshop and explains any modifications that will be made to the geochemistry program as a result of the discussions.

Study 8.3.1.3.7.2: Demonstration of applicability of laboratory data to repository conditions, is intended to address these concerns, and the Yucca Mountain Project Office is coordinating its efforts with those of the DOE Office of Defense Programs on radionuclide migration.

M. Performance Assessment Methodology

"Develop methodology to demonstrate performance assessments."

Response:

Continuing development of the principles, practices and procedures for performance assessment is a primary goal of the performance assessment program. DOE has described its general approach in the Performance Assessment Strategy Plan and in the SCP. The specific activities for implementing the performance assessment strategy are described in the Performance Assessment Implementation Plan. DOE has also initiated Preliminary Performance Assessment Calculational Exercises (PACE). These assessments have helped to demonstrate what DOE needs to accomplish in order to further develop its approach to performance assessment.

N. Preliminary Performance Assessment

"Carry out preliminary performance assessment calculations to demonstrate that such computations are possible and to determine if any site characteristic has been detected that would disqualify the site."

Response:

DOE has been involved in performance assessment calculational exercises (PACE) since 1989. The goal of the PACE exercises was precisely to evaluate the current state of models, computational capabilities, and the availability of site data. These exercises are expected to be a continuing activity. Performance assessment teams have also provided significant input to the activities evaluating ESF alternatives, performing risk-benefit analysis of Calico Hills shaft penetrations, and establishing priorities for the surface-based testing program.

The Surface-Based Testing Priorities Task Group is developing performance-based approaches for evaluating the potential repository site to determine if site characteristics point to a need to disqualify the site. SCP section 8.3.5.20: "Analytical techniques requiring development," likewise addresses the issue of ensuring that performance assessment is capable of providing timely input to evaluation and design of the repository system.

O. RADTRAN/TRANSNET

"Validate the RADTRAN model and some components in the TRANSNET package."

Response:

DOE is documenting the RADTRAN model in accordance with OCRWM Quality Assurance Program requirements and is planning to have an independent group conduct a peer review of RADTRAN. DOE will base its plans for verification and validation of RADTRAN and some components in the TRANSNET package on the recommendations developed by this independent peer review group. These verification and validation plans will be discussed with the Board when they are developed.

P. Risk Models User-Needs Assessment

"Assess the needs of potential RADTRAN/TRANSNET users with respect to what the various civilian radioactive waste program users want to accomplish and the levels of detail they require for different applications."

Response:

Documentation for RADTRAN, including a user manual, is currently being written in accordance with OCRWM requirements. Data modules specific to DOE/OCRWM expected spent fuel and high-level waste shipments are being developed for RADTRAN/TRANSNET application. As new data modules are incorporated into the models, further evaluations will be made of RADTRAN/TRANSNET user needs for DOE/OCRWM shipments.

Q. ^{14}C Release Mechanism

"Expand studies of ^{14}C release mechanisms and initiate a consultive program with the EPA and the NRC to examine the appropriateness of the ^{14}C limit."

Response:

Both the Environmental Protection Agency (EPA) and the NRC have been informally made aware of DOE's concerns with their regulatory requirements for control of ^{14}C releases. DOE is now reviewing the technical and regulatory approaches for resolving this issue and will keep the Board informed of the progress being made.

SCP activities that address the issue of ^{14}C release from the repository system include:

8.3.1.3.8.1.1: "Physical transport mechanisms and rates - retardation mechanisms and transport with retardation"

8.3.1.3.8.1.2 "Gas transport measurements"

8.3.5.10.2.1.5: "Evaluation of the inventory and release of carbon-14 from zircaloy cladding"

8.3.5.13.3.1.2: "Development of a model for gas-phase releases"

STRATEGIC TECHNICAL AND NON-TECHNICAL RECOMMENDATIONS

"Strategic technical recommendations involve value judgments about technical and non-technical factors. On such matters, the Board will attempt to explain the issues more clearly, suggest possible mechanisms or processes for addressing and / or resolving the issues, or make judgments on them. The Board makes the following four recommendations to the DOE in this category."

A. System Safety

"Initiate a transportation system safety program."

Response:

DOE recognizes its responsibility for transportation safety within the OCRWM program. The transportation system and transportation casks will have to be designed, licensed and operated to comply with stringent NRC and Department of Transportation regulatory requirements. DOE's current strategy expects that compliance with these requirements will provide the conservative degree of safety that is necessary for transportation of spent fuel and high level waste. DOE is presently evaluating steps to more clearly introduce system safety elements in the transportation program, and plans to discuss the subject further with the Board.

B. Human Factors

"Initiate a human factors program for transportation safety."

Response:

DOE has recognized the importance of human factor studies and, in fact, commissioned the report by Abkowitz et al., 1988, cited by the Board. DOE has also considered human factors in the design and review of transportation casks. DOE is evaluating the introduction of dedicated human factors components into the transportation program, and plans to discuss the subject further with the Board.

C. Operational Planning

"Evaluate the use of risk-based planning tools in developing a broad based and complete transportation operational plan."

Response:

DOE is, at the present time, studying the applicability of the Management Oversight Risk Tree (MORT) to the transportation program. DOE plans to discuss the results of these studies with the Board.

D. Environmental and Public Health Program

"Develop a systems approach to the Yucca Mountain ecosystem studies program so that each individual study is integrated into an overall environmental program."

Response:

DOE uses a systems approach to its ecosystem studies program, which monitors the effects of site characterization activities on biological resources. Within the scope of site characterization impacts, the program integrates studies focusing on four categories: 1) site characterization effects, 2) desert tortoise, 3) reclamation support and, 4) radiological support.

These studies are coordinated and integrated into other parts of the environmental program. For example, the findings of the ecosystems studies are provided to the reclamation program and radiological monitoring program. The ecosystem studies also provide input to mitigation strategies and are used to keep current the Environmental Monitoring and Mitigation Plan and other environmental program elements.

A more detailed description of the ecosystems study program was provided to the Environment and Public Health Panel of the Board on April 24-26, 1990. Further discussion of the integrated systems approach that is underway can be scheduled with the Board as needed.

SCIENCE POLICY RECOMMENDATIONS

"Science policy recommendations involve decisions typically dealt with in the upper echelons of the Executive Branch or Congress. Such issues involve storage, disposal, and transportation of spent nuclear fuel; the development of EPA standards and NRC regulations; and the repository licensing process. Three recommendations are presented in this category."

A. DOE and State of Nevada Interactions

"Continue efforts to resolve the present impasse on permitting of site characterization studies."

Response:

As the Board is aware, the matter is being litigated. Currently, none of the required State of Nevada permits—the permit for underground injection, the air registration certificate, and the groundwater appropriation permit—has been obtained. The State has refused to issue these permits on the grounds that State law prohibits the disposal of spent fuel and high-level waste in Nevada. Although this matter is being litigated, DOE will continue its efforts to obtain the permits and is willing to work with the State to resolve specific permit issues. DOE is making every effort to resolve the impasse. To the extent that it can, DOE is collecting relevant data in strict accordance with the requirements of applicable Nevada statutes.

B. The EPA Standard: 40 CFR 191

"Consider six modifications when EPA Standard: 40 CFR 191 is revised."

Response:

DOE has advised EPA of its concerns in the past. DOE will continue to advise EPA of its concerns and the basis for these concerns in its comments on Working Draft 2 of 40 CFR 191 and on the proposed rule when it is published for comment.

C. Consideration of Uncertainties in Setting Standards

"Regulatory agencies should consider inherent uncertainties and limitations in geologic information and data projected for periods of tens of thousands of years in regard to the rigor of formulating acceptable and realistic environmental radiation protection standards."

Response:

DOE has been working with EPA to ensure that the repromulgation of 40 CFR 191 results in a reasonable standard. DOE continues to discuss with NRC the meaning of certain regulatory criteria and both agencies meet regularly on topics of importance to the program.

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Glossary

Because this report will be of interest to technical and nontechnical readers, a glossary of scientific and technical terms has been compiled to aid readers in understanding such terms used in the report. It is not meant to be a formal glossary, nor to have the completeness of a dictionary,* but rather, it is intended to help the reader understand in a general sense technical terms used regularly by the Board.

Accessible environment: The atmosphere, land surface, surface water, oceans, and portions of the earth's crust that are outside of the controlled area (the area that will be marked by suitable monuments extending no more than 5 kilometers in all directions from the repository boundary).

Alluvium: A surface or near-surface deposit of unconsolidated or poorly consolidated gravel, sand, silt, or clays deposited by a stream or other body of running water

Analog studies: See "Natural analog."

Backfilling: The placement of materials, originally removed or new, into the excavated areas of a mine, including waste-emplacement holes, drifts, accessways, and shafts

Baseline: Defined and controlled element (e.g., configuration, schedule, data, values, criteria, or budget) against which changes are measured and compared

Block: An undeformed mountain-sized section of rock that may be bounded by large faults and / or large-scale topographic features (e.g., river valleys)

Biosphere: The zone of planet earth, where life naturally occurs, extending from the deep crust to the lower atmosphere. Earth's living organisms.

Borehole: An excavation, formed by drilling or digging, that is essentially cylindrical and is used for exploratory purposes

Borings: Holes drilled into the earth, usually vertically from the surface, but may be inclined

Canister: The structure surrounding a waste form (e.g., spent fuel rods) that facilitates handling for storage, transportation, and / or disposal

Cask: A massive container used to transport and / or store irradiated nuclear fuel or high-level nuclear waste. It provides physical and radiological protection and dissipates heat from the fuel.

Characterization: The collecting of information necessary to evaluate suitability of a region or site for geologic disposal

Container: A receptacle designed to hold spent fuel or radioactive material to facilitate movement and storage

Decision analysis: A structured approach whose aim is to enhance the decision-making process. It includes a logical decomposition of the problem, the solicitation of expert judgment, means for working out internal inconsistencies in these judgments, and the explicit treatment of uncertainties. Intuitively it can be thought of as "a formalization of common sense for decision problems which are too complex for informal use of common sense" (R. Keeney 1982).

Disposal: The isolation of radioactive materials from the accessible environment with no foreseeable intent of recovering them. Isolation occurs through a combination of constructed and natural barriers, rather than by human control. The Nuclear Waste Policy Act of 1982 specifies emplacement in mined geologic repositories.

Disqualifying geologic feature: A feature that, if present on the site, would eliminate the site from further consideration for development as a repository

Drift: A near-horizontal, excavated passageway through the earth

Engineered barrier system (EBS): The component of a disposal system designed to prevent the release of radionuclides from the underground facility or into the geohydrologic setting. It includes the radioactive waste form, radioactive waste containers, material placed over and around such containers, any other components of the waste package, and barriers used to seal penetrations in and into the underground facility.

Exploratory facility: An underground opening and structure constructed for the purpose of site characterization

Exploratory shaft facility (ESF): An exploratory facility defined in the Site Characterization Plan consisting primarily of two adjacent shafts

Fault: A plane in the earth along which differential slippage of the adjacent earth has occurred

Fault displacement: Relative movement of two sides of a fault such as that which occurs during an earthquake

Fission product: A nuclide produced by the fission of a heavier element

Folding: A curving or bending of a planar structure, such as rock strata or bedding planes. A fold is usually a product of deformation.

Fracture: Any break in a rock (i.e., a crack, joint, or fault), whether or not accompanied by displacement

Geologic block: That portion of Yucca Mountain in which placement of the proposed repository site is being considered

Geologic repository: A system, requiring licensing by the Nuclear Regulatory Commission, that is intended to be used, or may be used, for the disposal of radioactive waste in excavated geologic media. A geologic repository includes (1) the geologic repository operations area and (2) the portion of the geologic setting that provides isolation of the radioactive waste and is located within the controlled area.

Ghost Dance Fault: A near vertical north-south trending fault that crosses the eastern side of the Yucca Mountain geologic block

Ground motion: The vibratory movement of the ground caused by earthquakes. It is often characterized in terms of acceleration, velocity, or displacement.

Groundwater table: The upper surface of the zone of water saturation in rocks, below which all connected interstices and voids are filled with water

High-angle joint and fault system: A system of near-vertical joints and faults

High-level waste (HLW): (1) Irradiated reactor fuel, (2) liquid wastes resulting from the operation of the first cycle solvent extraction system, or equivalent, and the concentrated wastes from subsequent extraction cycles, or equivalent, in a facility for reprocessing irradiated reactor fuel, and (3) solids into which such liquid waste have been converted

Holocene epoch: That period of geologic time extending from 11,000 years ago until the present

Host rock: The rock in which the radioactive waste will be emplaced; specifically, the geologic materials that will directly encompass and will be in close proximity to the underground repository

Human factors engineering: A technical discipline that applies what is known about human psychological, physiological, and physical limitations to the design and operation of systems to enhance safety

Igneous activity: The emplacement (intrusion) of molten rock (magma) into material in the earth's crust or the expulsion (extrusion) of such material onto the earth's surface or into its atmosphere or surface water

Inclined dry-drilling: Drilling (at an angle) in which rock and cuttings are lifted out of a borehole by a current of air, rather than a drilling fluid

Infiltration: The flow of a fluid into a solid substance through pores or small openings; specifically the movement of water into soil or porus rock

Interim storage or storage: Temporary storage of high-level waste with the intention and expectation that the waste will be removed for subsequent treatment, transportation, and/or isolation

Isotope: A class of atomic species, of a given element, having differing atomic weights but identical atomic numbers and slightly differing chemical and physical properties

Metric ton: 1,000 kilograms; about 2,205 pounds

Monitored retrievable storage facility: A facility to collect spent fuel in a central location, where it can be stored until the fuel can be accepted at a repository

Natural analogue: A naturally occurring geologic setting that can provide information on aspects of repository performance

Near field: The region where the natural hydrogeologic system has been altered by the excavation of the repository or the thermal environment created by the emplacement of high-level waste

Nevada Test Site (NTS): A geographic area located in southern Nevada that is owned and operated by the U.S. Department of Energy and devoted primarily to the underground testing of nuclear devices

Nonwelded tuff: A tuff that has not been consolidated and welded together by temperature, pressure, or a cementing mineral

Performance allocation: The process whereby components of the proposed repository system are assigned expected quantified levels of performance

Performance assessment: Any analysis that predicts the behavior of a system or a component of a system under a given set of constant or transient conditions. In this case, the system includes the repository and the geologic, hydrogeologic, and biologic environment.

Postclosure: The period of time after the closure of the repository

Preclosure: That time prior to the backfilling of the repository

Quality Assurance (QA): The management process used to control and assure the quality of work performed

Quaternary period: The second part of the Cenozoic Era (after the Tertiary) beginning about 2 million years ago and extending to the present

Radiation-induced corrosion: A corrosion process that is initiated or controlled by chemical species that are produced by irradiation

Radiometric age dating: The calculation of the age of a material by a method that is based on the decay of radionuclides that occur in the material

Radionuclide: An unstable radioactive nuclide that decays toward a stable state at a characteristic rate by the emission of particles or ionizing radiation(s)

Radionuclide migration: The measurable or predictable movement of radionuclides, generally by liquids or gases, through a rock formation

Repository: A site and associated facilities designed for the permanent isolation of high-level radioactive waste and spent nuclear fuel. It includes both surface and subsurface areas, where high-level radioactive waste and spent nuclear fuel handling activities are conducted.

Repository horizon: A particular geologic sequence or layer where radioactive waste is intended for disposal. The Yucca Mountain repository horizon is 900 to 1,200 feet beneath the surface of the mountain.

Reprocessing: The process whereby fission products are removed from spent fuel and the fissionable parts are recovered for repeated use

Risk: Possibility of suffering harm or loss due to some event. The magnitude of the risk depends on both the probability of occurrence of an event and the consequences should the event occur.

Rock matrix: The solid framework of a porous rock

Saturated rock: A rock in which all of the connected interstices or voids are filled with water

Seismicity: (i.e., seismic activity) The worldwide, regional, or local distribution of earthquakes in space and time; a general term for the number of earthquakes in a unit of time

Sensitivity analysis: The process of varying an independent variable in a calculation and observing the relative effect on the final answer

Shaft: A near-vertical opening excavated in the earth's surface

Site characterization: See "characterization"

Sorption: The deposition or uptake of radionuclides or other species from gas or solution onto geologic materials (e.g., granite, basalt, tuff)

Sorption characteristics: Attributes exhibited by rocks and minerals that affect the deposition and/or uptake of radionuclides or other species on their surfaces

Spent nuclear fuel: An irradiated fuel element not intended for further use in a nuclear reactor

Stratigraphic evidence: Evidence obtained through the analysis of the form, distribution, composition, and properties of layered rock

Subsurface water: All water beneath the land surface and surface water

Systems safety: A technical discipline that provides a life-cycle application of safety engineering and management techniques to the design of system hardware, software, and operation

Tectonic features and processes: Those features (e.g., faults, folds) and processes (e.g., earthquakes and volcanism) that are related to the large-scale movement and deformation of the earth's crust

Thermal zone: Those regions of the repository where temperature has been increased by the presence of high-level waste

Tuff: A rock composed of compacted volcanic ash. It is usually porous and often relatively soft.

Unsaturated rock: A rock in which some or all of the connected interstices or voids are filled with air

Unsaturated zones: Rock/geologic formations that are located above the regional groundwater table

Volcanism: The process by which molten rock and its associated gases rise from within the earth and are extruded on the earth's surface and into the atmosphere

Waste canister: A metal vessel for consolidated spent fuel or solidified high-level waste. Before emplacement in the repository, the canister may be encapsulated in a disposal container.

Waste package: The waste form and any containers, shielding, packing, and other sorbent materials immediately surrounding an individual waste container

Welded tuff: A tuff that has been consolidated and welded together by heat, pressure, and possibly the introduction of cementing minerals

Zeolites: (zeolite minerals) A large group of white, faintly colored, or colorless silicate minerals characterized by their easy and reversible loss of water or hydration, their ready swelling when heated, and their high adsorption capacity for dissolved metal ions in water. They primarily occur in basalts and tuffs.

$^{14}CO_2$: Carbon dioxide containing the radioactive isotope of carbon, ^{14}C