Appendix A
Nuclear Waste Technical Review Board Members: Curricula Vitae

Dr. John E. Cantlon, Chair

President George Bush appointed Dr. Cantlon to chair the Nuclear Waste Technical Review Board on May 27, 1992. His term of office will expire April 19, 1996. President Ronald Reagan first appointed Dr. Cantlon to the Board on January 18, 1989.

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

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

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

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

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

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

Dr. Cantlon resides in East Lansing, Michigan.

Dr. Clarence R. Allen

President George Bush appointed Dr. Allen to a second term on the Nuclear Waste Technical Review Board for a four-year term expiring on April 19, 1996. President Ronald Reagan first appointed Dr. Allen to the Board on January 18, 1989.

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

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

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

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

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

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

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

Dr. Garry D. Brewer

President George Bush appointed Dr. Brewer to serve on the Nuclear Waste Technical Review Board for a four-year term that will expire April 19, 1996.

Dr. Brewer is professor of resource policy and management and dean of the School of Natural Resources and Environment at the University of Michigan. He has more than 18 years' teaching experience and is author, coauthor, or editor of nine books and more than 175 professional publications. He edited *Policy Sciences* (1974-76, 1990-91) and *Simulation & Games* (1977-79) and served or serves on the editorial boards of seven other professional journals, including the *Journal of Conflict Resolution* and *Public Administration Review*.

From 1970 to 1974, Dr. Brewer was on the senior staff of the RAND Corporation in Santa Monica, California, dividing his efforts between strategic studies and evaluations of large-scale social service systems for people who are disabled. In 1974, Dr. Brewer joined the founding faculty of Yale's School of Organization & Management. He then took a year's leave to become a fellow at the Center for Advanced Study in the Behavioral Sciences, Palo Alto, California, returning to the Yale faculty in 1975. From 1975 until 1991, Dr. Brewer was a member of the Yale faculty, holding the Frederick K. Weyerhaeuser Chair (1984-90) and the Edwin W. Davis Chair (1990-91). He served in leadership roles in Yale's Center for International and Area Studies and the Institution for Social and Policy Studies, the latter of which he directed in 1991.

Dr. Brewer's professional activities include membership on the boards or executive committees of the Woods Hole Oceanographic Institution (1987-92), the Organization for Tropical Studies (1989-93), and the Yosemite National Institutes (1990-95). He also serves the National Academy of Sciences as a member of the Board on Environmental Studies and Toxicology, the Polar Research Board, the Committee on the Outer Continental Shelf, and the Committee on Environmental Research. Since 1981, he has served on the faculty of the International Executive Forum of the Western Behavioral Sciences Institute in La Jolla, California, and taught courses on environmental management at INSEAD, the European Institute of Business Administration in Fontainebleau, France. He continues to consult with the Rockefeller Brothers Fund for the International Management Center in Budapest, Hungary.

Professional awards include Yale School of Forestry & Environmental Studies Distinguished Teacher of the Year (1988 and 1990); the American Fisheries Society's silver medal (1988); election to the Connecticut Academy of Arts and Sciences (1990); life membership in the Oceanographic Society (1990); the *Fusion de Dos Culturas* silver medal from the government of Mexico (1991); and the Karl Bosworth Award from the American Society for Public Administration (1991).

Dr. Brewer earned an A.B. in mathematical economics from the University of California, Berkeley (1963) and an M.S. in public administration (development) at San Diego State University (1966). He earned an M.S. in public administration (1966), an M.A. (1968) and Ph.D. (with distinction in 1970) in political science from Yale University. He was a Kent Fellow from 1966 to 1970, after which he was invited to join the fellowship of the Society for Values in Higher Education.

Dr. Brewer resides in Ann Arbor, Michigan.

Dr. Edward J. Cording

On June 15, 1992, President George Bush appointed Dr. Cording to serve on the Nuclear Waste Technical Review Board for a four-year term that will expire April 19, 1996.

Dr. Cording is professor of civil engineering at the University of Illinois at Urbana-Champaign. He has more than 25 years' teaching experience and is author, coauthor, or editor of more than 60 professional publications. Dr. Cording was the recipient of the 1976 American Society for Testing and Materials Hogentogler Award and the American Society of Civil Engineers Thomas A. Middlebrooks Award for 1985. He was elected to the National Academy of Engineering in 1988 and is a member of Chi Epsilon, the civil engineering honor society.

Dr. Cording brings to the Board special expertise in tunneling and tunnel supports and linings, as well as his knowledge of soil movement, ground stability, large chamber design. He is particularly interested in tunnel behavior and movement in various soil and rock conditions.

Dr. Cording is a member of the American Society of Civil Engineers and a Fellow of the Geological Society of America. He served as President of the Commission on Teaching of Rock Mechanics (International Society for Rock Mechanics) from 1974 to 1981. He is also a member of the Association of Engineering Geologists, the International Association of Engineering Geologists, and the International Society for Soil Mechanics and Foundation Engineering. He served the U.S. National Committee on Tunneling Technology as chairperson of the Commission on Education and Training (1977-1980), vice-chairperson of the Committee (1980-1981), and chairperson (1981-1982).

As a consultant, Dr. Cording has provided geotechnical engineering and applied rock and soil mechanics advice to governments and organizations around the world. He has been a part of the Washington, D.C. Metro system, the Baltimore Subway, New York's Holland Tunnel, and numerous other projects in the United States. Abroad he has worked with groups in Argentina, Bolivia, Colombia, Rhodesia, South Africa, Zaire, Nepal and Taiwan.

In 1960, Dr. Cording earned a B.S. in geology from Wheaton College in Illinois, where he was elected to the Wheaton College Scholastic Honor Society. He earned his M.S. (1963) and his Ph.D. (1967) in civil engineering from the University of Illinois. From 1960 until 1967, he also served variously as a research assistant at the University of Illinois, as a soils engineer in Chicago and Seattle, as a mining engineer at the Nevada Test Site, and as a captain (soils engineer) in the U.S. Army Corps of Engineers. In 1967, he began his distinguished teaching career as a professor of civil engineering at the University of Illinois, Urbana-Champaign.

Dr. Cording resides in Urbana, Illinois.

Dr. Patrick A. Domenico

President George Bush appointed Dr. Domenico to a four-year term on the Nuclear Waste Technical Review Board on May 31, 1990.

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

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

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

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

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

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

He presently resides in College Station, Texas.

Dr. Donald Langmuir

President George Bush appointed Dr. Langmuir to a four-year term on the Nuclear Waste Technical Review Board on June 23, 1992. President Ronald Reagan appointed Dr. Langmuir to his first term on January 18, 1989.

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

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

During the last ten years, Dr. Langmuir has served on or chaired almost a dozen expert panels assessing the various research programs of the Department of Energy, Nuclear Regulatory Commission, Environmental Protection Agency, and Lawrence Berkeley Laboratory. He was state president of the 8,000-member Colorado Mountain Club in 1990.

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

During the last 28 years, Dr. Langmuir has published more than 140 professional papers and articles and been awarded 23 grants and contracts supporting the research of more than 30 students pursuing their masters or doctorate degrees. He has consulted for clients in 16 states, as well as in Australia, Canada, France, and Sweden.

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

Dr. Langmuir resides in Golden, Colorado.

Dr. John J. McKetta, Jr.

President George Bush appointed Dr. McKetta to serve a four-year term on the Nuclear Waste Technical Review Board on February 18, 1992.

Dr. McKetta is the Joe C. Walter Professor of Chemical Engineering emeritus at the University of Texas, Austin, and brings to the Board some 55 years experience in practicing and teaching chemical engineering. He is a recipient of the Herbert Hoover Award for “unselfish service to society” (1989), a former president of the American Institute of Chemical Engineers (1962), and an honorary fellow of the Society of Technical Communicators. He serves on the boards of directors of Howell Corporation, Kinark Corporation, and Tesoro Petroleum Corporation.

Dr. McKetta has special expertise in two areas of research: solubility of hydrocarbon systems at high pressure and vapor-liquid-liquid equilibrium in hydrocarbon-water systems.

Among his numerous awards for professional achievement are: the F.J. Van Atwerpen Award for Outstanding Contributions to the Field of Chemical Engineering (1985) from the American Institute of Chemical Engineers, the Fuels and Petrochemical Division Award (1983), and the Warren K. Lewis Award for Excellence in Chemical Engineering (1969). Dr. McKetta also received the Boris Pregel Award in Science and Technology from the New York Academy of Sciences (1978) and the Charles M. Schwab Memorial Award from the American Iron and Steel Institute (1973). He is a member of the National Academy of Engineering, the American Chemical Society, the American Gas Association, and the American Institute of Mining, Metallurgical, and Petroleum Engineers.

In 1946, Dr. McKetta began his distinguished teaching career as a professor of chemical engineering at the University of Texas, Austin. Dr. McKetta also has been the University’s E.P. Schoch Professor of Chemical Engineering (1970-1982), dean of the College of Engineering (1963-1969), and chairman of the Department of Chemical Engineering (1950-1952). He received his B.S. in chemical engineering from Tri State University in 1937 and also has three degrees from the University of Michigan: a B.S.E. (1943), an M.S. (1944), and a Ph.D. (1946). He has published 495 articles and books.

Dr. McKetta resides in Austin, Texas.

Dr. D. Warner North

President Ronald Reagan appointed Dr. North to serve on the Nuclear Waste Technical Review Board on January 18, 1989. Although his term expired on April 19, 1990, President George Bush reappointed Dr. North to a four-year term on August 7, 1990.

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

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

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

Dr. North has served on committees of the Science Advisory Board (SAB) of the EPA since 1978. From 1982 to 1990, he was a member of the Environmental Health Committee, and he currently serves as a consultant to this committee. During 1988-89, he chaired the Global Climate Change Subcommittee for the SAB review of two EPA reports to Congress on climate alteration from carbon dioxide and other radiatively active gases in the atmosphere. Dr. North also has reviewed the carcinogen risk assessment guidelines, chaired the subcommittee that reviewed EPA's risk assessment research, and served as vice chair of the subcommittee that advised EPA on the congressionally mandated revision of the Hazard Ranking System used to select Superfund sites. From March 1987 to June 1989, Dr. North was a member of the California Governor's Scientific Advisory Panel for the Proposition 65 Toxics Initiative, passed in 1986.

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

He resides in Woodside, California.

Dr. Dennis L. Price

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

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

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

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

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

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

He resides in Blacksburg, Virginia.

Dr. Ellis D. Verink, Jr.

President Ronald Reagan appointed Dr. Verink to serve on the Nuclear Waste Technical Review Board from January 18, 1989, to April 19, 1990. On October 30, 1990, President George Bush appointed Dr. Verink to a second, four-year term.

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

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

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

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

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

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

He resides in Gainesville, Florida, where he is a past president of both the Kiwanis Club and the YMCA.

Appendix B
Panel Organization

1. Panel on Structural Geology & Geoengineering

Chair:	Dr. Clarence R. Allen	Staff:	Mr. R.K. McFarland
Members:	Dr. Edward J. Cording		Dr. Leon Reiter
	Dr. D. Warner North		
	Dr. Dennis L. Price		

2. Panel on Hydrogeology & Geochemistry

Co-Chair:	Dr. Patrick A. Domenico	Staff:	Dr. Victor V. Palciauskas
Co-Chair:	Dr. Donald Langmuir		
Members:	Dr. Edward J. Cording		
	Dr. John J. McKetta, Jr.		

3. Panel on the Engineered Barrier System

Chair:	Dr. Ellis D. Verink, Jr.	Staff:	Dr. Carlos A.W. Di Bella
Members:	Dr. Donald Langmuir		
	Dr. John J. McKetta, Jr.		
	Dr. Dennis L. Price		

4. Panel on Transportation & Systems

Chair:	Dr. Dennis L. Price	Staff:	Dr. Sherwood C. Chu
Members:	Dr. Garry D. Brewer		
	Dr. D. Warner North		
	Dr. Ellis D. Verink, Jr.		

5. Panel on the Environment & Public Health

Chair:	Dr. Garry D. Brewer	Staff:	Dr. Daniel J. Fehringer
Members:	Dr. John E. Cantlon		Dr. Daniel S. Metlay
	Dr. D. Warner North		
	Dr. John J. McKetta, Jr.		

6. Panel on Risk & Performance Analysis

Chair:	Dr. D. Warner North	Staff:	Dr. Leon Reiter
Members:	Dr. Garry D. Brewer		Dr. Daniel S. Metlay
	Dr. Patrick A. Domenico		
	Dr. Dennis L. Price		
	Dr. Ellis D. Verink, Jr.		

7. Panel on Quality Assurance

Chair:	Dr. John E. Cantlon	Staff:	Dr. Sherwood C. Chu
Members:	Dr. Clarence R. Allen		
	Dr. Donald Langmuir		

Appendix C
Meeting List for 1992–1994*

January 7-8, 1992	**Board Meeting** *Arlington, Virginia* Topic: Overview of Office of Civilian Radioactive Waste Management (OCRWM) program priorities and budget allocations
January 8, 1992	**Board Business Meeting** *Arlington, Virginia* Topic: Board activities Minutes available
January 8-10, 1992	**Board Trip to Surry Nuclear Power Station (closed)** *Williamsburg, Virginia*
January 22-23, 1992	**Meeting** **Panel on Structural Geology & Geoengineering** *Irvine, California* Topic: Seismic vulnerabilities
February 10, 1992	**Meeting** **Panel on Engineered Barrier System** *Augusta, Georgia* Topic: Overview of defense management activities
February 11-12, 1992	**Board Tour of Savannah River Site (closed)** *Augusta, Georgia*
February 12, 1992	**Board Tour of Chem-Nuclear Systems, Inc.** *Barnwell, South Carolina*

* *Unless otherwise indicated, transcripts are available for all Board Meetings.*

March 10-11, 1992	**Meeting** **Panel on Transportation & Systems** *Arlington, Virginia* Topic: Transportation system safety issues and monitored retrievable storage concept design.
April 6, 1992	**Board Business Meeting** *Dallas, Texas* Topic: Board activities Minutes available
April 7-8, 1992	**Board Meeting** *Dallas, Texas* Topic: Early site-suitability evaluation, total system performance assessment
April 9, 1992	**Board Business Meeting** *Dallas, Texas* Topic: Board activities Minutes available
May 11-14, 1992	**Meeting** **Panel on the Engineered Barrier System** *Hanford Plant, Richland, Washington* *Idaho National Engineering Laboratory,Idaho, Falls, Idaho* Topic: Overview of defense high-level waste management activities
June 9-17, 1992	**Board International Trip (closed)** *Finland, Switzerland* **Publication of Board's** *Fifth Report*
July 6, 1992	**Board Business Meeting** *Denver, Colorado* Topic: Board activities Minutes available
July 7-8, 1992	**Board Meeting** *Denver, Colorado* Topic: DOE update on site suitability; update on the role of the M&O contractor

July 9-10, 1992	**Board Business Meeting** *Keystone,CO* Topic: Board activities Minutes available
September 14-15, 1992	**Meeting** **Panel on Structural Geology & Geoengineering** *Las Vegas, Nevada* Topic: Volcanism; update on characterization, probability, and volcanic effects studies
September 16, 1992	**Tour** **Panel on Structural Geology & Geoengineering** **Field trip to areas of recent geologic investigations near Lathrop Wells and Crater Flat**
September 16-22, 1992	**Board Visit (closed)** **Panel on Engineered Barriers** *Tokyo, Japan* Topic: Current and planned research on Japan's repository development program and EBS
October 12, 1992	**Board Business Meeting** *Las Vegas, NV* Minutes available
October 13, 1992	**Board Business Meeting** *Las Vegas, Nevada* Minutes available
October 14-15, 1992	**Full Board Meeting** *Las Vegas, NV* Topic: Source term
October 15, 1992	**Full Board Meeting** *Las Vegas, NV* Topic: YMPO budget
October 15, 1992	**Board Business Meeting** *Las Vegas, NV* Minutes available

November 4-5, 1992	**Meeting** **Panel on Structural Geology & Geoengineering** *Las Vegas, NV* Topic: Exploratory Studies Facility (ESF) Design and Construction Strategy
December 16, 1992	**Tour (closed)** **Panel on Engineered Barrier System** *Barberton, OH* *Babcock & Wilcox Research Center*
December 17, 1992	**Discussion and Tour** **Panel on Engineered Barrier System** *West Valley, NY* Topic: West Valley Demonstration Project Operations
December 18, 1992	**Tour (closed)** **Panel on Engineered Barrier System** *Aiken, SC* *Defense Waste Processing Facility* *Savannah River Plant* **Publication of Board's** *Sixth Report*
January 5-6, 1993	**Full Board Meeting** *Arlington, VA* Topics: System Implications of Interim Storage, Mission 2001 Update
January 6, 1993	**Board Business Meeting** *Arlington, VA* Minutes available
January 7, 1993	**Board Business Meeting** *Arlington, VA* Minutes available

January 8, 1993	**Board Media Training** *Arlington, VA*
March 2, 1993	**Publication of Board's seventh report, the** *Special Report*
March 3, 1993	**Meeting with NRC Commissioners** *Rockville, MD* Topic: Briefing on NWTRB views of OCRWM program
April 19, 1993	**Tour** **Panel on the Environment & Public Health** *Las Vegas, NV* Topic: Proposed site for a high-level nuclear waste repository at Yucca Mountain
April 20, 1993	**Board Business Meeting** *Reno, NV* Minutes available
April 21-22, 1993	**Board Meeting** *Reno, NV* Topic: Decision-making on DOE study plans (e.g., infiltration)
April 26-30, 1993	**International High-Level Waste Management Conference** *Las Vegas, NV*
June 1-12, 1993	**International Trip (closed)** *United Kingdom, France, Belgium* Topic: Status of technical programs, key issues of concern
July 12, 1993	**Board Business Meeting** *Denver, CO* Minutes available
July 13-14, 1993	**Board Meeting** *Denver, CO* Topic: Thermal-loading effects: science and engineering for waste package and repository design

July 15, 1993	**Board Business Meeting** *Denver, CO* Minutes available
October 1993	**Publication of Board's eighth report, the** *Underground Exploration and Testing at Yucca Mountain*
October 19-20, 1993	**Full Board Meeting** *Las Vegas, NV* Topic: DOE drilling program / surface and underground testing / study plans
October 21, 1993	**Board Business Meeting** *Las Vegas, NV* Minutes available
November 1-2, 1993	**Meeting** **Joint Panels on Transportation & Systems and Engineered Barrier System** *Dallas, TX* Topic: The technical challenges of interim storage of spent fuel
November 22, 1993	**Meeting** **Panel on the Environment & Public Health** *Las Vegas, NV* Topic: Review of progress in the Yucca Mountain environmental program
January 10-12, 1994	**Full Board Meeting** *Arlington, VA* Topic: Systems engineering performance assessment, and public trust and confidence / alternative licensing strategies, site characterization update
February 24, 1994	**Publication of Board's ninth report, the** *Letter Report*
March 8-9, 1994	**Meeting** **Panel on Structural Geology & Geoengineering** *San Francisco, CA* Topic: Probabilistic assessment of seismic and volcanic hazards

March 10-11, 1994	**Meeting** **Panel on the Engineered Barrier System** *Pleasanton, CA* Topic: Current and planned EBS research
March 21, 1994	**Tour** **Panel on the Environment & Public Health** *Las Vegas, NV* Topic: Field trip to Yucca Mountain
March 22, 1994	**Meeting** **Panel on the Environment & Public Health** *Las Vegas, NV* Topic: Review of the Yucca Mountain Environmental Program
April 11-12, 1994	**Board Meeting** *Reno, NV* Topic: Use of science in site assessment, saturated zone hydrology, site characterization update
April 13, 1994	**Board Business Meeting** *Reno, NV* Minutes available
July 11-13, 1994	**Full Board Meeting** *Denver, CO* Topic: Transportation issues, radionuclide transport, site characterization update
October 12-14, 1994	**Full Board Meeting** *Las Vegas, NV* Topic: Environmental issues, engineered barrier system, site characterization update

Appendix D
List of Presenters

The following people made presentations during Board or panel meetings held from September 1, 1993, through December 31, 1993. This list is arranged alphabetically by organization. The Board also wishes to thank those who made presentations to Board or panel members during various trips and tours taken during recent months.

American Electric Power Company
1 Riverside Plaza
Columbus, OH 43017
(614) 223-1500

Draper, E. Linn

Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439
(708) 252-2000

Bates, John K.

Babcock & Wilcox Fuel Company
101 Convention Center Drive
Las Vegas, NV 89109
(702) 794-1800

Benton, Hugh A.
Doering, William W.
Stahl, David

Beak Consultants, Ltd.
14 Abacus Road
Brampton, Ontario
Canada, L6 T 5B7
(416) 794-2325

Garisto, Nava C.

Blandy Experimental Farm
P.O. Box 175
Boyce, VA 22620
(703) 837-1758

Bowers, Michael

Boretec, Inc.
29100 Hall Street
Solon, OH 44139
(216) 248-3303

Home, Lok

Committee on Natural Resources
Subcommittee on Energy and Mineral Resources
818 O'Neill House Office Building
Washington, DC 20515
(202) 226-4086

Tousley, Dean

Critical Mass
215 Pennsylvania Avenue, SE
Washington, DC 20003
(202) 546-4996

Magavern, William

Disposal Safety Inc.
1660 L Street, NW
Suite 510
Washington, DC 20036
(202) 293-3993

Ross, Ben

Duke Engineering & Services, Inc.
526 South Church Street
P.O. Box 1004
Charlotte, NC 28201-1004
(704) 382-9800

Segrest, Alden M.

Wells, Alan H.

Duke Power
422 S. Church Street
Charlotte, NC 28202
(704) 382-4080

Rasmussen, Bob

E.R. Johnson Associates, Inc.
2650 Park Tower Drive
Vienna, VA 22180
(703) 204-8920

Clark, Jim K.

EG&G Energy Measurements, Inc.
101 Convention Center Drive
Suite 1010
Las Vegas, NV 89109
(702) 794-7474

Green, Ron A.
Ostler, Kent
Rakestraw, Danny L.
Raustenstrauch, Kurt R.
Wills, Cathy

Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, CA 94304
(415) 855-2000

Shaw, Robert A.
Starr, Chauncey
Williams, Robert F.
Yang, Rosa L.

INTERA, Inc.
2650 Park Tower Drive
Suite 800
Vienna, VA 22180
(703) 204-8849

Andrews, Robert
Duguid, James

Intera Information Technologies
3609 S. Wadsworth Boulevard
Denver, CO 80127
(303) 985-0005

Apted, Mick J.

J.E. Friant & Associates
1352 SW 175th
Seattle, WA 98166
(206) 243-2558

Friant, James E.

J.K. Research Associates, Inc.
2650 Park Tower Drive
Suite 800
Vienna, VA 22180
(703) 204-8561

Cotton, Tom

L. Lehman & Associates, Inc.
1103 West Burnsville Parkway
Suite 209
Burnsville, MN 55337
(612) 894-0357

Lehman, Linda

Lawrence Berkeley Laboratory
University of California
One Cyclotron Road
Berkeley, CA 94720
(510) 486-4000

Bodvarsson, Gudmundur
Myer, Larry
Pruess, Karstein
Tsang, Chin-Fu

Lawrence Livermore National Laboratory
University of California
P.O. Box 808
Livermore, CA 94550
(510) 422-1100

Bourcier, William L.
Buscheck, Thomas
Glassley, William

Halsey, William
McCright, Daniel
O'Connell, William J.
Palmer, Cynthia
Ramspott, Lawrence
Steward, Steven A.
Stout, Ray B.
Van Konynenburg, Richard A.
Wilder, Dale
Wolery, Thomas J.

Los Alamos National Laboratory
101 Convention Center Drive
Suite 820
Las Vegas, NV 89109
(702) 794-7097

Elkins, Ed Z.
Crowe, Bruce M.
Bish, David

Los Alamos National Laboratory
P.O. Box 1663
Los Alamos, NM 87545
(505) 667-5061

Poths, Jane
Valentine, Gregory A.

Massachusetts Institute of Technology
77 Massachusetts Avenue
54-1120
Cambridge, MA 02139
(617) 253-2927

Hodges, Kip

Maxwell S-Cubed Division
3398 Carmel Mountain Road
San Diego, CA 92121
(619) 453-0060

Garg, Sabodh

Mifflin & Associates, Inc.
3230 E. Flamingo Road
Suite 205
Las Vegas, NV 89121
(702) 434-9733

Mifflin, Martin

Morrison Knudsen Corporation
101 Convention Center Drive
Las Vegas, NV 89109
(702) 794-1800

Allan, James
Bhattacharyya, Kal
McKenzie, Daniel

National Association of Regulatory Utility Commissioners
Illinois Commerce Commission
160 North LaSalle Street
Suite 800
Chicago, IL 60601
(312) 814-2859

Shishido-Topel, Lynn

National Association of Regulatory Utility Commissioners
Iowa Utility Board
Lucas State Office Building
Des Moines, IA 50319
(515) 281-5325

George, Emmit

National Center for Atmospheric Research
1850 Table Mesa Drive
Boulder, CO 80303
(303) 497-1628

Thompson, Starley

National Congress of American Indians
Nuclear Waste Projects
900 Pennsylvania Avenue, SE
Washington, DC 20003
(202) 546-9404

Holden, Robert

Nevada Agency for Nuclear Projects
Nuclear Waste Project Office
Capitol Complex
Carson City, NV 89710
(702) 687-3744

Frishman, Steve
Johnson, Carl

Northern States Power
414 Nicollet Mall
Minneapolis, MN 55401
(612) 330-5750

Kapitz, Jon

Nye County
Nuclear Waste Repository Program
P.O. Box 1767
Tonopah, NV 89049
(702) 482-8183

Bradshaw, Les W.

Nye County
Nuclear Waste Repository Project Office
1925 North Lynn Street
Suite 500
Arlington, VA 22209
(703) 818-2434

Niedzielski-Eichner, Phillip A.

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

Mussler, Robert

Office of the Nuclear Waste Negotiator
3050 Lake Harbor Lane
Suite 100
Boise, ID 83703
(208) 334-9876

Lempesis, Charles B.

Ontario Hydro
Radioactive Materials Management Engineering
700 University Avenue
Toronto, Ontario M5G 1X6
Canada
(416) 592-6024

Rao, Mohan

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

Einziger, Robert E.
Engel, David W.
Gray, Walter J.

Reynolds Electrical and Engineering Company
101 Convention Center Drive
Las Vegas, NV 89109
(702) 794-7560

Frasier, Dale
Pritchett, Robert

S.H. Bartholomew, Inc.
P.O. Box 3360
Chico, CA 95927-3360
(916) 894-7411

Bartholomew, S.H.

Sacramento Municipal Utility District
Rancho Seco Nuclear Generating Station
14440 Twin Cities Road
Herald, CA 95638
(916) 452-3211

Miller, Ken

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

Barnard, Ralston W.
Blejwas, Thomas

Dockery, Holly
Pott, John
Rautman, Christopher
Ryder, Eric
Sanders, Thomas L.
Wilson, Michael L.

Sierra Club
National Energy Policy Committee
5711 Summerset Drive
Midland, MI 48640
(517) 835-1303

Sinclair, Mary P.

Smithsonian Institute
Department of Mineral Sciences
Washington, DC 20560
(202) 357-1947

Melson, William G.

Southwest Research Institute
Center for Nuclear Waste Regulatory Analyses
6220 Culebra Road
San Antonio, TX 78238
(210) 522-5263

Murphy, William

TRW Environmental Safety Systems
101 Convention Center Drive
Phase II, Suite P110
Las Vegas, NV 89109
(702) 794-1800

Sandifer, Robert
Saterlie, Steven
Sinnock, Scott
Younker, Jean

Table Top Consultants
17 Main Street
Rapid City, SD 57701
(605) 343-3534

Gnirk, Paul

Tennessee Governor's Office
308 John Sever Boulevard
Nashville, TN 37219
(615) 741-5782

Smith, Ben L.

The Robbins Company
P.O. Box 97027
Kent, WA 98064
(206) 872-0500

Dahmen, Neil

Tunnel Construction Consultant
636 Paloma Drive
Boulder City, NV 89005
(702) 293-6858

Sperry, P.E.

U.S. Department of Energy
Office of Civilian Radioactive Waste Management
1000 Independence Avenue, SW
Washington, DC 20585
(202) 586-2000

Barrett, Lake H.
Bartlett, John W.
Lemeshwesky, William A.
Milner, Ronald A.
Pomrehn, Hugo
Williams, Jeffrey R.

U.S. Department of Energy
Yucca Mountain Site Characterization
Project Office
101 Convention Center Drive
Las Vegas, NV 89109
(702) 794-7920

Blanchard, Maxwell
Boak, Jeremy
Clanton, Uel S.
Dyer, J. Russell
Gertz, Carl P.
Girdley, Arch
Harrison, Diane
Jones, Susan B.
Nesbit, Jeanne C.

Newbury, Claudia
Simecka, William
Smith, Linda
Stucker, Dean
Williams, Dennis

U.S. Geological Survey
345 Middlefield Road
Menlo Park, CA 94025
(415) 853-8300

Bredehoef, John
Duane, Champion
Herkelrath, William
Turrin, Brent

U.S. Geological Survey
Denver Federal Center
P.O. Box 25046
Lakewood, CO 80225
(303) 236-5900

Chornack, Michael
Hayes, Lawrence R.
Hoxie, Dwight T.
Kwicklis, Edward
Rousseau, Jospeh
Spengler, Richard W.
Stuckless, John S.
Luckey, Richard

U.S. Geological Survey
National Headquarters
Reston, VA 22092
(703) 648-4000

Roseboom, Eugene

U.S. Geological Survey - HRF
Nevada Test Site
P.O. Box 327
Area 25 - Building 4215
Mercury, NV 89023
(702) 295-5970

Flint, Alan

U.S. Nuclear Regulatory Commission
Washington, DC 20555
(301) 492-7000

Ahn, Tae M.
Bernero, Robert M.
Codell, Richard B.
Holonich, Joseph
McConnell, Keith
Trapp, John

Underground Consultants, Inc.
151 Kalmus Drive
Suite K-3
Costa Mesa, CA 92626
(714) 979-0262

Cronin, Hugh E.

University of California - Berkeley
Department of Geology and Geophysics
301 McCone Hall
Berkeley, CA 94720
(510) 643-7686

DePaolo, Donald

University of California - Riverside
Department of Earth Sciences
Riverside, CA 92521
(909) 787-3434

Wells, Steve G.

University of Nevada at Las Vegas
4505 Maryland Parkway
Las Vegas, NV 89154
(702) 895-3011

Ho, Chih-Hsiang
Martin, Mark W.
Smith, Eugene

University of New Mexico
Department of Geology
Northrop Hall
200 Yale Boulevard
Albuquerque, NM 87131
(505) 277-0111

Geissman, John W.
McFadden, Leslie D.
Perry, Frank

University of Utah
Department of Biology
Salt Lake City, UT 84112
(801) 581-7623

Ehleringer, James R.

University of Utah Research Institute
391-A Chipeta Way
Research Park
Salt Lake City, UT 84108
(801) 584-4428

Moore, Joseph

Virginia Power
5008 Dominion Boulevard
Glen Allen, VA 23261
(804) 273-2214

Smith, Marvin L.
Moore, F. Kenneth

Woodward-Clyde Federal Services
101 Convention Center Drive
Phase II, Suite P110
Las Vegas, NV 89109
(702) 794-1800

Statton, Thomas

Consultants:

Koranda, John
19522 Via Real Drive
Saratoga, CA 95070
(703) 837-1758

Matyas, Robert M.
409 Hanshaw Road
Ithaca, NY 14850
(703) 837-1758

Appendix E

Reports by the Nuclear Waste Technical Review Board

The following reports are available from the Nuclear Waste Technical Review Board.

First Report to the U.S. Congress and the U.S. Secretary of Energy March 1990

The first report sets the stage for the Board's evaluation of the Department of Energy's program to manage the disposal of the nation's spent fuel and high-level waste. The report outlines briefly the legislative history of the nation's spent fuel and high-level waste management program including its legal and regulatory requirements. The Board's origin is described, along with its protocol, panel breakdown, and reporting requirements. The report identifies major issues and highlights five cross-cutting issues.

Second Report to the U.S. Congress and the U.S. Secretary of Energy November 1990

The Board's second report begins with the background and framework for repository development and then opens areas of inquiry, making 20 specific recommendations concerning tectonic features and processes, geoengineering considerations, the engineered barrier system, transportation and systems, environmental and public health issues, and risk and performance analysis. The report also offers concluding perspectives on DOE progress, the state of Nevada's role in site characterization at Yucca Mountain, the project's regulatory framework, the nuclear waste negotiator, other oversight agencies, and the Board's future plans.

Third Report to the U.S. Congress and the U.S. Secretary of Energy May 1991

The third report briefly describes recent Board activities and congressional testimony. Substantive chapters cover exploratory shaft facility alternatives, repository design, risk-benefit analysis, waste package plans and funding, spent fuel corrosion performance, transportation and systems, environmental program concerns, the DOE task force studies on risk and performance assessment, federal quality assurance requirements for the repository program, and the measurement, modeling, and application of radionuclide sorption data. Fifteen specific recommendations are made to the DOE. Background information on the German and Swedish nuclear waste disposal programs is included in Appendix D.

Fourth Report to the U.S. Congress and the U.S. Secretary of Energy December 1991

The fourth report provides an update on the Board's activities and explores in depth the following areas: ESF construction; test prioritization; rock mechanics; tectonic features and processes; volcanism; hydrogeology and geochemistry in the unsaturated zone; the engineered barrier system; regulations promulgated by the EPA, the NRC, and the DOE; the DOE performance assessment program; and quality assurance in the Yucca Mountain project. Ten recommendations are made across these diverse subject areas. Chapter 3 offers insights from the Board's visit with officials from the Canadian nuclear power and spent fuel disposal programs. Background on the Canadian program is in Appendix D.

Fifth Report to the U.S. Congress and the U.S. Secretary of Energy June 1992

The Board's fifth report focuses on the cross-cutting issue of thermal loading. It explores thermal-loading strategies (U.S. and others) and the technical issues and uncertainties related to thermal loading. It also details the Board's position on the implications of thermal loading for the U.S. radioactive waste management system. Included are updates on Board and panel activities during the reporting period. The report offers fifteen recommendations to the DOE on the following subjects: ESF and repository design enhancements, repository sealing, seismic vulnerabilities (vibratory ground motion and fault displacement), the DOE approach to the engineered barrier system, and transportation and systems program status.

Sixth Report to the U.S. Congress and the U.S. Secretary of Energy December 1992

The sixth report begins with a summary of recent Board activities, congressional testimony, changes in Board makeup, and the Little Skull Mountain earthquake. Chapter 2 details panel activities and offers seven technical recommendations on the dangers of a schedule-driven program; the need for top-level systems studies; the impact of defense high-level waste; the use of high capacity, self-shielded waste package designs; and the need for prioritization among the numerous studies included in the site-characterization plans. In Chapter 3, the Board offers candid insights to the high-level waste management program in five countries, specifically those areas that might be applicable to the U.S. program including its size and cost, the responsibility of the utilities, repository construction schedules, and alternative approaches to licensing. Appendix F provides background on the Finnish and Swiss programs.

Special Report to Congress and the Secretary of Energy March 1993

The Board's seventh report provides a nontechnical approach for those not familiar with the details of the DOE's high-level nuclear waste management program. It highlights three important broad-based issues: (1) the program is driven by unrealistic deadlines, (2) there is no integrated waste management plan, and (3) program management needs improvement. The Board makes three specific recommendations: amend the current schedule to include realistic intermediate milestones; develop a comprehensive, well-integrated plan for the overall management of all spent nuclear fuel and high-level defense waste from generation to disposal;

and implement an independent evaluation of the Office of Civilian Radioactive Waste Management's organization and management. These recommendations should be implemented without slowing the progress of site-characterization activities at Yucca Mountain.

Underground Exploration and Testing at Yucca Mountain — A Report to Congress and the Secretary of Energy October 1993

The eighth report focuses on the exploratory studies facility at Yucca Mountain, Nevada: The conceptual design, planned exploration and testing, and excavation plans and schedules. In addition to a number of detailed recommendations, the Board makes three general recommendations. First, the DOE should develop a comprehensive strategy that integrates exploration and testing priorities with the design and excavation approach for the exploratory facility. Second, underground thermal testing should be resumed as soon as possible. Third, the DOE should establish a geoengineering board with expertise in the engineering, construction, and management of large underground projects.

Letter Report to Congress and the Secretary of Energy February 1994

Issued in letter format contemporaneously with impending legislative hearings on the Department of Energy's fiscal year 1995 budget and new funding mechanism sought by the Secretary of Energy, this eight-page report (ninth in the NWTRB series) restates a recommendation made in the Board's *Special Report*, that an independent review of the Office of Civilian Radioactive Waste Management's management and organizational structure be initiated as soon as possible. The report adds two additional recommendations: ensure sufficient and reliable funding for site characterization and performance assessment, whether the program budget remains level or is increased, and build on the Secretary of Energy's new public involvement initiative by expanding current efforts to integrate the views of the various stakeholders during the decision-making process — not afterward.

Appendix F
NWTRB Statements before Congress

Statement of Dr. John E. Cantlon, Chairman, Nuclear Waste Technical Review Board

At a joint hearing of the Subcommittee on Energy and Power, Committee on Energy and Commerce, and the Subcommittee on Energy and Mineral Resources, Committee on Natural Resources, U.S. House of Representatives, July 1, 1993

Chairman Sharp, Chairman Lehman, and members of the Subcommittees. I am John Cantlon, Chairman of the Nuclear Waste Technical Review Board. With me today are two other Board members, Drs. Clarence Allen and Dennis Price. We are pleased to be here today at this joint hearing to discuss key issues of concern related to the civilian radioactive waste management program. I will provide a brief statement summarizing the findings of the Board's recent *Special Report to Congress and the Secretary of Energy*, and, with your permission, request that the full text of the Report — some 20 pages — be entered into the record.

As you know, the Board's congressional mandate is to review the activities undertaken by the DOE to evaluate the potential suitability of the site at Yucca Mountain, Nevada, for a permanent repository for the disposal of spent fuel and about 8,000 metric tons of high-level defense waste. Congress also charged the Board with evaluating the DOE's plans to package and transport the waste that would be disposed of at the repository. We are required to report our findings and recommendations twice a year to Congress and the Secretary of Energy.

Our first six reports dealt primarily with technical aspects of the DOE program. However, as our review has continued, it has become clear that in certain cases it is difficult to separate technical decisions from the policies that guide them. Consequently, in March of this year, the Board released a more broadly based *Special Report to Congress and the Secretary of Energy*. The Board's primary objective in writing a short special report was to make a timely and constructive contribution to the improvement and progress of the civilian radioactive waste management program. Indeed the Board made its recommendations at a time it hoped would be most useful to the Congress and the new Secretary. We would like to thank the Chairmen and members of the Subcommittees for providing us this opportunity to present the three major policy and management issues contained in the Board's report.

I will briefly summarize these issues in just a moment. But first, I want to emphasize that the Board believes there are many, very capable people working on this program. Also, based on currently available data, we see no technical reason for abandoning either the Yucca Mountain site or deep geologic disposal. Furthermore, the Board strongly believes that the concerns raised in our *Special Report* can and should be addressed without slowing the momentum of important site-characterization activities currently under way at Yucca Mountain. I also would like to point out that the Board's *Special Report* was released just as Secretary O'Leary assumed leadership of the DOE. Consequently, some of the issues raised may be addressed as the Secretary continues her review of the program. That said, I will briefly summarize the observations contained in our *Special Report* and outline the Board's recommendations.

First, the Board believes that it is highly unlikely that the DOE will meet the 1998 date for waste acceptance at an MRS or its 2010 deadline for beginning repository operations. The Board is concerned that attempting to meet these unrealistic deadlines may cause the DOE to make important decisions without performing sufficient long-term testing and scientific analyses. This could cause licensing problems, increase overall program costs, and ultimately delay the program.

For example, in its fifth report, the Board stated that the DOE's baseline thermal-loading strategy lacked an adequate technical basis. This is especially important because the thermal-loading strategy selected may be fundamental to the performance of the repository and affects many aspects of waste disposal, including the size and design of the repository, ageing of the spent fuel, and the design of the waste package. The Board recommended that the DOE undertake a comprehensive evaluation of alternative thermal-loading strategies, and the M&O contractor has initiated some work in this area. However, the heater tests needed to support this important decision are not planned to begin until 1996. Several DOE contractors have commented to the Board that these tests could take up to a decade or more to complete. The Board is concerned that the DOE's repository development schedule may not allow sufficient time to complete these and other essential scientific tests.

Therefore, recognizing the need for a schedule to measure progress and maintain program momentum, the Board recommended that the DOE concentrate on establishing and meeting important intermediate goals — such as getting underground, determining site suitability, and completing essential scientific testing. Adopting this approach could help the DOE avoid costly errors, save money, and speed *real* program progress in the long run. It also could facilitate the licensing of the facility, should the site be found suitable. Secretary O'Leary has recently indicated that final deadlines will not compromise technical requirements. The Board welcomes this assurance and looks forward to seeing tangible evidence of such a policy.

The Board's second major concern relates to the DOE's overall plan for managing civilian spent fuel and defense high-level waste. Since it issued its first report, the Board has repeatedly recommended that the DOE approach the management of spent fuel and high-level waste as an integrated system that includes storage, transport, and disposal. Many advantages to this approach are enumerated in the Board's *Special Report*. Unfortunately, the DOE's current plan is not well integrated and contains significant gaps.

For example, even if the currently planned monitored retrievable storage facility and a repository are constructed and operating by the dates in the DOE's current optimistic schedule, substantial amounts of spent fuel will remain at utility reactor sites for decades. Despite this, the DOE's current plan does not consider the implications of extended at-reactor storage for other parts of the waste management system. In addition, the impact on the repository of the disposal of high-level defense waste and other high-level wastes has not been thoroughly evaluated and integrated into an overall program plan.

The DOE has recognized the existence of problems in this area, and in 1991 hired an M&O contractor to integrate the various activities and entities involved in the program. The M&O has made some progress in meeting this objective. However, the Board believes that more work on developing an overall system framework for the program is needed.

To that end, the Board recommended in its *Special Report* that the DOE place a high priority on developing a comprehensive, well-integrated plan for managing all the spent fuel and high-level waste that eventually may find its way into a permanent repository. Such a plan should take into consideration the interdependent nature of the system and subsystem components involved in storage, transport, and disposal of radioactive waste. Secretary O'Leary has recently called for the appointment of a chief scientist for the Yucca Mountain Project Office; this is one step that could improve the integration of site-characterization activities.

The third and final issue raised in the Board's *Special Report* focuses on the organizational structure and program management of the Office of Civilian Radioactive Waste Management. As I mentioned before, there are many, very capable people working on this program. However, the large number of organizations involved, the program's multilayered organizational structure, and the fact that the entities are geographically dispersed create substantial challenges for program managers. And responsibility for decision making seems to be shared among the people at headquarters, the project office, the M&O contractor and other private contractors, the national labs, and the U.S. Geological

Survey. Furthermore, in the Board's view, the M&O contractor, which was hired to integrate the program, is not being used as effectively as it could be.

The Board also is concerned about the allocation of program funds. The very high overhead and infrastructure costs for the program leave limited amounts for actual site work and other important research and development.

In light of these concerns, the Board recommended that an independent evaluation of OCRWM's management and organizational structure be undertaken. By this we do *not* mean to suggest reconsidering the overall objectives or policies underlying the development of a deep geologic repository. I also would like to clarify that such an independent management evaluation would, by definition, *not* be an internal review conducted by the DOE.

The Board notes with interest that several issues raised in its *Special Report* — specifically the optimistic nature of the schedule, the risk of short-circuiting important scientific tests, and the relatively small amount of funding available for site-characterization activities — are quite consistent with the findings in the GAO report that also will be discussed today. However, there are differences in the bases for the findings in the two reports that are worth noting. For example, the conclusion in the GAO's report that site investigation may take 5-13 years longer than currently scheduled is based primarily on its evaluation of past and projected DOE program funding requests; whereas the Board arrived at its observation that the current schedule is unlikely to be met by estimating the actual time that will be required to complete some critical scientific tests. Although we have said that adequate and predictable funding should be provided for the program, the Board believes that simply increasing program funding will not ensure that the DOE will meet its 1998 and 2010 deadlines. In addition, in making its observation about the limited availability of funding for site work and research and development, the Board considered only the impact of the Yucca Mountain project's infrastructure costs. The GAO considered in its calculations the funding requirements for transportation casks and siting a centralized monitored retrievable storage facility.

As pointed out in the GAO report, the funding priorities given to siting a monitored retrievable storage facility and transporting spent fuel to such a facility by 1998 have substantially shifted support away from activities related to repository development. This is an example of how decisions made about one component of the waste management program may have significant consequences for another part of the program. It also demonstrates the importance of resolving the policy issues associated with the acceptance of spent fuel. These difficult issues need to be addressed by Congress, the DOE, the utilities, and the other stakeholders.

Chairman Sharp and Chairman Lehman, in closing, I would like to emphasize that the job the Congress has given the DOE is important and necessary, but it also is difficult and complex. This is true not just because of the scientific and technical questions associated with the development of this first-of-a-kind geologic repository, but also because of the many political, institutional, and public acceptance considerations that are involved. However, the Board believes that without a strong and defensible scientific and technical underpinning the other challenges facing the program will be even more formidable.

We are all working toward the same objective — finding a safe and environmentally acceptable long-term option for managing the nation's spent fuel and high-level waste. The Board looks forward to continuing to play a role in this crucial national effort.

Thank you once again for allowing the Board to present its views. My colleagues and I will be happy to respond to any questions you may have.

Statement of Dr. Sherwood C. Chu, Senior Professional Staff, Nuclear Waste Technical Review Board

At a hearing of the Subcommittee on Energy, Committee On Science, Space, and Technology, U.S. House of Representatives, Newport News, Virginia, November 8, 1993

Madame Chairman, and members of the subcommittee. I am Sherwood Chu, a member of the senior professional staff of the Nuclear Waste Technical Review Board. With me today is my colleague, Dr. Carl Di Bella. We provide the technical staff support to the Board in the areas of transportation, storage, and the engineered barrier system. On behalf of the Board, I would like to thank you for inviting us to participate in today's hearing. Dr. John Cantlon, the Board's chairman, could not be here today, so he has asked us to represent the Board this morning.

Very briefly, our Board was created by Congress in the Nuclear Waste Policy Amendments Act of 1987. Congress directed us to evaluate the scientific and technical activities associated with the DOE's program to manage commercial spent fuel and defense high-level waste. Our Board is *not* part of the Department of Energy.

The subcommittee has asked the Board to comment on the potential of the multipurpose container concept and related research and development needs. While addressing the potential of the multipurpose container concept, I will outline for you some of the Board's concerns. Several of these concerns were discussed at length at a recent Board meeting held last week on the broader subject of the interim storage of spent nuclear fuel. Finally, I will make a few statements about the research and development needed before final decisions about a multipurpose container can be made.

The potential of the MPC concept

Let me first emphasize that the multipurpose container — the MPC — is presently only a concept. As a *concept*, the Board believes it offers potential. It has the potential of addressing a number of broad issues that the Board has identified in the past, including, enhancing safety; developing a systems approach to manage the storage, transport, and disposal of spent fuel; and standardizing the features in the waste management system.

The Board has for some time been urging the DOE to assess alternatives to its current "baseline" design concept for managing the disposal of the nation's spent fuel and high-level waste. From early on, the Board has been concerned about the many handlings and transfers of spent fuel required in this "baseline" scenario, which calls for the use of different single-purpose casks for storage, transportation, and disposal. To reduce handling

and enhance safety throughout the system, the Board recommended that the DOE look at alternative technologies, including the development of a universal, or multipurpose container concept that could be used for storage, transport, *and* disposal.

The MPC concept also could substantially reduce the potential problems arising from the proliferation of nonstandard technologies. For example, as some utilities begin to run out of storage space in their spent fuel pools, they are facing the need for the dry storage of spent nuclear fuel at their reactor sites. As the need for dry storage has increased, a number of different storage systems have been installed by the utilities. A diversity of technologies may pose problems of compatibility for the civilian radioactive waste management system.

An additional advantage of the MPC concept is that it, by its very nature, may force a systems approach to the waste management process. If the MPC concept is developed properly, the DOE will have looked at the storage, transport, and disposal functions in an integrated manner. However, the Board has concerns about how the MPC concept may be developed.

Board concerns

As mentioned already, the Board has consistently stated that the functions of storage, transportation, and disposal are strongly interconnected. Because of this, the Board has urged the DOE to use systems analysis when making decisions about different parts of the waste management process. This kind of work is a prerequisite for design, and, although some future iteration may be necessary, systems analysis should not entail a large-scale effort. Doing a systems analysis will allow the DOE to evaluate the pros and cons of alternative concepts for major pieces of the system.

A systems analysis also will provide a technical basis for making decisions related to various MPC performance criteria and design features. Such an analysis should take into account aspects of the rest of the waste management system, including, for example, the MPC's effects on the design of the repository and thermal-loading options. A systems analysis should also be performed to determine if the various potentials of the MPC concept — such as safety enhancement and cost savings — can indeed be achieved. As was noted at our meeting last week, a complete systems analysis is not currently available, and the DOE itself acknowledged that much remains to be done in this area.

In its March 1993 *Special Report to the U.S. Congress and the U.S. Secretary of Energy*, the Board observed that the overall civilian radioactive waste management program is being driven by unrealistic deadlines. This appears to be the case with the MPC as well. The DOE seems to be rushing to settle on a design so the MPC will be ready to meet the 1998 date for federal acceptance of spent nuclear fuel from the utilities. But, if systems analyses have not been completed, the premature specification of a design could preclude more desirable options later on — or even result in program delays and additional costs.

Another of the Board's concerns is that to meet the 1998 date, the disposal function may be given low priority during MPC development. This could result in a dual-purpose container that can be used only for transport and storage. The Board believes that if the disposal function is lost, the appeal of the MPC concept will be substantially diminished. Therefore, when assessing any multipurpose container concept, the DOE should evaluate its potential for transport, storage, *and* disposal of the spent fuel — *not* just storage and transport.

MPC research and development

I would like to make some brief comments about MPC research and development. In the absence of sufficient analysis to support the definition of the MPC's desired design features, it is too early to talk about an MPC research and development program except in a very general sense. However, it is important to note that the Board has long advocated sufficient and consistent funding for efforts to develop a robust, long-lived disposal waste package, which, after burial, should work together with the geology of the site to form a multibarrier, defense-in-depth approach to waste isolation. To be able to project the performance of waste package materials with reasonable confidence for several thousand years, careful, long-term research will be required. Unfortunately, the level of research and development related to selecting materials for the disposal waste package has been very low; much work in this area has not yet been planned. Research work also is needed to evaluate the potential problems involved with welding thick packages filled with spent fuel and, most particularly, on developing methods for examining the welds of such packages. The Board has repeatedly urged the DOE to increase its emphasis on research and development in the area of waste package design.

In closing, I would like to reiterate that the Board believes that the MPC has potential as a concept. However, the Board has a number of concerns about how the development of the MPC concept progresses. Technical decisions concerning the MPC design should not be driven by a desire to meet a deadline; the choice of the ultimate MPC design should be supported by a thorough systems analysis; and the disposal function should not be sacrificed during design efforts.

Thank you. We would be happy to respond to questions.

Statement of Dr. John E. Cantlon, Chairman, Nuclear Waste Technical Review Board

Before the Subcommittee on Energy and Water Development, Committee on Appropriations, U.S. House of Representatives, March 14, 1994

Mr. Chairman and members of the Subcommittee: I am John Cantlon, Chairman of the Nuclear Waste Technical Review Board. With me this morning is another member of the Board, Dr. Warner North. We are pleased to be here today to present the Board's appropriation request for fiscal year 1995.

I will begin, this morning, by briefly summarizing our request. In addition, I will outline three recommendations concerning the civilian radioactive waste management program that were included in a letter report submitted by the Board to the Secretary of Energy and Congress three weeks ago. A detailed document containing the specifics of our request and supporting data also has been prepared. With your permission, Mr. Chairman, I would like to submit this more detailed document together with the Board's letter report for inclusion in the hearing record.

Appropriation request

The Board's appropriation request for fiscal year 1995 is $2,664,000. This will partially fund the Board's activities. The balance of the funds required will come from an unobligated carryover from fiscal year 1994 in the amount of $709,000.

Background

Mr. Chairman, as you know, in 1987, Congress created the Nuclear Waste Technical Review Board to provide an unbiased review of the technical and scientific validity of activities undertaken by the Secretary of Energy related to the management of civilian spent fuel and some defense high-level waste. In the same law, Congress directed the Department of Energy to evaluate a site at Yucca Mountain, Nevada, to determine if it is suitable for the development of a permanent underground repository for the disposal of this waste.

During its five-year review, and especially during the past year, the Board has witnessed considerable progress in the program. For example, after several delays, underground excavation of the exploratory facility at Yucca Mountain has begun, and the management and operating contractor is beginning to integrate all the components of the waste management system. The Board believes strongly that the momentum of these activities should be maintained.

The Board also commends Secretary O'Leary for her recent efforts to improve the program. For example, she has created the position of chief scientist; she is proceeding with a financial and management review of the Yucca Mountain project; and, she has taken steps toward broadening stakeholder participation in the program. In addition, Dr. Daniel Dreyfus was confirmed as director of the Office of Civilian Radioactive Waste Management on October 7, 1993.

The Board is encouraged by these actions. However, we believe much remains to be done. And from comments he has made to the Board and others, it is apparent that in the very short time he has been director, Dr. Dreyfus also has recognized that a number of key issues need to be addressed in the coming months.

In an effort to provide timely and constructive comments on some of these important issues, the Board on February 24, 1994, submitted a short letter report to the Secretary and Congress. The letter report contains the following three recommendations.

Summary of Recommendations

First, the Board reiterates its recommendation of a year ago that an independent review of the entire OCRWM's management and organizational structure should be initiated as soon as possible. (I would just parenthetically add here that the review of the *project* that has been initiated by the Secretary could be part of this overall review. However, it is not an adequate substitute for the more comprehensive review of organizational structure and management of the *entire* program we are recommending.)

The Board believes that such an independent review of the OCRWM will provide an excellent basis for the needed reshaping of the program, regardless of future funding scenarios. Considering the proposed changes in both the method and levels of funding for the OCRWM in fiscal year 1995, this review is needed now more than ever. The Board believes that improving the program's management and organizational structure will contribute to the quality and timeliness of the scientific and technical bases for important site-characterization or other critical research essential to an effective program.

Such a review should not take long, nor should it require a large staff. More important, the Board believes that program activities should not be impeded while this review is taking place. In fact, we believe that the review we have recommended could actually speed real program progress.

Second, the Board believes that whether or not the program receives the increase in funding it has requested, program management should ensure sufficient and reliable funding for site-characterization and performance assessment activities. During the past three years, the OCRWM has cited a lack of funds as the reason for postponing or slowing critical site-characterization activities. For example underground excavation, surface-based testing, and research related to engineered barriers and a robust, long-lived waste package, have all been delayed to one degree or another due to funding considerations. At the same time, however, the number of contract employees working on the program has continued to grow.

The Board believes that relatively too little funding has been allocated to the direct costs of determining whether the Yucca Mountain site is a suitable location for a permanent repository.

Program managers need to place a greater emphasis on a number of important site-characterization and research activities. At the very least, sufficient monies should be guaranteed for those activities that will expedite finding any features that could disqualify the site.

Finally, the Board recommends that the OCRWM build on the Secretary's new public involvement initiative by expanding current efforts to integrate the views of the various stakeholders into the civilian radioactive waste management program during the decision-making process — not afterward.

In conclusion, Mr. Chairman, the Board recognizes that in the United States, as well as in all other countries dealing with these issues, there are no quick fixes for the challenges associated with the safe, permanent disposal of nuclear waste. With that said, however, the Board strongly believes that, no matter what future program funding trends may be, implementing the Board's recommendations will help achieve a more efficient and cost-effective program.

As the only agency charged by Congress with providing an independent review of all technical and scientific aspects of the DOE's efforts to dispose of high-level radioactive waste, the Board looks forward to continuing to report to Congress and to making recommendations to the Secretary as we work together to improve and facilitate progress in this important program.

Thank you.

Dr. North and I will be happy to respond to questions.

Appendix G
Department of Energy Responses to the Recommendations in the Board's Reports

As part of its effort to keep the Nuclear Waste Technical Review Board informed of its progress, the Department of Energy (DOE) submits a summary of initial responses to recommendations the Board makes in its reports. Included here are the DOE's responses to the (1) *Sixth Report (December 1992), (2) the NWTRB Special Report* (March 1993), and (3) the report on *Underground Exploration and Testing at Yucca Mountain* (October 1993). Inclusion of DOE's responses does not imply Board concurrence.

Department of Energy
Washington, DC 20585

April 4, 1994

RECEIVED
APR 4 1994
NUCLEAR WASTE T.R.B.

Dr. John E. Cantlon
Chairman
Nuclear Waste Technical Review Board
1100 Wilson Boulevard
Arlington, Virginia 22209

Dear Dr. Cantlon:

This letter transmits the Department of Energy's response to the Nuclear Waste Technical Review Board's report entitled *Underground Exploration and Testing at Yucca Mountain* that was issued on October 15, 1993. Our response to the Board's observations and recommendations may be found in the enclosure.

As noted in the Board's report, our plans for underground exploration and testing, including the design of the Exploratory Studies Facility, have evolved substantially over the past few years. Many of these changes resulted from the Board's previous reports. The Department appreciates the Board's latest observations and recommendations, and as noted in our response, intends to work with the Board and its staff to resolve these issues. In our response, we have identified areas where further elaboration or clarification is needed to fully address the concerns that the Board has raised. We will provide a supplemental response to each issue when we receive this information.

In response to the widespread criticism regarding project management, the Department of Energy has taken significant steps to improve our management practices. We are committed to these efforts to ensure that the increased funds made available through the proposed special account for program expenditures will be effectively utilized to complete our priority activities. We believe that these efforts also address the concerns raised in the Board's latest report. For example, an independent financial and management review of the Yucca Mountain Site Characterization Project was initiated in January and should be completed late Spring 1994. This review will encompass an evaluation of the funding allocation decisions as the Board recommended. We intend to use the results of this review, along with the products of other management improvement initiatives to reduce infrastructure and to maximize the funds available for scientific studies at Yucca Mountain.

The Department appreciates the Board's constructive review and insightful recommendations regarding our technical program. We are looking forward to receiving the Board's views on our approach to addressing its latest concerns within the other constraints on the program. If you have any questions, please contact me at (202) 586-6850.

Sincerely,

Daniel A. Dreyfus, Director
Office of Civilian Radioactive
Waste Management

Enclosure

DOE Response to the Recommendations of the Nuclear Waste Technical Review Board in Its
Sixth Report to the U.S. Congress and the U.S. Secretary of Energy, December 1992

(Submitted to the NWTRB on May 11, 1993)

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 in the Office of Civilian Radioactive Waste Management.

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 seven reports to date. The sixth report, issued on December 23, 1992, includes seven recommendations in three broad areas: (1) transportation and systems; (2) the engineered barrier system; and (3) risk and performance analysis. Also included in the sixth report are observations and conclusions supporting a fourth broad subject area, international activities.

These recommendations, which are found on page XI of the Executive Summary, and the Departmental responses are presented in this report. In addition, the Department has chosen to respond in general to the observations and conclusions with regard to international activities. Each recommendation is quoted verbatim from the Board's report of December 23, 1992, and is followed by the response.

TRANSPORTATION AND SYSTEMS

These recommendations from the Board concern the interactions and interfaces between the various components of the waste management system and the Department's approach to managing and implementing the overall waste management system.

Recommendation 1:

To ensure the safe performance of the waste management system, the program should not be overly motivated by the need to meet a tight schedule driven by target dates. Instead, the Board urges the DOE to ground all major technical decisions in sound scientific analysis that includes the careful evaluation of alternatives.

Response:

The Department recognizes the Board's concerns regarding the Civilian Radioactive Waste Management Program's schedule, and understands the inherent risks in our efforts to maintain that schedule. At the same time, the Department is committed to achieving progress consistent with the mandates set forth in the Nuclear Waste Policy Act of 1982, as amended, to maintain the support of Congress and other program stakeholders. Intermediate milestones have been established in all major program areas to measure that progress. These intermediate milestones are consistent with the use of “interim goals” as recommended in the Board’s *Special Report*. However, system safety and scientific integrity will not be compromised in our efforts to maintain the schedule.

In response to the Board’s concerns, the program has placed increased emphasis on the implementation of an improved, top-level decision-making process, which requires that sound studies and analyses provide the basis for management decisions in the resolution of both technical and programmatic issues. This process includes the review of the issues and supporting analyses by an executive committee, composed of senior managers from all program elements, to ensure that the system-wide impacts are thoroughly understood before a decision is made.

In addition, the Department has recently completed a comprehensive review of the existing plans for system analyses and related activities with respect to the Board’s previous recommendations. This review has resulted in the development of an action plan, which was discussed with members of the Board’s technical staff in March, to ensure that the Department’s system analyses adequately consider the interdependent nature of waste storage, transportation, and disposal in the evaluation of alternative concepts.

Recommendation 2:

The Board continues to urge the DOE to conduct timely, iterative, top-level system studies so that the results can be used to identify enhancements, evaluate alternatives, rationalize acquisition decisions, and provide for contingencies, thus, reflecting sound program planning.

Response:

The Department recognizes the importance of timely system studies as a part of sound program planning and understands the Board’s concerns regarding the scope and underlying assumptions in the previous system studies. The program is performing iterative system studies to evaluate the merits or impacts of potential enhancements and alternative configurations before major design or acquisition decisions are made. In addition, the Working Group, introduced in the Department’s response to the previous Board recommendation, is currently evaluating the overall constraints and the underlying assumptions of the top-level system studies. This evaluation, undertaken in response to previous Board recommendations (June 1992), and the resulting recommendations will help focus the program’s system study effort.

Furthermore, the program is implementing a structured decision process, which requires that specific, appropriate system studies provide a sound technical basis for timely management decisions. The system studies will analyze and quantify the impacts of contingency scenarios and verify that adequate system flexibility will exist.

ENGINEERED BARRIER SYSTEM

The following Board recommendations pertain to the production of the defense high-level waste and its impact on various system parameters and the design of the engineered barrier system and its contribution to the overall system waste isolation performance.

Recommendation 3:

The DOE should establish and document for defense wastes the relationship between the requirements of the draft Waste Acceptance Preliminary Specifications document and the regulatory requirements of 10 CFR 60.

Response:

The regulatory requirements regarding high-level waste stated in 10 CFR 60, which are applicable to the waste producers, are incorporated in the program technical baseline in the Waste Acceptance System Requirements Document. The draft Waste Acceptance Preliminary Specification Document, referred to in the Board's recommendation, has been superseded by the Waste Acceptance System Requirements Document, which was approved in December 1992. This document, developed through a joint effort between the Office of Civilian Radioactive Waste Management and the Office of Environmental Restoration and Waste Management, sets forth the relationship between applicable 10 CFR 60 regulatory requirements and the defense and commercial high-level waste specifications.

The Waste Acceptance Systems Requirements Document provides technical criteria for acceptance of waste. Verification of compliance with this document will confirm that the canisters are of consistent quality and contain a durable glass. The high-level waste canisters will be designed to meet the criteria for waste form design provided in 10 CFR 60.135(c). The waste form will also contribute toward meeting the remaining design criteria for the waste package and the engineered barrier system performance objectives in 10 CFR 60.113. Therefore, the Waste Acceptance System Requirements Document addresses that portion of the overall regulation which pertains specifically to the waste form.

Recommendation 4:

A study should be initiated to assess the impact of the projected number of canisters of defense waste - projections range from 15,000 to 200,000 - on repository design and cost, as well as on total waste management system costs.

Response:

The Department is presently analyzing various pretreatment and disposal options for the tank wastes at the Department's Hanford facility in Washington, and at the Idaho National Engineering Laboratory. Therefore, a range of possible numbers of high-level waste canisters, based upon different disposal options, were discussed with the Board. The program has established a baseline documenting and controlling the number of high-level waste canisters for acceptance into the Civilian Radioactive Waste Management System. Currently, the Waste Acceptance System Requirements Document provides for the acceptance of up to 13,200 canisters of vitrified high-level waste for disposal in the first repository from Savannah River and Hanford. More recent estimates of the potential number of canisters of defense high-level waste, documented in the 1992 Integrated Data Base prepared for the Department by Oak Ridge National Laboratory, range from approximately 23,600 to 48,600 canisters. This estimate includes an assessment of the single shell tanks at Hanford. The system-wide impacts of these new estimates will be analyzed as the projections are refined. In the future, the technical baseline control process will ensure that changes in the allowable number of canisters will be assessed for impacts on the Civilian Radioactive Waste Management System, including impacts on repository design and cost.

In addition, the Department analyzes, on an ongoing basis, the impact of alternative waste quantities — both spent nuclear fuel and defense high-level waste — on the cost of the waste management system. The published Total System Life Cycle Cost (DOE/1990) reports consider a wide range of waste quantities from civilian and defense sources. In the fall of 1992, the Department initiated a study that focuses on the cost impacts of alternative projections of defense high-level waste, paying particular attention to the single shell tank waste at the Department's Hanford facility. The various pretreatment options and canister designs that are being considered may influence the number of shipments and emplacement method and, therefore, the disposal costs. In this study, which is still under way, a wide range in the projected number of canisters for Hanford waste are being analyzed for their cost implications.

The Department is also preparing a report to Congress on the adequacy of current programs and plans for the management of nuclear waste. The report, which is required by Section 803 of the Energy Policy Act of 1992, is due to be released on October 24, 1993. The purpose of the report is to determine whether the current programs and plans for the management of nuclear waste as mandated by the Nuclear Waste Policy Act of 1982, as amended, are adequate for the management of any additional volumes or categories of nuclear waste that might be generated by new nuclear power plants that might be constructed and licensed after enactment of the Energy Policy Act of 1992.

Recommendation 5:

The DOE should perform a study to determine if the planned methodology for estimating the radionuclide composition of filled defense waste canisters is adequate for compliance purposes.

Response:

The Waste Acceptance System Requirements Document provides the requirements for the acceptance of waste including the associated documentation and product specifications the waste producer is to provide for performance assessment and regulatory compliance purposes. The Civilian Radioactive Waste Management Program has established these requirements, in consultation with the waste producers and after review by the Nuclear Regulatory Commission, to ensure the methodology and documentation is adequate for regulatory compliance purposes. The waste producer, in turn, will develop the appropriate product description documents and control processes to ensure that the waste form and accompanying documentation complies with the Waste Acceptance System Requirements Document.

Specifically, the Waste Acceptance System Requirements document requires that the high-level waste producer report the estimated total and individual canister inventory of radionuclides (in Curies) that have half-lives longer than 10 years and that are, or will be, present in concentrations greater than 0.05 percent of the total radionuclide inventory. To document and substantiate inventory data, the producer is required to provide: (1) a Waste Form Compliance Plan, to show how they demonstrated compliance with this requirement; (2) a Waste Form Qualification Report, to document waste form testing and analysis results; and (3) Production Records. The current Waste Form Compliance Plan, dated March 1990, defines the Producer's strategy for complying with the Waste Acceptance System Requirements. The calculations, analyses, and sampling techniques the Producer plans to use, and the estimated errors are included in this document. The methods include: estimates based on contents of unprocessed waste, and the analysis of actual final waste form samples.

Recommendation 6:

The Board strongly recommends that high-capacity, self-shielded waste package designs — including designs compatible with multipurpose cask concepts — be included in the set of waste package conceptual designs now being developed.

Response:

The Department has included a large, self-shielded, waste package incorporating a multi-purpose canister among the design concepts now being considered during the Advanced Conceptual Design phase of the waste package development program.

As discussed with the Board at the January 5-6, 1993, meeting, the program has recently completed an integrated study of the feasibility of the multi-purpose canister concept. On the basis of this study and other input, the Department has decided that the multi-purpose canister concept merits further analysis. The program will develop design criteria that identify requirements that a canister / cask must meet for storage, transportation, and disposal. Also discussed with the Board in January, self-shielded canister concepts were considered in the study and will be considered during the waste package advanced conceptual design phase.

RISK AND PERFORMANCE ANALYSIS

This Board recommendation pertains to the prioritization of the various studies in the site characterization of the candidate Yucca Mountain repository site.

Recommendation 7:

Based on Sandia's and Pacific Northwest's total system performance assessments, the Early Site Suitability Evaluation, and other relevant and available studies, the DOE should provide a timely reassessment of its priorities among the numerous studies that are part of site-characterization plans. Of critical importance is the definition of those data most needed for assessing site suitability.

Response:

The Department continually reassesses the priorities for site studies on the basis of all relevant information. The Department evaluates near-term priorities as schedules for site activities are developed. The relative benefits of data to be derived from the various trenching, laboratory, and drilling activities are considered as near-term operational plans are finalized. The Department establishes longer term priorities as a part of the annual budget allocation, especially with regard to priorities for surface, laboratory, and preparation for testing in the Exploratory Studies Facility.

The Department developed a focused approach for prioritizing the site testing program during late 1991 and early 1992. The Department integrated and used information from previous performance assessments, the Early Site Suitability Evaluation, and other relevant sources as input to a spreadsheet prioritization model. The criteria to prioritize tests were: (1) detection of unsuitable conditions; (2) improving the basis for regulatory compliance; (3) increasing scientific confidence; and (4) cost. By weighting the criteria in the spreadsheet model according to current priorities, the Department can produce a rank-order of site studies to facilitate prioritization. Rankings of the top 20 studies on each criterion are shown in Figure 1.

Figure 1. Rank order for the top 20 studies in each criterion.

Unsuitability	Regulatory Compliance	Scientific Confidence
Surface-based unsaturated zone percolation	Surface-based unsaturated zone percolation	Surface-based unsaturated zone percolation
Exploratory Studies Facility unsaturated zone percolation	Exploratory Studies Facility unsaturated zone percolation	Exploratory Studies Facility unsaturated zone percolation
Unsaturated zone hydrochemistry	Waste package environment hydrology	Site saturated zone flow system
Waste package environment hydrology	Postemplacement environment changes	Site specific subsurface information
Gaseous radionuclide transport	Site saturated zone flow system	Engineered barrier system field tests
Unsaturated zone infiltration	Man-made materials	Quaternary regional hydrology
Site saturated zone flow system	Unsaturated zone hydrochemistry	Site area faulting
Postemplacement environment changes	Site specific subsurface information	Faulting near facilities
Stratigraphic units	Engineered barrier system field tests	Demonstrate applicability
Structural features	Unsaturated zone infiltration	Natural resources
Saturated zone hydrochemistry	Unsaturated zone fracture flow	Volcanic features
Unsaturated zone gaseous movement	Saturated zone hydrochemistry	Unsaturated zone infiltration
Modern regional climate	Dissolved species	Unsaturated zone fracture flow
Mineralogy and petrology	Quaternary regional hydrology	Stratigraphic units
Batch sorption	Stratigraphic units	Structural features
Dissolved species	Structural features	Regional saturated zone flow system
Water movement test	Regional saturated zone flow system	Batch sorption
Regional saturated zone flow system	Waste package environment mechanical attributes	Waste package environment hydrology
Lake, playa, and marsh	Water movement test	Postemplacement environment changes
Terrestrial paleoecology	Diffusion	Man-made materials

INTERNATIONAL ACTIVITIES

The following is a response to the Board's observations and suggestions derived from their review of waste management programs in other countries, as presented in the Sixth Report.

"In summary, the Nuclear Waste Technical Review Board would like to suggest that both Congress and the U.S. Secretary of Energy review the U. S. program with respect to specific approaches countries visited by the Board are taking in the design and implementation of their programs to manage the disposal of spent-fuel and high-level radioactive waste." (NWTRB Sixth Report, pg. 58, Summary Section, first paragraph).

The Department commends the Board's efforts to survey the status and progress of radioactive waste management programs in other countries, to interact with officials involved with waste management programs abroad, and to compare and contrast the approaches being used in these foreign programs with our program. The Department concurs with the Board's statements about the difficulty in comparing the approaches taken by other countries with those in the United States because of the differing historical, cultural, and institutional frameworks which these programs have developed. In spite of these important differences, the Department believes strongly in the value of keeping abreast of the approaches and developments in other programs and actively interacting with the international waste management community.

The Board's interest and comments come at an opportune time. The program periodically performs a review of the trends apparent in the design and management of foreign waste programs, as well as technical approaches and strategies. The intent of these periodic reviews is to identify management as well as technical strategies and approaches that may serve as models for the program, or that could be adapted to fit the requirements and constraints of the United States situation. The last review was done in 1989, and the program is currently performing another such review. The Board's observations about waste management programs abroad are welcomed, and we are considering them in our ongoing review. We look forward to informing the Board of the results of our review and, if desired, interacting with the Board during its progress. Should Congress also elect to follow the Board's suggestion to review the program from an international perspective, the Department would look forward to supporting their efforts as requested.

Although we share the Board's enthusiasm for the potential for deriving benefits from the foreign example, we agree that the degree to which foreign approaches can serve as domestic models is limited by the unique features of the program. As a consequence of these unique features (identified in Chapter 3, page 39), the research and development priorities and program management structures of other countries can be quite different than in the United States and not always transferable. There are also institutional differences between the United States and other countries which limit direct comparison. The Board recognizes the size of the Federal research establishment involved in the program and the impact on cost. The technical community in the United States is sufficiently large to allow for many external independent review groups to extensively monitor and evaluate the program progress and technical quality. In addition, the United States has a complicated system of local, State, and Federal levels of program review and involvement, as well as a system of public hearings and judicial redress through which controversies are addressed. The Department of Energy must be responsive to all of these diverse constituencies. While all of these factors add to the cost of the program, the elimination of them in order to reduce cost or to preserve schedules is unlikely to be acceptable.

However, there are many areas where approaches and technology (including operational experience) from abroad may be transferable to the program and particularly timely. Recently the program has undertaken initiatives to carefully examine the utility of standardized multi-purpose containers to be used for transportation, storage, and disposal, and to define a strategy for a phased approach to licensing the disposal system. We are particularly interested in available technology, approaches, and experience from abroad concerning these subjects. Other examples of potential transferability include waste package development, techniques, and experience in public education and involvement. We are examining the international experience in these and other areas for insight and opportunities that will help us better execute the program in a technically defensible and cost-effective manner. The Board's observations are appreciated, and we look forward to further interactions with the Board on these subjects.

DOE Response to the Recommendations of the Nuclear Waste Technical Review Board in Its

Special Report to Congress and the Secretary of Energy, March 1993

(Submitted May 14, 1993)

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 in the Office of Civilian Radioactive Waste Management.

The Board is required to report, not less than two times per year, to Congress and the Secretary of Energy, its findings, conclusions, and recommendations. The Board has issued seven reports to date. The *Special Report*, issued on March 2, 1993, is the most recent of these reports.

The following responds to the three observations and related recommendations found on page v of the Executive Summary in the *Special Report*. Each set of observations and related recommendation is quoted verbatim from the Board's report of March 2, 1993, and is followed by the Department's response.

Observation 1: Unrealistic Deadlines Are Driving the Program

The DOE's civilian radioactive waste management program is being driven by unrealistic deadlines to begin federal acceptance of spent fuel from the utilities in 1998, and to commence repository operations in 2010. Repository development schedules do not reflect a realistic assessment of the technical requirements associated with the development of a first-of-a-kind geologic repository. Attempting to meet these unrealistic deadlines may force the DOE to make important technical decisions without first performing the appropriate technical and scientific analyses.

Recommendation:

The Board recommends a more flexible schedule for the development of this first-of-a-kind geologic repository. Such a schedule should contain realistic target dates for achieving important interim goals, such as getting underground, determining site suitability, and completing critical testing. The DOE should set testing and funding priorities to achieve these interim goals. Once some of the interim goals have been achieved, it should become easier to realistically predict long-term schedules for repository operation.

Response:

The Department realizes that the program has fallen into the untenable position of attempting to meet schedules without adequate funding. The Secretary has recently directed that the program not be inappropriately schedule driven, with the attendant risk of sacrificing high-quality science to meet artificial and unrealistic deadlines. However, the Department believes that measurable and continued progress toward meeting program goals is essential to maintain the support of Congress and other program stakeholders. Therefore, the Civilian Radioactive Waste Management Program will develop a flexible schedule based on interim milestones. Presently, the program is focusing on achieving the goal of determining the suitability of the Yucca Mountain site for the development of a geologic repository. In parallel with site characterization activities, a range of options with respect to initiating waste acceptance in 1998, including utility compensation alternatives, a full range of options for the near-term storage of spent fuel pending ultimate disposal, and alternative repository licensing strategies will be examined in consultation with stakeholders.

The Secretary has also indicated that the program suffers from the lack of a process for ensuring the serious and systematic involvement of program stakeholders in shaping program decisions. To improve this area, Secretary O'Leary has directed that the program confer with key national stakeholders and report back with a plan for broad consultation on specific issues. As a part of that consultation, the program will work with stakeholders to develop, for the Secretary's approval, a process for their regular involvement in the program.

In addition, the Department believes that consistent funding is essential to sound program management and sustaining program progress. Therefore, the Secretary has also directed that a proposal for revolving fund legislation be developed for consideration.

Observation 2: The Program Needs an Integrated Waste Management Plan

Existing DOE plans for managing spent fuel and high-level waste are not well integrated and contain significant gaps. In developing its plans, the DOE has not considered sufficiently the interdependent nature of the system and subsystem components involved in the transport, storage, and disposal of radioactive waste. Consequently, crucial decisions may be made without an adequate technical evaluation of their impacts on other system components.

Recommendation:

The Board recommends that the DOE place a high priority on developing a comprehensive, well-integrated plan for the management of all spent fuel and high-level waste, including its storage, transport, and disposal. This plan should be based on a systematic assessment of the interdependent nature of the various waste management components. It should include an evaluation of the following:

- *a range of options for accomplishing the long-term storage of all spent fuel;*
- *the development of a multi-purpose container concept that will help minimize handling of the spent fuel;*
- *the incorporation of system safety and human factors engineering to enhance the safety performance of the total system;*
- *the relative trade-offs associated with choosing among the various alternative thermal- loading strategies;*

- *the potential contribution of engineered barriers, including a robust, long-lived waste package to reduce the uncertainties associated with the long-term performance of the repository;*
- *the potential impacts of various options for incorporating disposal of other types of wastes into the waste management system; and*
- *the desirability of maintaining retrievability of the spent fuel beyond the currently projected period of 50 years after initial emplacement.*

Response:

The Department recognizes the importance of a well-integrated approach that fully considers the interdependent nature of storage, transportation, and disposal to the safe and cost-effective management and disposal of spent fuel and high-level waste. The Department believes that a firm understanding of the system architecture and the interrelationships between components is an essential prerequisite to developing an integrated system. As discussed with the Board in July 1992, the Civilian Radioactive Waste Management System is presently in the concept definition phase of development. At this time, alternative system concepts and architectures are being evaluated as the system requirements are being documented. The Department is placing a high priority on conducting *top-level* system studies, which are critical to understanding the interdependent behavior of the system components. Program participants are working with the Board's technical staff to ensure that our approach to conducting these studies will address the Board's specific concerns and previous recommendations.

The top-level system studies that are underway, or are being planned, will provide a comprehensive evaluation of the key elements of the system, and include many of the studies identified by the Board. These include cask and canister concepts, thermal-loading scenarios, interim storage requirements, and other key system-level parameters. Other issues noted by the Board, such as the long-term retrievability of waste emplaced in a geologic repository and the potential contribution of engineered barriers to waste isolation, will be carefully evaluated as a part of the repository and waste package development processes. The Department will keep the Board informed as to the status and results of these efforts.

Observation 3: Program Management Needs Improvement

The large number of organizations involved in the U.S. program and the diffuse nature of its organizational structure create substantial challenges for program managers. As a result, management problems seem to be adversely affecting some critical technical aspects of the program.

Recommendation:

The Board recommends that an independent evaluation of the Office of Civilian Radioactive Waste Management's management and organizational structure be undertaken. Reviewing approaches used in other countries could be useful in such an evaluation.

Response:

The Secretary of Energy is currently reviewing all aspects of the Civilian Radioactive Waste Management Program, as she stated she would do in her confirmation hearing. This review, presently in its early stages, has already resulted in redirection of the Civilian Radioactive Waste Management Program in several areas. This new direction includes an increased emphasis on the highest quality of scientific work and the more effective inclusion of external parties in the program's development and implementation. As this review progresses, reports from several independent review bodies and stakeholders will be solicited, and additional future direction will be given. The Board's past reports and recommendations, including a review of the approaches taken in other countries, are being carefully considered in the course of this review.

In the meantime, the program is continuing to address many of the Board's concerns regarding program management. The transition of activities to the Management and Operating Contractor is continuing along with the consolidation of contracts. This transition is being phased in so as not to impede work in progress. In addition, the Department shares the Board's concerns regarding the overhead and infrastructure costs in the program. In response, the Director has taken aggressive action to reduce these costs so that more funds can be allocated to scientific studies of Yucca Mountain. As a result of this effort, approximately $10 million has been shifted from the Yucca Mountain infrastructure to scientific work in the coming fiscal year alone. In parallel with this activity is an ongoing effort to reduce the overall cost of the Yucca Mountain Site Characterization Project.

DOE Response to the Recommendations of the Nuclear Waste Technical Review Board in Its Report on *Underground Exploration and Testing at Yucca Mountain* (October 1993)

(Submitted April 4, 1993)

Executive Summary

The Board's report on *Underground Exploration and Testing at Yucca Mountain*, issued on October 15, 1993, includes eight recommendations and a number of significant observations addressing the Department's plans for underground exploration and testing, the design and excavation of the Exploratory Studies Facility, and the project management of the activities. The Department of Energy's responses to the Board's latest recommendations are presented in this report. In addition, the Department has chosen to respond to a number of additional observations contained in the report. Like the Board, the Department believes its plans for exploration and testing have evolved substantially and are an improvement over previous efforts. However, these plans are not finalized and the Board's recommendations and observations will have to be considered carefully in the ongoing planning and design process.

As the Board is aware, the project funding over the past several years has not been consistent with the planning basis; nor are the existing detailed plans fully consistent with the anticipated funding. Given these realities, the Department has revised its approach to the excavation and testing activities and is developing a sequential excavation and testing strategy to determine the suitability of Yucca Mountain. As part of this strategy, the Department is implementing a phased approach to the design and excavation of the Exploratory Studies Facility that results in inconsistencies between our present activities and our past plans. Several of the Board's observations and recommendations highlight these inconsistencies. These issues are being addressed and resolved in a systematic manner as the design and testing packages are produced and reviewed. The Department will address many of the Board's concerns and specific comments as it reaches the individual project milestones.

One of the Board's recommendations is that the Department resume thermal testing as soon as possible. The Department recognizes the importance of thermal testing in validating many of the repository and waste package design assumptions and their relationship to the overall system. However, while the Department recognizes the benefits of conducting off-site underground thermal testing, the program lacks the funding to construct such a facility. Instead, the Department has chosen to conduct a large-block thermal test at the surface while the Exploratory Studies Facility is being excavated. This alternative provides the opportunity to test instrumentation and gain testing experience while the underground facility is being developed.

The Board also makes several observations and three recommendations with regard to project management. The Department is aware of the criticism regarding the management of the Yucca Mountain Site Characterization Project. In response to this criticism, Secretary of Energy Hazel R. O'Leary has directed that an independent financial and management review of the project be undertaken. This review will encompass the financial and business management techniques, the project schedule and credibility of project milestones, contracting practices, internal planning processes, and organizational effectiveness of the project. This review is discussed in detail in the response and is currently underway. In addition, the Department has undertaken initiatives to reduce program overhead and infrastructure and to streamline management practices.

The underground excavation and testing at Yucca Mountain will require significant increases in funding over the next several years. The Administration has acknowledged this situation and has proposed a new funding approach for program expenditures to ensure that the program receives adequate and predictable funding to carry out its mission. The Department intends to address stakeholder's concerns regarding project management and will continue its efforts to reduce program costs. However, if the current program funding imbalance is not corrected, the program will have to be restructured to ensure that program objectives are consistent with Congressional budget decisions.

Introduction

The Board's report on *Underground Exploration and Testing at Yucca Mountain*, issued on October 15, 1993, includes eight recommendations and a number of significant observations addressing the Department's plans for underground exploration and testing, the design and excavation of the Exploratory Studies Facility, and the project management of the activities. The following are the Department of Energy's responses to the recommendations and significant observations contained in the Report. Each recommendation and observation is quoted verbatim from the Board's report of October 15, 1993, and is followed by the response.

Recommendations for Exploration and Testing

Recommendation 1:

Explore across the block to access the major geologic features, many of which are near vertical and north-south trending. These features should be explored above, at, and below the repository level. Any changes to this plan should result from sound analysis of site-characterization issues. (page 20)

Response:

The Department agrees. To provide better access to the major geologic features, we have proposed several modifications to the layout of the Exploratory Studies Facility. These changes were discussed with the Board at the July 1993 Full Board Meeting in Denver, Colorado and at the October 1993 Full Board Meeting in Las Vegas, Nevada. The proposed new configuration of the repository-level Exploratory Studies Facility includes two extensions from the main-loop across the block to the Solitario Canyon fault and short drifts into the Ghost Dance Fault from the north-south main loop. Exploration of significant features above the repository level is being addressed through focused surface-based studies. Additional information from the block above the repository horizon will be gathered from the evaluation of features accessed by the north and south ramps. To explore the block below the repository, the Department plans a drift through the Calico Hills unit.

We believe that this combination of surface-based and underground exploration and testing will provide adequate geologic data to understand the site. However, if it does not, we will undertake further exploration. For example, if additional data above the repository horizon is required, an optional shaft is included in the Title I Exploratory Studies Facility design.

Recommendation 2:

The DOE should reinitiate its underground thermal testing program as soon as possible to allow the development of instrumentation and procedures and to gain as much testing experience as possible prior to initiating testing in the core test area. Given the potential for continuing program delays—including delay in excavating the core test area—development of an underground testing facility (outside the core test area) may prove very timely and cost-effective. (page 20)

Response:

As discussed during the July 1993 Full Board Meeting in Denver, Colorado, the field thermal testing program is being reinitiated with the large heated-block test that is currently being set up at the surface near Fran Ridge. The Fran Ridge tests will provide an opportunity to develop and test instrumentation, procedures, and test-coupled models prior to testing in the core test area. While we understand the limitations in applying the data to be obtained from the large block testing to predict repository performance, we believe that it is a prudent investment and will serve as an excellent foundation for the underground thermal-testing program.

The Board has suggested that program delays, including delays in excavating the core test area, may be mitigated through development of an off-block underground testing facility. The Department has determined that its limited resources should be expended on the development of the primary underground test facility (i.e., the Exploratory Studies Facility).

Development of an off-site facility would require funding allocations similar to those required for more rapid excavation of the Exploratory Studies Facility. Consequently, diversion of funds to an off-block, underground testing facility would likely delay development of the Exploratory Studies Facility. The estimated cost of the large block test is $6 million compared to an estimated $38 million for an off-site facility. The large block test, therefore, is an alternative that expedites development of thermal testing equipment and field testing of models, and also remains within current budget constraints. We would appreciate the Board's views as to what testing or other activities could be deferred to fund development of an off-block test facility.

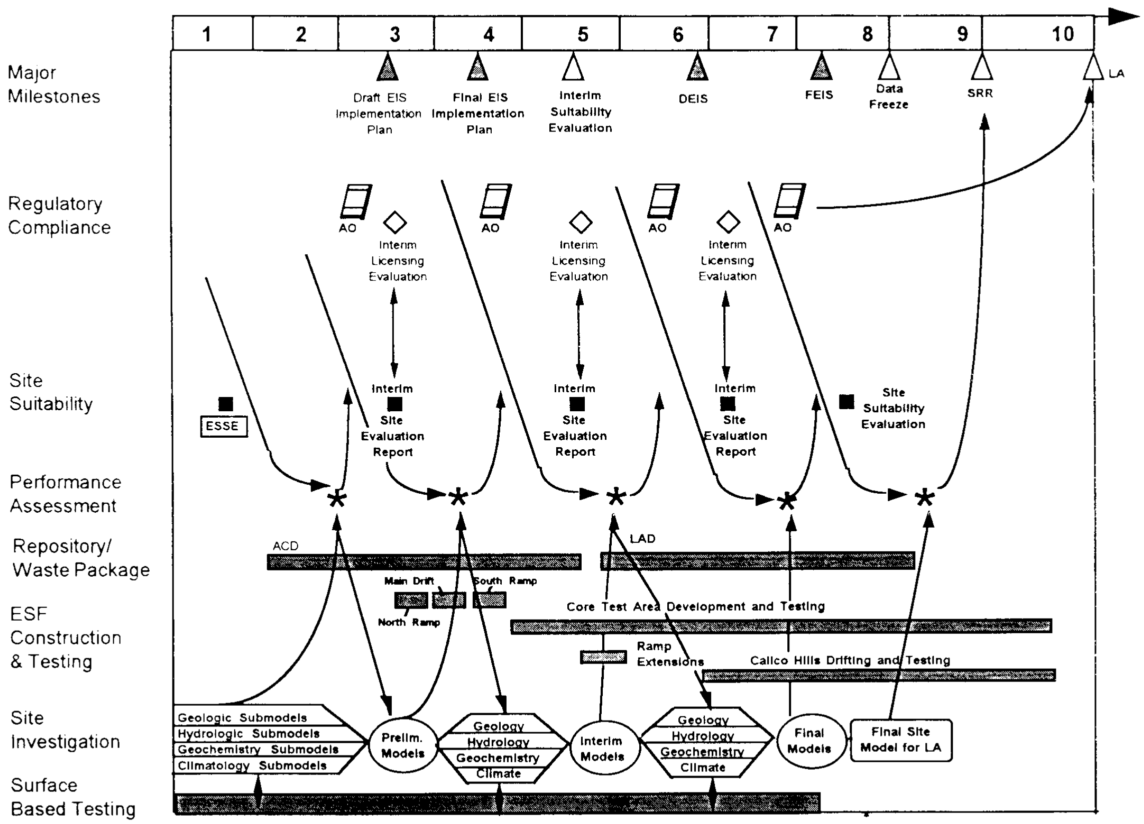
Recommendation 3:

Existing plans should be expanded to produce a comprehensive strategy for exploration and testing. Priorities and goals should be based on specific intermediate goals and be consistent with the scientific needs of site characterization and with realistic funding expectations. The strategy should reflect an integration of exploration and testing priorities with efficient excavation of the underground facility based more on current practices in the underground construction industry. (page 21)

Response:

The Department recognizes the shortcomings in the integration of existing plans and agrees that a more comprehensive strategy should be developed. Expansion of existing project plans into a "comprehensive strategy" for exploration and testing was discussed at the October 1993 Full Board meeting in Las Vegas, Nevada. At that time, the framework for a comprehensive strategy (see attached figure titled "Integrated Site Investigation Program"), and a process for integrating exploration and testing with efficient excavation of the Exploratory Studies Facility and waste package and repository concep-

Integrated Site Investigation Program



EIS = Environmental Impact Statement
DEIS = Draft Environmental Impact Statement
FEIS = Final Environmental Impact Statement
SRR = Site Recommendation Report
LA = License Application
AO = Annotated Outline
ESSE = Early Site Suitability Evaluation
ACD = Advanced Conceptual Design
LAD = License Application Design

tual design development were presented. The framework identified the role and timing of intermediate project goals. These goals were defined in terms of periodic programmatic milestones that will capture the current state-of-knowledge in the context of project requirements and will present such information in the form of formal reports (Interim Site Evaluation Reports). The proposed strategy will also address the timing of these reports and the relationship among total system performance assessments, construction of the Exploratory Studies Facility, and advanced conceptual design of waste package and repository elements. The criteria for these Interim Site Evaluation Reports is being developed and will be provided to the Board when it is available. The Department believes that a comprehensive strategy is the fundamental element of the long-range plan currently being developed. The Yucca Mountain Site Characterization Project Office has addressed the difficulties associated with maintaining focus on such a planning effort by organizing a planning group whose efforts in 1994 will be singularly focused on the production of annual, near-term, and long-range plans.

Observations Related to Exploration and Testing

Observation:

"The only tests that should be undertaken during the excavation of the portal-to-portal loop would be to gather initial data on hydrologic properties across fault zones." (page 6)

Response:

The Department plans to conduct only those tests during excavation of the loop that, if deferred, would result in the loss of irretrievable data. These tests are primarily associated with the various faults expected to be encountered. However, other factors could arise, such as encountering perched water, and zones of saturation encountered at major stratigraphic transitions (e.g., from Tiva Canyon to the non-welded, bedded tuff unit above the Topopah Spring) that could require temporary halting of tunnel boring machine activities until testing is done. Routine geologic mapping, consolidated sampling, and other non-deferable tests and non-deferable components of tests will have to be completed during the tunneling.

Observation:

"After the portal-to-portal loop has been excavated, tunnels can be excavated east and west to penetrate the Imbricate Fault and Solitario Canyon Fault zones." (page 6)

Response:

The current excavation plan calls for various east and west cross-drifts to be excavated following completion of the loop. However, according to the current plan, the core test area will be excavated prior to those drifts as it is to be the site of the long-term heater tests. As the Board has noted, the data from the heater tests will be critical to design and confirmation of design assumptions regarding many system components, including multipurpose canisters. The excavation sequence will also reflect other factors such as available funding, equipment availability, and testing priorities.

Observation:

"At the Board's July 1993 meeting, the DOE proposed several changes to the design of the exploratory facility; one calls for realigning the main tunnel so that it parallels the Ghost Dance Fault...This realignment could provide additional flexibility to the exploration and testing program and reduce the risks normally associated with excavating large tunnels through fault zones. However, since there may be secondary faults adjacent to the primary Ghost Dance Fault zone, flexibility in locating the main drift will be necessary so that it does not run along a secondary fault..." (page 8)

Response:

The Department recognizes that it must remain flexible when planning and undertaking underground excavations. Data from additional surface-based drillholes are expected before the final design of the main drift is completed. However, even with these data, there will be some uncertainty as to the conditions to be encountered at-depth, which will only be dispelled by tunneling. If conditions are encountered in the excavation of the planned alignment that indicate the need to alter the bearing and / or the grade of the tunnel, the adjustment can be made within the change process already in place on the project. Such an adjustment would be done gradually so that the conveyor and rail haulage systems would be accommodated. Corrections, if needed, would be no more severe than the current north ramp curve, which has a 305 meter radius and a -2.06% slope.

Observation:

"Recently, the DOE has mentioned budget constraints as a possible reason to forgo exploration across the block below the repository horizon in the Calico Hills. The Board strongly believes that any decision to forego exploration in the Calico Hills using tunneling should be based on a thorough scientific and technical analysis of site-characterization issues." (page 8)

Response:

As discussed at the October 1993 Full Board Meeting in Las Vegas, Nevada, the Department's current plans do include drifting in the Calico Hills unit. As discussed in response to the previous recommendation, the Department periodically evaluates the present state of knowledge versus the testing requirements to prioritize tests. It is likely that the requirements for exploration in the Calico Hills will be evaluated as part of the design process for the Calico Hills Drifting. These evaluations are consistent with the Department initiatives to reduce program costs that consider the merits of additional testing and drifting. The Department concurs, however, that "any decision to forgo exploration in the Calico Hills using tunneling should be based on a thorough scientific and technical analysis of site-characterization issues."

Observation:

"Although the Board believes the plan [DOE Test Planning Package (YMPO, September 1992)] is a good one, it feels that the facility design and test support are more complex than required for a well-prioritized and sequential testing program. Many of these testing activities could be combined or carried out sequentially." (page 9)

Response:

Test sequencing and coordination in the Exploratory Studies Facility is being evaluated by the Department along with its principal investigators and lead project participant liaisons. This process has resulted in the development of a consolidated sampling program for the Exploratory Studies Facility. The Department has developed a consolidated program of construction monitoring tests that combines five individual site characterization plan activities. Consolidation of thermal and coupled-processes tests are also being considered.

Observation:

"The DOE should develop a comprehensive strategy for exploration and testing. The current revised plans for conducting sequential exploration and testing, although much improved, are still evolving. The plans appear to reflect some degree of general prioritization; however, no detailed documentation has been made available to the Board that identifies either specific priorities or a basis for any prioritization." (page 12)

Response:

The current Exploratory Studies Facility test program is based on a comprehensive test strategy that is tied to the site characterization program baseline and is currently represented by a preliminary test plan. This test plan is implemented based on program priorities, as reflected in annual technical implementation plans and the long-range planning activities previously discussed. Technical implementation plans are being developed for each work area (i.e., third-level work breakdown structure element). Each plan discusses priorities for the current fiscal year and how the planned work scope addresses those priorities. These technical implementation plans are similar to the Fiscal Year 1993 Annual Plan for Surface-Based Testing and the draft Fiscal Year 1994 Site Investigations Annual Plan. An overall 1994 Technical Implementation Plan, covering all work areas, will be provided to the Board when completed in early 1994.

Observation:

"The lack of a comprehensive testing strategy is reflected in the current complex design of the underground facility, which contains excessive test support facilities and utilities." (page 12)

Response:

The Department supports limiting, to the extent possible, the test support and utilities consistent with our testing requirements. As discussed above, the current Exploratory Studies Facility test program is based on a comprehensive test strategy that is tied to the site characterization program baseline. The program is currently represented by a preliminary test plan that is implemented based on program prioritization, as reflected in annual and long-range planning. The Department asks that the Board provide specific instances of excessive test support so that this issue may be clarified and resolved.

Observation:

"The DOE should consider relocating some tests presently planned for the surface-based drilling program to drill sites within the exploratory facility....Given the slow drilling rate of the LM-300 deep dry coring drill and the long drill lengths required when drilling from the surface, shifting appropriate tests to the underground could speed program progress and reduce costs." (page 12)

Response:

As discussed at the October 1993 Full Board Meeting in Las Vegas, Nevada regulatory requirements (10 CFR 60.15 (c) (3)) direct the Department to drill boreholes where shafts or large unexcavated pillars are planned. Drilling from the Exploratory Studies Facility would create potential pathways from the repository level into the primary barrier. For this reason, deep-drilling from within the Exploratory Studies Facility is not planned. In addition, there are logistical problems associated with such drilling, including health and safety issues such as adequate ventilation and dust control. Finally, the surface-based drilling program aims to investigate specific features or to provide statistical sampling of material properties across the block, both above and below the potential repository horizon. The Exploratory Studies Facility and surface-based testing programs complement each other.

Recommendations for Design and Excavation

Recommendation 1:

The DOE's plan to excavate all tunnels other than the portal-to-portal loop using smaller tunnel boring machines is a good one. However, considering the schedule for the portal-to-portal loop, plans must be made now to acquire at least one smaller tunnel boring machine so that excavation of other tunnels can begin as soon as the portal-to-portal loop has been completed. The construction contractor, rather than the DOE, should write the specifications for and purchase its own machines based on the needs of the project. (page 21)

Response:

The Department agrees that plans must be made to acquire additional excavation equipment for use in the Exploratory Studies Facility and we have developed baseline and contingency plans to procure capital equipment. Due to the restricted 1994 funding, the Department has had to defer surface construction work and minimize the Title II design effort. Our available funding of $55 million is directed toward procurement and construction of those items required to support the receipt, assembly, and start-up of the first tunnel boring machine, and to excavate the first 30 meters of the north ramp in Fiscal Year 1994. Consequently, there is no funding available to initiate procurement of additional tunnel boring machines or other excavation machinery this year. While Title II design is being conducted on those portions of the facility that will be excavated in 1994 and 1995, the Department has made plans to procure an additional tunnel boring machine based upon available funding.

The Administration's Fiscal Year 1995 Budget proposes establishment of a new funding approach that would make available to the program an additional portion of each year's utility fee receipts. Of the $532 million requested by the program for Fiscal Year 1995, $101 million is allocated for the development of the Exploratory Studies Facility. If the final appropriation is consistent with the request, the

Department will initiate procurement of a second, smaller-diameter tunnel boring machine in October 1994. If the appropriated fiscal year 1995 funding is significantly less than requested, the tunnel boring machine procurement would probably not be started until fiscal year 1996. However, the Director of the Office of Civilian Radioactive Waste Management has stated that he will recommend restructuring the program if funding increases are not forthcoming. Such restructuring would undoubtedly affect the project's excavation plans.

The Department is currently reviewing options for obtaining equipment. These options range from leasing to the Federal government furnishing equipment to the subcontractor organization. Reynolds Electrical and Engineering Company, as the construction contractor, could subcontract for the equipment.

Recommendation 2:

Surface and subsurface facilities and utilities should continue to be simplified to reflect the new excavation sequence; as part of this effort, the core test area also should be simplified so that it can be excavated using a full-face tunnel boring machine. (page 21)

Response:

As design packages are released, they will continue to be evaluated to ensure the design is as simple as possible. However, the Department requests that the Board clarify specifically what it means by simplification. The requirements for the core test area excavation are being developed as the testing community finalizes its plans. Overriding considerations such as test interference and coordination are presently reflected in the core test area layout. If the Board wishes to discuss specific design issues, an informal meeting between the Board's staff and the project design engineers may be advisable. In addition, we welcome the Board's specific comments regarding simplification or other issues on the design packages as they are developed.

The core test area, the site of the long-term heater tests, was designed during Title I to be excavated by a device called the "Mobile Miner." This machine uses the same disc cutter technology as a tunnel boring machine, but with a different configuration. As experience with this machine has not been promising in mining applications, it is very likely that some other excavation concept will be investigated during Title II design. The project must, therefore, re-evaluate the excavation mechanism for the core test area, as well as the core test area configuration during Title II design. It is possible that a tunnel boring machine with a short turning radius could be employed for this task. Procurement of this machine will have to be initiated in fiscal year 1995 in order to begin core test area development in a timely manner after completion of the initial loop in late 1996. The Department will evaluate using a flexible machine to excavate the core test area and other drifts such as the Calico Hills loop.

Observations Related to Design and Excavation

Observation:

"The Board believes that several of the proposed design changes (e.g., reducing tunnel gradients) offer improvements over the previous design. Some of the changes being considered require further evaluation (e.g., realigning the portal-to-portal loop; for example, at what distance should the portal-to-portal loop parallel the Ghost Dance Fault?" (page 13)

Response:

The distance at which the loop should parallel the Ghost Dance fault is being investigated by surface mapping, drilling, and geophysical surveys. Mapping of the Ghost Dance fault at the surface is an ongoing activity. Results will be factored into design of the loop. Similarly, results from borehole drilling along the proposed alignment will provide input to design of the final loop position. Seismic reflection surveys across the Ghost Dance fault were also conducted in October 1993 to support this design need and preliminary results have been provided to the Board. Selection of the final loop alignment will be based on the results of this integrated testing program.

Observation:

"The Board recommends the use of rail, rather than rubber tired vehicles, to support tunnel boring machine operations." (page 14)

Response:

The Department has adopted the Board's recommendation and is finalizing change proposals directing that rail haulage be employed in support of drifting for the bulk of the Topopah Spring level excavation. The proposal documenting the modifications to the layout of the

Exploratory Studies Facility, which facilitates the use of rail haulage, is under final review by the change control board. The design package for the north ramp, which includes rail haulage, is also under formal review.

Recommendations for Management at the Project Level

Recommendation 1:

Consistent with practices in the underground construction industry, the DOE should establish a geoengineering board with four-to-seven members who have expertise in the engineering, construction, and management of large underground projects. Members should be nationally recognized and be selected based on their previous *experience serving on similar boards. Such a geoengineering board would meet regularly with Yucca Mountain project management, staff, and contractors to review detailed decisions early on—as they are being made and to provide guidance on improving the management of the design and excavation of the exploratory facility. (page 26)*

Response:

After careful consideration, the Department believes that establishing a formal board made up of experts in underground construction not presently working for the project, as recommended by the Board, is not needed given the existing project oversight, the use of outside experts as discussed below, and the widespread concerns regarding project infrastructure. However, the Department recognizes the potential benefits that may be available from the periodic formal review of design decisions by a panel of experts and is investigating other means to obtain this expertise. The Department would appreciate receiving the Board's views on the scope of work and responsibilities that a geoengineering board would have on this project.

In lieu of a formally established geoengineering board, the Department will continue to draw upon experts who work for contractors on the project, but are not presently working on the Yucca Mountain project. The services of these experts will be obtained for review of specific issues that arise. The experts from whom the expertise will be drawn are Kiewitt-Parsons Brinkerhoff (the underground subcontractor to Reynolds Electrical and Engineering Company) and Morrison-Knudsen (the architect who is part of the management and operating contractor).

Recommendation 2:

The DOE should develop a more efficient system for managing the exploratory facility design and construction that contains greater accountability and incentives for cost-effective and timely performance of the contractors. (page 26)

Response:

The Department provides incentives in the design and construction contracts by tying the award fee directly to performance. The amount of the award fee is based upon contractor performance, as measured against predetermined objectives. In order to completely address the Board's concern, the Department requests that the Board provide clarification of what is meant by a "more efficient system."

Recommendation 3:

The Secretary of Energy's review of the financial aspects of the civilian radioactive waste management program should include an evaluation of the program's funding allocation decisions. This review should help find ways to maximize the funds that are being made available for scientific studies and to ensure that the momentum of the exploration and testing program under way at Yucca Mountain is maintained. (page 26)

Response:

The Department is aware of the criticism regarding the management of the Yucca Mountain Site Characterization Project. Secretary of Energy Hazel R. O'Leary has directed that an independent financial and management review of the project be undertaken. This review will encompass the financial and business management techniques, the project schedule and credibility of project milestones, contracting practices, internal planning processes, and organizational effectiveness of the project. To ensure the independence and enhance the credibility of the results, a two-person panel has been established to oversee the review. One member was selected by the Secretary of Energy, the other member was appointed by the Governor of Nevada. The review will be conducted by a management consulting firm chosen by the panel. However, the panel will be responsible for the integrity of the final product. The results of this review are expected in late Spring 1994.

The new funding level requested in the Administration's Fiscal Year 1995 Budget Request and the funding profile that would be made available through the use of the new funding approach will allow the project to maintain a balanced site characterization program concentrating on surface-based studies and the excavation of the Exploratory Studies Facility, which are the project's top priorities. Additionally, to maximize funding for scientific/technical activities, the project has initiated several major cost-reduction initiatives to reduce infrastructure and to increase the funds available to perform the priority activities.

Observations Related to Management at the Project Level

Observation:

"The Board remains concerned that, because of past delays in initiating underground exploration and attempts to comply with overly optimistic schedules, the DOE is making important technical decisions about the design and approach to excavation of the exploratory facility without sufficient analysis." (page v)

Response:

We do not agree with the Board's characterization and believe that the analysis leading to recent technical decisions was sufficient and was accomplished in a timely manner on a reasonable schedule. To help identify decisions that may require reevaluation, we ask that the Board provide specific examples of decisions that it believes lack an adequate technical basis so that the Department may address the Board's specific concerns.

Observation:

"The Board has found that important project decisions often do not reflect what would be considered standard practice in the underground construction industry....To help control the cost and time required for exploratory facility construction, the DOE should develop cost and schedule incentives for current contracts. The Board also suggests that the DOE consider using conventional fixed-price or cost-plus incentive-fee contracts on future portions of the exploratory facility....The Board also believes that, to avoid the potential litigation associated with contractual relationships, a disputes review board should be included in all construction contracts." (page 22-23)

Response:

Various contracting scenarios are considered whenever a procurement is planned. The phased approach being used to design and construct the Exploratory Studies Facility does not lend itself well to fixed-price contracting because of potential technical and scientific revisions of the construction and test plans. While we understand the potential economic disadvantages of proceeding in this fashion, we firmly believe that it is the most prudent approach given our operating constraints. Nevertheless, the Department has used an incentive-based contracting mechanism, namely, the cost plus award fee system. Under this system, the contractor has incentives to perform well, as a portion of its fee is determined directly by how well it has performed in the execution of the assigned tasks.

A disputes review board is required primarily for fixed-price contracts to resolve disputes relating to “in-scope / out-of-scope” issues. The current system of dispute resolution in Federal government contracts is quite similar to the disputes review board system. If future contracts are entered into on a fixed-price basis, such a board could be considered.

Appendix H
Radioactive Waste Management in Three European Countries
(Belgium, France, and the United Kingdom)

Belgium

Report Outline

I. Background

A small country nestled among the Netherlands, Germany, and France, Belgium has a population of almost 10 million people. Seven operating nuclear plants produce approximately 60 percent of the country's electricity. During the mid 1970s a moratorium on any new nuclear plants was ordered; however, in 1983, the moratorium was lifted. Despite this, the addition of an eighth plant has been decided against for the time being.

Belgium's waste management strategy centers around reprocessing of spent fuel (earlier at Mol in Belgium; currently in France by COGEMA). The program calls for vitrification of high-level waste and storage for 50 years; investigation of disposal of all radioactive wastes in boom clay formations; treatment and immobilization of other wastes; and investigation of shallow-ground disposal of low-level waste. Sea-dumping of low-level wastes was halted in 1983.

Table H.1 — Energy Production in Belgium

Population	1989	9.7 million
Electric Power	1989	66.8 TWh
		62% nuclear
		27% coal
		8% gas
		3% oil
		1% gas
	1990	60% nuclear
	1995	58% nuclear
	2000	51% nuclear
Nuclear Power	1991	5.5 GWe
	1995	5.5 GWe
	2000	5.5 GWe
Reactor Mix	1991	PWR — 7 (1975–85)

Source: DOE-RW-0371P

Recently, the government delayed implementation of the country's latest nuclear spent fuel reprocessing contracts for five years to reevaluate the method and to consider direct disposal as an alternative. (Reversible contracts had been signed with COGEMA in 1990, following agreements since 1980 with COGEMA for reprocessing services.) The Belgian government is seeking an alternative customer for COGEMA.

II. Waste Types

Belgium divides it waste into the following categories:

Category A: beta-gamma waste (comparable to U.S. low-level waste). This includes small quantities of short- or medium-lived radionuclides (half-life not exceeding 30 years). This waste comes from daily operation of reactors and medical, industrial, and research laboratory wastes.

Category B: alpha waste (comparable to U.S. transuranic wastes). This includes alpha-emitting wastes (half-life over 30 years), which generates very little heat. This waste comes from specific fuel cycle operations during spent fuel reprocessing or fuel assembly manufacturing.

Category C: high- and very high-level wastes (U.S. high-level reprocessing wastes). This waste contains a mixture of short- or medium-level radionuclides in high concentrations and long-lived radionuclides that are usually alpha emitters. This waste is produced during spent fuel reprocessing and generates heat owing to its high concentration of beta and gamma emitters.

By the year 2050, the following amounts of waste will require disposal:

- Category A: 150,000 cubic meters
- Category B: 25,500 cubic meters
- Category C: 4,500 cubic meters

III. Organizational Framework

A law passed in 1980 delegated all aspects of the management of radioactive waste to The National Agency for Radioactive Waste and Enriched Fissile Materials (ONDRAF/NIRAS), an independent government agency set up under the Minister of Economic Affairs. ONDRAF/NIRAS's board of directors is made up of representatives of various ministerial departments and of Belgium's regional executive bodies. Two commissioners are appointed by the Minister of Economic Affairs and the Minister of Public Health. The agency's responsibilities include:

- transport of radioactive wastes, spent fuel, enriched fissile materials and plutonium-containing materials;
- conditioning of radioactive wastes for producers who do not own adequate facilities;
- storage, outside the producer's facilities, of radioactive wastes prior to conditioning or disposal;
- disposal of conditioned radioactive wastes;
- storage of spent fuel outside the nuclear power plants and reprocessing plants; and
- storage of enriched materials or plutonium that are not directly required to secure the operation of the facilities that produce or use them.

In performing these duties ONDRAF/NIRAS is entitled to act either by its own means, by subcontracting its control, or by participating in or creating subsidiary companies. ONDRAF/NIRAS subcontracts transportation services to companies specializing in transport services. CEN/SCK, universities, and research institutes perform much of the R&D work under the auspices of ONDRAF/NIRAS. And in 1986, BELGOPROCESS became a subsidiary company of ONDRAF/NIRAS.

CEN/SCK, the National Nuclear Energy Research Center, is charged in a 1991 Royal Decree to undertake research in many fields related to nuclear science. With respect to waste, the SCK/CEN studies a wide range of issues, including the safe conditioning and disposal of radioactive waste; and characterization and safety assessment work pertinent to waste disposal.

Belgoprocess was formed in 1976 by Synatom, a company that provides commercial fuel cycle services, and the Ministry of Economic Affairs. Belgoprocess is the nuclear operator in charge of operations at its sites in Mol-Dessel, including management of the sites, processing, conditioning and storage of radioactive waste, and reorganization and decommissioning of installations.

IV. Funding

The basic principle in financing the Belgian radioactive waste management program is that those who produce the waste pay for the services that are required, including studies, R&D and investments.

ONDRAF/NIRAS is entirely financed by the waste producers in proportion to their share in the overall volume of waste generated. Contracts are entered into with each producer. Long-term operations are financed through a "long-term fund." Waste producers pay into the fund proportional to the volume of waste collected from them (a "disposal tariff").

For surface disposal, total costs are estimated at approximately 5 billion Belgian francs (BEF) ($150 million U.S.), of which 1 billion BEF ($ 28 million U.S.) is estimated to be spent on R&D. For deep geologic disposal, the total cost is estimated at 21 billion BEF ($600 million U.S.). Four billion BEF ($112 million U.S.) of that is the estimate for preliminary studies and site characterization.

V. Interim Storage of Nuclear Waste

Radioactive waste in Belgium is processed, conditioned, stored. ONDRAF/NIRAS has centralized many of its activities, i.e., processing, conditioning, and interim storage. The program is centralized because this makes the most sense from an economic point of view. In Belgium, the distances between localities are short, and the total volume of waste is small. Therefore, to set up separate facilities at different sites is not necessary and would increase unit costs substantially.

Wastes from the whole country are transported to the central site of BELGOPROCESS, whether they have been conditioned or not. Wastes, if they have not been conditioned yet, are conditioned at the central site. The wastes are then stored in buildings specially designed for that purpose on the central site of BELGOPROCESS in anticipation of its disposal. ONDRAF/NIRAS has constructed several interim storage buildings for the different classes of waste with sufficient capacity to meet all needs until final disposal is put into operation.

VI. Nuclear Waste Disposal Concept

Options for permanent disposal are under investigation for low-level and short-lived wastes, and for high-level and long-lived wastes.

Disposal at or near the surface is under consideration for low-level wastes. The goals of disposal would be to isolate the waste for a long enough period of time to allow a majority of radionuclides to attain a negligible level of activity *and* to enable unrestricted use of the site at the end of the isolation period. The disposal facility would be erected on a site with a permeable surface layer (such as sand), overlying an impermeable layer (e.g.) clay. The disposal facility would be designed in the form of a concrete silo where waste drums would be stored. All containment measures would be aimed at preventing water from infiltrating the silo, since water would be the main transporter of radioisotopes.

The Belgian strategy for disposal of high-level and long-lived wastes is based on geologic disposal in sedimentary rocks (clay and shale). An inventory was made of the sedimentary rocks most suitable for this type of waste. The formation chosen for further research was the boom clay of the Oligocene, one of the slightly indurated rocks of the Cenozoic era. This layer is about 90 meters thick, extends to a depth of 190 to 280 meters and covers several hundred square kilometers. The site is located in the northeastern part of the country. For approximately 20 years, research and development work has been underway in the Boom clay, focusing on the short, intermediate, and long-term safety offered by the deep clay layer and on the technical feasibility of proposed designs for a potential repository. Tentative program target dates include beginning construction of a permanent repository for Class B & C waste by 2020, with disposal operations beginning in 2030. (See chapter 1 for a discussion of the evolution and current concept for a deep geologic repository.)

VII. Radiation Protection

In its research CEN/SCK has applied the safety criteria and principles advocated by international authorities in its modeling. The limit adopted for the safety study specific to boom clay was fixed at 0.1

mSv / year. General directives have been established by the Belgian government, including safety standards for the public and workers, based on the ALARA principle, i.e., all exposures should be kept as low as reasonably achievable.

VIII. Research & Development

In 1974, when the first Belgian nuclear power stations started operation, CEN / SCK began an R&D program aimed at solving the problem of safe and final disposal of high-level and long-lived waste. The program is now managed by ONDRAF / NIRAS, but CEN / SCK conducts much of the research. Periodic “Safety Assessment and Feasibility Interim Reports” are issued for the Belgian government to report on the progress in R&D and to outline future work. Current research includes over 10 years of work in HADES, an underground research laboratory constructed between 1980-84. Research in the fields of diffusion, convection, permeability, gas production, corrosion and the influence of heat have been conducted. These studies have focused on the more important system components of a proposed repository: the waste package; the near field; the host geological medium; surrounding geologies; and geotechnical and construction-related matters, including backfilling and sealing issues.

In addition, long term safety assessments have been conducted in the framework of the European Commission’s (CEC) performance studies referred to as PAGIS, PACOMA, and EVEREST. In all three cases, the SCK / CEN site in boom clay was the reference for the clay option. The objective has been to evaluate safety during the operational and postclosure phases of an underground facility, while bearing in mind that the functions filled by the engineered barriers in the proposed Belgian repository would weaken over time. Consequently, the performance of the natural barriers must be analyzed over long geologic periods. Calculations to date show that all scenarios considered produce doses that are several orders of magnitude below the dose limit recommended by the ICRP.

In addition, more in-situ tests are planned at HADES to demonstrate combined effects that could be expected to occur in a final repository.

France

Report Outline

I. Background

II. Waste Types

III. Organizational Framework

IV. Reprocessing

V. High-Level Waste Disposal Strategy

VI. Research and Development

I. Background

France is about 220,000 square miles and has a population of about 56 million people, or 255 people per square mile. France is a republic, consisting of 22 regions, which are subdivided into 96 departments. Currently, 57 nuclear power plants supply 73 percent of the nation's electricity. The French intend to build approximately 1 new reactor per year through 2005 (See Table H.2).

France's strong nuclear power program calls for developing a capability in all aspects of the nuclear fuel cycle except the supply of uranium, for which foreign sources must be relied on. Heavily subsidized industrial firms implement federal policy. The central government provides regulatory oversight of all nuclear activities, including licensing, and runs the waste disposal programs. France belongs to international nuclear organizations and works with other countries on activities leading to improvements in radioactive waste management and environmental protection.

France reprocesses its spent fuel. The overall objective in France is to reduce, in volume and activity, the B (transuranic) and C (high-level) wastes containing long-lived radionuclides. High-level waste will be vitrified and stored in engineered storage facilities for indefinite periods, then emplaced in a geologic repository. The French are currently looking at clay and granite sites. Transuranic waste will be immobilized in bitumen, cement, or polymers. Low-level waste will be immobilized in bitumen, concrete, or resin and disposed of in engineered surface facilities. A low-level waste repository at Soulaines, Centre de l'Aube, began activities in January 1992.

Table H.2 - Energy Production in France*

Population	1989	56 million
Electric Power	1989	403.0 TWh
		76% nuclear
		12% hydro / geoth.
		9% coal
		3% oil
		1% gas
	1990	75% nuclear
	1995	76% nuclear
	2000	75% nuclear
Nuclear Power**	1991	56.6 GWe
	1995	59.7 GWe
	2000	64.1 GWe
Reactor Mix	1991	GCR — 1
		PWR — 54
		4 under construction
		LMFBR — 2

* DOE / RW-0371P (updated)

** France has a vigorous nuclear power program, scaled down recently to construction of fewer than one new reactor per year, commercialization of the breeder reactor, and export of nuclear plants and services.

II. Waste Types

For purposes of disposal, waste types are divided into two major classes:

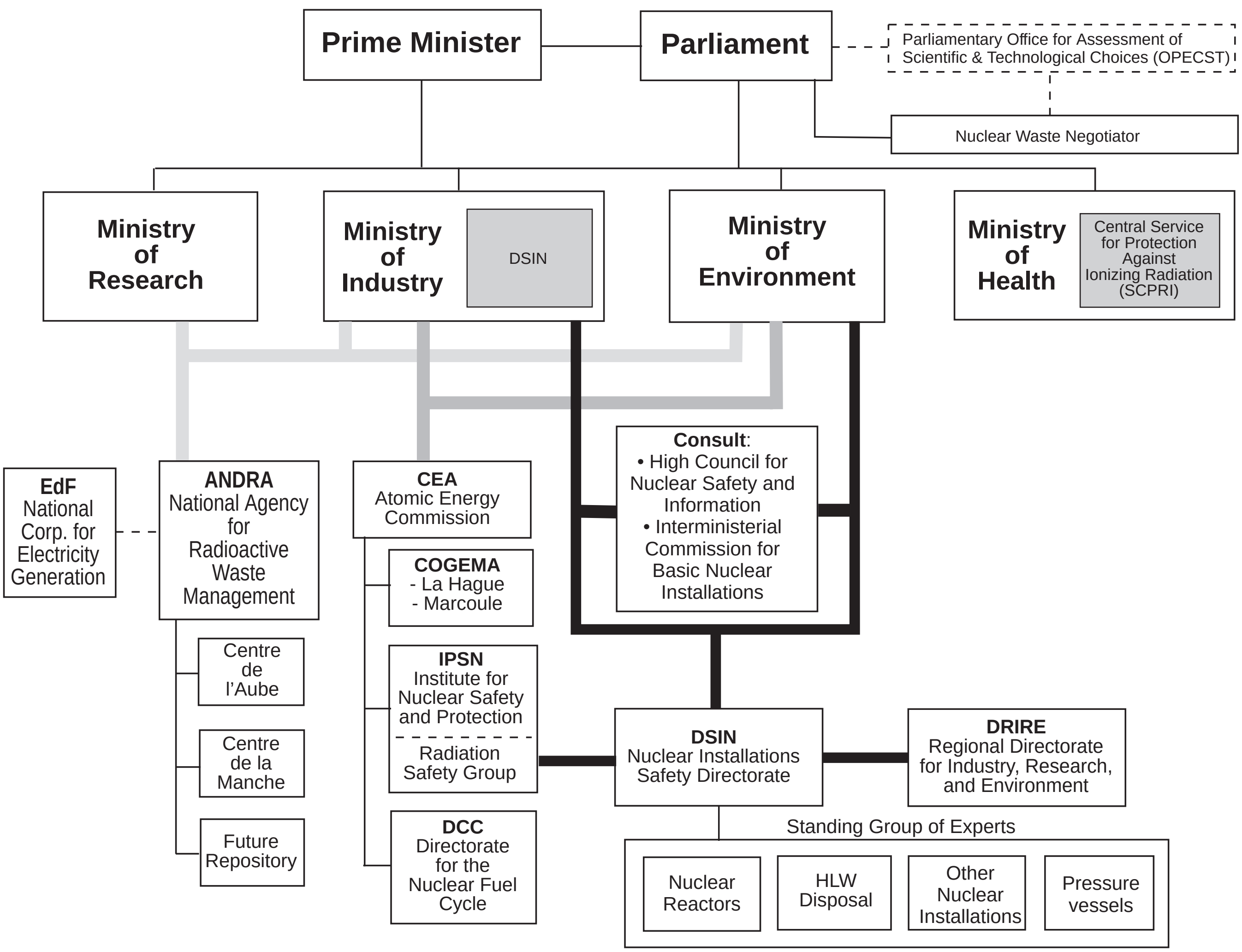
- waste that is disposed of in near surface facilities (A waste) in France, including short-lived waste with radionuclides with half-lives of less than 30 years for beta / gamma emitters and, in a very few cases, a very low percentage of long-lived emitters with a mass alpha activity of less than 370 bequerels per gram; and

- waste that comes from reprocessed and unreprocessed spent fuel and contains significant quantities of long-lived elements such as transuranics (B and C waste). Reprocessed fuel produces two waste types:
  - alpha waste with low or medium activity levels and low heat releases; and
  - vitrified waste, named after its solidification process. It contains both long-lived emitters and substantial quantities of fission products, which release a large amount of heat.

III. Organizational Framework

The French central government develops waste management policy; designs, sites, and constructs and operates all long-term disposal facilities; develops safety criteria; and authorizes and issues licenses. The waste producers pay for disposal and are responsible for preparing all waste so that it is suitable for disposal. Many organizations are involved in some aspect of the French nuclear program. Figure H.1 illustrates the organizational relationship among a number of these organizations. (The Ministry of Defense is not included as information was not made available to the NWTRB on defense-related nuclear wastes.) A few key organizations are:

Figure H.1 — Nuclear Waste Disposal: French Organizational Chart



1. *ANDRA* (National Waste Management Agency): Principal activities are management of existing disposal facilities; designing, siting, constructing and operating new long-term disposal facilities; research in underground laboratories, development of waste form specifications, and preparation of a national radioactive waste inventory. Became a public corporation owned by the French government at the end of 1991.

2. *CEA* (Atomic Energy Commission): Responsible for the development of all nuclear energy production. Two of the many CEA operating directorates[1] are

- *IPSN* (Institute for Protection and Nuclear Safety), which directs research related to safety for reactors, nuclear facilities, fuel cycle installations, and waste disposal, and provides technical support to the DSIN.

- *DCC* (Directorate for the Nuclear Fuel Cycle), which oversees technical development activities related to the nuclear fuel cycle, i.e., enrichment, reprocessing, waste disposal, decontamination, decommissioning, etc.

3. *COGEMA* (Compagnie Generale des Matieres Nucleaires): A wholly owned subsidiary of the CEA, COGEMA supports the entire nuclear fuel cycle through its own company and numerous subsidiaries. Services performed by COGEMA include operating the reprocessing and waste management facilities at La Hague and Marcoule. COGEMA is also proprietor and operator of all reprocessing and high-level waste immobilization facilities and is responsible for temporary storage of high-level waste at the La Hague and Marcoule reprocessing centers.

4. *DSIN* (Nuclear Installations Safety Directorate): develops basic safety and technical rules for nuclear operations, handles licensing procedures, conducts safety inspections of nuclear facilities, ensures emergency preparedness in case of an accident, and develops information on nuclear safety for the public. Reports to the Ministry of Industry and Foreign Trade and the Ministry of the Environment. DSIN receives advice on safety issues pertaining to high-level wastes from:

- Permanent Advisory Group for Facilities for the Storage and Disposal of Long-Lived High-Level Waste.

5. *EdF* (Electricité de France, 100% government): The French national utility responsible for production and distribution of all electricity in France, including electricity produced by nuclear power.

IV. Reprocessing

There are two main reprocessing sites with a total of three facilities:[2]

La Hague is France's principal site for the reprocessing of light water reactor fuels. Built in 1959 by the CEA, the facility is located on the northern coast of France on a peninsula, 20 kilometers west of Cherbourg. It began operations in 1966 on gas-cooled reactor fuels. The COGEMA assumed management in 1976 and the site is now dedicated strictly to reprocessing of fuels. It has two reprocessing facilities:

- **UP3** with a capacity of 800 THM/y in operation since 1990 reprocesses French and foreign fuels.

- **UP2** presently operating at a capacity of 400 THM/y is being expanded to process 800 THM/y by 1994 (it then will be called UP2-800). UP2 (and later UP2-800) are devoted to domestic spent fuels only.

The second site is the *Marcoule* plant in Southern France, which has a capacity ranging from 800 to 1,000 metric tons of heavy metal per year (THM/y). The Marcoule plant is devoted to the reprocessing of gas-cooled reactor and LMR fuels.

The vitrified high-level wastes consist primarily of a vitreous combination of elemental oxides; major ele-

1 *Prior to 1992, the ANDRA also was an operating directorate of the CEA.*

2 *The French vitrification technology has been licensed to British (BNFL) and Japanese (PNC) companies.*

ments include silica, sodium, boron, and aluminum. Minor elements include iron, chromium, nickel, magnesium, and calcium. Fission product oxides make up 1.3 to 13.0 wt.% of the glass, depending on the type of fuel from which the high-level wastes were derived. Control of operating parameters is relied on to produce a consistent and satisfactory glass quality.

In addition to reprocessing its own waste, France also has undertaken an aggressive commercial program that includes the export of plants, equipment, and services, including uranium enrichment and spent fuel reprocessing.

Spent fuel/HLW storage and transport

Spent fuel is stored in cooling pools at the reactors or at a reprocessing site until it can be reprocessed. (An exception is the dry storage of the spent fuel from the Phenix and Superphenix breeder reactors). Spent fuel is transported in specially designed casks certified by COGEMA. Transport is carried out primarily by rail; trucks are sometimes used for short hauls; ship transport is used for fuel coming from countries not on the continent. Liquid high-level wastes are collected in stainless steel tanks within the reprocessing facility until vitrified; canisters of vitrified wastes are placed in a dry-storage facilities for 30 years or more adjacent to the vitrification facility.

V. High-Level Waste Disposal Strategy

Between 1983-1987 the ANDRA had assembled an inventory of 30 zones covering the four main geologic settings in France. In 1987 four candidate sites were selected for further evaluation: clay (Aisne); granite (Deux-Sèvres); Schist (Maine et Loire); and salt (Ain). A three-year surface investigation program of each site began.

In 1990, as a result of local opposition, the Prime Minister placed a one-year moratorium on further site characterization and recommended an independent review of the program. This review led to parliamentary recommendations and the French High Level Waste Act (January 1992). The legislation now provides for the selection of sites based on a voluntary process conducted by a nuclear waste negotiator, and construction of two deep underground research laboratories. It prohibits emplacement of waste for 15 years and then only after a positive vote by the French parliament to transform the laboratory into a repository. Under the legislation, the ANDRA is responsible for work on the laboratories and R&D work on alternative waste management strategies.

Other provisions of the act are:

- High-level waste must be retrievable.
- Permanent storage of waste originating from foreign countries is not allowed.
- Before starting any on-site work, the “concertation” with local populations and local authorities shall develop according to the provisions defined through an executive order.
- Radioactive sources may be used by the labs for experimental purposes only.
- Compensation will be provided to offset local nuisances resulting from the installation of the laboratories,including the payment of 60 million francs per year to host communities (approximately $10 million USD) for economic development, and the creation of high-technology research centers in support of the underground laboratories.
- Authorization for the installation of labs shall be given by executive order following an environmental impact study and favorable opinion from local and regional councils following public hearings.
- Exploration by the government of all paths of nuclear waste management, including direct spent fuel disposal, long-term engineered storage, and methods of actinide partitioning and transmutation *in parallel* with the current program to construct underground laboratories.

Since the law was enacted, a negotiator was appointed, and 30 candidate sites were identified. The ANDRA screened these sites for geological interest, after which the list was narrowed to 10 sites. Two of the 10 sites were eliminated after preliminary meet-

Figure H.2— Map of France showing research sites, potential repository sites, and low-level waste sites

ings, at which time the negotiator conducted 8 "information missions" to determine if there was broad consensus in the departments (counties) in support of building an underground research laboratory. Four of the eight organized sufficient support to secure a favorable vote through their local councils. In December, 1993, the negotiator issued the "Bataille report", in which four departments were recommended. (Three of the sites are in clay; one is in granite.) The ANDRA has since begun preliminary surface investigations at the four sites, and in two years, will recommend two of the four sites for construction of an In-Situ Site Validation Laboratory (ISVL) (See Figure H.2).

Some rough estimates of the costs involved are as follows: 1.5 billion francs ($256 million U.S.) to construct each URL, employing 120 people for 5 years; 70 million francs ($12 million U.S.) per year for operations; and 200 million francs ($34 million U.S.) per year for R&D, employing approximately 100 people.

Should two of the four sites be approved for construction of an underground research laboratory, then a national law addressing construction of the laboratories would be required.

Funding

Costs for managing radioactive wastes up to the point of disposal are the responsibility of the waste generator. Operating costs of disposal centers and the ANDRA's operations are directly billed to the waste-producing organizations in proportion to their deliveries. The annual disposal contracts are first established on the basis of the deliveries: the waste producer pays for disposal of the wastes according to their quantity and nature. To prepare future work and financial forecasts, a permanent update on future deliveries is carried out with the producers. The construction of disposal centers will be financed by loans, the costs of which will be shared by the different producers according to the proportion of waste produced.

Waste Disposal Design Concept

France is in the conceptual stage in regard to designing a deep geologic repository; final specifications and criteria are yet to be established. A multi-barrier approach is envisioned, however, in a system of shafts and caverns at a depth of 400 to 1,000 meters. Under one very preliminary design vitrified waste canisters would be stacked 20 high in vertical boreholes drilled in the floors of horizontal galleries and backfilled with compacted bentonite; the repository would have 42 horizontal galleries, each containing 43 boreholes spaced 35 meters apart. While current thinking is that a long-lived canister would make public acceptance easier, the approach is to place greater reliance on the geologic barrier and shaft sealing materials to isolate radionuclides from the environment over the long-term. The system's actual design, however, will depend on the geology finally chosen and the site-specific information gathered there.

Regulatory Approach

The French regulatory approach is to avoid prescriptive, detailed regulations in determining safety goals. ANDRA has been provided several scenarios which it must prove are within certain safety limits before a repository can be licensed. This approach is intended to give ANDRA some flexibility in how it designs and constructs a safe repository system. The Ministry of Trade and Industry (DTI) has established a Basic Safety Rule covering site criteria, performance assessment and safety demonstration. (Much of this work is based on studies conducted by groups of experts over the years.) Individual radiation exposure is limited to less than .25 millisievert per year for extended exposure coming from probable events. The limits must be quantitatively demonstrated for the first 10,000 years of repository operation. Qualitative predictions of releases are permitted after that time, and individual barriers are note required to meet quantitative performance objectives. Figure H.3 illustrates the general process that ANDRA must undertake in securing a license for disposal of nuclear waste.

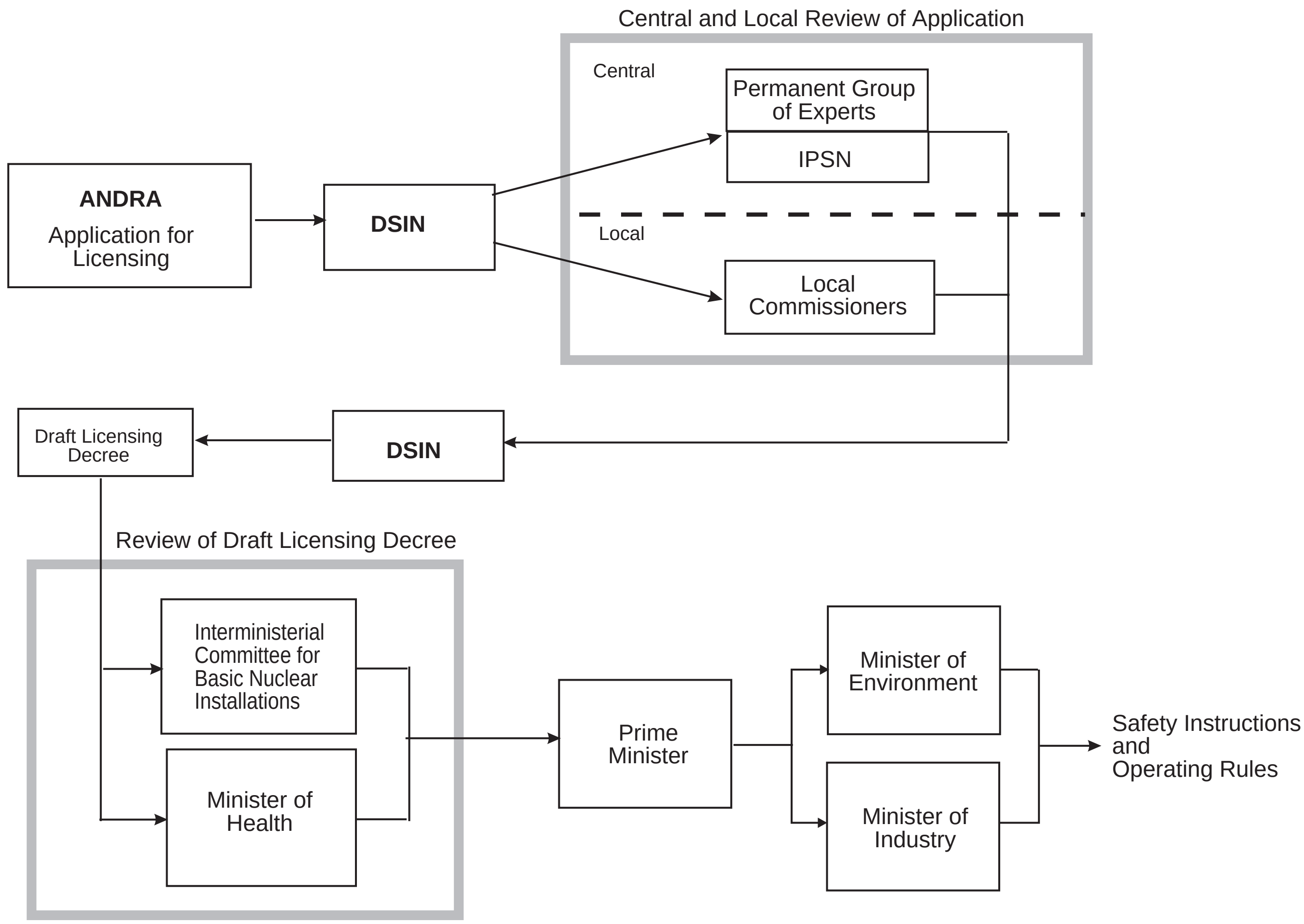
VI. Research and Development

Until the moratorium, in 1990 France had been conducting extensive geoscience R&D in support of development of a deep geologic repository. Most of this research was conducted at Fontenay-aux-Roses. Underground research was also conducted at several sites. At the Fanay-Augeres uranium mine near Limoges, the IPSN developed an underground research laboratory. Scientists there gathered information on the properties of granite and the behavior of fractured granite. Two of the R&D programs completed were:

1. A study of the influence of scale effects on measured values of permeability and dispersion coefficients. Ten boreholes, each 50 meters long were drilled from a 100-meter drift, 170 meters below the surface; water injections between packers in chambers of different lengths provided permeability information.

2. Thermo-hydro-mechanical properties were evaluated. Heat sources of 1 kW were placed in five horizontal boreholes at three meters below the floor of a 10 x 10 meter excavated room. The room was placed in a 100-meter-long drift, 170 meters below the surface. The heating phase was to last 50 days and the observation phase was to last six months. Information was sought on changes in individual fractures, effects on hydraulic conductivity, rock deformation, and rock stresses.

Figure H.3 — Nuclear Waste Disposal: French License Application Process



Current R&D

Provisions passed in the French High Level Waste Act (January 1992) state that three R&D programs will be carried out simultaneously to:

- study storage options in deep underground geologic formations, essentially through the implementation of deep underground laboratories;
- develop methods for separating and transmuting the long-lived radionuclides present in wastes; and
- study the packaging and storage processes for the long-term surface disposal of the above wastes.

Studies are underway to develop methods for separation of actinides and, further, for their incineration either in reactors or through the use of dedicated accelerators. The program SPIN (separation-incineration) is to be developed in two steps:

1. PURETEX (by year 2000) to improve plutonium separation, to implement separation of minor actinides, and to reduce the volume of waste to be stored underground, and

2. ACTINEX (beyond 2000) to define new processes for separating long-lived radionuclides. This program involves all actinides and all long-lived fission products present in spent fuels.

Collaborative Projects

France has also been involved in a number of collaborative projects with other countries in Europe including Belgium (at Mol), Germany (at Asse), Sweden (at Stripa), and Switzerland (at Grimsel Pass). In addition, two performance assessment projects are of note.

CEC PAGIS project: This was a CEC project in performance assessment, which evaluated the performance of deep geologic repositories at four locations. The Auriet site near Limoges in granite was one of the four sites involved in this project. Some of the work here will be extended in the Everest project.

CEC Everest project is a cooperative project of five organizations of the European Community involved in waste management: ANDRA (France), CEN / SCK (Belgium), ECN (The Netherlands), GRS (Germany), and IPSN (France). The project consists of the evaluation of the sensitivity of the radiological consequences associated with deep nuclear waste disposal systems to the different elements of performance assessment. The work covers three types of geologic formations (granite, salt, and clay). It is to last from April 1991 to September 1994.

France is relying on predictive modeling of release scenarios for its proposed deep geologic repository to demonstrate safety over the long periods of concern. Effort has been and is continuing on modeling the source terms, ground hydrology, various release scenarios, migration through the geosphere, distribution in the ecosphere, and potential doses to humans. The probability of various events also are being estimated.

United Kingdom

Report Outline

I. Background and General Information

II. Waste Types

III. Reprocessing / Interim Storage

IV. Waste Disposal Strategy

V. Select Organizations Involved in Nuclear Waste Disposal

VI. Legislation / Regulatory Criteria

VII. Radiation Protection

VIII. Site Characterization — Research and Development

IX. Public Involvement

I. Background and General Information

The United Kingdom is roughly 95,000 square miles in size and has a population of 58 million, or 611 people per square mile. In 1992 nuclear power provided the United Kingdom with about 20 percent of its electricity, which is expected to continue for the foreseeable future. Other domestic energy sources include coal, oil, and natural gas. The government is currently reviewing its nuclear power program. See Table H.3 for a breakdown of energy production.

Most spent fuel is reprocessed because it is considered a resource that can be recycled to recover uranium and plutonium. The government owns British Nuclear Fuels (BNFL), a corporation that provides commercial fuel cycle services and provides extensive reprocessing services for domestic and foreign customers. However, reprocessing has been questioned lately with considerable debate focusing on BNFL's request to begin operations at THORP, a thermal oxide reprocessing plant constructed by the BNFL. The government recently granted approval to begin operations at THORP following a formal public inquiry and extensive public consultation. At about the same time, however, Scottish Nuclear, one of the country's utilities, announced it plans to store its used fuel for up to 100 years instead of immediately reprocessing it.

Table H.3 - The United Kindom Energy Industry*

Population	1990	58 million
Electric Power	1989	310.7 TWh
		65% coal
		12% nuclear
		10% oil
		2% hydro / gas
	1990	20% nuclear
	1995	17% nuclear
	2000	15% nuclear
Nuclear Power**	1991	11.6 GWe
	1995	12.0 GWe
	2000	10.5 GWe
Reactor Mix	1991	GCR — 22 (1956–72)
		AGR — 14 (1976–89)
		PWR — 1 (1994)
		FBR — 1 (1976)
Reactor Development		PWRs; future LMFBR development

* Source: DOE / RW-0371P

**Policy: Continue nuclear power as a significant element of total electricity production; substantially based, to date, on gas-cooled reactors, but now diversifying to PWRs; eventual active FBR pursuit expected.

II. Waste Types

The U.K. system of classification of radioactive wastes depends heavily on the origins of the waste, denoting the wide variety of material types occurring in solid, liquid, and gaseous forms. The four main classes are high-level waste, intermediate-level waste, low-level waste, and very low level waste. The main waste origins in the United Kingdom, in order of volume, are reprocessing, nuclear power generation, military uses, and other uses (including medical).

High-level wastes: wastes in which the temperature may rise significantly as a result of their radioactivity, such that this factor must be taken into account for storage and disposal facility design. In the United Kingdom this constitutes liquid waste from reprocessing that is vitrified to yield approximately 30 cubic meters per year. The current reactors are expected to generate approximately 1,280 cubic meters of high-level waste by the year 2000.

Intermediate-level wastes: wastes with a radioactivity exceeding the boundaries for low-level waste, but which do not require heating to be taken into account in the design of storage or disposal facilities. Intermediate-level wastes derive from many sources, but primarily from waste metal from fuel rods that are reprocessed (swarf in the case of Magnox), sludges, ion exchange resins, and contaminated equipment. Approximately 257,000 cubic meters of intermediate-level waste will be generated by the year 2030.

Low-level wastes: wastes containing radioactive materials other than those acceptable for dustbin disposal, but not exceeding defined numerical classification limits. Low-level wastes arise from both the nuclear industry and research and medical facilities. It includes paper products, protective clothing, laboratory equipment, building products, contaminated soils, decommissioning products, and fluids such as cooling water. Approximately 728,000 cubic meters of low-level waste will be generated by the year 2030.

Very low level wastes: wastes that are regarded as suitable for disposal with household refuse (referred to as dustbin disposal). These wastes contain levels below the threshold limit value of the Radioactive Substances Act 1960.

III. Reprocessing/Interim Storage

The U.K. obtains uranium from diverse foreign sources. It has developed and maintains complete fuel cycle capability (UF_6 conversion, enrichment, UO_2 and MOX fuel fabrication, spent fuel reprocessing) and sells fuel cycle services abroad.

Because of fuel cladding corrosion in water storage, Magnox fuels (uranium metal housed in magnesium alloy) must be reprocessed soon after irradiation (within 6 to 12 months) or moved into dry storage, which allows a longer storage period (possibly several years). A dry storage facility has been built at Wylfa for Magnox fuels. Advanced gas-cooled reactor (AGR) fuel cladding, while more durable than that of Magnox fuels, also suffers from corrosion in water, and wet storage is limited to about three years. Dry storage of AGR spent fuel also is being considered to provide more flexibility in planning reprocessing. The capacity of the spent fuel pool at the only PWR in the U.K. (Sizewell B - still under construction) is sufficient for 18 years of operation.

BNFL reprocesses Magnox fuels at Sellafield and has constructed a thermal oxide reprocessing plant (THORP) for AGR and PWR fuels at Sellafield. THORP recently was authorized to begin operations in December 1993. A smaller facility at Dounreay (northern Scotland) reprocesses spent fuel from test and breeder reactors. Both facilities service foreign customers as well. By 1989, 30,000 metric tons of uranium had been reprocessed.

Interim Storage

Radioactive wastes are being stored at several sites.

1. Sellafield - BNFL is building interim storage for the cemented cladding from Magnox, AGR, and light reactor fuels; for the graphite removed from AFR fuels; for the stainless steel hardware from AGR fuels; and for the cemented residues from the enhanced actinide removal plant.

2. Dounreay - Interim storage is in place for high alpha-beta-gamma wastes, for high beta-gamma wastes, and for high alpha wastes. A cementation plant includes an 800-cubic-meter concrete vault-type storage facility for drummed wastes.

3. Winfrith - Interim storage capability for both low-level waste and intermediate-level waste (not suitable for Drigg) is in place, with another facility for unshielded 500-liter drums of cemented intermediate-level wastes. This is an engineered, above-ground facility.

4. Harwell - Storage for intermediate-level wastes consists of water basin storage (for radiation sources), tank storage for liquids, shielded storage for high beta-gamma wastes, and unshielded storage for low beta-gamma wastes.

5. Fife, Scotland - The Royal Navy is constructing an interim storage facility for intermediate-level wastes from nuclear-powered submarines at its Rosyth dockyard in Fife. The facility will be able to hold the expected wastes through 2010. Prior to 1983, these wastes were disposed of at sea.

IV. Waste Disposal Strategy

Any review of the radioactive waste management policy in the United Kingdom must begin with the Royal Commission on Environmental Pollution's sixth report, published in 1976, and commonly known as the *Flowers Report*. Prior to 1976, no major review of the status of radioactive waste management had been conducted. The *Flowers Report* recommended that the formal responsibility for setting out a management and disposal strategy should be given to the Department of the Environment. The Flowers Report also stated that there be no commitment to a fission program until it has been demonstrated that a method exists to ensure the safe containment of long-lived, highly radioactive wastes for the indefinite future. In 1981, it was decided that high-level waste should be temporarily stored and aged for at least 50 years. *No decisions were made or foreseen on ultimate disposal.*

Because of the relatively small volume of high-level waste and the availability of adequate storage, the need to dispose of high-level waste is not seen as a high priority. In addition, when the government attempted to investigate several potential sites in the late 1970s, the project had to be cancelled due to public opposition. Currently, high-level wastes are vitrified and will be dry stored for 50 to 100 years at which time the government will make decisions concerning their disposal.

Low-level wastes are disposed of in engineered surface facilities. Low-level wastes were originally packed in steel drums and placed in shallow trenches excavated in glacial sediments and underlain by clays at Drigg near Sellafield. In recent years, however, a tighter regulatory environment has resulted in the use of concrete vaults constructed in the trenches. When filled, the trenches are backfilled and covered with soil and plastic sheeting. Discharges from the site are collected, tested, and, if found to be within acceptable limits, allowed to flow to the sea. Future plans call for supercompacting of the wastes to extend the useful life of the facility at Drigg. Low-level waste also is disposed of in a small excavation in sandstone at Dounreay in Scotland.

The government is now focusing its efforts on early disposal of intermediate- and low-level wastes in a deep underground geologic repository. U.K. Nirex Ltd. (Nirex), a private limited company (see below), has been given the responsibility of providing facilities for the disposal of these wastes. The current investigation phase started in 1989 when, after extensive consultation, Sellafield in Cumbria and Dounreay in Caithness were nominated for preliminary study as potential sites for deep geologic repositories for low- and intermediate-level radioactive wastes. In July 1991, Nirex announced that it planned to concentrate resources on investigations at Sellafield and, in particular, the area between the Sellafield works and the main road on the western boundary of the Lake District National Park. Nirex is particularly interested in the 500-million-year-old basement rocks of the Borrowdale Volcanic Group, which are overlain by sandstone on much of the West Cumbrian coastal plain and crop out in the Lake District National Park.

V. Select Organizations Involved in Nuclear Waste Disposal

No organization has been assigned responsibility for disposing of high-level radioactive wastes. Waste producers, primarily nuclear utilities, however, are responsible for the waste they create. To manage and dispose of low- and intermediate-level waste, the nuclear industry formed the U.K. Nirex Ltd. The Department of Environment (DOE) is responsible for designing and implementing a national waste disposal strategy. In England and Wales, the regulatory authority is Her Majesty's Inspector of Pollution (HMIP), together with, in the case of licensed sites, the Ministry of Agriculture, Fisheries and Food.

Scotland and Northern Ireland have similar environmental and regulatory organizations.

A brief description of some of the key organizations follows.

BNFL (British Nuclear Fuels plc): Headquartered in Risley, Cheshire (near Manchester), is a government-owned, commercially operated corporation that provides fuel cycle services for domestic and foreign customers. BNFL holds one-third interest in each of three international consortia: URENCO (uranium enrichment by gas centrifuge), United Reprocessors GmbH (reprocessing), and Nuclear Transport Limited (spent fuel transportation). BNFL operates several facilities in the United Kingdom.

DoE (Department of the Environment): The DoE assumed the responsibility for management of radioactive wastes in 1977. Responsibilities include the implementation of the national waste disposal strategy, performance of related research, and review of the work of the waste generators.

HMIP (Her Majesty's Inspectorate of Pollution): HMIP is, administratively, a part of the DoE. HMIP has three primary responsibilities: regulatory development for the national waste disposal strategy; funding and coordination of waste treatment and waste isolation R&D at Harwell, the British Geological Survey, and the NRPB; and regulation of the discharge of radioactive materials to the environment.

NRPB (National Radiation Protection Board): This organization, located at Harwell, was established under the Radiological Protection Act of 1970 to provide an authoritative reference point (advisory only) on radiological protection in the United Kingdom.

RWMAC (The Radioactive Waste Management Advisory Committee): Advises the Secretaries of State for the Environment, Scotland, and Wales on the technical and environmental implications of major policy pertaining to the management of civil radioactive waste, including research and development.

U.K. Nirex Ltd. This organization was set up in 1985 by the government with the purpose of providing disposal facilities for intermediate and low level radioactive wastes. It is a government-owned corporation under the Department of Trade and Industry (DTI), with shares held by the DTI, BNFL, Nuclear Electric plc, and Scottish Nuclear plc. One special share is owned by the Secretary of State for Trade and Industry, and that share has absolute veto power. Nirex's purpose is to provide disposal facilities for intermediate- and low-level radioactive wastes.

VI. Legislation/Regulatory Criteria

Before any repository can go into operation, certain requirements must be met. Nirex must seek planning permission to build a repository, and, if the repository is built in England, permission to dispose of the wastes from Her Majesty's Inspectorate of Pollution (HMIP) and from the Ministry of Agriculture, Fisheries and Food. Nirex must also seek a nuclear site license from the Nuclear Installations Inspectorate. Legal requirements are set forth by the authorizing departments in the document, "Disposal Facilities on Land for Low and Intermediate Level Wastes: Principles for the Protection of the Human Environment" (HMSO, 1984), and by the NII in its document "Safety Assessment Principles for Nuclear Plants."

Licensing Process

Licenses are actually granted by the Health and Safety Executive (HSE) through its Nuclear Installations Inspectorate (NII) after receiving approval from all appropriate agencies.

The Nuclear Installations Inspectorate's approach to licensing includes:

a. preparation of a Preliminary Safety Report (PSR) and a Pre-Construction Safety Report (PSCR) by the applicant,

b. a decision on proceeding with licensing based upon review and approval by the authorizing departments mentioned above,

c. conduct of a Public Inquiry by the NII,

d. approval of construction following revision of the PCSR by the applicant to incorporate information / decision developed in the review process,

e. preparation of a Pre-Operational Safety Report by the applicant reflecting the knowledge gained during the construction period, and

f. approval of operation followed by continuing inspection and regulation during the lifetime of the project.

VII. Radiation Protection

The principal requirements for authorization of a repository, under the Radioactive Substances Act, are set out by the Authorizing Departments, in the "Principles Document." In designing and building a repository, Nirex also takes into account the 1990 recommendations of the International Commission on Radiological Protection (ICRP) and the National Radiological Protection Board's (NRPB) statements on radiological protection objectives for waste disposal.

The main numerical requirement states that the appropriate target applicable to a single repository at any time is, therefore, a risk to an individual in a year equivalent to that associated with a dose of 0.1 mSv: about 1 chance in a million. (In practice, Nirex has adopted a more stringent risk factor of 0.06 SV^{-1}.)

In addition to the numerical requirement, the principles include the following:

1. Radiation exposure of individuals and the collective dose to the population shall be reduced to levels that are as low as reasonably achievable (ALARA), economic and social factors being taken into account.

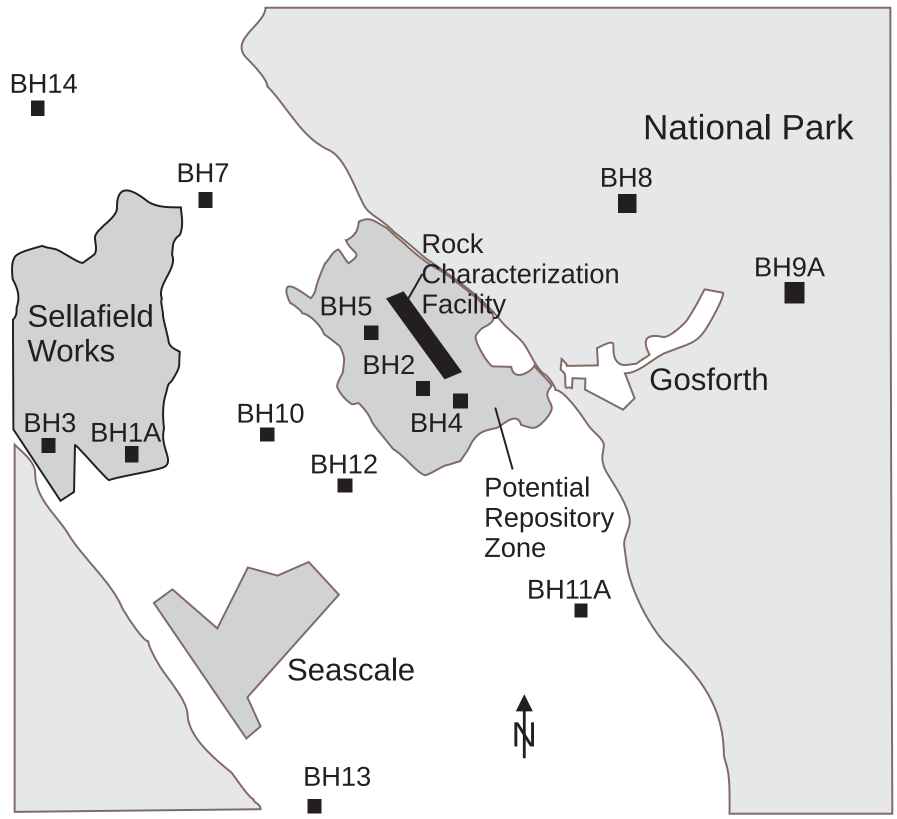
2. Future movement of radioactivity from a facility should not lead to a significant increase in the radioactivity naturally occurring in the general locality of a facility. Implicit in the requirements is the understanding that the disposal system should not rely on monitoring or intervention to ensure safety. Future generations may wish to monitor it, but Nirex intends to develop a strategy that provides safety without the need for intervention.

VIII. Site Characterization— Research and Development

The United Kingdom has an array of research and development (R&D) activities under way in support of all its nuclear programs. Nirex, however, is the primary organization responsible for R&D towards the development and eventual operation of a deep geologic repository. To that end, the company has developed a disposal concept that uses a multi-barrier containment system. Caverns would be excavated at depth in a stable geologic environment. The waste, set in steel or concrete packages, would then be backfilled with a cement-based material. The backfill, for which a patent application has been filed, is designed to meet certain requirements to help promote uniform chemical conditions and high sorption capacity across the repository.

Nirex has been conducting research and development since 1982, including a deep borehole drilling program. Thus far, Nirex has drilled twelve deep boreholes into the basement rocks around Sellafield, and received planning permission for the 13th. Nirex also wants to drill several boreholes as part of its rock characterization faculty. (See Figure H.4.) Testing is carried out both during and after drilling to determine parameters such as ground-water pressure and hydraulic conductivity, which affect the pattern and likely rate of ground-water flow through the rock. One of the major achievements has been to establish a subdivision of the rocks into several formations that can be correlated between boreholes over distances of several kilometers. This, in turn, has enabled a more detailed description of the Borrowdale Volcanic Group (BVG), where a potential repository would be located. Research to date indicates that the flow of water through the BVG is likely to be controlled by the presence of fractures in the rock. Flow fractures (fractures through which water flows) are relatively wide-spaced, and sealing of fractures by mineralization is extensive, which may explain, in part, the sparsity of flow fractures being found. Using cross-hole seismic tomography, Nirex is also studying the extent to which fractures are connected to help determine the ground-water flow in the BVG.

Figure H.4 — Location of regional boreholes around the Sellafield site.



Source: U.K. Nirex Ltd.

Once active testing is completed in the boreholes, they will be converted to long-term monitoring of ground-water conditions. Ultimately the instrumentation will make up a network for monitoring the response of the ground-water system to the construction of a proposed rock characterization facility. Nirex wants to construct such a facility to provide geologic and hydrogeologic characterization data and scope for a model validation program, which would permit firmer assessment of long-term safety. It also would provide the data needed to choose the design and construction plan for a repository. It would yield additional geotechnical data on rock competence and fracture characteristics so decisions on repository construction methods could be made and cost estimates could be refined. Work in the laboratory would focus on measuring ground-water travel time, the effects of fracturing, and gas migration. Sealing and back-filling experiments would also be conducted.

The proposed laboratory, which would consist of two vertical shafts some 50 meters apart, would be sunk, using conventional techniques, to a target depth of 650 meters below sea level. The overlying water-bearing strata would be frozen during excavation and then lined with concrete to prevent water entering the shafts. Following shaft construction, lateral galleries would be driven at depth. Three small galleries would be established within the shaft walls at various depths above the main laboratory level to allow the drilling of a network of small-diameter boreholes, enabling a very large volume of rock to be sampled.

Nirex is conducting the Nirex Safety Assessment Research Programme, which consists of studies aimed at exploring the potential containment ability with the waste form and repository and those factors that will influence the return of radionuclides to the environment. The study includes research on ground-water pathways, the containment ability of carbon and stainless steel waste canisters, the evolution of the chemical environment in the repository over time, the driving forces behind ground-water flow, the transport of radionuclides in the ground water, potential gas pathways. Those processes near the earth's surface that could influence dose and the consequent risk to members of a future critical group also are being studied.

Nirex is also using MASCOT, a probability safety assessment program, and several submodels, to help identify and model the processes and pathways by which residual radionuclides from a repository may eventually return to the human environment. This work is part of the postclosure safety analysis, which needs to be developed prior to licensing. To date, the Nirex assessment has focused on three major pathways: transport of radionuclides in ground water, migration of radionuclides in gases; and return of radionuclides to the environment as a result of natural disruptive events or inadvertent human intrusion.

IX. Public Involvement

Since 1980, public awareness and involvement in nuclear decisions has increased, as has been evidenced in the public hearings on radiation releases from Sellafield, selection of potential disposal sites for radioactive waste, and inclusion of pressurized water reactors in the United Kingdom's reactor inventory. Procedures for greater public review have been put in place.

1. In the United Kingdom, any proposal to extend an existing nuclear site or create a new one must be sent to the relevant local planning authority (borough or county) under the Town and Country Planning Acts, where it is reviewed. Local planning authorities are made up of locally elected representatives, who will consider public comments that are submitted in writing.

2. If the local planning authority refuses to approve the proposal, the applicant may appeal to the Secretary of State, who can set up a public, local inquiry (conducted before a member of the judiciary, in a courtroom setting) to help him or her in determining the case. The Secretary of State can overrule the local authority after the public inquiry.

3. Since 1980, and particularly since the Chernobyl accident, United Kingdom agencies and organizations have expanded their public relations activities substantially to include the following:

a. round-the-clock information service for media,

b. speakers for technical meetings and public debates,

c. encouragement of the inclusion of information on radiation in school science curricula and sponsorship of teachers to work in the nuclear industry for one year,

d. participation in conferences and exhibitions, and

e. initiation of the Sellafield Visitors Center, which hosts *more than 150,000 visitors* each year.

References

ANDRA. 1993. French Radioactive Waste Management National Agency. "The Centre De L'Aube Low-Level Waste Disposal Facility: A Decade of Experience from Site Selection to Start-Up." Paper presented to the NWTRB by J.C. Fernique, June 1993.

ANDRA. 1993. French Radioactive Waste Management National Agency. *Radioactive Waste Management in France: What is Safe Radioactive Waste Management?* Presentation to the NWTRB, June 1993.

Barre, J-Y. 1992. "French Achievements in Radioactive Waste Management." *Pennsylvania Energy*, vol. 6, No. 2, Fall 1992.

Berkhout, F. 1991. *Radioactive Waste: Politics and Technology*. London: Routledge.

British Nuclear Fuels, plc 1990. *Company Profile*. Risley, Warrington, U.K.: BNFL Information Services.

Deacon, D. and C. Ealing. 1982. "GEC Vault Storage Designs." Paper prepared for Spent Fuel Management & Waste Disposal Seminar in Washington, Institute of Nuclear Materials Management. 20-22 October 1982. GEC Energy Systems Limited; Whetstone, Leicester, U.K.

DSIN. 1993. "Main Nuclear Sites in France." Presentation to the NWTRB by the Nuclear Installation Safety Directorate. June 1993. France.

Environmental and Energy Services Co. 1989. *Public Perception and Acceptance of the Siting of Nuclear Waste Facilities in Seven Countries*. ERCE-R/89-42. Fairfax, Virginia. September 1989.

France, Embassy of. Fact Sheet on Reprocessing in France. French Nuclear Attache.

Knill, J. 1992. "Radioactive Waste Disposal in the United Kingdom." Presentation to the NWTRB, July 30, 1992.

IPSN. 1993. "Protection and Nuclear Safety Institute." Presentation to the NWTRB by the Institute for Protection and Nuclear Safety. June 1993. France.

Lefevre, J. and M. Bourgeois. 1992. "French Strategy and Program to Reduce Volume and Activity Level of Wastes Containing Long-Lived Radionuclides." Presentation at the Symposium on Separations Technology and Transmutation Systems, January 13-14, 1992, Washington, D.C.

U.K. Nirex Ltd. 1993. *United Kingdom Nirex Limited Annual Report 1992-1993*. October 1993. Harwell, Didcot, Oxfordshire, U.K.

U.K. Nirex Ltd. 1993. *Scientific Update 1993: Nirex Deep Waste Repository Project, Report no. 525*. U.K. Nirex Limited. December 1993. Harwell, Didcot, Oxfordshire, U.K.

Nuclear Notes from France (supplement). 1994. *The French Nuclear Program: An Outline*. February 1994.

ONDRAF/NIRAS. (undated). National Agency for Radioactive Waste and Enriched Fissile Materials. *Status, Mission, Competences*. Brussels, Belgium.

ONDRAF/NIRAS. (undated). *The Belgian Deep Repository Project*. National Agency for Radioactive Waste and Enriched Fissile Materials. Brussels, Belgium.

PNL. 1992. Pacific Northwest Laboratory International Program Support Office. *Highlights Report*. Monthly reports prepared for the DOE/OCRWM. January 1992 - April 1992.

"Reprocessing: Waste conditioning plants now in use at Sellafield." *Nuclear News*, April 1992, pp. 71-75.

RWMAC. 1990. *WASTE WATCHERS: The First Decade of the Radioactive Waste Management Advisory Committee*. Radioactive Waste Management Advisory Committee Secretariat. August 1990. London, U.K.

SAFIR. 1989. *SAFIR Summary Report*. National Agency for Radioactive Waste and Enriched Fissile Materials. June 1989. Brussels, Belgium.

Schechter, H.B. and J.C. Scarborough (undated). *Trip Report on Commissioner Rogers' Visit to the UK (May 6-16, 1989)*. United States Nuclear Regulatory Commission. Washington, D.C.

The French High Level Waste Act, English translation.

UK. 1991. *Environment in Trust: Radioactive Waste Management — A Safe Solution*. Department of the Environment. London, U.K.

U.S. DOE. 1991. *National Briefing Summaries: Nuclear Fuel Cycle and Waste Management*. PNL-6241, Rev.2. Pacific Northwest Laboratory, Battelle Memorial Institute. April 1991.

U.S. DOE. 1992. *International Nuclear Fuel Cycle Fact Book*. DOE/RW-0371P. Office of Scientific and Technical Information, Oak Ridge, Tenn. September 1992.

U.S. DOE. 1993. *International News Brief*. Civilian Radioactive Waste Management System, International Technology Information Center, CRWMS M&O/ITIC. April 15, 1993. Vienna, Virginia.

References

Allison, J.D., D.S. Brown, and K.J. Novo-Gradac. 1990. "MINTEQA2, A Geochemical Assessment Database and Test Cases for Environmental Systems: version 3.0 User's Manual," Report EPA/600/3-91/-21, Athens, Georgia. Environmental Research Laboratory, U.S. Environmental Protection Agency.

Carter, L.J. 1987. *Nuclear Imperatives and Public Trust; Dealing with Radioactive Waste.* Resources for the Future, Inc.: Washington, D.C.

Center for Nuclear Waste Regulatory Analyses. 1993. *Expert Elicitation of Future Climate in the Yucca Mountain Vicinity, Iterative Performance Assessment Phase 2.5.* August 1993.

Czarnecki, J.B. 1985. "Simulated effects of increased recharge on the ground water flow system of Yucca Mountain and vicinity, Nevada-California." *U.S. Geological Survey Water-Resources Investigations Report 84-4344.*

Department of Energy. 1987. *Site Characterization Plan Conceptual Design Report*. Compiled by H.R. MacDougall et al., prepared by Sandia National Laboratories, multi-volume, SAND84-2641.

———. 1988. *Site Characterization Plan, Yucca Mountain Site, Nevada Research and Development Area, Nevada,* DOE/RW-0199.

———. 1991. *Waste Acceptance Preliminary Specifications for Vitrified High-Level Waste Forms* Draft, DOE/RW-xxxx. Office of Civilian Radioactive Waste Management, April 1991. Transmitted from John P. Roberts to William D. Barnard under a cover letter dated July 23, 1992.

———. 1992. *Report of Early Site Suitability Evaluation of the Potential Repository Site at Yucca Mountain, Nevada.* Office of Civilian Radioactive Waste Management. Science Applications International Corporation.

———. 1993a. *Yucca Mountain Site Characterization Project Waste Package Implementation Plan Revision 0,* Office of Civilian Radioactive Waste Management, February 1993, YMP/92-11, Rev. 0.

———. 1993b. *Yucca Mountain Site Characterization Project Waste Package Plan Revision 1*, Office of Civilian Radioactive Waste Management, March 1993, YMP/90-62, Rev. 1.

———. 1993c. "Multi-Purpose Canister (MPC) Implementation Program Conceptual Design Phase Report, Final Draft," September 30, 1993.

Electric Power Research Institute. 1993. "Feasibility Evaluation of the Universal Container System," February 1993, EPRI TR-101988.

Forster, R.M. and A. J. Smith. 1992. "Microfossils as indicators of paleohydrology and paleoclimate." OECD Workshop on Paleohydrological Methods and Their Applications for Radioactive Waste Disposal, Paris 1992.

GRIP. 1993. Greenland Ice-core Project Members. "Climate Instability During the Last Interglacial Period Recorded in the GRIP Ice Core," *Nature*, v.364, 1993, pp. 203-207.

Hackbarth, C. J. 1985. *Disposal of High-Level Radioactive Wastes in the Unsaturated Zone: Technical Considerations and Response to Comments Final Report*, USNRC, October 1985, NUREG-1046.

Hoskins, R.E. 1989. "A Systems Evaluation of the High Level Nuclear Waste Management System Based on Integration of Dual Purpose Cask into the System as Alternative to DOE's Proposed Monitored Retrievable Storage Facility as an Integral Part of the System," University of Tennessee, June 30, 1989.

Houghton, J.T., B.A. Callander, and S.K. Varney (editors). 1992. *Climate Change 1992, The Supplementary Report to the IPCC Scientific Assessment*, Published for the Intergovernmental Panel on Climate Change by Cambridge University Press.

Houghton, J.T., G.J. Jenkins, and J.J. Ephraums (editors). 1990. *Climate Change: The IPCC Scientific Assessment*. Published for the Intergovernmental Panel on Climate Change, by Cambridge University Press.

IAEA. 1992. International Atomic Energy Agency. *Geological Disposal of Spent Fuel and High Level and Alpha Bearing Wastes. Proceedings of a Symposium in Antwerp*. October 19 to 23, 1992. Vienna, Austria.

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

Kerr, R. 1993. “Fossils Tell of Mild Winters,” *Geotimes*, pp. 6-7, (November 1993).

Levy, S.S. 1991. “Mineralogic Alteration History and Paleohydrology at Yucca Mountain, Nevada.” *High Level Radioactive Waste Management Proceedings of the Second International Conference*, 1991, pp. 477-585.

Mangold, D.C. and C. Tsang. 1991. “A Summary of Subsurface Hydrological and Hydrochemical Models.” Reviews of Geophysics, vol. 29, no. 1, 51-80.

Marshall, B.D., Z.E. Peterman, and J.S. Stuckless. 1993. “Sr Isotopic Evidence for a Higher Water Table at Yucca Mountain.” *High Level Radioactive Waste Management Proceedings of the Fourth Annual International Conference*, pp. 1928-1952.

Nuclear Regulatory Commission. 1988. “Qualification of Existing Data for High-Level Nuclear Waste Repositories, ” NUREG-1298, February 1988.

National Research Council. 1992. Board on Radioactive Waste Management. *Ground Water at Yucca Mountain, How High Can It Rise?* Final Report of the Panel on Coupled Hydrologic / Tectonic / Hydrothermal Systems at Yucca Mountain. Washington, D.C.: National Academy Press.

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

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

———. 1991a. *Third Report to the U.S. Congress and the U.S. Secretary of Energy*. May 1991. Washington, D.C.: U.S. Government Printing Office.

———. 1991b. *Fourth Report to the U.S. Congress and the U.S. Secretary of Energy*. December 1991. Washington, D.C.: U.S. Government Printing Office.

———. 1992. *Fifth Report to the U.S. Congress and the U.S. Secretary of Energy*. 061-000-00785-7. June 1992. Washington, D.C.: U.S. Government Printing Office.

———. 1992. *Sixth Report to the U.S. Congress and the U.S. Secretary of Energy*. December 1992. Washington, D.C.: U.S. Government Printing Office.

———. 1993a. *Special Report to Congress and the Secretary of Energy*. March 1993. Washington, D.C.: U.S. Government Printing Office.

———. 1993b. *Underground Exploration and Testing at Yucca Mountain; A Report to Congress and the Secretary of Energy*. October 1993. Washington, D.C.: U.S. Government Printing Office.

———. 1994. *Letter to Congress and the Secretary of Energy*. February 1994. Arlington, Virginia.

Paces, J.B., E.M. Taylor, and C. Bush. 1993. "Late Quaternary History and Uranium Isotopic Compositions of Ground Water Discharge Deposits, Crater Flat, Nevada." *High Level Radioactive Waste Management Proceedings of the Fourth International Conference*, pp. 1573-1580.

Parkhurst, D.L., D.C. Thorstenson, and L.N. Plummer. 1982. "PHREEQE— A Computer Program for Geochemical Calculations." U.S. Geological Survey Water Resources Inv. 80-96, Revised.

Ramspott, L.D. 1991. "The Underground Retrievable Storage (URS) High-Level Waste Management Concept," in *Proceedings of the Symposium on Waste Management*, Tucson, Arizona, February 24-28, 1991.

Roseboom, E. H., Jr. 1983. *Disposal of High-Level Nuclear Waste Above the Water Table in Arid Regions*, Geological Survey Circular 903, 1983

RWMAC (Radioactive Waste Management Advisory Committee). 1990. *Eleventh Annual Report* made to the Secretary of State for the Environment, the Secretary of State for Scotland, and the Secretary of State for Wales. London, England: HMSO Publications Centre.

SAFIR Summary Report. 1989. ONDRAS / NIRAS, National Agency for Radioactive Waste and Enriched Fissile Materials. SCK / CEN. June 1989. Brussels, Belgium.

Smith, M.L. 1992. "Universal Storage / Transport / Disposal Packages." Presented at the International High Level Waste Management Conference, Las Vegas, Nevada. April 12-16, 1992.

Westinghouse Electric Corporation. 1984. "Preliminary Cost Analysis of a Universal Package Concept in the Spent Fuel Management System," WTSD-TME-032.

Winograd, I.J. 1991. *Yucca Mountain as a Nuclear-Waste Repository—Neither Myth nor Millennium*, U.S. Geological Survey Open-File Report 91-179.

Winograd, I.J. et al. 1985. "Two-Million-Year Record of Deuterium Depletion in Great Basin Ground Waters," *Science*, vol. 227, pp. 519-522 (1985).

Wolery, T.J. 1992. "EQ3 / 6, A Software Package for Geochemical Modeling of Aqueous Systems: Package Overview and Installation Guide (version 7)," UCRL-MA-110662, Pt. 1. Lawrence Livermore National Laboratory, Livermore, California.

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.

10 CFR 960 (Code of Federal Regulations). 1990. Title 10, *Energy*, Part 960, "General Guidelines for the Recommendations of Sites for Nuclear Waste Repositories." 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.

Glossary

The following glossary of scientific and technical terms has been compiled to aid in the reading of the Board's reports. The glossary 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 some of the 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 accessible to humans through air and water

Aluminosilicate: A compound in which silicon and aluminum atoms are joined by sharing linking oxygen atoms. Silicate compound in which some of the silicon atoms have been replaced by aluminum.

Analogue: A thing or part that is analogous. As used in this report, a naturally occurring phenomenon or something resulting from human activity that can provide information on or add understanding to aspects of repository performance. Analogues generally are broken into two categories: natural and anthropogenic. Natural analogues occur through natural phenomena. Anthropogenic analogues result from human activity. "Archaeological analogue" generally is used to refer to an analogue resulting from the activities of ancient cultures.

Anthropogenic: Caused by humans.
(See **Analogue**.)

Anion: The dissolved negative ion of a salt

Apatite: A group of phosphate mineral with the general formula $X_5(YO_4)_3Z$, where X is usually Ca or Pb, Y is P or As and Z is F, Cl, or OH

Areal power density: The concentration of thermal energy produced by emplaced waste, which is averaged over the area of the repository and expressed in watts per square meter or in kilowatts per acre

Backfilling: The placement of materials, originally removed or new, into underground excavated areas, including waste-emplacement holes, drifts, tunnels, and shafts

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

Basement rocks: Crust of the earth below sedimentary deposits (such as clays)

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

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)

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

Borehole emplacement: The DOE's baseline plan calls for the emplacement of canisters of spent fuel and high-level waste in boreholes excavated in the walls of tunnels in the proposed repository

Borings: Holes drilled into the earth

Borosilicate glass: A silicate glass containing boric acid and used to immobilize or encapsulate and stabilize commercial or defense high-level waste from reprocessing

Burnup: A measure of reactor fuel consumption expressed as the percentage of fuel atoms that have undergone fission, or the amount of energy produced per unit weight of fuel. Burnup history refers to the length of time spent fuel remains in the reactor. There is a direct correlation between burnup history and thermal output.

Burnup credit: To "receive burnup credit" means that the NRC will depart from its previous practice and allow the DOE to take into account in its MPC design the fact that the MPCs will be loaded with *spent* fuel, which is less reactive than fresh, unused fuel and is therefore less likely to "reach criticality" if a container should be breached during storage, transportation, or disposal.

Calcine: A solid that has been heated to a high temperature without melting, usually in the presence of oxygen

Canister: The structure surrounding a waste form (e.g., high-level waste immobilized in borosilicate glass) that facilitates handling, storage, transportation, and / or disposal. Before emplacement in a repository, the canister may be placed in a disposal container.

Cask: A 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. (See **Universal cask**.)

Characterization: The collecting of information necessary to evaluate suitability of a region or site for geologic disposal. Data from characterization also will be used during the licensing process.

Colloid: A suspension of very fine-grained material

Container: A receptacle used to hold radioactive material (usually spent fuel)

Criticality: Being in a state sufficient to sustain a nuclear chain reaction

Curie (Ci): The unit used in measuring radioactivity. One curie equals 3.7×10^{10} spontaneous nuclear disintegrations per second; also the quantity of a material having the activity of one curie.

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.

Disturbed zone: That portion of the surrounding rock whose physical or chemical properties have changed as a result of construction or "as a result of heat generated by the emplaced radioactive waste such that the resultant change of properties may have a significant effect on the performance of the geologic repository" (10 CFR 60).

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

Engineered barrier system: The constructed, or engineered, components of a disposal system designed to prevent the release of radionuclides from the underground facility or into the geohydrologic setting. It includes the thermal-loading strategy, repository design, waste form, waste containers, material placed over and around such containers, and backfill materials.

Environmental issues: Issues covering the potential effects that site-characterization activities and development, operation, and closure of a repository could have on the environment, which includes air, water, soil, biologic, cultural, and socioeconomic resources at and downstream, in surface water or ground water, or downwind from the site for thousands of years. Environmental issues also include reclamation and restoration after, or mitigation of effects of, site characterization and repository construction, operation, and closure.

Evapotranspiration: The overall process of water vapor escaping into the atmosphere by evaporation from soil surfaces, by evaporation from open bodies of water, and by transpiration from the soil by plants

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. Now called the exploratory studies facility.

Exploratory studies facility (ESF): New designation for the exploratory shaft facility

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

Flux: The rate at which ground water flows across an area of porous or fractured media, which is at right angles to the direction of the flow

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

Frit: A mixture of calcified solids from which glass is made; its consistency is usually that of a sand or powder

Fuel aging: Storage of radioactive materials especially spent nuclear fuel, to allow the decay of radionuclides. Young spent fuel has a higher thermal output than aged spent fuel.

Fuel assembly: (See **Fuel rod**.)

Fuel rod: A rod or tube made out of zircaloy into which fuel material, usually in the form of uranium pellets, is placed for use in a reactor. Many rods or tubes, mechanically linked, form a fuel assembly or fuel bundle.

Geochemistry: Geochemistry at the Yucca Mountain site is concerned primarily with the potential migration of radionuclides to the accessible environment. Geochemists are studying the chemical and physical properties of the minerals, rocks, and waters that might affect the migration of radionuclides from a repository.

Geoengineering: Refers to the design, construction, and performance of the exploratory studies facility, surface drilling operations, and underground openings at the repository, taking into account the engineering properties of the geologic materials and their spatial variations

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 an excavated geologic medium. 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.

Ground water: Water that exists or flows in a zone of saturation between land surfaces

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

Half-life: The time required for a radioactive substance to lose 50 percent of its activity by decay. Some radioactive materials decay rapidly. For example, the fission products strontium-90 and cesium-137 have half-lives of about 30 years. Others decay much more slowly: plutonium-239 has a half-life of about 25,000 years.

High-level waste: (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 wastes have been converted. (See **Reprocessing**.)

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

Hydrogeology: Refers to the study of the geologic aspects of surface and subsurface waters. At the Yucca Mountain site, emphasis is placed on the study of fluid transport through the rock matrix and fractures. Ground water is considered to be a prime means by which radionuclides (atoms that are radioactive) could be transported from the repository to the accessible environment.

Hydrolysis: The chemical reaction between water and the ion of a weak acid or a weak base

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

In-place disposal: Disposal of a waste material without moving it

Interim storage or storage: Temporary storage of spent fuel or 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

Jointed rock: Rock containing fractures or partings without displacement

Kinetics: Study of the rates of chemical reactions

Leach: To partially or completely dissolve and remove chemical components of a solid usually by an aqueous solution. The rate at which this occurs is the leach rate.

Long-lived waste package: Generally used in this report to refer to a waste package that has the capability to contain wastes for at least many thousands of years

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. An example is contaminated medical waste.

Magma: The molten rock material from which igneous rocks are formed

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

MTHM: Metric tons of heavy metal (nuclear fuel)

Monitored retrievable storage (MRS) 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

Multipurpose cask: A concept for a cask that can be used for more than one purpose, for example, to store and transport, and perhaps dispose of spent fuel

Natural analogue: (See **Analogue**.)

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

Nonvolatile: A material that changes from a solid or liquid state to a gaseous state insignificantly at a temperature of interest

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

Noble metals: Silver, mercury, gold, and the platinum metals (ruthenium, rhodium, palladium, osmium, iridium, and platinum)

Partitioning/transmutation A chemical solvent extraction or a dry process (partitioning) using fast neutron reactors or accelerators to obtain radionuclides with short half-lives in the waste packages (transmutation)

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.

Plutonium: A radioactive element with an atomic number of 94. Its most important isotope is fissionable plutonium-239, produced by neutron irradiation of uranium-238.

Portal: Opening to the underground; the rock face at which a tunnel is started

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

Preclosure: That time prior to the backfilling of the repository

Pressurized water reactor: A reactor system that uses pressurized water in the primary cooling system. Steam formed in a secondary cooling system is used to turn turbines to generate electricity.

Public health issue: An issue involving potential direct or indirect effects on, or risk to, human health during repository development, operation, and after closure. The possible public health and environmental consequences of the handling and transportation of high-level radioactive waste from points of origin to the repository are also of concern.

Quality assurance: 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

Radioactivity: The spontaneous emission of radiation from the nucleus of an atom. Radioisotopes of elements lose particles and energy through this process of radioactive decay. Radioactivity is measured in terms of the number of nuclear disintegrations occurring in a unit of time. The common unit of radioactivity is the curie (Ci).

Radiolysis effects: Radiation-induced dissociation of molecules; radiation-induced dissolution of molecules

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: A radioisotope that decays at a characteristic rate by the emission of particles or ionizing radiation(s)

Radionuclide migration: The movement of radionuclides, generally in liquids or gas forms, through a rock formation

Ramp: An inclined tunnel. Here, ramps would allow exploration and research of rock features and other phenomena critical to characterizing an underground repository site, while at the same time allowing for future use as an entrance to the underground repository should the site prove qualified.

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 fissionable parts are recovered for repeated use

Retrievability: The capability to remove waste packages from the repository

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.

Risk and performance analysis: Here it refers to the assessment of the long-term performance of a waste repository. Such analysis provides a means for incorporating all scientific and technical aspects into an integrated description of the entire repository system. Iterative performance analysis also can be used to help determine which site-characterization studies need to be emphasized or moderated to provide information more focused on timely assessment of site suitability.

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

Semivolatile: A material that changes from a solid or liquid state to a gaseous state slowly at a temperature of interest

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

Shear stress: That component of stress that acts tangentially to a plane through any given point in a body

Shotcrete: Fine aggregate concrete sprayed under high pressure onto the rock face between rock bolts, after wire netting has been attached between the rock bolt plates and the rock face. The resulting reinforcement produced by the wire netting and concrete, anchored by the rock bolts, forms a semi-smooth appearance and significantly reduces the formation and fall of stress slabs.

Silicate: A metal salt containing silicon and oxygen in the anion

Silica: Natural silicon dioxide

Site characterization: (See **characterization**.)

Slurry: A thin mixture of liquid and fine solids

Sorption: Retardation (of transport) through the binding of radionuclides by the surfaces of geologic materials along the flow path

Sorption characteristics: Characteristics describing the ability of rocks and minerals to bind, reversibly or irreversibly, radionuclides or other chemical species on their surfaces

Source term: The compositions and the kinds and amounts of radionuclides that make up the source of a potential release of radioactivity from the engineered barrier system to the host rock

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

Stochastic calculation: A numerical calculation based on probabilistic laws

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

Stress slabs: Slabs of rock (of varying thickness) that "peel" off the exposed rock surfaces of an excavation. The slabs are caused by the forces being exerted on the rock surfaces by internal rock pressure and gravity after excavation provides a void into which the pressure can be released.

Structural geology: Refers to the study of the deformational features of rocks induced by processes such as folding, faulting, and igneous activity. As used in this report, it also includes a study of the processes themselves.

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

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

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

Thermal energy: Heat; in this case produced by the decay and transformation of radioactive waste over time

Thermal load: The amount of heat distributed and affecting the near-field and overall repository material, including geophysical and engineered barriers, that is induced by waste emplacement (usually measured in kilowatts per acre)

Thermal-loading strategies: The determination of waste emplacement to cause specific effects on the repository by the heat generated by the waste. These strategies are based on such criteria as whether it is desirable to initially place the repository at a temperature below or above the boiling point of water, or what effect various temperature ranges will have on long-lived waste packages. Thermal-loading is usually measured in kilowatts per acre.

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

Thermo-mechanical effects: Stresses or strains induced by temperature changes

Transportation and systems: As used here, it refers to a system for moving spent nuclear fuel from approximately 110 commercial nuclear reactors located at 70 sites throughout the nation and transporting the high-level radioactive waste from Department of Energy defense facilities to a disposal site. It is not merely the activities associated with packaging spent fuel in a shipping cask and shipping it by highway, rail, or water. Transportation and systems also includes all processes involved before and after the trip — removing spent fuel from its storage facility, loading it into the cask, loading and unloading it at the various handling sites, storing it, and finally emplacing it in a repository.

Transuranic: Containing elements or isotopes having atomic numbers higher than uranium (92). TRU wastes may take a long time to decay (i.e., have a long half-life).

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 in Carlsbad, New Mexico, where waste consists primarily of clothing, equipment, machine parts, and some liquid waste contaminated during reprocessing at U.S. defense facilities.

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

Tunnel: An underground passage that is open to the surface at both ends

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

Unsaturated zone: Rock / geologic formation that is located above the regional ground-water table

Uranium: A naturally radioactive element with the atomic number 92 and an atomic weight of approximately 238. The two principal naturally occurring isotopes are the fissionable U-235 (0.7 percent of natural uranium) and the fertile U-238 (99.3 percent of natural uranium). Uranium may be measured in metric tons of uranium (MTU).

Volatile: A material that changes from solid or liquid state to a gaseous state quickly at a temperature of interest

Volatilization: Conversion from a solid or liquid state to a gaseous state

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 package: The waste form and any containers, shielding, packing, or 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 of hydration and their high adsorption capacity for dissolved metal ions in water

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