Appendix A
Panel Organization

1. Panel on 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. Panel on Hydrogeology & Geochemistry

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

3. Panel on the 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. Panel on 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. Panel on 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. Panel on 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. Panel on 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 B
Meeting List for 1990–91

January 18-19, 1990

Meeting (open)
Panel on Containers & Transportation
Pleasanton, California
Topic: Briefings on the waste package environment and waste package container
Transcript available

January 18, 1990

Board Meeting (closed evening session)
Pleasanton, California
Topic: Board activities
Minutes available

January 19, 1990

Board Meeting (closed evening session)
Pleasanton, California
Topic: Board activities
Minutes available

February 1, 1990

Technical Exchange (open)
Panel on Structural Geology & Geoengineering
Denver, Colorado
Topic: DOE presentation on the exploratory shaft facilities (ESF) alternatives
Transcript not available (meeting not recorded)
Presentation briefing book available

March 2-3, 1990

Board Meeting (closed)
Tucson, Arizona
Topic: Board-related activities
Minutes available

March 19-20, 1990

Joint Meeting (open)
Panel on Risk & Performance Analysis and the Panel on Structural Geology & Geoengineering
Denver, Colorado
Topic: Repository system design requirements
Transcript available

March 20, 1990

Ad Hoc Board Meeting (closed evening session)
Denver, Colorado
Topic: Board activities
Minutes available

March 22, 1990

Release of First Report to the U.S. Congress and the U.S. Secretary of Energy

April 7, 1990

Technical Exchange (open)
Panel on Structural Geology & Geoengineering
Las Vegas, Nevada
Topic: Briefings by DOE on the ESF alternatives analysis study, repository configuration, and repository construction methods
Transcript not available (meeting not recorded)
Presentation briefing book available

April 7, 1990

Board Meeting (closed evening session)
Las Vegas, Nevada
Topic: Board-related activities
Minutes available

April 8, 1990

Board Meeting (closed morning session)
Las Vegas, Nevada
Topic: Board-related activities
Minutes available

April 12, 1990

Technical Exchange (open)
Panel on Structural Geology & Geoengineering
Las Vegas, Nevada
Topic: DOE briefings on seismic issues at the proposed repository site
Transcript not available (meeting not recorded)
Presentation briefing book available

April 24-26, 1990

Meeting (open)
Panel on Environment & Public Health
Las Vegas, Nevada
Topic: Presentations by the State of Nevada, the Western Shoshone National Council, and the DOE and its contractors
Two-day field trip
Transcript available

May 18, 1990	**Technical Exchange (open)** **Panel on Transportation & Systems with the Nuclear Regulatory Commission (NRC)** *Arlington, Virginia* Topic: NRC's role in several key issues relating to safe handling and transportation of spent nuclear fuel Transcript not available (meeting not recorded) Presentation briefing book available
May 26-June 2, 1990	**Board Trip to Sweden and the Federal Republic of Germany** Discussion of Board observations in *Third Report*
June 1990	**No meetings**
July 23, 1990	**NRC Briefing (open morning session)** *Atlanta, Georgia* Topic: NRC briefing on licensing support system (LSS) Transcript available
July 23, 1990	**Board Meeting (closed afternoon session)** *Atlanta, Georgia* Topic: Board activities Minutes available
July 24-25, 1990	**Board Meeting (closed evening sessions)** *Atlanta, Georgia* Topic: Board activities Minutes available
July 24-25, 1990	**Joint Meeting (open)** **Panel on Structural Geology & Geoengineering and the Panel on Hydrogeology & Geochemistry** *Atlanta, Georgia* Topic: ESF alternatives study and surface-based testing program Transcript available
July 26, 1990	**Board Meeting (closed)** *Atlanta, Georgia* Topic: Board activities Minutes available

August 17, 1990

Public Hearing: Panel on Transportation & Systems

Amargosa Valley, Nevada

Topic: Transportation and systems issues affecting the proposed repository

Transcript available

August 28-29, 1990

Meeting (open)
Panel on the Engineered Barrier System

Pleasanton, California

Topic: Briefings by DOE and contractors on DOE strategy for development of packaging for spent fuel and high-level waste; overview of current spent fuel studies

Transcript available

September 1990

No meetings

October 10, 1990

Board Meeting (open morning session)

Arlington, Virginia

Topic: NRC / Electric Power Research Institute presentations on performance assessment

Transcript available

October 10, 1990

Board Meeting (closed afternoon session)

Arlington, Virginia

Topic: Board activities

Minutes available

October 11, 1990

Technical Exchange (open)
Panel on Structural Geology & Geoengineering

Arlington, Virginia

Topic: DOE briefings on surface-based testing prioritization and Calico Hills risk / benefit analysis

Transcript not available (meeting not recorded)

Presentation briefing book available

October 15, 1990

Public Hearing: Panel on Environment & Public Health

Reno, Nevada

Topic: Environment and public health issues relating to the possibility of the development of a high-level waste repository at Yucca Mountain, Nevada

Transcript available

October 16, 1990

Meeting (open)
Panel on the Environment & Public Health
Reno, Nevada
Topic: Briefings by representatives from DOE, Western Shoshone National Council, State of Nevada, and the State's Nye County Office on Socioeconomic Issues
Transcript available

October 22, 1990

Meeting (open)
Panel on Transportation & Systems
Washington, D.C.
Topic: Transportation safeguard and operational activities
Transcript available

November 1-2, 1990

Meeting (open)
Panel on Quality Assurance
Arlington, Virginia
Topic: Briefings by the DOE and the NRC on quality assurance requirements and implementation process
Transcript available

November 19, 1990

Public Hearing: Panel on Transportation & Systems
Reno, Nevada
Topic: Transportation issues concerning the development and operation of a high-level waste repository at Yucca Mountain, Nevada
Transcript available

November 19-20, 1990

Technical Exchange (open)
Panel on Structural Geology & Geoengineering
Denver, Colorado
Topic: DOE and contractors brief panel on interim report activities on ESF alternatives analysis study
Transcript not available (meeting not recorded)
Presentation briefing book available

November 28, 1990

Release of *Second Report to the U.S. Congress and the U.S. Secretary of Energy*

December 1990

No meetings

January 15, 1991	**Board Meeting (closed)** *Arlington, Virginia* Topic: Board activities Minutes available
January 16, 1991	**Board Meeting (open)** *Arlington, Virginia* Topic: Briefings by environmental groups, industry groups, public policy groups, and state organizations Transcript available
January 17, 1991	**Board Meeting (open morning session)** *Arlington, Virginia* Topic: Briefings by DOE officials on the Office of Civilian Radioactive Waste Management program, systems integration, and future interactions with the Board Transcript available
January 17, 1991	**Board Meeting (closed afternoon session)** *Arlington, Virginia* Topic: Board activities Minutes available
February 1991	**No meetings**
March 1, 1991	**Meeting (open)** **Panel on Structural Geology & Geoengineering** *Tucson, Arizona* Topic: Briefings by DOE and contractors on potential and past volcanic activity within the Yucca Mountain vicinity Transcript available
March 6-7, 1991	**Joint Meeting (open)** **Panel on Structural Geology & Geoengineering and the Panel on Hydrogeology & Geochemistry** *Denver, Colorado* Topic: Briefings on site-suitability review, Calico Hills\ESF alternatives analysis study, and test prioritization Transcript available

March 14-15, 1991

Meeting (open)
Panel on Transportation & Systems
Albuquerque, New Mexico
Topic: DOE and contractors' discussions on nature and scope of Waste Isolation Pilot Project transportation program
Transcript available

March 26-27, 1991

Joint Meeting (open)
Panel on Quality Assurance and the
Panel on Structural Geology & Geoengineering
Dallas, Texas
Topic: Quality assurance on ESF preliminary design; follow-up on DOE quality assurance program
Transcript available

April 16-17, 1991

Board meeting on Analogues (open)
Reno, Nevada
Topic: DOE and other presenters provide Board members with information on field studies, possible natural analogue sites, and the potential for using archaeological studies as analogues
Transcript available

April 17, 1991

Board Meeting (closed afternoon session)
Reno, Nevada
Topic: Board activities
Minutes available

April 18, 1991

Board Meeting (closed)
Reno, Nevada
Topic: Board activities
Minutes available

May 20-21, 1991

Meeting (open)
Panel on Risk & Performance Analysis
Arlington, Virginia
Topic: Performance assessment
Transcript will be available

June 9-15, 1991	**Board trip to Canada**
June 25-27, 1991	**Joint Meeting (open)** **Panel on Hydrogeology & Geochemistry and the Panel on Structural Geology & Geoengineering** *Las Vegas, Nevada or Denver, Colorado* Topic: Review of proposed testing for saturated zone, unsaturated zone, rock mechanics, and geochemistry Transcript will be available
July 15-16, 1991	**Meeting (open)** **Panel on Structural Geology & Geoengineering** *Arlington, Virginia* Topic: To be determined Transcript will be available
July 16-18, 1991	**Board Meeting (open and closed sessions)** *Arlington, Virginia* Topic: To be determined Transcript will be available for open sessions Minutes will be available for closed sessions
August 12-14, 1991	**Board Trip to Waste Isolation Pilot Plant (WIPP)** *Carlsbad, New Mexico*
August 15-16, 1991	**Public Hearing: Panel on Transportation & Systems** *Denver, Colorado* Topic: Transportation issues Transcript will be available
September 4-5, 1991	**Meeting (open)** **Panel on Structural Geology & Geoengineering** *Salt Lake City, Utah* Topic: Seismic risk Transcript will be available
September 18-19, 1991	**Meeting (open)** **Panel on Structural Geology & Geoengineering** *Albuquerque, New Mexico* Topic: Borehole sealing and backfilling; ESF design review Transcript will be available

September 25-27, 1991	**Meeting (open)** **Panel on Transportation & Systems** *Arlington, Virginia* Topic: DOE update on transportation issues Transcript will be available
October 8-11, 1991	**Board Meeting (open and closed sessions)** *Las Vegas, Nevada* Topic: Thermal loading / repository design Transcript will be available for open sessions Minutes will be available for closed sessions
November 12-13, 1991	**Meeting (open)** **Panel on Structural Geology & Geoengineering** *Location to be determined* Topic: Test prioritization; site suitability (10 CFR 960); ESF design review study Transcript will be available
December 1991	**No meetings scheduled**

Appendix C
Presenters and Witnesses List

The following people made presentations to the Board or panel(s) from August 1, 1990, through January 31, 1991. This list is arranged alphabetically by organization and divided into three sections: presenters at Board meetings, witnesses at Board-sponsored public hearings, and those who submitted Statements for the Record. Citizens and independent consultants are listed at the ends of their respective sections.

Presenters at Board Meetings

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

Hollis Call
Lee Merkhofer

Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439-4815
(708) 972-2000

John Bates

Clark County Nuclear Waste Division
301 East Clark, Suite 570
Las Vegas, NV 89101
(702) 455-5175

Jerry Duke

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

Robert Shaw

Environmental Protection Agency
401 M Street, SW
Washington, DC 20460
(202) 475-9464

Nancy Wentworth
Dean Neptune

Geomatrix Consultants
One Market Plaza
Spear Street Tower, Suite 717
San Francisco, CA 94105-1001
(415) 957-9557

Kevin Coppersmith

Golder Associates, Inc.
4104-148 Avenue, NE
Redmond, WA 98052
(206) 883-0777

Charles Voss

Hydrogeologic, Inc.
1165 Herndon Parkway, Suite 900
Herndon, VA 22070
(703) 478-5186

John Robertson

Impact Assessment, Inc.
330 South 3rd, Suite 850
Las Vegas, NV 89101
(702) 386-9331

John Petterson

J.K. Research Associates
77 Fox Run Road
Hamilton, MA 01982
(508) 468-7917

Susan Wiltshire

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

William Bourcier
Carol Bruton
Leslie Jardine
Kevin Knauss
Herman Leider
Henry Shaw
David Short
Raymond Stout

Lincoln County Nuclear Waste Project
P.O. Box 90
Pioche, NV 89043
(702) 962-5497

Geri Ann Stanton

Los Alamos National Laboratory
101 Convention Center Drive
Las Vegas, NV 89109
(702) 794-7097

Ned Elkins

Los Alamos National Laboratory
Los Alamos, NM 87545
(505) 667-5061

Richard Herbst

National Association of Regulatory Utility Commissioners
Subcommittee on Nuclear Waste Disposal
1400 16th Street, NW
Washington, DC 20036
(202) 939-3420

Ronald Callen

Natural Resources Defense Council
1350 New York Avenue, NW
Washington, DC 20005
(202) 783-7800

Dan Reicher

Nuclear Waste Project Office for the State of Nevada
Capitol Complex
Carson City, NV 89710
(702) 687-3744

Robert Halstead

Nye County Board of Commissioners
P.O. Box 1510
Reno, NV 89505
(702) 323-4141

Consultant to Commissioners:
Stephen Bradhurst

Nye County Commissioner
P.O. Box 1310
Pahrump, NV 89041
(702) 727-5777

Cameron McRae

Office of the Nuclear Waste Negotiator
1823 Jefferson Place, NW
Washington, DC 20036
(202) 634-6244

David Leroy

Pacific Northwest Laboratory
Battelle Boulevard
P.O. Box 999
Richland, WA 99352
(509) 375-2121

Robert Einziger
Harry Smith
Richard Walling
Charles Wilson

Planning Information Corporation
1625 Broadway, Suite 2670
Denver, CO 80202
(303) 629-9777

James Williams

Raytheon Services Nevada
101 Convention Center Drive
Las Vegas, NV 89109
(702) 794-7979

William Kennedy

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

Paul Gnirk

Remcor, Inc.
701 Alpha Drive
P.O. Box 38310
Pittsburgh, PA 15238
(412) 963-1106

Colin Heath

Risk Engineering, Inc.
5255 Pine Ridge Road
Golden, CO 80403
(303) 278-9800

Robin McGuire

Savannah River Laboratory
14 Caw Caw Court
Aiken, SC 29803
(803) 725-2170

M. John Plodinec

Science Applications International Corporation
101 Convention Center Drive
Las Vegas, NV 89109
(702) 794-7000

John Carlson
Ernest Hardin
Jean Younker

Southern Nuclear Operating Company
Inverness
Building 42, Bin B-065
Birmingham, AL 35243
(205) 877-7560

Louis Long

Southern States Energy Board
3091 Governors Lake Drive
Suite 400
Norcross, GA 30071
(404) 242-7712

Michael Martinez

State of Nevada, Agency for Nuclear Projects
Capitol Complex
Carson City, NV 89710
(702) 687-3744

Carl Johnson
Robert Loux

University of Buffalo
Department of Geology
4240 Ridge Lea Campus
Buffalo, NY 14260
(716) 831-3051

Michael Sheridan

U.S. Department of Energy
Chicago Operations Office
9800 South Cass Avenue
Argonne, IL 60439
(708) 972-2134

Michael Klimas
Robert Rothman

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

John Bartlett
Alan Brownstein
James Carlson
Beth Darrough
Donald Horton
Christopher Kouts
William Lake
Dwight Shelor

U.S. Department of Energy
Richland Operations Office
P.O. Box 550
Richland, WA 99352
(509) 376-7391

Robert Brown

U.S Department of Energy
Sandia National Laboratories
P.O. Box 5800
Albuquerque, NM 87185
(505) 844-5678

Thomas Blejwas
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
Michael Cloninger
Uel Clanton
David Dobson
Wendy Dixon
Carl Gertz
Eric Lundgaard
Edgar Petrie

U.S. Geological Survey
875 Parfet Street
Lakewood, CO 80215
(303) 236-5048

William Dudley

U.S. Nuclear Regulatory Commission
11555 White Flint North
Rockville, MD 20852
(301) 492-7000

Robert Bernero
John Cook
Kenneth Hooks

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

Ian Zabarte

West Valley Nuclear Services Company
P.O. Box 191
West Valley, NY 14171
(716) 942-4934

Ronald Palmer

Consultants:

Erskine Harton
Independent Consultant
1310 Tracy Place
Falls Church, VA 22046
(703) 534-7851

Rex Massey
Independent Consultant
5131 Driftstone Avenue
Reno, NV 89523
(702) 746-9451

Robert Mullen
Independent Consultant
1321 Crestline Drive
Santa Barbara, CA 93105
(805) 682-0120

Public Hearing Witness List

The following people presented testimony at public hearings sponsored by the panels on Transportation & Systems and Environment & Public Health between August 1, 1990, and January 31, 1991. The list is arranged in alphabetical order by organization. Citizens are listed separately at the end.

Association of American Railroads
Washington, D.C.

Conan Furber
Consultant
T&S Public Hearing, November 1990

California Energy Commission
Sacramento, California
Represented by:

Lori Friel
Attorney
Western Interstate Energy Board
Denver, Colorado
T&S Public Hearing, November 1990

Daniel Nix
Co-Chair, High-Level Waste Committee
Western Interstate Energy Board
Denver, Colorado
T&S Public Hearing, November 1990

Citizen Alert
Reno, Nevada

Bob Fulkerson
Executive Director
T&S Public Hearing, November 1990

Paul Rodarte
Director, Native American Program
T&S Public Hearing, November 1990

J.R. Wilkinson
Administrative Assistant
E&PH Public Hearing, October 1990
T&S Public Hearing, November 1990

Clark County Nuclear Waste Division
Las Vegas, Nevada

Dennis Bechtel
Planning Coordinator
T&S Public Hearing, August 1990

Jerry Duke
Principal Planner
T&S Public Hearing, August 1990

Consolidated Rail Corporation
Philadelphia, Pennsylvania

Alan Fisher
Director for Operating Rules
T&S Public Hearing, August 1990

Edison Electric Institute/UWASTE Program
Washington, D.C.
Represented by:

Howard Shimon
Chairman
EEI / UWASTE Transportation Working Group
Milwaukee, Wisconsin
T&S Public Hearing, November 1990

John Vincent
Nuclear Resources Manager
GPU Nuclear
Parsippany, New Jersey
T&S Public Hearing, November 1990

Esmeralda County
Goldfield, Nevada

Brad Mettam
Project Director
T&S Public Hearing, November 1990

International Physicians for the Prevention of Nuclear War
U.S.S.R.

Zura Keshileva
Vice President
Kasakhstan, U.S.S.R.
E&PH Public Hearing, October 1990

Vladimir Popov
Secretary
Moscow, U.S.S.R.
E&PH Public Hearing, October 1990

Inyo County
Independence, California

Roger DeHart
Planning Director
T&S Public Hearing, November 1990

Charles Thistlethwaite
Associate Planner
T&S Public Hearing, November 1990

League of Women Voters of Nevada
Carson City, Nevada

Abby Johnson
Representative
T&S Public Hearing, November 1990

Nevada Nuclear Waste Study Committee
Las Vegas, Nevada

Rick Dale
Representative
T&S Public Hearing, August 1990

Ernest Travis
Representative
T&S Public Hearing, August 1990

Nevada Nuclear Waste Task Force
Las Vegas, Nevada

Judy Treichel
Executive Director
T&S Public Hearing, August 1990

Nevada State Retired Teachers Association
Carson City, Nevada

Gerard Prindiville
President
E&PH Public Hearing, October 1990

Nuclear Assurance Corporation
Norcross, Georgia

Ivan Stuart
Vice President of Engineering
T&S Public Hearing, November 1990

Nuclear Waste Project, Lincoln County
Pioche, Nevada

Geri Ann Stanton
Planning Assistant
E&PH Public Hearing, October 1990

Nuclear Waste Project Office for the State of Nevada
Carson City, Nevada

Robert Halstead
Transportation Advisor
T&S Public Hearing, August 1990

Nye County Board of Commissioners
Reno, Nevada

Stephen Bradhurst
Consultant to the Commissioners
T&S Public Hearing, August 1990

Peace Camp
Las Vegas, NV

Charles Hilfenhaus
Representative
T&S Public Hearing, August 1990

Physicians for Social Responsibility
Portland, Oregon

Dick Belsey
Member of Physicians Task Force on Nuclear Weapons & Public Health
E&PH Public Hearing, October 1990

Regional Transportation Commission of Clark County
Las Vegas, Nevada

Lee Gibson
Planning Coordinator
T&S Public Hearing, August 1990

Sierra Club
Reno, Nevada

Marjorie Sills
Representative
E&PH Public Hearing, October 1990

State Senator
Fallon, Nevada

The Honorable Virgil Getto
T&S Public Hearing, August 1990

Western Shoshone National Council
Austin, Nevada

William Rosse, Sr.
Chair, Environmental Protection Commission
E&PH Public Hearing, October 1990
T&S Public Hearing, November 1990

Citizens:

Ken Garey
Amargosa Valley, Nevada
T&S Public Hearing, August 1990

Mike Gilgan
Amargosa Valley, Nevada
T&S Public Hearing, August 1990

Bill Greis
Las Vegas, Nevada
T&S Public Hearing, August 1990

Charles Holtz
Amargosa Valley, Nevada
T&S Public Hearing, August 1990

Doris Jackson
Amargosa Valley, Nevada
T&S Public Hearing, August 1990

Thomas Tabacco
Carson City, Nevada
T&S Public Hearing, November 1990

Bill Tobin
Reno, Nevada
E&PH Public Hearing, October 1990

Shane Tureson
Reno, Nevada
E&PH Public Hearing, October 1990

Frederick George Wilson
Sparks, Nevada
E&PH Public Hearing, October 1990

Statements for the Record

The following individuals submitted statements to the Board for the record.

Board of County Commissioners, Lincoln County
Pioche, Nevada

Edward Wright
Vice-Chairman

U.S. Department of Energy
Yucca Mountain Project Office
Las Vegas, Nevada

Carl Gertz
Project Manager

Western Shoshone Elders Council
Austin, Nevada

Alyce Williams
Representative

Citizens / Consultants:

Juanita Cox
Citizen
Sparks, Nevada

Cynthia Mitchell
Consulting Economist
Reno, Nevada

Harold Rogers
Citizen
Carson City, Nevada

Richard Schimdt
Citizen
Reno, Nevada

Appendix D
The German and Swedish Nuclear Waste Disposal Programs — Background

Overview of Sweden's Nuclear Waste Program

Background

According to recently published reports, 45 to 50 percent of Sweden's electricity currently is produced by nuclear reactors located at four sites: four reactors at Ringhals, which is on the west coast; two reactors at Barsebäck, which is on the southwest coast near Denmark; and three reactors at Oskarshamn and Forsmark, both of which are located on the east coast of Sweden. Sweden's first reactor was commissioned in 1972, and its two newest reactors were commissioned in 1985. According to a publication of the Swedish Nuclear Fuel and Waste Management Company (SKB)—the company responsible for managing the Swedish nuclear waste disposal program—Sweden is totally dependent on "imports of uranium and certain services within the nuclear fuel cycle."*

Despite its reliance on nuclear power, a public referendum in 1980 led to a parliamentary decision that by 2010 all nuclear power plants in Sweden would cease operation and be decommissioned. If this decision remains in effect, Swedish utilities can fairly accurately project the amounts of low-, intermediate-, and high-level waste that will need disposing of in the coming years (7,800 metric tons of spent fuel; 230,000 cubic meters of low- and intermediate-level waste; 110,000 cubic meters of decommissioning waste).**

There is some, but not a great, effort to date to reconcile the large energy shortage that will occur if the parliamentary decision goes into effect. During the Board's visit to Sweden, Dr. Bjurström, president of the SKB, stated that even with the moratorium, energy use will increase 2 percent annually. He said the country is searching for an energy policy that will satisfy all political parties; natural gas supplies from Denmark, Norway, and the Soviet Union are under consideration. Other professionals indicated that potential global greenhouse effects of fossil fuel combustion may influence Sweden's eventual energy strategy.

SKB's philosophy, however, is that regardless of the future of nuclear power, there still will be nuclear waste to dispose of. One participant suggested that the referendum to phase out nuclear power may in fact help focus public attention on the need to solve the nuclear

* Dr. Sten Bjurström, President, SKB. Introductory Statement to the NWTRB in "SKB- Swedish Nuclear Fuel and Waste Management Company-Activities." May 27, 1990.

** Sweden and Germany use a system to classify nuclear waste that is slightly different from that used in the United States. *Spent fuel* is nuclear fuel that has been irradiated to the extent of its useful life. *High-level* waste is the waste stream resulting from the first cycle of fuel reprocessing. It contains long-lived radionuclides found in spent fuel and requires both heavy shielding and cooling to be handled safely. *Intermediate-level* describes waste with significant beta / gamma activity but generally low alpha activity. It requires some radiation shielding, but no cooling. *Low-level* waste contains negligible amounts of long-lived radionuclides and can be handled without shielding. *Decommissioning* waste consists of parts of the nuclear reactor activated and / or contaminated during operation of the reactor. In Sweden, decommissioning waste is classified as low- and intermediate-level waste. See the Glossary for U.S. definitions of spent fuel, high-level waste, low-level waste,and transuranic waste.

waste problem. There is already a consensus in the country to handle its own waste problems and not export them to other countries.

Organizational Structure

Swedish law has determined that responsibility for the safe management and final disposal of the radioactive waste produced by nuclear power plants in Sweden belongs to the nuclear power utilities. SKB, which was created in 1972 and is jointly owned by four utilities, is the company responsible for all handling, transportation, storage, and permanent disposal of spent nuclear fuel and radioactive waste from nuclear power plants. The company also is responsible for the planning and construction of all facilities and pertinent research and development work.

A number of government agencies review and assess the activities of the SKB. They include (1) the National Board for Spent Nuclear Fuel (SKN), (2) the Swedish Nuclear Power Inspectorate (SKI), and (3) the National Institute of Radiation Protection (SSI). SKN, a small governmental agency of 10 people reporting to the Ministry of Environment, is the central authority responsible for evaluating and supervising the nuclear industry's research and development program on the management and disposal of spent nuclear fuel and the safe decommissioning and dismantling of nuclear plants.

SKN administers the Swedish system for financing nuclear waste management. The projected costs of all waste handling, storage, and disposal facilities in Sweden is approximately $8 billion. This total includes the costs of Forsmark and CLAB, the interim storage facility, and the projected cost of decommissioning and dismantling all nuclear power plants and other facilities.

SKI and SSI are larger agencies with regulatory powers to supervise the safety and radiation protection aspects of nuclear power. These agencies are responsible for studying and appraising the nuclear safety and radiation protection of proposed facilities and processes. SKI employs approximately 90 people and operates on an annual budget of $17 million. SSI employs approximately 130 people and operates on an annual budget of approximately $10 million.

The SKB System

SKB has developed a waste management system for the collection, transport, storage, and disposal of spent fuel and radioactive waste that consists of a ship built specifically to transport nuclear waste, and facilities at Forsmark (the Swedish Final Repository for low- and intermediate-level radioactive waste) and at Simpevarp (Central Storage Facility for Spent Nuclear Fuel - CLAB). CLAB, located adjacent to the Oskarshamn Power Station on the east coast south of Stockholm, is an interim storage facility for spent nuclear fuel. CLAB will be able to accommodate fuel into the late 1990s.

Although some reprocessing has been contracted for by SKB, no additional reprocessing is planned.* The decision not to reprocess resulted partly from economic concerns and partly from concerns about nuclear proliferation. Current policy and practice are to store spent fuel at the reactors for one year, then transfer it to CLAB, where it will age for approximately 40 years prior to final disposal.

SKB recently announced plans to begin characterizing three Swedish sites for a permanent high-level waste repository (SFL). The sites will be named in 1992. Site-characterization activities should start in 1993. Detailed investigation of two sites will begin in 1996. After the government decides on a suitable site (about 2006), SKB will build a permanent repository for high-level waste. Construction is planned to begin by 2010.

Transportation

Since all Swedish nuclear power plants are located along the coast, low-, intermediate-, and high-level waste is transported by ship. The *M/S Sigyn* is a com-

* Reprocessing is the recovery of fissile material from irradiated nuclear fuel by chemical separation from fission products and other radionuclides.

bined roll-on, roll-off and lift-on, lift-off vessel. Machinery, electrical system, and so on, have been designed for high reliability, and the cargo hold is surrounded by a double hull and a double bottom, to ensure high floatability and to contain and protect the cargo in the event of collision or grounding. The ship measures 90 x 18 meters with a draft of 4 meters; payload maximum capacity is 1,400 metric tons. After the ship puts into a harbor, terminal transport vehicles convey the transport casks from the ship's hold to the various facilities and vice versa.

The transport cask, designated the TN17-Mark 2, is 6.15 meters long and 1.95 meters in diameter. It is fabricated from forged steel with a stainless steel coating. The cask can carry 17 boiling water reactor assemblies (3.0 MTU) or 7 pressurized water reactor assemblies (3.1 MTU) and has a gross weight of 80 metric tons. The cask is equipped with cooling fins to limit the fuel assembly temperature to no more than 450°C. The cask was designed to withstand a free fall from a height of 9 meters, a fire for 30 minutes at 860°C, and an external pressure equivalent to a water depth of 4,000 meters. Since 1985, 1,200 metric tons of spent fuel have been transported to CLAB without incident.

Waste transportation is planned in close cooperation with the nuclear power plants. Lead time for scheduling a shipment is about one year. A description file is prepared for each category of waste to be deposited in the Swedish Final Repository (SFR). The file contains information on content, manufacturing process, and requirements made on each package in connection with transport and disposal. Data on content and radiation level are collected and stored in a computerized waste register at the nuclear power plant and in the SFR. The data are used to plan the emplacement of different packages in the SFR. When the waste arrives at the SFR, personnel know exactly where each package is to be placed.

SFR Forsmark Nuclear Power Station

The Forsmark Station, the final repository for low- and intermediate-level waste, is located on the east coast of central Sweden, north of Stockholm. The SFR site is near the power plant at a depth of about 50 meters below the Baltic seabed outside the harbor. The sea depth over the site is approximately 5 meters. The waste is stored in various chambers built at the SFR into a large rock cavern.

Transports to and among the different parts of the underground repository take place using special diesel-powered, rubber-tired waste transport vehicles via a two-lane tunnel system. Two parallel, kilometer-long access tunnels connect the SFR with the surface. The operating tunnel is the larger of the two access tunnels and is used during the deposition phase for all waste transports.

Intermediate-level waste from the operation of Swedish nuclear power plants, as well as similar radioactive waste from industrial and medical sources and from the research plant at Studsvik, is disposed of in the SFR. Total capacity of the SFR is about 90,000 cubic meters. Neither spent nuclear fuel nor other high-level waste will be disposed of in the SFR. The SFR will remain operative until the nuclear power plants have been decommissioned (2010) and dismantled (about 2025).

Four storage chambers were built at the SFR based on the variety of waste to be stored there and the type of packaging to be used. The chambers are 160 meters long but vary in width, height, and interior design.

- Two rock chambers accommodate intermediate-level waste in concrete tanks.
- One rock chamber accommodates intermediate-level waste in concrete molds, metal drums, etc.
- A silo holds intermediate-level waste in concrete molds, metal drums, etc.

The silo, which receives the waste containing the most radioactivity, has been equipped with special engineered barriers against the future escape of radioactive materials. The vault has a diameter of 30 meters and a height of 70 meters. (The silo within it is 50 x 26 meters.) A barrier of bentonite clay fills the space between the slipform-cast silo and the vault containing it. The inside of the silo is divided into square vertical pits, measuring 2.5 meters per side. After a layer of waste packages has been emplaced, it is grouted with concrete. All handling in and around the silo takes place in radiation-shielded areas using automatic or remote-controlled equipment, commandeered from a control center.

Materials buried in the rock vaults are surrounded by a series of barriers. The outermost barrier is the rock mass that hosts the SFR. When the SFR is filled, it will be sealed, or backfilled, and the tunnels will be blocked with concrete. After sealing, the drainage pumps will cease, and the repository will gradually fill with water. The barriers are intended to prevent, or retard, the transport of radioactive materials with the groundwater.

CLAB — Interim Storage for Spent Nuclear Fuel

The Central Storage Facility for Spent Nuclear Fuel (CLAB) is a wet-pool interim storage facility designed to hold spent fuel from all Swedish nuclear power plants from the time it leaves the cooling pools at the nuclear power plants until removal for final disposal (30-40 years). At the time CLAB was designed (1976), the technology of storing waste in dry casks was in its infancy and not expected to be licensable. Consequently, dry-cask storage was not considered seriously.

When spent fuel is discharged from the reactor, it is stored on-site for approximately one year in a spent fuel pool. It then is shipped to CLAB. Although shipping cask capacities could be increased by leaving the spent fuel at the reactors for a longer period of time, this is not done because of limited lifting capabilities at the reactors. Some pools have higher density racks, but newer reactors are not so equipped because of the existence of CLAB.

The storage building is in a rock cavern, the roof of which is located about 25 meters below ground level. All handling and storage of the fuel takes place underwater in four storage pools and one small central pool. Transportation down to the storage area takes place in a water-filled container that runs in its own elevator shaft. Each pool holds 3,000 cubic meters of water and 750 metric tons of spent fuel in storage canisters.

According to the president of SKB, Dr. Sten Bjurström, CLAB will not become the permanent repository.

SFL — Swedish Final Repository for High-Level Waste

Since 1977, SKB has undertaken a number of site investigations to determine the geologic conditions prevailing at potential final disposal sites. Specifically, SKB is examining the properties of the bedrock, the pattern of fracture zones, and the physical and chemical conditions of the groundwater. The investigations are performed in and adjacent to rock formations that are thought large enough to host all the spent fuel (7,500 metric tons) that will be generated by the year 2010. Demographics, transport conditions, and economics also are being considered. A large number of sites (14) were investigated from 1977 to 1985.

SKB has developed a number of repository concepts. The concept that has been most thoroughly studied is referred to as KBS-3, which is similar in some ways to the repository concept being proposed in the United States for Yucca Mountain. Other concepts examined by SKB include very deep boreholes, very long inclined or horizontal undersea boreholes, as well as other innovative underground designs.

The KBS-3 concept consists of an array of parallel tunnels excavated at a depth of approximately 500 meters, at a selected site in Swedish Precambrian bedrock, which is more than 600 million years old and underlies a good part of the Scandinavian peninsula. According to current plans, the parallel tunnels would be 3.3 x 4.5 meters. They would be located 25 meters apart. Along the floor of the tunnels, vertical holes would be excavated, 1.5 meters in diameter, 7.5 meters deep, at intervals of 6 meters. Waste canisters would be placed in these holes, and the holes and tunnels then backfilled with compacted bentonite clay.

Although the spent fuel is to be aged for at least 40 years prior to emplacement in the repository, residual heat still will be generated by the waste. To restrict the maximum geologic temperature to no greater than 80°C, a typical waste canister would be loaded with approximately 1.4 metric tons of spent fuel and would have a thermal output of approximately 800 watts when placed in the repository. The local area power density for this configuration would be approximately 22 kilowatts per acre. If an optional, two-level repository is adopted, and the two levels are separated by 100 meters, the 80°C-maximum temperature constraint would be met by increasing the tunnel spacing to 33 meters, center-to-center. Such a configuration would have a local areal power density of 33 kilowatts per acre. (The proposed Yucca Mountain configuration has an equivalent loading of 57 kilowatts, or 57,000 watts, per acre.)

The proposed SKB waste package would consist of a copper canister, 0.8 meters in diameter and 4.5 meters long. Two alternative methods are being studied for fuel encapsulation. In one method, the spent fuel assemblies are placed in a fabricated copper canister; the cavity is filled with molten lead, and a lid is then welded to the canister.

In the second method, the cavity would be filled with copper powder and a lid placed on the canister. The canister would then be heated in a furnace to 500°C, placed in a pressure cell, and subjected to an isostatic pressure of 150 MPa,* thereby transforming the copper powder to solid copper, and joining the lid tightly to the canister. The completed canisters would weigh between 18.6 and 22 metric tons, depending on the encapsulation method used. The resulting canisters are expected to contain the radionuclides for at least 100,000 years.

SKB has developed a plan for siting and developing its proposed geologic repository. In summary, the plan entails the following steps:

1992-94	Identification and preliminary investigations of three candidate sites.
1994-96	Approval of two sites for detailed site investigation.
1996	Selection of shaft location at each site.
1996-2002	Shaft sinking and detailed site characterization.
2003-06	Final selection and licensing of site.
2010	Start of construction.
2020	Start of waste emplacement.
2020-50	Expansion of repository and successive selection of emplacement positions.

Stripa Mine Research Project

The Stripa mine has been used by SKB as a site for research on techniques for long-term storage of radioactive waste in granite. The mine is located in an old mining district, a three-hour drive west of Stockholm. The Stripa mine, which was mined out in early 1977, is considered a “very dry mine.” The total length of the drifts is approximately 25 kilometers, and the deepest mining level is 430 meters. The mined-out ore consisted of a quartz-banded hematite and occurred in a leptite formation. Adjacent to the leptite is a large body of grey-to-light-red, medium-grained granite. The age of the granite has been determined to be Precambrian. All experiments are carried out in this formation.

Work began at Stripa in late 1976. The Stripa Project (1977-1980) was a Swedish-American cooperative project with three parts.

- Heater experiments
- Assessment of fracture hydrology
- Geophysical measurements

As a result of experiments, extensive information was obtained on the mechanical response of the rock to heat load and on the groundwater flow in the rock.

This initial research led in 1980 to the International Stripa Project, which involves investigation of groundwater-rock / engineered barrier interactions. Development of methods and techniques for such studies and the verification of previously obtained laboratory results are the general objectives of the project. There are several fracture systems, but the majority of the fractures are sealed mainly with chlorite, occasionally with calcite. About 500 meters of new drifts have been excavated into the granite formation from the existing drifts

* MPa (megapascal) is a measure of pressure. 1MPa = 145.04 pounds per square inch.

at the 360-meter level in the mine. Smooth-wall blasting techniques were used when the new drifts were excavated to minimize fracturing of the walls of the tunnel.

The project is carried out autonomously under the sponsorship of the Organization for Economic Cooperation and Development's Nuclear Energy Agency and is managed by the SKB. Over the course of the project, participating countries have included Canada, Finland, France, Japan, Spain, Sweden, Switzerland, the United Kingdom, and the United States. Sweden contributes $8 million; the United States contributes $4 million; the other countries each contribute $2 million. Total contributions amount to more than $25 million. Research is divided into the following areas.

Detection and mapping of fracture zones

This involves developing geophysical and hydraulic methods and instruments to detect and map fracture zones. Electromagnetic, radar, seismic, and hydraulic techniques also are being evaluated. Holes have been drilled in the rock, and special tools built that employ inflatable "packers" to seal off given sections of the hole while pressure and flow-rate tests are conducted.

Groundwater characteristics and nuclide migration

Water sampling in boreholes down to a maximum depth of 1,230 meters is undertaken to determine the chemical properties and history of the groundwater. This includes sampling and analysis of water in crystalline rock to increase knowledge about the extent to which leaking radioactive material may be transported by groundwater. Investigations also involve developing methods to determine the hydraulic conductivity of the rock in both vertical and horizontal boreholes. Migration tests were performed using sorbing and nonsorbing tracers. In one drift, hundreds of square-meters of rock face were "wallpapered" with plastic sheeting in 2-square-meter sections to catch the water as it migrated out of the higher rock. Nonradioactive tracers were injected into the water above the drift, and the arrival at this catch system was carefully recorded.

Bentonite clay for backfilling and sealing

Activities involve testing the integrated behavior of heat-producing waste canisters, bentonite materials, rock, and groundwater in the Precambrian granite. In one test, large heaters were inserted into caverns to simulate canisters of nuclear waste. The caverns were sealed with bentonite, a clay that is a known barrier against moisture and heat. Bentonite clay also is being investigated as a potential sealing material for boreholes, shafts, and tunnels.

Researchers are presently in Phase III of the project, which is directed toward the investigation of groundwater flow, as well as fracture sealing, and the redirection of flow from the waste. Phase III began in 1986 and will be completed in 1991.

Overview of Germany's Nuclear Waste Program

Background

By the end of 1989, 21 nuclear power plants were operational in the western half of Germany. They provided approximately 40 percent of the electrical power produced in the West (population about 60 million). The installations used approximately 400 metric tons of spent nuclear fuel annually.

No further construction of nuclear power plants is anticipated for the foreseeable future, in part because of the negative public attitudes toward nuclear power since the Chernobyl accident. Changes brought about through the unification of the two Germanys in October 1990 may result in a reevaluation of Germany's energy policy. Since unification, five nuclear power plants in what used to be East Germany have been deemed unsafe and were to be shut down by January 1, 1991. Such decisions may affect current nuclear waste disposal plans.

During its trip to the Federal Republic of Germany (Germany), the Board visited two sites: Gorleben and Asse. The Gorleben interim storage facility is located approximately 180 miles southeast of Hamburg on the Elbe River. The Asse II Salt Mine is located just southeast of Braunschweig and is the site for current research and development into direct disposal of spent nuclear fuel.

German Waste Management Strategy as of Spring / Summer 1990

The German spent nuclear fuel and high-level waste management concept stems from provisions in federal law enacted since 1979 and involves five major elements. They are (1) interim storage of spent fuel at nuclear power plants and in off-site interim storage facilities, (2) reprocessing of spent fuel and reuse of the nuclear material recovered in nuclear power plants, (3) development of direct disposal for spent fuel for which reprocessing is not technically feasible nor economically viable, (4) conditioning and intermediate storage of high-level waste in interim storage facilities, and (5) disposal of spent fuel and high-level waste in a deep geologic repository. Permanent disposal means the waste cannot and will not be retrieved.

Until recently, German policy and funding had focused on developing domestic reprocessing capacity, relying on France and Great Britain for reprocessing services in the interim. Under the German Atomic Energy Act, Germany must reprocess its spent nuclear fuel unless it is economically or technically infeasible. The Karlsruhe experimental reprocessing plant (WAK) had been in operation since 1987 at the nuclear research center in Karlsruhe. The WA-350 commercial reprocessing plant at Wackersdorf, Bavaria, was designed and completed. Also, plans were initiated to develop a reprocessing plant at Gorleben. In mid-1989, however, domestic reprocessing was totally abandoned for political and economic reasons. The political climate against nuclear power has become even stronger since Chernobyl. Also, one of the utilities, VEBA, entered into a cost-effective agreement with France for a joint reprocessing venture. Germany also is negotiating for reprocessing services with British Nuclear Fuels, despite mounting pressure in Great Britain against reprocessing foreign spent nuclear fuel. For now, Germany has abandoned all efforts at domestic reprocessing and intends to rely on France and Great Britain for reprocessing services in the future. Waste resulting from reprocessing will be shipped back to Germany, where the heat-generating waste will be disposed of in a repository located in a salt dome (possibly Gorleben).

The current focus in Germany is on the development of a program for direct disposal of spent fuel. A "Research and Development Program on Direct Disposal" has been launched, covering the time period 1986-1994. This program consists of building a pilot-scale conditioning and encapsulation plant at Gorleben, where demonstration tests are being performed on a 1:1 scale*. Cask development and transport studies and drift and borehole emplacement studies, including thermal simulation studies are being conducted as part of this project. A number of tests are being conducted at the Asse II Mine Research Site. The second part of the project consists of examining several different repository designs and configurations in an effort to determine a system for permanently disposing of both waste resulting from reprocessing and spent nuclear fuel in a common repository.

All findings from the aforementioned and other studies will be available before the licensing procedure for Germany's first heat-generating waste repository begins. Many of the tests and studies have been conducted or are in the latter stages at this time. German plans provide for a permanent repository, possibly at Gorleben, licensed and built by the year 2008*. Approximately $300 million has been budgeted to develop the capability to dispose of the spent fuel and high-level waste.

Organizational Structure

The responsibilities for spent fuel management and waste disposal are divided among the federal government, the states, and the utilities. The federal government is to coordinate the German nuclear program, sponsor R&D, build and operate radioactive waste disposal facilities, and set licensing rules. Waste management activities are federally licensed, but state governments actually issue the licenses, acting in the name of the federal government. The utilities transport and perform conditioning and disposal of the spent nuclear fuel and reactor waste.

While the utilities remain legally responsible for waste disposal, the current Federal Environment Minister has imposed a plan for reorganizing the industrial sector's participation in waste management activities. Specifically, competition for waste management services has been eliminated. A new subsidiary of the federal railway, Nuclear Cargo and Service (NCS), is now a monopoly transporter of spent fuel and radioactive wastes in Germany. The firm GNS, Company for Nuclear Service, owned by the nuclear utilities (80%) and STEAG Kernenergie GmbH (20%), now holds a monopoly on waste treatment and will take over operations at the Gorleben and Ahaus facilities.

There are several key organizations in Germany for managing radioactive wastes working under the Federal Ministry for Research and Technology (BMFT) and the Federal Ministry for Environmental Protection and Reactor Safety (BMU). The Board met with personnel from some of these organizations (shown in boldface below) during its trip to the Gorleben site and the Asse research mine.

The BMFT is the federal ministry with research and development authority on radioactive waste management. Under its auspices are:

- GSF/IFT (Company for Radiation and Environmental Research/Institute for Underground Storage under the BMFT) manages the waste disposal R&D program and operates the Asse mine facility. GSF has made the Asse mine available for a number of the tests that are part of the R&D program on direct disposal and is participating in these tests. This organization, under the direction of Prof. Dr.-Ing. Klaus Kühn, organized and coordinated the Board's FRG trip.

- **BGR (Federal Institute for Geosciences and** Natural Resources) has been involved with geologic surveys and with salt dome repository R&D and is assisting in research projects underway at Asse.

- **KfK (Karlsruhe Nuclear Research Center)** is a research organization (somewhat similar to a U.S. national laboratory) that has been involved with R&D of spent fuel management including reprocessing, waste treatment, and vitrification. The Alternative Spent Fuel Management Technologies Project Group (PAE) at Karlruhe is coordinating the R&D Program on Direct Disposal.

*** Conditioning is the process of disassembling and cutting spent fuel elements to ready them for encapsulation. Encapsulation is packaging the spent fuel for permanent storage.

* The current Social Democratic government of Lower Saxony has stalled the excavation work on a second exploratory shaft in the Gorleben salt dome. PNL/IPSO *Highlights Report*, December 1990.

The BMU is responsible for storage, transportation, and disposal of radioactive wastes. Unlike the U.S. program, where construction/operation and licensing responsibilities are divided between the Department of Energy and Nuclear Regulatory Commission, respectively, the BMU also is responsible for nuclear safety and radiation protection and for supervision of state licensing activities. Under its auspices are:

- BFS (Office for Radiation Protection), established in 1989 under the BMU, is responsible for licensing transport and storage of waste, for constructing and operating waste repositories, and for conducting nationwide radiological monitoring. It will act as future owner of the permanent repository on behalf of the federal government. (BFS assumed the duties of the former PTB.)

- **DWK (German Fuel Reprocessing Company)**, established and funded by the nuclear power utilities, was previously responsible for spent fuel management including reprocessing and for radioactive waste storage and treatment. Due to the recent change in reprocessing policy in the FRG, DWK's responsibilities have changed to developing cask and spent fuel conditioning technologies.

- **GNS, Company for Nuclear Service** owned by the Nuclear Utilities (80%) and STEAG (20%), is responsible for the pilot-conditioning facility (PKA) at Gorleben. The PKA will be a facility for the development and demonstration of conditioning processes for spent fuel prior to direct disposal.

- **DBE (Company for Construction and Operation** of Waste Disposal Facilities), a consortium of mining companies reporting to the BFS, is responsible for the construction and operation of Gorleben. DBE has been commissioned to carry out the demonstration projects under the direct disposal R&D program and to plan the permanent repository.

- **RSK (Federal Reactor Safety Commission) and** the SSK (Radiation Protection Commission) issue licensing requirements on behalf of the BMU.

Interim Storage Before and After Reprocessing

Wet storage of spent fuel is provided at most reactors for three to ten years, but some reactors with less capacity use dry storage in dual-purpose nodular cast iron casks, similar to those used at the Virginia Electric Power Company's Surry reactor. Interim away-from-reactor storage at Gorleben and/or Ahaus also is planned. Ahaus GmbH., a daughter company of DWK and STEAG Kernenergie GmbH., Essen, managed construction of the facility at Ahaus, located on the western border between Germany and the Netherlands. Each facility's capacity is approximately 420 canisters or a maximum of 1,500 metric tons of uranium. Interim storage at both facilities has not been implemented to date.

If spent fuel is reprocessed, it will be transferred to foreign reprocessing facilities within about one to five years from the time it is discharged from the reactor. Interim storage of acidic high-level liquid waste (to be vitrified) is carried out in metal tanks. Dry storage of vitrified high-level waste in metal casks at away-from-reactor facilities is planned but has not yet been implemented.

A number of reasons were suggested by DWK personnel for selecting dry-cask technology over wet-pool storage for interim storage.

1. It is cheaper.

2. It is passive.

3. It can be designed for no releases.

4. There is no technical limit on its lifetime.

5. It is easy to decommission.

6. It is more politically acceptable because it appears less permanent.

7. There are advantages to using the casks for both transportation and storage.

8. It is flexible in that additional storage capacity can be added easily.

Transportation

Almost all transportation of nuclear waste in Germany is by rail except for the fuel undergoing reprocessing in the United Kingdom, which has to be loaded on ships to cross the English Channel. Some waste is transported by truck, but dedicated trains are not used because of local opposition from environmental groups. During transportation, police are present but no satellite tracking takes place. Until recently, private industry was responsible for all transportation of the waste.

Now, the Nuclear Cargo Service (NCS), a subsidiary of the federal railway, has assumed that responsibility. It is not clear, however, what the impact of this change will be. It seems likely industry will continue to transport the waste, only now it will be under the auspices of the NCS.

Permanent Disposal

A maximum of 333,000 cubic meters of spent nuclear fuel and high-level waste is anticipated by the year 2000. Solidified high-level waste is destined for deep geologic disposal, but efforts are also underway to examine the potential for permanently disposing of reconditioned waste and spent fuel at the same site. The Gorleben salt dome is under investigation as a candidate site for a permanent repository for all categories of waste and spent nuclear fuel. The Konrad mine, planned for full operation in the early 1990s, would be the final disposal site for approximately 200,000 cubic meters of low- and intermediate-level waste (up to the year 2000). Spent fuel—which cannot be stored at Konrad—would have to be placed in interim dry storage until Gorleben is operational. Other low-level waste could continue to be stored in conventional facilities, such as state-operated storage sites, at reactors, and at the interim fuel rod storage facility at Gorleben, until final storage at Konrad or Gorleben is available.

Currently, Gorleben has the capacity to store 1,500 metric tons of spent fuel or high-level waste in dry storage for up to 40 years. Its storage capacity for low-level waste is approximately 40,000 drums, containing 200 liters each. The facility employs a staff of approximately 60 people.

Studies are underway at the Asse II Research Mine and elsewhere to determine the potential for disposing of the waste at Gorleben. The current plan is to emplace the waste at a depth of about 800 meters. Aboveground exploration has been carried out, and belowground exploration was started in 1986 with the sinking of shaft No. 1. If the Gorleben site is ruled acceptable for a repository, the facility is expected to be operational in about 2008.

Both Gorleben and Asse are associated with salt domes; large (14 and 8 kilometers, respectively) dome- or mushroom-shaped salt formations, which extend to within 250 meters of the ground surface and whose source is the 2,000-meter deep Permian (240-million-year-old) Zechstein salt formation. The advantages of using a salt dome as a repository are (1) the absence of water over many millions of years, otherwise the salt would have dissolved; (2) high plasticity leading to self-sealing of fissures and drillholes and, in the long term, of the mined cavities containing the waste; (3) high-heat conductivity of the salt; and (4) good performance of the salt during mining operations. The salt's impermeability may be compromised by the presence of "impurities" such as anhydrite, the pores of which can contain water, and which can form seams that could act as preferential pathways for water. Another potential problem could be the presence of polyhalite, a mineral that contains structural water. The salt in Asse contains only about 0.04 percent water. The movement of salt to fill in the mined cavities approaches several centimeters per year at some locations. It was observed that crushed salt is being used to backfill drums of low-level waste, and that the less dense crushed salt surrounding the drums is being compressed by the inward flow of surrounding salt bedrock. The salt eventually seals the drums off so completely that their emplacement is invisible to the naked eye except for a fine fracture in the salt.

The Konrad iron ore mine is located in the Salzgitter area, about 35 miles southeast of Hannover. From 1976 until 1982, the Company for Radiation and Environmental Research investigated the mine's features for its suitability as a possible repository. Upon successful completion of the tests, an application was submitted, initiating licensing procedures. Since waste with a negligible thermal output is to be disposed of at Konrad mine, and because extensive reprocessing is expected to take place, the bulk of the material generated in western

Germany is planned for storage at Konrad. (With reprocessing, more than 95% of the total volume would be suitable for the mine.) The facilities will be able to handle 20,000 cubic meters with initial peaks of up to 40,000 cubic meters, while employing approximately 250 people.

Engineered Barriers

There are two types of casks being considered primarily for transportation and interim storage.* One system consists of casks, made of nodular cast iron. Although approved for use in dry storage in the United States, they have not been approved for use in transportation because the Nuclear Regulatory Commission considers cast iron to be too brittle. The casks range in size from 2 to 15 metric tons. These casks have been subjected to extensive safety tests over a period of several years. The second system consists of casks made of forged steel. Some versions have been approved for use in the United States.

The permanent disposal plan for spent fuel currently involves the emplacement of 5.5-meter-long, 65-ton, triple-purpose casks in drifts of a repository mine in a salt dome. This cask system, which would be used for transportation, storage, and disposal of spent fuel, comprises (1) cask for horizontal disposal in drifts and (2) canister for disposal in vertical boreholes. By varying the dimensions, lid systems, and internal configuration, the canister can be adapted to the requirements of different radioactive materials. The canister is designed for final disposal of spent fuel rods. Transport and interim storage of wastes in canisters, however, can be done only in shielded containers.

Present plans call for the casks to be manufactured of a manganese-nickel steel alloy. Coating techniques that prevent corrosion also are being investigated. The casks will have two lids; the inner one will be screwed on and the outer one will be welded to the container. The design criteria are based on "tightness" lasting 500 years.

Research Projects

The Asse II salt mine was purchased by the Federal Ministry of Research and Technology in 1965. The mine is being used to investigate the potential suitability of the Gorleben site to be a permanent repository and to develop methods for the disposal of low- and intermediate-level waste. Asse currently holds 124,500 drums of low-level waste and 1,300 drums of intermediate-level waste. Although more than adequate space and technical capacity exist here to dispose of other low- and intermediate-level waste, disposal was stopped for political reasons.

The research and development program at the mine is conducted under the auspices of GSF. The objectives of the program are as follows.

1. Investigate rates and amounts of water and gas release resulting from production of heat and gamma radiation by nuclear material and the resulting increased pressure inside sealed disposal boreholes.

2. Develop and test transportation and handling systems for canisters of high-level radioactive waste.

3. Investigate thermally induced stresses and resulting pressure loads to the waste canisters, the deformation and closure of rooms, galleries, and pillars above the disposal boreholes.

4. Develop and test suitable methods and techniques to obtain data on safety during construction and operation of a repository.

* The terms cask, container, and canister refer to slightly different entities, depending on a particular country's definition. For purposes of this report, the European definitions are used. Cask means a massive container used to transport and/or store irradiated nuclear fuel. It provides physical and radiological protection and dissipates heat from the fuel. Canister refers to a receptacle designed to hold spent fuel or radioactive material to facilitate movement and storage. (Note that the term canister is used in Sweden and Germany in those instances where the term container would be used in the United States.)

Many experiments are being conducted to determine the thermal and mechanical properties of salt, the effect of gamma radiation (which appears to be very limited), and the rates and distances at which different brines migrate. All in all, a wide range of experiments are being conducted that should provide the knowledge needed to successfully characterize the salt and to safely dispose of the waste.

In the Asse mine, two parallel drifts have been excavated, each of which is to accommodate three dummy containers equipped with electric heaters and backfilled with crushed salt. Measuring instruments evaluate the thermal and mechanical behavior of the formation and backfilling material.

Two strategies for final disposal are being pursued. In one, full-scale mockups of self-shielded, 65-ton Pollux casks are placed in a tunnel and backfilled with salt. In the other, full-scale mockups of smaller Pollux canisters are lowered into vertical boreholes about 15 meters deep (versus actual depth of 300 meters in the repository). The purpose of the tests is to determine the suitability of these methods for disposing of spent fuel and vitrified* high-level waste from reprocessing. The maximum temperature permissible in the salt as a result of waste emplacement is 200°C. A shaft transport system also is being tested. The system must have a load capacity of 800 kilonewtons (180,000 pounds force). Machines capable of approximately 650 kilonewtons are to be developed, constructed, and tested for use in emplacing the waste.

* Vitrified high-level waste is one form of reprocessed waste. It is the conversion of high-level waste materials into a glassy or noncrystalline solid for disposal. Under the German program, waste reprocessed in France may, in part, return to Germany in vitrified form.

Appendix E
Department of Energy Response to the Recommendations made in the Board's *Second Report* (November 1990)

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 March 29, 1991, a summary of initial responses to recommendations the Board made in its *Second Report*. The Board has included those responses along with the transmittal letter in this report. Inclusion of these responses does not necessarily imply Board concurrence.

Department of Energy
Washington, DC 20585

March 28, 1991

MAR 29 1991

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

Dear ~~Dr. Deere~~: Don

On behalf of the Department of Energy (DOE) and the Office of Civilian Radioactive Waste Management (OCRWM), I would like to thank the Nuclear Waste Technical Review Board (NWTRB) for its thoughtful and effective review of our site evaluation, waste packaging, environment, and transportation activities.

Enclosed are DOE's responses to the Board's recommendations in its Second Report to the U.S. Congress and the U.S. Secretary of Energy. The responses address the seven broad areas of the Board's recommendations. You will note that a number of the responses refer to past DOE/NWTRB technical interactions and ongoing evaluations that will provide a basis for significant program decisions. We will keep the Board informed of progress in these evaluations.

I would like to take this opportunity to call to the Board's attention the relationship between technical issues addressed by the Board and our strategic planning for the program. As you know, we have been conducting a series of predecisional workshops with representatives of interested and affected parties, in order to obtain their input to strategic principles and plans for the programs. These workshops are proving to be highly valuable in helping us select, focus, and prioritize the strategic issues and decisions we must address. The results of these workshops will be reflected in our Mission Plan Amendment to be issued later this year.

Among other contributions, the Strategic Principles workshops are demonstrating how technical issues, such as those addressed by the Board, are embedded in program strategy and in timing and sequencing of technical activities. It is evident that our ability and need to interact with the Board on technical issues will be strongly driven by program evolution, and we will keep the Board advised of our priorities and needs in order to aid the Board's planning for use of its resources.

Another factor which will affect the priorities and content of our interaction with the Board is our progress and plans for characterization of the Yucca Mountain site. As you know, we are currently trying to resolve the impasse with the State of Nevada which is preventing us from expanding our site evaluation activities. When new surface-based and underground evaluation activities do get started, they will be highly focused on determining if the Yucca Mountain site, and the geologic setting it provides, is a suitable location for a high-level waste repository.

With this strategic focus for Yucca Mountain activities, we expect emphasis on acquisition of site data and its use in evaluating site suitability. Acquisition and use of data for repository and engineered barrier system design will have a secondary priority, since effort on repository features will depend first on whether or not the site is suitable, and second on what the site properties that affect the engineered systems are.

I would, therefore, like to suggest that the agenda for the interactions between the Board and OCRWM be selected, to the extent practicable, to reflect the focus on issues of current strategic importance within each technical sector, as indicated above. I will direct our staff to work closely with the Board to achieve this objective.

I greatly appreciate the many contributions the Board has already made toward helping assure quality and effectiveness in the OCRWM program, and I look forward to a continuing productive relationship.

Sincerely,

John W. Bartlett

John W. Bartlett, Director
Office of Civilian Radioactive
Waste Management

Enclosure

DEPARTMENT OF ENERGY RESPONSES TO RECOMMENDATIONS IN THE NUCLEAR WASTE TECHNICAL REVIEW BOARD'S *SECOND REPORT* (November 1990)

INTRODUCTION

The Nuclear Waste Policy Amendments Act of 1987 established the Nuclear Waste Technical Review Board to evaluate the technical and scientific validity of activities undertaken by the Department of Energy (DOE) in the Civilian Radioactive Waste Management Program.

The Board is required to report, not less than two times per year, to the Congress and the Secretary of Energy its findings, conclusions, and recommendations. The Board has issued two reports to date. The first report was released in March 1990. The second report was issued on November 27, 1990. The second report contains 20 recommendations in 7 broad areas: (1) effects of seismicity and faulting on facility design and site suitability; (2) testing for site suitability; (3) performance assessment; (4) long-lived waste packages; (5) waste container materials, configurations, and disposal environments; (6) coordination and integration of environmental studies; and (7) human factors and system safety in transportation and handling of spent fuel.

These recommendations and DOE's responses are presented in this report. Each recommendation is quoted verbatim from the Board's report of November 27, 1990, and is followed by the response.

EFFECTS OF SEISMICITY AND FAULTING ON FACILITY DESIGN AND SITE SUITABILITY

In these recommendations to DOE, the Board addresses how potential seismic and faulting risks should be considered in determining site suitability and developing criteria for facility design.

Recommendation 1

Increased emphasis should be placed on understanding the engineering, public safety, and environmental consequences of seismic events at Yucca Mountain, including earthquakes of magnitudes larger than those that are likely to occur during the lifetime of the facility.

Response

DOE will include engineering, public safety, and environmental consequences of seismic events and other natural hazards in the basis for determining the suitability of a site or a design. Earthquakes are potential events in the region during a repository's operational and postclosure periods; however, it is their potential consequences to workers and public health and safety that are of primary concern, not their potential for occurrence. The evaluation of these consequences should be based on the analysis of a range of potential seismic events, including those high-magnitude events that have a relatively low probability of occurring during the lifetime of the facility. DOE has completed a preliminary evaluation of this type, and the results are described in a report by Subramanian et al., (1989).

As discussed with the Board's Structural Geology and Geoengineering Panel during the April 12, 1990, meeting on seismic hazards, it is the current DOE policy that the seismic design basis for the repository facilities is to be an earthquake large enough to have a very low probability of occurring during the lifetime of the facility. Once a design basis is selected, further design analyses will be carried out to evaluate the consequences of hypothetical events that are both larger and smaller than the design basis. DOE is concerned with this approach in that the hypothetical very-low-probability, high-magnitude events that are used in conducting such evaluations may be taken to be the "expected" by the public and regulatory agencies. This may lead to pressure to adopt increasingly more conservative designs that may be unwarranted when the probability of the event and its potential consequences are considered. DOE believes that analyses are important in evaluating the response of repository facilities to events that exceed facility design bases and for evaluating the potential health and safety consequences of any failures that may result from a seismic event or other natural hazard.

Reference

C. V. Subramanian, N. Abrahamson, A. H. Hadjian, L. J. Jardine, J. B. Kemp, O. K. Kiciman, C. W. Ma, J. King, W. Andrews, and R. P. Kennedy, *Preliminary Seismic Design Cost-Benefit Assessment of the Tuff Repository Waste-Handling Facilities*, SAND88-1600, Sandia National Laboratories, Albuquerque, New Mexico, 1989.

Recommendation 2

Discussions of site suitability should be based on the likelihood of adverse consequences and not on the occurrence of earthquake ground motion or fault displacement alone.

Response

DOE concurs that the ultimate determination of site suitability should be based on the potential consequences of seismic events or other hazards, in conjunction with their potential for occurrence. DOE is currently developing a methodology for an early determination of site suitability and will continue analyses of this type as additional information on natural hazards becomes available. In addition, the Test Prioritization Task will focus on identifying the parameters and activities needed to increase confidence in the assessments of site performance. This information will be used in developing the site-suitability methodology.

In licensing the repository, emphasis should be placed on evaluating the health and safety consequences of a wide range of potential events (e.g., the potential for releases of radionuclides to the accessible environment) rather than placing regulatory emphasis on the potential occurrence of a specific design event or natural phenomena related to a particular hazard. The evaluation of health and safety consequences should include the consideration of high-probability events that are equal to or smaller than a nominal design-basis event and very-low-probability events that may exceed a given design basis. The implementation of such an approach does not necessarily mean that additional information on the nature of potential natural hazards is not required. Considerable additional information will be required to adequately define the range of potential events and the probability of occurrence of specific events within that range and to increase confidence that the results provide the appropriate degree of "reasonable assurance."

Recommendation 3

Formulation of a specific tectonic model, acceptable with a high degree of confidence, should not be viewed as a prerequisite to site suitability or to ensuring public safety and environmental protection.

Response

DOE shares the Board's view that the formulation of a specific tectonic model, acceptable with a high degree of confidence, is not necessary for assessing site suitability. As explained in the Site Characterization Plan (SCP), section 8.3.1.17.4.12, and as discussed with the Board's Structural Geology and Geoengineering Panel on April 12, 1990, DOE is committed to the formulation and evaluation of tectonic models that include the range of credible descriptions of the candidate site. Since these alternative conceptual models are expected to differ significantly in their prediction of the potential effects of tectonics on waste isolation (e.g., through prediction of differing effects over time of crustal strain, faulting, and volcanism on gas and fluid travel paths and travel time or on water-table elevation), their use will assist DOE to assess the range of uncertainty in estimates of repository performance.

If performance estimates based on data-constrained models and subsequent numerical models vary widely with a resulting high degree of uncertainty regarding total-system radionuclide releases, DOE will seek to reduce uncertainty by designing tests, collecting additional data, and performing analyses to identify the more plausible alternative models.

The explicit formulation and evaluation of a full range of credible tectonic models will help increase public confidence that all plausible and significant tectonic events and scenarios that could occur during the preclosure and the postclosure periods have been considered.

Recommendation 4

Geologic licensing criteria and standards for the repository and its surface facilities should reflect the nature and relative vulnerability of the repository complex and the problems it poses. The criteria and standards should ensure public safety and environmental protection in light of current scientific knowledge and engineering practice, including the feasible mitigation of adverse consequences.

Response

DOE concurs that licensing criteria and standards should reflect the nature and relative vulnerability of a repository complex as discussed in the Board's recommendation. As discussed with the Board's Structural Geology and Geoengineering Panel on April 12, 1990, DOE's comments on the NRC draft technical position "Methods of Evaluating the Seismic Hazard at a Geologic Repository" (June 1989) are consistent with the Board's position that suitability should be judged on the basis of the potential risk, and not just on the potential occurrence of a natural phenomena, such as earthquake ground motion or fault displacement, independent of consequences to health and safety. DOE has taken the position that Appendix A to 10 CFR Part 100 should not be used in siting and licensing a repository and its surface facilities because of the marked differences between the hazards posed by a nuclear reactor and the hazards posed by a geologic repository, and because Appendix A relies on outdated risk-assessment techniques. (See also the response to Recommendation 2.)

TESTING FOR SITE SUITABILITY

The following Board recommendations on proposed geologic tests are made so that site suitability can be evaluated by DOE as early as possible.

Recommendation 5

Planned scientific testing of the Yucca Mountain geologic block should be re-evaluated to give highest priority to those tests and studies that provide the data essential to assess the suitability of the site. Each proposed study should be evaluated in terms of procedures, technologies, test locations, and appropriateness in meeting stated objectives.

Response

DOE is addressing the Board's recommendation that the highest priorities be given to tests and studies that will provide the data essential for assessing the suitability of the candidate site. As noted by the Board, DOE has initiated a management and technical analysis, known as the Test Prioritization Task (TPT), to identify and prioritize site-characterization tests that could influence early decisions about the suitability of the candidate site. Preliminary results were discussed at the October 11, 1990, meeting with the Board. The phase 1 report of the TPT was completed on March 1, 1991 (DOE, 1991a) and results were discussed at the Structural Geology & Geoengineering and Hydrogeology & Geochemistry joint panel meeting held on March 6, 1991.

TPT activities are now included as part of the Early Site Suitability Evaluation (ESSE) and will make use of the integrated results obtained from the Calico Hills Risk / Benefit Analysis (DOE, 1991b) and the Exploratory Shaft Facility Alternatives Study (Stevens and Costin, 1991) as part of this effort. If new concerns are identified by the ESSE, they will be factored into the test prioritization efforts.

Study Plans have been or are being developed for the tests identified in the Site Characterization Plan and considered as part of the TPT. These Study Plans describe the procedures, test locations, and the appropriateness of these tests for meeting their stated objectives, which will be evaluated as part of the Study Plan formal review process. Further management or technical review of individual studies or activities may be necessary to implement the approved recommendations of the site suitability task dependent upon the issue under consideration. (See also the response to Recommendation 2).

References

U.S. Department of Energy, *Testing Priorities at Yucca Mountain: Recommended Early Tests To Detect Potentially Unsuitable Conditions for a Nuclear Waste Repository*, YMP, Las Vegas, Nevada, 1991.

U.S. Department of Energy, *Risk/Benefit Analysis of Alternative Strategies for Characterizing the Calico Hills Unit at Yucca Mountain*, YMP-91-6, Las Vegas, Nevada, 1991.

Stevens, A.L. and L.S. Costin, *Findings of the ESF Alternatives Study, An Executive Report*, SAND90-3232, Albuquerque, New Mexico, 1991.

Recommendation 6

The DOE should consider expanding its development program for dry-drilling equipment to include the capability to drill inclined holes.

Response

DOE recognizes the potential benefits of inclined boreholes to maximize investigative capabilities relative to near-vertical joint and fault systems. As the Board has noted, DOE has developed new technology to recover core from vertical boreholes at depths of several thousand feet without introducing any fluids, as discussed at the October 11, 1990, meeting with the Board. Specifications for the dry-coring system include a borehole size of approximately 12-14 inches to allow for instrument installation and long-term monitoring. As a result of the required specification, the present system consists of a heavy dual-wall pipe with an open-center rotary type reaming bit which allows core recovery ahead of the reaming bit. However, because of the design of the present system (particularly because of estimated induced sideloads on the drill bit) inclined deep dry drilling and dry coring are not feasible with the present system.

DOE's current plans are to evaluate the need for additional data on near-vertical structures and will compare the costs and the benefits of drilling inclined boreholes with other means of obtaining similar information, such as in-situ testing along exploratory drifts in the Topopah Springs or the Calico Hills unit from the underground test facility. If a need is demonstrated, then DOE will evaluate options. Such an analysis would evaluate the need for dry drilling in boreholes and could also consider a broad range of possibilities within the existing drilling technology, including air-drilled inclined boreholes without core recovery and "wet-drilled" (including air foam) inclined boreholes with core recovery.

PERFORMANCE ASSESSMENT

In these recommendations to DOE, the Board addresses methodologies and alternative approaches that can be used for assessing repository performance.

Recommendation 7

The DOE should continue using decision-aiding methodology to provide more explicit and formal means for relating program decisions to risk and performance issues. Such methods should be used in an iterative and ongoing fashion to explain the reasoning behind major programmatic decisions before these decisions are committed. The four existing DOE task force studies applying these methods should be closely coordinated.

Response

DOE will continue using decision-aiding methodology when appropriate for relating program decisions to risk and performance issues. In the past, DOE has used decision-aiding methodology for a comparative analysis of five potential repository sites (DOE, 1986). Two other studies that have used decision-aiding methodologies and have been closely coordinated are the Calico Hills Risk / Benefit Analysis (DOE, 1991) and the Exploratory Shaft Facility Alternatives Study (Stevens and Costin, 1991).

DOE will employ decision-aiding methodologies in an iterative manner to evaluate major programmatic decisions centered around test prioritization, design issues, and performance issues as appropriate. DOE will maintain a high degree of coordination between various groups applying decision-aiding methodologies (e.g., the Test Prioritization Task now included in the Early Site Suitability Evaluation).

References

DOE (U.S. Department of Energy), 1986, *A Multiattribute Utility Analysis of Sites Nominated for Characterization for the First Radioactive Waste Repository - A Decision-Aiding Methodology*, Office of Civilian Radioactive Waste Management, RW-0074, Washington, D.C.

DOE (U.S. Department of Energy), *Risk/Benefit Analysis of Alternative Strategies for Characterizing the Calico Hills Unit at Yucca Mountain*, YMP-91-6, Las Vegas, Nevada, 1991.

Stevens, A.L. and L.S. Costin, *Findings of the ESF Alternatives Study, An Executive Report*, SAND90-3232, Albuquerque, New Mexico, 1991.

Recommendation 8

The DOE should continue to develop methods for assessing expert judgment in areas of significant uncertainty. Furthermore, the DOE should incorporate into the current task force studies the views of technical experts <u>outside</u> the DOE and its contractors. The basis for each expert judgment needs to be carefully documented.

Response

DOE will continue to use expert judgment effectively in making decisions that require its use. Emphasis is being placed on documenting the decision process, including the basis for the expert judgment used in the process. Other issues DOE is addressing include the question of bias and coordinating multiple expert-judgment panels so that they complement each other.

Efforts in the past where significant outside expertise has been used as part of, or in review of, programmatic initiatives include: 1) establishing the basis for the tectonics evaluation in the Environmental Assessment (DOE, 1986); 2) the cost / benefit analysis of seismic design for waste handling facilities; 3) the peer review to evaluate planned studies with respect to calcite-silica deposits; 4) the evaluation of the Szymanski hypothesis; 5) a peer review of the unsaturated zone hydrology program; and 6) a peer review for geophysical methods for site characterization.

In the past year DOE has employed several outside experts in decision analysis in the course of ongoing studies, to obtain the views of DOE and DOE contractor personnel who are considered to be experts in areas with high uncertainty. In the future, DOE will continue to seek opportunities to use a diverse group of experts and, where appropriate, increase the use of different outside experts on major issues where peer reviews are warranted.

Reference

DOE (U.S. Department of Energy), 1986, *Final Environmental Assessment: Yucca Mountain Site, Nevada Research and Development Area, Nevada*, DOE/RW-0073, Washington, D.C.

Recommendation 9

The DOE should consider investigating more extensively the use of the natural analogues to support performance assessment for a potential repository at the Yucca Mountain Site.

Response

DOE continues to be interested in using data from analogue studies to support performance assessment. Several activities focused on analogue studies are underway or are being planned. For example, DOE recently completed field work on a multinational natural-analogue study in Brazil. Data from this study will be used as a test case in the next phase of the INTRAVAL project, an international effort focused on the techniques and limitations of validating performanceassessment models. The conclusions and consensus that develop from the INTRAVAL project on validation techniques and limitations may have a bearing on similar efforts in the OCRWM program.

DOE also monitors natural-analogue work in other countries and participates in the Natural Analogue Working Group under the Council of European Communities. (The objective of the Working Group is to promote understanding and consensus on the use of analogue studies in geologic disposal programs.) In addition, DOE is considering participation in a number of new international cooperative analogue studies.

In its plans for the characterization and performance assessment of the Yucca Mountain candidate site, DOE is considering the use of natural-analogue studies, including analogues for hydrothermal systems and other natural systems, as well as analogues for engineered systems and human activities. The needs of performance assessment will play a significant role in developing criteria for selecting new analogue studies and the technical review and evaluation involved in planning and managing the studies. As part of this effort, DOE is developing guidance for the selection of analogues and the conduct of studies. DOE also will consider the applicability of data associated with weapons testing at the Nevada Test Site, with the intent to cooperate with ongoing and contemplated analogue studies. In addition, data from natural-analogue studies may provide methods for the validation of models used in performance assessment. Close coordination between DOE's work on natural analogues and performance-assessment activities was established during planning for fiscal year 1991, and it will continue during the planning of future activities.

LONG-LIVED WASTE PACKAGES

These Board recommendations stress the importance of using long-lived waste packages as a means of ensuring repository performance.

Recommendation 10

At a future meeting, the DOE should respond to the Engineered Barrier System (EBS) Panel's four questions of January 6, 1990, relating to EBS performance. It should be emphasized that the Board's interest in a robust, extended-life EBS does not imply a diminished interest in the geologic barriers' contribution to overall repository performance; rather, the Board is suggesting engineered barriers may reduce the adverse consequences associated with difficult-to-predict geologic or climatological events occur.

Response

DOE is continuing to consider the implications of the questions raised in January 1990 by the Board's Engineered Barrier Systems Panel on the performance of the engineered-barrier system (EBS). To address these questions, we are using a structured systems-engineering approach, as reflected, for example, in the development of the Waste Package Plan (YMP / 90-62).

A key consideration in responding to questions about the feasibility of developing waste packages designed for very long performance is a clear understanding of the challenges of demonstrating performance with reasonable assurance. Such a demonstration must address complex interactions among the components of the waste package and the repository environment, and it must rely on predictions that cannot be validated over long times.

As detailed in the Waste Package Plan, the first steps in systematically developing and evaluating waste-package concepts include determining requirements and defining the characteristics of the waste form and the near-field environment. Reports addressing these factors are being developed. These reports, together with the planned EBS workshop (discussed in the response to Recommendation 11), represent the initial steps in responding to this recommendation.

Reference

U.S. Department of Energy, *Yucca Mountain Project Waste Package Plan*, YMP / 90-62, Las Vegas, Nevada, 1990.

Recommendation 11

A workshop should be held to investigate the practicality, advantages, and disadvantages of developing a robust, extended-life EBS that would contribute to containment for periods of time well beyond 1,000 years. The Board would be pleased to assist in developing an agenda for such a workshop.

Response

DOE has initiated planning for a workshop with the objective of investigating the practicality of developing concepts for a robust, extended-life EBS, as recommended by the Board. This workshop is tentatively scheduled for June 1991. The format of the workshop will permit the structured presentation of a number of alternative EBS concepts by DOE and other interested parties. Such a workshop would involve convening qualified individuals in the appropriate disciplines to discuss the practicality, advantages, and disadvantages of pursuing the development of such concepts. Preliminary planning for this workshop has been informally discussed with the Board's staff, and DOE will continue to keep the Board apprised of the workshop plans as they are developed.

WASTE CONTAINER MATERIALS, CONFIGURATIONS, AND DISPOSAL ENVIRONMENTS

These Board recommendations to DOE pertain to evaluating further a number of options on waste package design.

Recommendation 12

Studies of alternative materials should be restarted. These studies should include evaluation of container materials and designs, emplacement designs, and container configurations, including both internal adsorbing materials and external backfill materials.

Response

Since the release of the Board's second report, DOE has completed and issued the Waste Package Plan. This plan, which has been provided to the Board, describes a comprehensive process for developing alternative design concepts for the waste packages and other components of the engineered-barrier system, including the identification and evaluation of alternative materials, as recommended by the Board. In the meeting with the Board's Engineered Barrier System Panel on August 28-29, 1990, DOE described the approach and plans for implementing this process. The pace of implementation for this plan will be dictated by the priority assigned to development of the engineered systems and the availability of resources.

As stated in the Secretary's Report to the Congress in November 1989, major activities related to the design of a repository and the waste package are being deferred, pending availability of more information concerning the suitability of the candidate site. DOE does, however, intend to proceed with limited implementation of the plan, as resources permit.

References

U.S. Department of Energy, *Yucca Mountain Project Waste Package Plan,* YMP/90-62, Las Vegas, Nevada, 1990.

U.S. Department of Energy, *Report to Congress on Reassessment of the Civilian Radioactive Waste Management Program*, DOE/RW-0247, Washington, D.C., 1989.

Recommendation 13

Heater tests should be re-initiated. These tests should examine the effects of alternative emplacement orientations and three-dimensional and multiple heat sources for a range of thermal loads.

Response

OCRWM does not currently have access to a suitable facility for performing in situ field tests in an unsaturated welded volcanic tuff. Therefore, it will not be possible to conduct field tests using electrically-heated simulators of waste packages prior to the development of the ESF.

Recommendation 14

The EBS development and testing program should be coordinated and funded at a level sufficient to produce a statistical basis for assessing its contribution to long-term predictions of repository behavior. Tests should be long-term preferably exceeding five years and include both laboratory and field testing.

Response

DOE will coordinate and fund long-term laboratory and field testing to provide a sound basis for predicting the contribution of the EBS components to the performance of the repository system. Limited laboratory tests, primarily involving the degradation of container materials and mechanisms for the release of radionuclides from spent fuel and vitrified high-level waste, have been underway for several years. These tests have focused on the identification and quantification of the phenomena that affect waste-package performance as opposed to statistically testing all of the EBS configurations that have been considered.

Long-term laboratory testing, especially when it involves tests of radioactive materials or tests in ionizing-radiation environments, are inherently costly in test facility preparation and operation. Therefore, DOE has been conservative in committing resources to these tests until the EBS concept development has advanced to a level of maturity where materials have been selected and the test environment parameters have been established. The process for establishing these selections and parameters is discussed in the responses to Recommendations 10 and 12.

In regard to producing a statistical basis, DOE believes that the Board's recommendation may not be practical, because of the diversity of characteristics, particularly for the waste forms, and the multiple interactions between materials that are possible. The intent of the testing strategy is to address characteristic diversity by carefully selecting representative materials for testing and to identify the most significant degradation modes and interactions to establish the long-term test matrix.

It is DOE's strategy to initiate field tests when the exploratory shaft facility becomes available and, assuming that the candidate site is determined to be suitable, to continue them, as appropriate, as an integral part of a performance confirmation program as required under Subpart F of 10 CFR Part 60. This approach would allow the tests to continue during the licensing and repository construction period.

COORDINATION AND INTEGRATION OF ENVIRONMENTAL STUDIES

These Board recommendations pertain to the need for the environmental study program at Yucca Mountain to be coordinated with respect to the various stakeholders involved and integrated with respect to the different subject areas of investigation.

Recommendation 15

The DOE should continue to include in its study plans the interests and concerns of Native Americans, the States of California and Nevada, the National Park Service, the Soil Conservation Service, and the Fish and Wildlife Service.

Response

DOE will continue to work with these parties and devote considerable effort to satisfy their concerns and interests. The following information summarizes the actions taken by DOE.

Sixteen Official Tribal Representatives (OTRs) from the various bands and Tribes in the area have been interacting with DOE on a regular basis regarding programmatic activities and events. These OTRs have been interacting with DOE for almost 2 years, and DOE intends to continue these interactions. Currently, DOE is discussing and developing methods whereby Native American concerns can be addressed in the course of Yucca Mountain Project environmental activities. Additional discussions with the OTRs are expected to be scheduled in the spring of 1991.

DOE has developed an environmental field program that it believes is technically appropriate to the site characterization phase. This program consists of ongoing monitoring programs in the areas of air quality, meteorology, terrestrial ecosystems, archaeology, reclamation, and background radiation. Water-resource monitoring and regional soil surveys will begin later this spring. All DOE management plans describing these field monitoring programs were shared with the State of Nevada.

DOE has not finalized environmental study programs in the State of California. DOE is conducting passive ongoing monitoring activities in California. In the near term, the DOE may need to commence water-sampling studies and other ecological surveys in and around the Ash Meadows area. These studies will be planned in consultation with the U.S. Fish and Wildlife Service (USFWS) and the National Park Service (NPS), both of whom have an interest in the area. When activities are near commencement in the State of California, DOE plans to contact appropriate State agencies to ensure regulatory compliance and to keep the State of California apprised.

DOE has held several meetings with NPS regarding water monitoring. NPS had filed a protest to DOE's application, submitted to the State of Nevada, for water usage during site characterization. The effect of potential drawdowns are the primary issues of concern to NPS. As a result of several discussions, DOE accelerated the preparation of a monitoring plan specific to the concerns of NPS. This monitoring plan addresses the measurement of water levels in a monitoring network located south from Yucca Mountain to the Ash Meadows area. The plan was finalized and submitted to the NPS on March 12, 1991 (DOE, 1991). In the transmittal, Yucca Mountain Project requested that NPS lift their protests to the water appropriation permit application and let the State know that they are lifting their protests. NPS has indicated that it will lift its protest.

Both the "Environmental Field Activity Plan for Soils" and the "Reclamation Implementation Plan" were sent to the Soil Conservation Service (SCS) for review and comment, and the agency's comments were incorporated into the final documents. A regional soil survey is expected to commence in April 1991 and will be conducted in accordance with SCS guidelines.

DOE worked closely with USFWS to develop a desert tortoise research and protection program even before the designation of the desert tortoise as an endangered species. After the designation, DOE prepared a biological assessment that formalized this program. It was accepted with minor changes by USFWS, and which issued a "No Jeopardy Biological Opinion" in February 1990. Since then, DOE has kept USFWS apprised of site investigations, and such interactions are expected to continue. DOE also sent its "Yucca Mountain Site Characterization Project Environmental Training Program" to USFWS for review and comment, and this document was subsequently amended in response to their comments.

Consultation with the Bureau of Land Management (BLM) concerning compliance with applicable parts of the Federal Land Policy and Management Act has resulted in the issuance of two right-of-way reservations one for access to approximately 52,000 acres of BLM-administered land and one for access to 19,000 acres of the Nellis Air Force Range. In addition, a 12 year land withdrawal from mining and mineral leasing laws for 4,255.5 acres of BLM land immediately over the proposed repository block was granted to maintain the physical integrity of the subsurface environment. In achieving these milestones, several environmental issues were addressed that resulted in stipulations designed to protect the environment.

Finally, DOE plans to continue discussions with all of the above mentioned agencies to the maximum extent practicable. DOE will continue to keep the Board informed of how the interests and concerns of these parties are included in the study plans.

References

U.S. Department of Energy, *Biological Assessment of the Effects of Site Characterization Activities on the Endangered Desert Tortoise*, Yucca Mountain Project Office, Las Vegas, Nevada, 1989.

U.S. Department of Energy, *Draft Reclamation Implementation Plan for the Yucca Mountain Project*, Yucca Mountain Project Office, Las Vegas, Nevada, 1990.

U.S. Department of Energy, *Draft Environmental Field Activity Plan for Soils,* Yucca Mountain Project Office, Las Vegas, Nevada, 1990.

U.S. Department of Energy, *Monitoring Program for Groundwater Levels and Springflows in the Yucca Mountain Region of Southern Nevada and California*, Yucca Mountain Project Office, Las Vegas, Nevada, 1991.

Recommendation 16

The DOE and the State of Nevada should explore the possibility of initiating a cooperative program to develop baseline environmental information.

Response

DOE has, in the past, extended several offers to the State to participate in DOE programs, but these offers have not been pursued by the State. DOE has also transmitted several requests to the State and its contractors to coordinate their environmental field activities with those of DOE in order to adequately protect the limited faunal populations at the site. This coordination is desirable to prevent oversampling of populations stressed by drought conditions, and to protect the desert tortoise, a species designated as threatened by the Federal Government. The State has not responded as of this date.

During the site characterization phase, DOE's objectives in the environmental arena are threefold: (1) to monitor the effects of site characterization activities and to develop and implement mitigation strategies as appropriate; (2) to collect monitoring data as part of an overall field program that may be used to fulfill potential permitting requirements; and (3) to conduct environmental activities to fulfill prerequisites established by DOE management for the initiation of site characterization activities. The environmental data gathered by these activities do not cover all the topics generally considered part of an "environmental baseline." However, all data gathered may be considered as "background" information to be used as corroborative data in support of the future baseline.

DOE believes that establishing an environmental baseline is an activity associated with the environmental impact statement (EIS) and will be initiated after the EIS scoping hearings and completion of the EIS Implementation Plan. The NWPA required that an environmental assessment (EA) be prepared on the basis of available data and that it provide an assessment of potential significant adverse environmental impacts due to site characterization activities. These analyses, as documented in the EA, determined that no significant adverse impacts were expected to result from site characterization. However, DOE has developed and implemented an extensive monitoring program in air quality, meteorology, background radiation, ecosystems, archaeology, and water resources to gather background data during site characterization so as to monitor site characterization activities. Establishing an environmental baseline prior to the conduct of the EIS scoping hearings may be interpreted as prejudging the results of the scoping process.

Reference

U.S. Department of Energy, *Final Environmental Assessment: Yucca Mountain Site, Nevada Research and Development Area, Nevada,* DOE/RW-0073, Washington, D.C., 1986.

Recommendation 17

All environmental programs at the Yucca Mountain Site funded by the Nuclear Waste Fund should be developed and conducted in a manner that the data obtained are appropriate to and can be used during licensing.

Response

DOE will ensure that all environmental data needed for licensing will be developed such that it is usable for that purpose.

Recommendation 18

An integrated environmental program that takes cognizance of ecosystem processes should be developed for the Yucca Mountain Site. The results of this program should permit assessment of the effects of site characterization and repository construction and operation on the local ecosystem. The program also should provide a basis for understanding ecologic pathways for any radioactive materials that might escape containment during repository construction, operation, and decommissioning.

Response

DOE has developed an integrated environmental program that focuses on the needs of the different project phases.

DOE believes that its program will identify ecosystem processes at Yucca Mountain and will evaluate the effects of repository development (including site characterization), construction, and operation on the local ecosystem. Since the program is currently in the site characterization phase, the environmental program is directed at addressing ecological concerns associated with site characterization. The potential effects of repository construction, operation, closure, and decommissioning will be addressed when the process of developing the EIS is begun with the publication of a notice of intent and EIS scoping hearings.

The current DOE ecosystem program addresses five areas: (1) site characterization effects; (2) desert tortoise research and mitigation activities; (3) reclamation feasibility studies and reclamation actions as necessary; (4) support to the radiation-monitoring program in small-mammal sampling; and (5) preactivity surveys, required as prerequisites to the management approval of site-characterization activities.

HUMAN FACTORS AND SYSTEM SAFETY IN TRANSPORTATION AND HANDLING OF SPENT FUEL

These Board recommendations pertain to enhancing the safety of spent fuel transportation when the scale of future transport activities becomes significantly large.

Recommendation 19

The NRC should develop policy statements, program guidelines, and, if feasible, criteria documents in human factors and system safety engineering that will help ensure that DOE's and utilities' system acquisition programs address future accident potentials. The goal should be for the system acquisition programs to be complete in all the technologies that can contribute to operations safety and efficiency, including emergency and mitigation planning.

Response

The Nuclear Regulatory Commission is the appropriate organization to respond to this recommendation. However, these activities are being addressed in the development of the OCRWM programmatic and physical system requirements documents.

Recommendation 20

Priority should be placed on developing a high-level waste management system that minimizes the handling of spent fuel.

Response

DOE recognizes that increased handling of spent fuel could lead to additional operational exposures and potential for mishandling incidents. DOE will limit the handling of spent fuel in the Federal waste-management system to the extent practicable and consistent with system operational requirements. DOE is also working with representatives of the utility industry to ensure compatibility between the Federal system and the spent-fuel storage options being pursued at the utility sites.

References

Allison, J. D., D. S. Brown, and K. J. Novo-Gradac. 1990. “MINTEQA2/PRODEFA2, A Geochemical Assessment Model for Environmental Systems: Version 3.0 User’s Manual.” Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Athens, Georgia.

Domenico, P.A., A. Lerman, and J.W. Bartlett. 1989. “The Disposal of Nuclear Waste: A Problem in Mass Management?” *Ground Water* 27(3), pp. 363-374.

KBS. 1983. *Final Storage of Spent Nuclear Fuel-KBS-3.* General Swedish Nuclear Fuel Supply Co./KBS Division, Stockholm, Sweden, May 1983.

Keeney, R. 1982. “Decision Analysis: An Overview,” *Operations Research.* 30, 803-838.

Krupka, K.M., and J.K. Morrey. 1985. “MINTEQ Geochemical Reaction Code: Status and Applications.” Conference on Application of Geochemical Models to High-Level Nuclear Waste Repository Assessment, Oak Ridge, Tennessee, October 2-5, 1984. G. K. Jacobs and S. K. Whatley (edit.). NUREG/CP-0062, pp. 46-53. U. S. Nuclear Regulatory Commission, Washington D.C.

Leigh, I.W. and S.J. Mitchell. 1990. *International Nuclear Fuel Cycle Fact Book,* Pacific Northwest Laboratory, PNL-3594 Rev.10, January 1990.

Mangold, D.C., and C.F. Tsang. 1991. “A Summary of Subsurface Hydrological and Hydrochemical Models.” *Reviews of Geophysics* 29(1), pp. 51-79.

Meijer, A. 1990. “Yucca Mountain Project Far-Field Sorption Studies and Data Needs.” LA-11671-MS, Los Alamos National Laboratory, Los Alamos, New Mexico.

Nuclear Regulatory Commission. 1990. “Clarification of the 300-1000-Year Period for Substantially Complete Containment of High-Level Wastes Within the Waste Packages Under 10 CFR 60.113(a)(1),(ii)(A).” Staff Position 60-001, July 27, 1990. Washington, D.C.

Nuclear Regulatory Commission. 1990. “Draft Technical Position of Regulatory Considerations in the Design and Construction of the Exploratory Shaft Facility.” 10 CFR Part 60. June 30, 1990. Washington, D.C.

Nuclear Waste Technical Review Board. 1990. *First Report to the U.S. Congress and the U.S. Secretary of Energy*, March 1990. 061-000-00747-4. Washington, D.C.: U.S. Government Printing Office.

Nuclear Waste Technical Review Board. 1990. *Second Report to the U.S. Congress and the U.S. Secretary of Energy*, November 1990. 061-000-00752-1. Washington, D.C.: U.S. Government Printing Office.

Oversby, D.M. 1987. “Important Radionuclides in High Level Nuclear Waste Disposal: Determination Using a Comparison of the U.S. Environmental Protection Agency and Nuclear Regulatory Commission Regulations.” *Nuclear and Chemical Waste Management*, V. 7, pp. 149-161.

U.S. Department of Energy. 1991. “Evaluation of and Recommendations from Sorption Workshop," Draft Report. The Radionuclide Adsorption Workshop, Los Alamos, New Mexico, September 11-12, 1990, Washington D.C.

U.S. Department of Energy, Energy Information Administration. 1989. *Commercial Nuclear Power 1989*. DOE/EIA-0438. Washington, D.C.

U.S. Department of Energy, Office of Civilian Radioactive Waste Management. 1988. *Environmental Program Overview*, DOE/RW-2207. December 1988. Washington, D.C.

U.S. Department of Energy, Office of Civilian Radioactive Waste Management. 1988. *Site Characterization Plan Overview*, DOE/RW-0198. December 1988. Washington, D.C.

White, A.F., and H.C. Claassen. 1979. “Dissolution Kinetics of Silicate Rocks-Application to Solute Modeling” *Chemical Modeling in Aqueous Systems*, Chapt. 22. E.A. Jenne (edit.). American Chemical Society Symposium, Ser. 93, pp. 447-473. American Chemical Society, Washington, D.C.

Wolery, T.J., K.J. Jackson, W.L. Bourcier, C.J. Brunton, B.E. Viani, K.G. Knauss, and J.M. Delany. 1990. “Current Status of the EQ3/6 Software Package for Geochemical Modeling.” *Chemical Modeling of Aqueous Systems II*, Chapt. 8, D. C. Melchior and R. L. Bassett (edit.). American Chemical Society Symposium, Ser. 416, pp. 104-116. American Chemical Society, Washington, D.C.

Yang, I.C., G.S. Davis, and T.M. Sayre. 1990. “Comparison of Pore Water Extraction by Triaxial Compression and High-speed Centrifugation Methods.” *Minimizing Risk to the Hydrologic Environment*. Alexander Saporogec (edit.). pp. 250-259. Dubuque, Iowa: Kendall/Hunt Publishing Company.

Yang, I.C., A.K. Turner, T.M. Sayre, and P. Montazer. 1988. “Triaxial-Compression Extraction of Pore Water from Unsaturated Tuff.” 88-4189. U.S. Geological Survey, Water Resources, Yucca Mountain, Nevada.

Standards and Regulations

10 CFR 60 (Code of Federal Regulations). 1990. Title 10, *Energy*, Part 60, “Disposal of High-Level Radioactive Wastes in Geologic Repositories.” Washington, D.C.

40 CFR 30 (Code of Federal Regulations). 1990. Title 40, Part 30, “General Regulation for Assistance Programs for Other than State and Local Governments.” Washington, D.C.

40 CFR 31 (Code of Federal Regulations). 1990. Title 40, Part 31, “Uniform Administrative Requirements for Grants and Cooperative Agreements to State and Local Governments.” Washington, D.C.

40 CFR 191 (Code of Federal Regulations). 1984. Title 40, *Protection of the Environment*, Part 191, “Environment Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes. ” Washington, D.C.

48 CFR 15 (Code of Federal Regulations). 1990. Title 48, Part 15, “Containing and Codification of Documents of General Applicability and Future Effect.” Washington, D.C.

EPA Order 5360.1. “Policy and Program Requirements to Implement the Quality Assurance Program.

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

Analogue: A thing or part that is analogous. As used in this report, a given natural setting or anything impacted by, or resulting from, human activity that can provide information on aspects of repository performance. Analogues generally are broken into two categories: natural and anthropological. Natural analogues occur through natural phenomena. Anthropological analogues result from human activity. "Archaeological analogue" generally is used to refer to an analogue resulting from the activities of ancient cultures.

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

Caisson: As used in the DOE programs, a caisson is a cylindrically shaped pipe, set vertically and with its open end upwards, packed with solid materials such as crushed tuff, and used to study the transport and sorption of dissolved species under saturated or unsaturated flow conditions. Caissons are often several feet in diameter.

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

Colloidal particles: (and **colloidal transport and filtration**) Colloidal particles are usually smaller than 1 micrometer (μm) in diameter and under many conditions can remain in suspension in water indefinitely without settling. They may then be transported at about the same velocity as groundwater, but are sometimes filtered out when the water moves though the small pores of a rock, such as through the matrix pores of a tuff.

Complex: A species formed by the association, usually of a positive and a negative ion (or ions), both of which may be dissolved, or one of which may be on a solid surface. (See **surface complexation model**). For example, UO_2CO_3 is a dissolved complex formed by association of uranyl ion (UO_2^{2+}) and carbonate ion (CO_3^{2-}).

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

Coprecipitation: The precipitation of a dissolved, usually trace, substance with and in a precipitate formed of major dissolved species, for example, the coprecipitation of uranium with a ferric oxide solid

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 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

Illite: A clay mineral that is less sorbent of metal ions and radionuclides than are the smectite clays (see **smectite**)

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 porous 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

Isotopic exchange: A reaction in which a specific isotope of an element distributes itself between two or more substances. For example, carbon-14 (C-14 or ^{14}C) tends to distribute itself by the isotopic exchange between the carbon of CO_2 (gas) and the carbon of the mineral calcite ($CaCO_3$).

K_d (distribution coefficient): Mass of species being sorbed on the solid phase, per unit mass of the solid phase, divided by concentration of species being sorbed in solution. Normally reported in milliliters per gram (ml / g).

Low-level (radioactive) waste: Radioactive material that is neither high-level radioactive waste, spent nuclear fuel, transuranic waste, nor byproduct material as defined in Section 11a(2) of the Atomic Energy Act of 1954. Examples include contaminated medical waste, which cannot be disposed of in the garbage.

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: See **analogue**

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

R_d (retardation coefficient): Equals the average linear velocity of the groundwater divided by the velocity of the midpoint of the concentration profile of the retarded constituent

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**

Smectite: A group of clay minerals that are generally strongly sorbent of metal ions such as Mg^{2+} and also of radionuclide cations (positively charged ion)

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

Surface complexation model: There are several surface complexation models. Such models describe the sorption of dissolved species on the surfaces of minerals or other solids. The sorption process is modeled as if it involved the formation of complexes between the dissolved species and surface sites on the solid.

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, 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

Transuranic waste (TRU): Waste containing more than 100 nanocuries of alpha-emitting transuranic isotopes, per gram of waste with half-lives greater than 20 years, except for (1) high-level radioactive wastes, (2) wastes that the U.S. Department of Energy with the concurrence of the Environmental Protection Agency Administrator, has determined do not need the degree of isolation required by 40 CFR 191, or (3) wastes that the U.S. Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with 10 CFR 61. Research on disposal of TRU is underway at the Waste Isolation Pilot Project (WIPP) in Carlsbad, New Mexico.

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

Period List of Elements Showing Atomic Number, Symbol, Element

1	H	Hydrogen	27	Co	Cobalt	53	I	Iodine	79	Au	Gold
2	He	Helium	28	Ni	Nickel	54	Xe	Xenon	80	Hg	Mercury
3	Li	Lithium	29	Cu	Copper	55	Cs	Cesium	81	Tl	Thallium
4	Be	Beryllium	30	Zn	Zinc	56	Ba	Barium	82	Pb	Lead
5	B	Boron	31	Ga	Gallium	57	La	Lanthanum	83	Bi	Bismuth
6	C	Carbon	32	Ge	Germanium	58	Ce	Cerium	84	Po	Polonium
7	N	Nitrogen	33	As	Arsenic	59	Pr	Praseodymium	85	At	Astatine
8	O	Oxygen	34	Se	Selenium	60	Nd	Neodymium	86	Rn	Radon
9	F	Fluorine	35	Br	Bromine	61	Pm	Promethium	87	Fr	Francium
10	Ne	Neon	36	Kr	Krypton	62	Sm	Samarium	88	Ra	Radium
11	Na	Sodium	37	Rb	Rubidium	63	Eu	Europium	89	Ac	Actinium
12	Mg	Magnesium	38	Sr	Strontium	64	Gd	Gadolinium	90	Th	Thorium
13	Al	Aluminum	39	Y	Yttrium	65	Tb	Terbium	91	Pa	Protactinium
14	Si	Silicon	40	Zr	Zirconium	66	Dy	Dysprosium	92	U	Uranium
15	P	Phosphorus	41	Nb	Niobium	67	Ho	Holmium	93	Np	Neptunium
16	S	Sulfur	42	Mo	Molybdenum	68	Er	Erbium	94	Pu	Plutonium
17	Cl	Chlorine	43	Tc	Technetium	69	Tm	Thulium	95	Am	Americium
18	A	Argon	44	Ru	Ruthenium	70	Yb	Ytterbium	96	Cm	Curium
19	K	Potassium	45	Rh	Rhodium	71	Lu	Lutetium	97	Bk	Berkelium
20	Ca	Calcium	46	Pd	Palladium	72	Hf	Hafnium	98	Cf	Californium
21	Sc	Scandium	47	Ag	Silver	73	Ta	Tantalum	99	Es	Einsteinium
22	Ti	Titanium	48	Cd	Cadmium	74	W	Wolfram	100	Fm	Fermium
23	V	Vanadium	49	In	Indium	75	Re	Rhenium	101	Md	Mendelevium
24	Cr	Chromium	50	Sn	Tin	76	Os	Osmium	102	No	Nobelium
25	Mn	Manganese	51	Sb	Antimony	77	Ir	Iridium	103	Lw	Lawrencium
26	Fe	Iron	52	Te	Tellurium	78	Pt	Platinum			