FINAL REPORT
U.S. Department of Energy

Title of Project: Low Dose Risk, Decisions, and Risk Communication

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3. Executive Summary

The research project conducted basic research on how people receive, evaluate, and form positions in response to scientific information and its relationship to low-dose radiation exposure. Three major areas of study were addressed in our research program. First was the development of theories, frameworks and concepts essential to guiding data collection and analysis. Second was a development of experimental studies on risk perception, evaluation of science information, the structure of individual positions regarding low-dose exposures, and the potential for identifying and conducting tradeoff conditions for programs and policies addressing low dose radiation exposures. This involves the study of existing knowledge and the evaluation of science information presented within a variety of formats — as educational information, news media stories, and alternative communication methods (personal contact, small group interaction, etc.). Third was the study of communities adjacent to existing nuclear industrial sites to examine how social conditions influence the development of attitudes and opinions about low-dose exposures, the available management options, control of radiation risks, and preferences for program and policy goals. The results of these efforts are presented in thirteen technical reports that are included in the Appendix below (Item 15).

4. Research Objectives

The overall research objective was to establish new levels of information about how people, groups, and communities respond to low dose radiation exposure. This is basic research into the social psychology of individual, group, and community responses to

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radiation exposures. The results of this research are directed to improving risk communication and public participation in management of environmental problems resulting from low dose radiation.

5. Methods and Results

The methods utilized for the several studies done during this project are described in detail in the various final reports attached in the appendix below. Experimental studies followed the standards of social psychology. Community case studies were conducted within the methodological standards of Sociology, Anthropology, Social Geography, and Political Science. The survey work followed the recommendations and standards of the American Association for Public Opinion Research.

6. Relevance, Impact and Technology Transfer

Improvements in risk communication have been identified as essential to reconcile expert judgments of the effects of low dose radiation exposure to humans and the environment. The biological research program entrusted to the DOE Low Dose Radiation Research Program is expected to produce new information on low dose effects. In order for these scientific advances to be of use to program and policy managers, they must be communicated to the public in such a way that they can be used to adjust exposure standards. These standards, in turn, have a direct effect on the time and cost of safely managing nuclear facilities producing low dose radiation. The current baseline of social science knowledge is not sufficient to support the outcome mission of the Low Dose Radiation Research Program. This risk communication research directed its attention to expanding the knowledge base about individuals, groups, and communities so that new and more informed communication efforts could be designed. The findings of this research project are transmitted to interested parties in presentations and talks, in reports made available through print and electronic venues, and through the development of publishable manuscripts. The impact of this work remains to be determined since the results of this research are in the early stages of dissemination.

7. Project Productivity

The principle investigator has directed many complex and large scale social science research efforts over the past 25 years. Based on that experience, he believes this was a very successful and productive project. Objective measures of productivity are somewhat difficult to provide. The extensive written reports and the number of presentations are one measure that is recorded in other sections of this Final Report. Beyond this, we expect

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that the future reception of the findings of this research by the social science communities and by risk communicators at all levels of radiation risk management will provide a better evaluation of the project productivity than can be shown at the time this report is being written.

8. Personnel Supported

Principle Investigator: James Flynn, Ph.D.
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Graduate Research Assistant, Jasmine Tanguay, Clark University
Graduate Research Assistant, Jennifer Wilhoit, Antioch New England Graduate School
Graduate Research Assistant, Josh Levin, Ph.D. University of Colorado
Carrie Goodwin, Research Assistant, Decision Research

9. Publications

- Flynn, J. and MacGregor, D. (in press). Commentary on Hormesis and Public Risk Communication: Is there a basis for public discussions? *BELLE Newsletter* with subsequent publication in *Human and Experimental Toxicology* (journal of the British Society for Toxicology).
- Flynn, J. (in press). Nuclear Stigma. Chapter 13 in N. Pidgeon, R. Kasperson, & P. Slovic (eds.), *The Social Amplification of Risk*. London: Cambridge University Press.
- Flynn, J. (in press). Entry for "Nuclear Energy/Nuclear Waste/Plutonium". *International Encyclopedia of Environmental Politics*. London: Routledge.
- Flynn, J., Slovic, P., and Kunreuther, H. (eds.) (2001). *Risk, Media, and Stigma*. London: EarthScan.

(Note: The research data obtained during this project were completed mid-way through 2002. We expect a number of manuscripts for publication will be written and submitted

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over the next year or so. Information on these publications will be forwarded to DOE as they are put into print.)

10. Interactions

The following list of dates, places, and subjects describe the main interactions resulting from this project.

10.1 Decision Research/ DOE Risk Communication Workshop June 12-14, 2000, Hilton Hotel, Eugene, Oregon

Subject: A review of existing risk communication studies, critique of work completed during the first six months of the project, and development of recommendations for continuing research by the study team.

Attendees from Decision Research: James Flynn, Donald MacGregor, Paul Slovic, Ellen Peters, Terre Satterfield, Robin Gregory, CK Mertz, Carrie Goodwin.

Other Attendees: Tony Brooks, Washington State University & DOE, Roger Kasperson, Clark University, Jeanne Kasperson, Clark University, Seth Tuler, Social and Environmental Research Institute & Clark University, William Freudenburg, University of Wisconsin, Sharon Friedman, Leigh University, Bryon Wynn, Lancaster University, UK, Nick Pidgeon, University of East Anglia, UK, Ellen Omohundro, Steve Johnson, University of Oregon,

Other Interactions: Presentations

- 10.2. James Flynn and Donald MacGregor, U.S. Department of Energy, Low-Dose Radiation Research Program, Office of Science, Contractor's Conference. "Low Dose Radiation, Risk, Decisions and Risk Communication," Rockville, MD, March 2002.
- 10.3. James Flynn, National Research Council/National Academy of Sciences, Workshop on Principles and Operational Strategies for Staged Repository Systems, "Public Interaction and Acceptance Issues," Washington, DC, September 5, 2001.
- 10.4. James Flynn and Donald MacGregor, U.S. Department of Energy, Low-Dose Radiation Research Program, Office of Science, Contractor's Conference. "The Design and Implementation of a Risk Communication Research Program," Arlington, VA, June 2001.

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- 10.5. James Flynn, American Chemical Society, Radiation, Health & Safety Symposium, "The Social Context for Communication about Radiation Risk," San Diego, CA, April 2001.
- 10.6. James Flynn, U.S. Department of Energy, Low-Dose Radiation Research Program, Office of Science, Workshop on Risk Communication. "The Confusing Context of Risk Communication," Arlington, VA, March 2001.
- 10.7. James Flynn, Gordon Conference, "Radiation Risk, Decisions, and Risk Communication," Sawyer-Colby College, New London, NH, July 2000.
- 10.8. James Flynn, International Conference on Trust, "Trust and Risk Management Communications," Western Washington State University, Bellingham, WA, June 2000.
- 10.9. James Flynn, Donald MacGregor and Paul Slovic, U.S. Department of Energy, Environmental Management, "The Social Geography of Risk Communication," Atlanta, GA, April 2000.
- 10.10. James Flynn, National Cancer Institute/Center for Disease Control, Workshop on I-131 fallout from Nevada Test Site, "The Social Context for Risk Communication," Rockville, MD, January 2000.
- 10.11. James Flynn, Society for Risk Analysis, "The Role of Risk Communication in Response to Technological Stigma," Atlanta, GA., December 1999.
- 10.12. Board on Radioactive Waste Management, National Research Council, "The Role of Stigmatization in Public Risk Perceptions of High-Level Radioactive Wastes," Irvine, CA, November 1999.
- 10.13. James Flynn, Social Amplification of Risk Workshop, UK Health and Safety Executive, "Nuclear Stigma," London, UK, September 1999.

11. Transitions

We expect that the results of this research and the publication of the findings will be applied within the field of risk communication over time. However, we cannot at this time describe those future uses.

12. Patents

No patents resulted from this project.

13. Literature cited

Each of the technical reports and the publications contains the appropriate bibliographies.

14. Feedback

Feedback to DOE on the progress and results of the research were made in annual written reports and in presentations at three contractor's meetings listed in item 10 above.

15. Appendices

Reports: Thirteen final reports resulted from the work performed during the 36-month project (September 1999 to September 2002). They are attached in electronic format. Each report has been uploaded to https://www.osti.gov/elink/index_2413.html with a completed copy of DOE F 241.3 and versions of these reports have been sent under separate cover to the three parties listed in Amendment A000, Part IV, and page 3 of our Agreement.

16. Quantities/Packaging

N/A

Low Dose, Risk, Decisions, & Risk Communication

List of Reports to Accompany the Final Report

Project Number 69904

Cooperative Agreement No. DE-FC07-99ER62879

Low Dose, Risk, Decisions, and Risk Communication

Principal Investigator James Flynn, Ph.D.
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prepared for the

U.S. Department of Energy
Low Dose Radiation Research Program

List of Reports to Accompany the Final Report

Report 1 of 13. Flynn, J. (in press). Nuclear stigma: Notes on the social history of radiation. In Pidgeon, N., Kasperson, R., & Slovic, P. (Eds.), *The social amplification of risk* (forthcoming, Summer 2002). London: Cambridge University Press. (filename: Report1of13-69904.pdf)

Report 2 of 13. Flynn, J., & MacGregor, D.G. *The social geography of risk communication* (Draft report). Eugene, OR: Decision Research. (filename: Report2of13-69904.pdf)

Report 3 of 13. MacGregor, D. G., Flynn, J., Slovic, P., & Mertz, C. K. (2002). *Perception of radiation exposure: Part I. Perception of risk and judgment of harm* (Draft report). Eugene, OR: Decision Research. (filename: Report3of13-69904.pdf)

Report 4 of 13. 4. MacGregor, D. G., Flynn, J., Mertz, C. K., & Slovic, P. (2002). *Perception of radiation exposure: Part II. Communicating about radiation exposure and health effects* (Draft report). Eugene, OR: Decision Research. (filename: Report4of13-69904.pdf)

Report 5 of 13. MacGregor, D. G., & Flynn, J. (2002). *Public perception of nuclear materials in space research*. Eugene, OR: Decision Research. (filename: Report5of13-69904.pdf)

Report 6 of 13. Peters, E., Burraston, B., & Mertz, C. K. (2002). *An emotion-based model of stigma susceptibility: Cognitive appraisals of emotion, affective reactivity, and worldviews in the generation of technological stigma..* Eugene, OR: Decision Research. (filename: Report6of13-69904.pdf)

Report 7 of 13. MacGregor, D. G. (2002, January). *Ionizing radiation: A tutorial on sources and exposures* (Ver. 2.0, Report No. 02-02). Eugene, OR: Decision Research. (filename: Report7of13-69904.pdf)

Report 8 of 13. MacGregor, D. G., & Mertz, C. K. (2002). *Communicating about low-dose exposure* (Draft report). Eugene, OR: Decision Research. (filenames: Report8of13-69904.pdf8, Report8of13-69904.pps, Report8of13-69904Viewer.exe)

List of Reports

Report 9 of 13. Gregory, R. & Arvai, J. L. (2002). *A decision-focused approach to DOE cleanup priorities* (Draft report). Eugene, OR: Decision Research. (filename: Report9of13-69904.pdf)

Report 10 of 13. 10. Satterfield, T., & Levin, J. (2002). *Risk communication, fugitive values, and the problem of tradeoffs at Rocky Flats* (Draft report). Eugene, OR: Decision Research. (filename: Report10of13-69904.pdf)

Report 11 of 13. Tuler, S. (2002). *Radiation risk perception and communication: A case study of the Fernald Environmental Management Project*. Leverett, MA: Social and Environmental Research Institute. (filename: Report11of13-69904.pdf)

Report 12 of 13. Webler, T. (2002). *Low dose risk perception and communication: A case study of the tritium controversy at Brookhaven National Laboratory*. Leverett, MA: Social and Environmental Research Institute. (filename: Report12of13-69904.pdf)

Report 13 of 13. Mertz, C.K., Flynn, J., MacGregor, D. G., Satterfield, T., Johnson, S. M., Tuler, S., & Webler, T. *Community surveys: Low dose radiation. Fernald, Ohio and Rocky Flats, Colorado* (Draft report). Eugene, OR: Decision Research. (filename: Report13of13-69904.pdf)

Low Dose, Risk, Decisions, & Risk Communication

Nuclear Stigma Notes on the Social History of Radiation¹

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A REPORT
Prepared for the

U.S. Department of Energy
Low Dose Radiation Research Program

September, 2002

¹ In press in *The Social Amplification of Risk*, ed. Nick Pidgeon, Roger Kasperson and Paul Slovic (London: Cambridge University Press, 2002).

Abstract

The problems confronting nuclear science and technology are clearly expressed in nuclear stigma, which functions as a composite evaluation of inherent hazards combined with the public history of management, and the perceptions of potential risks. The nuclear-stigma response runs wide and deep in American society. It is wide because concerns about nuclear facilities are shared across all segments of the population and for all forms of industrial radiation sources. It is deep because there is a long history that underlies public concerns. This history implies that organizations assigned to management of these hazards failed to provide the level of control and fiduciary responsibility for public health and safety expected by the public. The resulting public concern and opposition undercuts expert and government recommendations for future development of nuclear sciences and technologies. This is a major source of risk perceptions. Yet the problems with management of nuclear programs and projects are not part of nuclear risk assessments and risk analysis except in the public's intuitive judgment, which is expressed in nuclear stigma.

New developments in communication technologies are transforming the roles of risk analysis and public decision-making. News of events as understood in the social amplification of risk seems headed toward a broad-based public and interactive availability. Motivated advocates will gain more and earlier leverage. This has the potential to focus public attention ever more effectively on decision processes and to provide the means for new involvements in policy and program choices. Technological stigma and other ways of framing information, especially those approaches that provide quick, affective, and widely held guidelines, such as moral values, will become more important and influential. In addressing nuclear stigma, society must focus on organizational performance. Science and technology must be, and be seen as, the servant of human health and environmental preservation.

Organizational goals must be recreated to these ends if management of inherently hazardous technologies is to achieve public acceptance and fulfill its potential contributions on behalf of mankind.

Figure 1. A model of impact for unfortunate events. Adapted from Kasperson, "Social Amplification of Risk."

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News reports about the accidents and events associated with modern science and technology have, in certain cases, stigmatized places, products, or technologies.² Our understanding of these results are informed by the conceptual model outlined in the Social Amplification of Risk (SAR) and shown in modified form in Figure 1 to highlight the stigma effects.³ This paper considers nuclear stigma in the United States with attention to how it came about. Understanding how nuclear stigma was created is basic to understanding what to do about it.

The danger of nuclear technology is exposure to radiation with potential consequences of death, cancer, and genetic mutations. The long-lasting hazards of many radioactive materials, even at low or moderate exposures, which may or may not prove fatal until years later, constitute dreaded threats to existing and future biological existence.⁴ During the last quarter of the 20th Century a history of repeated failures in nuclear management was revealed. Some of this history goes back to the Manhattan atomic bomb project and taken together it provides a basis for nuclear stigma. This paper summarizes a study of the U.S. nuclear experience. It focuses on the official and expert standards, values, and levels of management performance applied to nuclear technologies in contrast with the public's expectations.

The use of risk analysis to inform public decisions directs attention to issues of control. The decision maker who can specify risks is in a very different position from, and potentially in conflict with, those who will experience the outcomes but who lack control over decisions or their implementation. Public acceptance of this decision condition requires trust that outcomes are made in the public interest and with full consideration of those put at greatest risk. When trust is missing, social and political opposition, which ultimately threaten to scuttle official decisions entirely, becomes the final, viable means of citizen control.

² Robin Gregory, James Flynn and Paul Slovic, "Technological Stigma," *American Scientist* 83 (1995): 220-23.

³ R. E. Kasperson, et al., "The Social Amplification of Risk: A Conceptual Framework," *Risk Analysis* 8 (1988): 177-87; R. E. Kasperson, "The Social Amplification of Risk: Progress in Developing an Integrative Framework of Risk," in *Social Theories of Risk*, ed. Sheldon Krinsky and Dominic Golding (New York: Praeger, 1992), 153-78.

⁴ Paul Slovic, "Perception of Risk," *Science* 236 (1987): 280-85.

The public's suspicions of nuclear decisionmakers have plentiful evidence of past faulty judgments and management failures. Such failures are an organizational risk added to the inherent dangers of the technologies. The high correlations between risk and distrust found in many social science studies should be considered as the public's intuitive estimate of organizational contributions to risk.⁵ The idea that organizations are a risk factor is almost never examined in formal risk assessments. In part this is because proponent organizations prepare risk assessments and they lack the required motivation and levels of organizational self-awareness to conduct such self-examinations. As it is, organizational personnel who benefit from the decision processes and who have long since rationalized to themselves, and proclaimed to their audiences, their own good motives, intentions, capabilities, organizational structure, and decision procedures define risk variables.⁶ This study shows that the organizations managing nuclear technologies are a major source of risk and their performance over half a century has shaped the creation of nuclear stigma.

What stories initiate the Social Amplification of Risk? The original definition was of "accidents and other events."⁷ Some stories carry "signals" about the source of an accident or event and provide clues about the causes. Signals in this context are messages about what might happen in addition to being reports of what did happen. These signals implicate analogous places and conditions as potentially dangerous; the report of a nuclear power plant problem casts doubt on all other such plants.

The rise and fall of nuclear power involves potential dangers that resonate with deeply responsive social-cultural beliefs and myths, reinforced in the large number of stories about nuclear-related events.⁸

⁵ J. Flynn, W. Burns, C. K. Mertz and P. Slovic, "Trust as a Determinant of Opposition to a High-Level Radioactive Waste Repository," *Risk Analysis* 12, no. 3 (1992): 417-29.

⁶ Charles Perrow, *Normal Accidents: Living with High-Risk Technologies* (New York: Basic Books, 1984); Freudenburg, W. 1993; W. Freudenburg and T. Youn, "A New Perspective on Problems and Policy." *Research in Social Problems and Public Policy*, 5 (1993), 1-20; L. Clark, "The Disqualification Heuristic: When Do Organizations Misperceive Risk?" *Research in Social Problems and Public Policy*, 5 (1993), 287-310.

⁷ Kasperson, "Social Amplification of Risk."

⁸ S. Weart, *Nuclear Fear: A History of Images* (Cambridge, MA: Harvard University, 1988).

An Overview of Nuclear Industrial Development

A brief overview of the dominant sources for nuclear stories is shown in Figure 2, which begins with the production of uranium fuel, the essential material for the United States weapons program and the civilian nuclear power industry. The final steps are disposal of radioactive residues, the “back-end” of nuclear cycles — reprocessing, decommissioning, and waste disposal.

Mining and Milling. Originally uranium was imported into the United States from the Belgian Congo (now Zaire) and Canada. However, by 1948 the AEC had created a new U. S. uranium mining industry and the AEC was the sole consumer of the industry output for more than two decades.⁹ Once mined and milled, uranium went through two additional steps, enrichment and fuel fabrication.¹⁰

Mining uranium was a dangerous occupation.¹¹ Hundreds of miners died extracting uranium ore, many of them Navajo Indians. The AEC did not implement available mine safety systems (e.g., in use at American coal mines) that could have been put into place quickly and economically even when public health reports recommended such systems to save miners’ lives. Then when legal suits were filed, the federal government fought for decades against accepting any responsibility for the results of their program.¹² After years of mining and milling uranium ore, the nation was left with “about 50 contaminated ore processing sites and about 5,000 nearby properties in various states and on some Indian tribal lands.”¹³ Eventually, Congress enacted the Uranium Mill Tailings Radiation Control Act of 1978 (PL 95-604), which assigned the remediation tasks to the U. S. Department of Energy (DOE) and mandated cleanup by March 1990, a deadline that has repeatedly been extended. DOE now estimates cleanup by 2014, probably an optimistic goal, with uncertain final costs greater than the original estimate of \$2.3

⁹ A more technical description is contained in: The Union of Concerned Scientists, *The Nuclear Fuel Cycle: A Survey of the Public Health, Environmental, and National Security Effects of Nuclear Power*, rev. ed. (Cambridge, MA: MIT Press, 1975). See especially chap. 2: A. Schurgin T. Hollocher, “Radiation-induced Lung Cancers Among Uranium Miners,” 9-40.

¹⁰ G. Clarfield W. Wiecek, *Nuclear America: Military and Civilian Nuclear Power in the United States, 1940-1980* (1984). See pp. 381-83 for Karen Silkwood case.

¹¹ J. Walker, *Containing the Atom: Nuclear Regulation in a Changing Environment 1963-1971* (Berkeley: University of California, 1992). See chap. X, “Regulating Mines and Mills,” 233-66.

¹² S. Udall, *The Myths of August: A Personal Exploration of Our Tragic Cold War Affair with the Atom* (New York: Pantheon Books, 1994). See, Section III “Above the Law: Radiation Tragedies at Home,” 181-271 for an account of the government litigation tactics. In this regard, see H. Ball, *Justice Downwind: America’s Atomic Testing Program in the 1950s* (New York: Oxford University, 1986), especially chaps. 6-9.

¹³ GAO, *Uranium Mill Tailings: Cleanup Continues, but Future Costs Are Uncertain*, GAO/RCED-96-37 (Washington, DC: GAO, December 1995).

Figure 2. Major components of U.S. nuclear industrialization. Compiled from U. S. Department of Energy, Office of Environmental Management, *Linking Legacies: Connecting the Cold War Nuclear Weapons Production Processes to Their Environmental Consequences* (1997), Appendix B, Figures B-2 and B-3 and R. Deutsch, *Nuclear Power: A Rational Approach* (Columbia, MD: Courseware, 1987), p. 68, Figure 10.

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billion.¹⁴ The problems are with residential areas as well as industrial waste sites. Waste materials were mixed into cement for sidewalks, basements, and other building components contaminating “about 3,300 buildings in and around Grand Junction, Colorado, a total of 5,000 buildings in all of Colorado,” and “perhaps another 1,000-2,000 buildings elsewhere in the United States.”¹⁵

The Nuclear Weapons Complex. The U. S. weapons program involved the most complex, long-standing, and inherently dangerous of all nuclear technologies. It is the original and most powerfully affective source of nuclear stigma. The bombing of Hiroshima and Nagasaki in August 1945 introduced the public to a new and massively destructive technology. This was followed by the Cold War rush to develop ever more powerful weapons and weapons delivery systems. Sudden, surprise attack with nuclear weapons flooded public consciousness. The Cold War profoundly influenced development of civilian nuclear technology. When the federal government initiated its civilian nuclear programs in the 1950s, it consciously created a vast scientific and technical capability that would benefit weapons as well as civilian applications.

The dominant nuclear enterprise during the last half of the 20th century was the vast Nuclear Weapons Complex, a tightly administered empire whose 14 major facilities in 13 states covered more than 3,350 square miles and in the year 1990 employed more than 100,000 people.¹⁶ Between the establishment of the Manhattan Engineering Project in 1942 and the termination of weapons production in 1992, “this enterprise manufactured tens of thousands of nuclear warheads and detonated more than a thousand.”¹⁷ Since 1951, U. S. nuclear weapons testing was done primarily at the Nevada Test Site, although various tests, some of them associated with attempts to develop civilian uses for nuclear explosions, also took place in Alaska, Colorado, Utah, and Mississippi.¹⁸ The largest single underground weapons explosion (five megatons) took place in 1970 at Amchita Island, Alaska, one of the Aleutian Islands. Only now are some key details of the weapons program becoming known.¹⁹ The overall effort involved radiation exposure to

¹⁴ T. Hollocher and J. MacKenzie, “Radiation Hazards Associated with Uranium Mill Operations,” chap. 3 in The Union of Concerned Scientists, *The Nuclear Fuel Cycle*, 41-69.

¹⁵ Hollocher and MacKenzie, “Radiation Hazards,” 41.

¹⁶ Office of Technology Assessment, *Complex Cleanup: The Environmental Legacy of Nuclear Weapons Production* (Washington, DC: GPO, 1991), 15.

¹⁷ K. O'Neill, “Building the Bomb,” chap. 1 in *Atomic Audit*, ed. S. Schwartz (Washington, DC: Brookings Institute, 1998); DOE, Office of Environmental Management, executive summary to *Estimating the Cold War Mortgage: The 1995 Baseline Environmental Management Report* (Springfield, VA: NTIS, March 1995), III.

¹⁸ Some of these tests were not weapons tests but rather tests for civilian uses of nuclear explosions under the auspices of the Plowshare Program.

¹⁹ O'Neill, D. (1994). *The Firecracker Boys*. New York: St. Martin's Griffin; J. St. Clair, “The Legacy of America's Largest Nuclear Test,” *In These Times* (8 August 1999): 21-3.

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workers, the general public, and the environment. Within this history is a range of anecdotes ranging from tragic to comic.²⁰

New information about the weapons complex appears at irregular intervals. One dramatic story revealed the December 1949 “green run” experiment conducted at Hanford, shortly after the August 1949 explosion of the Soviet Union’s first nuclear bomb. The Hanford facility normally cooled fuel, from which weapons grade plutonium was extracted, for a period of 80-100 days. This allowed short-lived radioactive elements time to decay. The suspicion was that the Soviets used “green” reactor fuel (with shorter cooling periods) and released unfiltered radiation into the atmosphere in their haste to develop an atomic bomb. To better understand data about Soviet weapons production, AEC officials released the radiation from one ton of 16-day-old fuel.²¹ The results were unexpected. The experiment released three times the anticipated amount of radioactivity and contaminated an area stretching from Hanford to Spokane, Washington (about 100 miles northeast) and Klamath Falls, Oregon (on the California/Oregon border, well over 200 miles south). This test and its results were classified as top secret, national security information.

The Green Run incident and numerous other releases became known with DOE declassification of 19,000 pages of documents in 1986 under pressure from the State of Washington. Even with these records available, Hanford officials denied that any health risk had resulted. It wasn’t until July 12, 1990 that then Secretary of Energy, James Watkins, in a dramatic break with government policy, admitted that Hanford “released enough radiation in the 1940s to pose a serious health hazard to nearby residents.” The earlier government practice was to classify all radiation data and information, to provide assurances of safety to the public and even to other governmental officials, and to deny problems or access to existing radiation data.²² And despite the new public access to records of the nuclear weapons complex, much remains sequestered under the doctrine of national security and large amounts of important historical information is said to be unavailable or to have been destroyed.²³

²⁰ In some cases there is a mixture of the comic and tragic. For example, a 1991 General Accounting Office report, “Hanford Single-Shell Tank Leaks Greater than Estimated,” GAO/RCED-91-1770 (Washington, DC: GAO, August 1991) found that Westinghouse Hanford had estimated that one tank of highly radioactive waste had leaked about 5,000 gallons. The GAO audit found that it had leaked much more, perhaps 800,000 gallons but this had been kept secret. In response, a Westinghouse said “it was following a long-standing practice at Hanford of not considering the water to be a pollutant after it came out of the tank, because at the time it went into the tank [to cool the wastes] it was clean.” *New York Times*, “Leakage at N-plant Concealed,” *Eugene [Oregon] Register-Guard* (20 September 1991): 5C.

²¹ For a journalistic account, see: H. Murphey, “Blowing in the Wind,” *Pacific Northwest* (January 1991): 9-13.

²² M. Stenehjem, “Indecent Exposure,” *Natural History* (September 1990): 6-22. This article provides a brief historical account of the period 1943 to the mid-1980s with a focus on the Columbia River and the Columbia Basin.

²³ A. Adler, “Public Access to Nuclear Energy and Weapons Information,” chap. 2 in *Controlling the Atom in the 21st Century*, eds. D O’Very, C. Paine, and D. Reicher (Boulder, CO: Westview, 1994); National Research Council, Committee on Declassification of Information for the Department of Energy Environmental Remediation and Related

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Nevertheless, the release of formerly confidential government documents since the mid-1980s has greatly increased public information about the nuclear weapons complex. One result of these developments has been a number of class action suits against past and current managers at the weapons complex sites.²⁴ When weapons production stopped in 1992, the weapons complex sites became environmental management and cleanup problems. After fifty years of on-site temporary radioactive waste storage, the federal government is attempting permanent disposal.

Nuclear Weapons Testing: Atomic Soldiers. Between 1946 and 1962 the United States conducted weapons tests that involved the exposure of military personnel to radioactive fallout. These tests began at Bikini in the south Pacific and after 1951 were mostly conducted at the Nevada Test Site. According to the Defense Nuclear Agency, about 225,000 military personnel were involved in nuclear blast tests after World War II, 57,000 as part of combat training exercises, where some soldiers experienced nuclear blasts from within two miles of ground zero.²⁵ A 1995 Associated Press report quotes a 1951 memo from Rear Admiral W. K. Mendenhall on the military viewpoint: "The field commander is not interested in the science of measuring radiation. He merely wants to know, can the troops tolerate the radiation to which they are being subjected for five minutes or five days."²⁶

The chances of getting a cancer from radiation exposure can take 20 to 30 years, depending upon the exposure and the individual. At that point it is almost impossible to demonstrate a causal relationship between a specific exposure and a resulting cancer. The burden of proof in the case of radiation exposure falls to the individual veteran, an almost impossible task as indicated by the fact that the Veteran's Administration recognized only 1 claim of the first 600 filed by atomic veterans. Records are often incomplete and files have been lost or destroyed. For example, official military records for more than 17 million veterans were destroyed in a 1973 fire at a St. Louis, Missouri federal storage building. After a long series of court cases and political action campaigns, Congress passed The Radiation-Exposed Veterans Compensation Act of 1988 (PL

Programs, *A Review of the Department of Energy Classification Policy and Practice* (Washington, DC: National Academy, 1995).

²⁴ M. Wald, "Energy Dept. to Pay \$73 Million to Settle Uranium Case in Ohio," *New York Times* (1 July 1989). Associated Press, "Uranium-peril Suit Settled," *Eugene [Oregon] Register-Guard* (27 January 1995). Department of Energy, Office of Environment, Safety, and Health, "Richardson Unveils Health Initiative for DOE Workers," press release, <<http://www.eh.doe.gov/portal/feature/071599pr.html>>, 15 July 1995; J. Flynn, E. Peters, C. K. Mertz and P. Slovic, "Risk, Media, and Stigma at Rocky Flats," *Risk Analysis* 18, no. 6 (1998): 715-27; Associated Press, "Uranium-peril Suit Settled," *Eugene [Oregon] Register-Guard* (27 January 1995).

²⁵ A. Makhijani and S. Schwartz, "Building the Bomb," in Schwartz, *Atomic Audit*; M. Manning, "Atomic Vets Battle Time," *The Bulletin of the Atomic Scientists* (January-February 1995): 54-60.

²⁶ Associated Press, "GIs Placed Near N-Blasts to Blunt Fear of Radiation," *Eugene [Oregon] Register-Guard* (2 June 1995), 11A.

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100-321). This act listed 13 cancers²⁷ as “presumptively service connected” and thereby compensable without a legally binding causal demonstration. Treatment and compensation for exposed military personnel required political action in lieu of scientific or medical assignment of causes for health claims. In 1994 Congress mandated (PL 103-446, section 508) an evaluation of whether or not it was feasible to study the genetic effects of radiation on children, grandchildren, and spouses for qualified veterans. The subsequent report from the Institute of Medicine concluded that the difficulties of conducting a scientific epidemiological study on this subject were “insurmountable.”²⁸ The problems of civilian exposures are even more difficult in most cases.

Downwinders. The term “downwinders” applies to people who were exposed through the transport of radiation to their geographical location. Most of these exposures were the unintended consequence of nuclear weapons testing or the operations of nuclear facilities. More than 900 nuclear tests were conducted at the Nevada Test Site with atmospheric tests conducted from 1951 to 1963 and underground tests from 1963-1992.²⁹ The Nevada tests concentrated exposure to downwind communities in Nevada, Arizona, and Utah, such as St. George, Utah. Regional “hotspots,” some as distant as the upper Midwest and even the Northeast, have subsequently been identified.

Opposition to programs producing fallout came from many sources including scientists, doctors, and other medical people. These public reactions forced the government to continually deal with demands to limit and stop fallout exposure. Federal officials assured the public that there was little or no danger from the nuclear weapons tests and mounted public relations programs to make their point. They denied all claims of damage in public and in court. When forced into litigation, the government employed every legal and political tactic to deny liability. In some cases they simply destroyed records. In these efforts, they relied heavily on claims of national security and federal sovereign immunity.³⁰ They opposed U. S. Public Health Studies even after the 1963 ban on atmospheric testing had reduced public concerns. The primary

²⁷ Leukemia, multiple myeloma, lymphoma except Hodgkin’s disease, and cancers of the thyroid, breast, pharynx, esophagus, stomach, small intestine, pancreas, bile ducts, gall bladder, and liver. Subsequently, the Act was amended in to add cancers of the salivary gland and urinary tract (PL 102-578).

²⁸ Institute of Medicine, *Adverse Reproductive Outcomes in Families of Atomic Veterans: The Feasibility of Epidemiologic Studies* (Washington, DC: National Academy, 1995).

²⁹ S. Schwartz, “Four Trillion Dollars and Counting.” *The Bulletin of the Atomic Scientists* (November-December 1995), 32-52; see figure p. 45.

³⁰ See Caufield, *Multiple Exposures*, chap. 12, “Fallout.” Various accounts of the AEC and DOE responses to public concerns about radiation from weapons testing are widely available, including the following: C. Titus, *Bombs in the Backyard: Atomic Testing and American Politics* (Reno & Las Vegas: University of Nevada, 1986); R. Miller, *Under*

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concerns were stated in a 1965 memo from the AEC general manager: “a) adverse public reactions; b) lawsuits; c) jeopardizing the program at the Nevada Test Site.”³¹

Despite federal government efforts, the basic outlines of the weapons testing program are known and in some cases, especially those that were litigated, there are plentiful details. Miller presents a history of the period with a set of appendices showing the fallout patterns from specific tests on national maps.³² Ball covers the same period but focuses more on the public health issues and the litigation over fallout.³³ One case involved the revival of the Bulloch case.

In 1982 U. S. District Judge Sherman Christensen reviewed the Bulloch suit 26 years after it originally went to trial. The original suit claimed damages resulting from the exposure of sheep to radiation fallout from a specific test at the Nevada Test Site, a claim the government denied. Christensen had dismissed the case on the testimony and evidence presented by the government in court proceedings during 1955-1956. Information about the case came up during a 1979 Congressional hearing in Salt Lake City where once-classified documents were presented. This information put the case back into Judge Christensen’s court. After a four-day hearing in 1982, Judge Christensen found that the government lawyers had intentionally deceived the original trial court by: “false and deceptive representations of government conduct,” “improper but successful attempts to pressure witnesses,” “a vital report intentionally withheld,” “information in another report presented in a deceitful manner,” “interrogatories deceptively answered,” and “deliberate concealment of significant facts with reference to possible effects of radiation upon plaintiff’s sheep.”³⁴ A plaintive motion for a retrial was ordered but it was rescinded on government appeal to the Tenth Circuit Court, an outcome that Udall called “a grotesque episode of American jurisprudence.”

Human Radiation Experiments. On October 3, 1995, President Clinton accepted the report from the National Advisory Committee on Human Radiation Experiments at a White House ceremony. The committee spent 18 months and examined more than 800,000 pages of documentation, 4,000 radiation experiments, and the records of hundreds of radiation releases from government facilities covering the period 1944 to 1974.³⁵ The questionable ethical standards

the Cloud: The Decades of Nuclear Testing (New York: The Free Press, 1986); Ball, *Justice Downwind*; Udall, *Myths of August*.

³¹ Titus, *Bombs in the Backyard*, p. 104

³² Miller, *Under the Cloud*.

³³ Ball, *Justice Downwind*.

³⁴ Ball, *Justice Downwind*, p. 209.

³⁵ DOE, *Report of the Advisory Committee on Human Radiation Experiments* (Washington, DC: GPO, October 1995); In addition to the departments of Energy (and its predecessor agencies, primarily the Atomic Energy Commission), Defense, Health and Human Services, and the Veterans Administration, there was some involvement by the Central

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used in these experiments were much noted as was the participation by government agencies and highly regarded medical research universities and institutions.³⁶ If anything, these reports understated the actual extent of human experimentation, which may never be known. The federal agencies involved are those most likely to classify information and many records have been lost, misplaced, and destroyed.³⁷

The Advisory Committee defended the need to understand the effects of radiation during the Cold War, arguing that: “Often nonbeneficial experiments on unconsenting patients constituted only minor wrongs. Often there was little or no risk to patient-subjects and no inconvenience.” The report does state that some experiments were “ethically troubling” such as those “conducted on institutionalized children, seriously ill and sometimes comatose patients, African-Americans, and prisoners.” News media were more dramatic and descriptive.³⁸ The highlighted stories included accounts of mentally retarded teenagers at a state school in Waltham, Massachusetts who were fed radioactive milk in the 1940s and 1950s by a group of Harvard and MIT scientists who dubbed their experiment “The Science Club.” Seven newborn infants were injected with radioactive iodine at the University of Tennessee in 1953. Vanderbilt University researchers gave 751 pregnant women radiation pills in the 1940s to determine the effects of radioactive iron on fetal development. The women thought they were taking normal iron pills. Six healthy patients were injected with uranium salts at the University of Rochester to determine how much it would take to damage their kidneys. From 1963 to 1971, researchers X-rayed the testicles of 131 prisoners at the Oregon State Prison and the Washington State Penitentiary to measure the effects of radiation on male fertility, an issue for workers at the weapons complex. Heavy doses of radiation, up to 250 rads (a 300-rad dose would be expected to kill half an exposed population), were administered to 87 terminally ill patients in a Cincinnati experiment. The average IQ of these subjects was a subnormal 86; 61 of the subjects were Black, and 25 of the patients died within 60 days. Radium and thorium were fed to 20 elderly patients in an MIT experiment conducted during the early 1960s to estimate the resulting internal doses.

Intelligence Agency and National Aeronautics and Space Administration. Also involved were some of the nation’s most highly regarded research centers such as those at the universities of Rochester, Cincinnati, Chicago, California, and Washington; Vanderbilt University, Harvard, MIT, the U. S. Naval Hospital at Bethesda, Maryland, Massachusetts General Hospital, and many more.

³⁶ D. Gordon, “The Verdict: No Harm, No Foul,” *The Bulletin of Atomic Scientists* (January-February 1996): 32-40; E. Welsom, *The Plutonium Files* (New York: The Dial Press, 1999).

³⁷ GAO, “Status of Federal Efforts to Disclose Cold War Radiation Experiments Involving Human,” Testimony by Victor S. Rezendes, Director, Energy and Science Issues, Resources, Community, and Economic Development Division before the Committee on Governmental Affairs, U. S. Senate, GAO/T-RCED-95-40, 1 December 1994.

³⁸ K. D. Steele, “Radiation Revelations: New Administration Brings the Spotlight Back to Dubious Experiments,” *Spokesman-Review*, 9 January 1994.

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The ethical standards of medical research were not as well formulated or enforced during the 1950s as they are today. Nonetheless, the principles were well-known and clearly articulated. One scientist involved in early experiments (1945-1947) where patients were injected with plutonium without their consent, warned the AEC that the research protocol had “a little of the Buchenwald touch,” referring to the notorious Nazi medical experiments on concentration camp prisoners during World War II.³⁹

Hilts reported that one major motive for restricting public information about these experiments was concern about lawsuits and unfavorable publicity.⁴⁰ The documents uncovered by the Advisory Committee contain numerous memos discussing the problems that might result from public knowledge of the experimental activities. In one case, an Oak Ridge manager wrote that release of information on radiation releases might adversely affect “insurance claims . . . labor relations, and . . . public sentiment.” As Hilts comments, these reasons may not be a legal basis for classifying medical research documents.

Nuclear Power. During the height of the Cold War while great effort was made to build new weapons, scientists, engineers, industrialists, and political leaders strove to find and develop the industrial benefits of the atom. The vision of harnessing nuclear energy to fuel that nation’s growing demand for electricity was especially attractive. After two decades of concentrated effort, the nuclear power industry was created and by 1975 more than 200 nuclear power reactors were built, under construction, or planned. Toward the end of the “great bandwagon period,” in the early 1970s, the Atomic Energy Commission forecast that 60% of the U. S. electric generation would be nuclear by the year 2000. The future of nuclear power looked bright.

But even as the most optimistic forecasts were being made, the downturn for nuclear power began. Between 1974 and 1979, 51 nuclear power plant orders were canceled. Nuclear power siting was being effectively opposed at the state and local levels.⁴¹ In an implausible turn of events, the anti-nuclear film *The China Syndrome* was two weeks into its highly publicized release when the March 1979 accident at Three Mile Island (TMI) shocked the public. No new nuclear power reactor has been ordered since that event. Public support sufficient for a revival of nuclear power in the United States any time soon is doubtful. The Bush administration program to

³⁹ The phrase is contained in a 1950 memo from biologist Dr. Joseph Hamilton to his AEC supervisor. See, Steele, “Radiation Revelations.”

⁴⁰ P. Hilts, “Inquiry on Radiation Tests Links U. S. Secrecy to Fear of Lawsuits.” *The New York Times*, 15 December 1994.

⁴¹ An excellent study of nuclear power in California is presented in T. R. Wellock, *Critical Masses: Opposition to Nuclear Power in California, 1958-1978* (Madison: University of Wisconsin Press, 1998).

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develop nuclear power announced early in 2001, quixotic even then, was critically undercut by the dramatic levels of public concern about nuclear power plants and waste storage facilities in response to the World Trade Center terrorist attack in September 2001. A more realistic prospect for the coming decades is a gradual and relentless closing of existing plants. This is a remarkable outcome for the first nuclear era.

Public discontent with nuclear power has led to a number of attempts by opponents to close nuclear power plants through political means, such as by public referenda or by influencing legislative, judicial, or executive actions. Most of these efforts have failed. The larger public has demonstrated a pragmatic view; for the most part voters and office holders have resisted closing operating plants. However a few closures have taken place, the most dramatic being the Shoreham station on Long Island in New York, which was decommissioned just before it was scheduled to begin commercial operation. This was the abandonment of a \$5.5 billion investment.⁴² An earlier case was the 1989 referendum vote that closed the Sacramento Municipal Utility District's Rancho Seco plant in California. A few years later, in 1993, owners of the Trojan nuclear power plant in Oregon closed the facility after fighting off four statewide referendum attempts. In this case, the utility maintained that the closure was for economic reasons and not as a response to the repeated political campaigns against the plant.

To better understand the role of public opinion in determining the differential success of nuclear power, Decision Research conducted an extensive survey in the United States and France during 1992. English and French versions of the same survey instrument were administered to more than 1,500 respondents in each country. French respondents were expected to record lower perceptions of risk from nuclear power than Americans, given the 75% dominance of electric production enjoyed by the French nuclear program. Surprisingly, nuclear power's risk ratings in France were almost identical to those in the United States. However, the survey data did provide responses that appear to be important in explaining the outcome differences for the two nuclear efforts.⁴³ Specifically, the French:

- Saw greater need for nuclear power and greater economic benefits from it.
- Had greater trust in scientists, industry, and government officials who design, build, operate, and regulate nuclear power plants.

⁴² D. McCaffrey, *The Politics of Nuclear Power: A History of the Shoreham Nuclear Power Plant* (Dordrecht, The Netherlands: Kluwer Academic, 1991).

⁴³ P. Slovic, J. Flynn, C. K. Mertz, M. Poumadere and C. Mays, "Nuclear Power and the Public: A Comparative Study of Risk Perception in France and the United States," in *Cross-Cultural Risk Perception: A Survey of Empirical Studies*, eds. O. Renn and B. Rohrmann (Dordrecht, The Netherlands: Kluwer, 2000), 55-102.

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- Were more likely to believe that decision-making authority should reside with the experts and government authorities, rather than with the lay people.

The French manage nuclear power with less public participation and more centralized control. Political scientists have argued that, in a climate of strong distrust, the French approach, in which policy formation and implementation is not as accessible to public intervention, is expedient.⁴⁴ Campbell agrees, arguing that U. S. democratic institutions providing political access to nuclear critics may be fundamentally incompatible with commercial success of nuclear power.⁴⁵ How well centralized decision making about nuclear power can be maintained in a period of rapidly expanding public communications and the rise of adversarial policy groups is an open question. In any case, public confidence in government management of nuclear power is clearly greater in France than in the United States.

These survey results indicate that public acceptance of nuclear power, if not active endorsement, requires positive judgments about (1) potential benefits, (2) management of the risks, and (3) necessity. An essential complicating factor is the contrast between the public's stigmatization of nuclear power, a widely held belief that certain nuclear technologies are inherently dangerous, unwise, unnatural, and even immoral, and the position of nuclear proponents who envision nuclear technologies as right, necessary, and inevitable because they are based on deep scientific and natural truths. Risk communication has been unable to bridge these gaps or even to fairly state the originating premises that are in conflict.

⁴⁴ J. F. Morone and E. J. Woodhouse, *The Demise of Nuclear Energy? Lessons for a Democratic Control of Technology* (New Haven, CT: Yale University, 1989).

⁴⁵ J. L. Campbell, *Collapse of an Industry: Nuclear Power and the Contradictions of U. S. Policy* (Ithaca, NY: Cornell University, 1988).

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Radioactive Wastes: Management, Storage, & Disposal. The “back end” of the nuclear power industry requires management and disposal of radioactive wastes; at a minimum they should be safely stored. The federal government has established programs to deal with weapons complex wastes, civilian low-level radioactive wastes, and high-level wastes, mostly spent fuel. These programs envision the shipment of wastes to centralized facilities using the nation’s rail and highway transportation systems. For example, the proposed high-level facility at Yucca Mountain, Nevada would require the transport of thousands of shipments through 43 states and hundreds of communities over a period of 30 years or more. The decommissioning of existing facilities, cleanup, transportation, waste disposal site development, and permanent storage for all levels of radioactive wastes present federal, state, local, and industry personnel with difficult problems in addressing public concerns.

Low-level radioactive wastes (LLRW). The Low-Level Radioactive Waste Policy Act of 1980 (Public Law 96-573) defines LLRW as: “radioactive waste not classified as high-level radioactive waste, transuranic waste, spent nuclear fuel, or byproduct material as defined in section 11(e) (2) of the Atomic Energy Act of 1954.”⁴⁶

“In 1990, 1.1 million cubic feet of LLW was sent to commercial disposal sites, with a total radioactivity of about 550,000 curies. Of this waste, nuclear power plants accounted for 56% by volume and 79% by radioactivity.”⁴⁷ The LLRW resulting from weapons production is permanently stored at the Nevada Test Site, Hanford, Washington, Savannah, South Carolina, and at other facilities in the weapons complex often in a temporary status.

Congress passed the Low-Level Waste Policy Act of 1980 (LLRWPA) after a determined effort by Washington, Nevada, and South Carolina to be removed as the three host states for civilian LLW. Other early sites for LLW disposal had experienced “casual” management, according to English,⁴⁸ with the result that facilities at West Valley, New York, Maxey Flats, Kentucky, and Sheffield, Illinois were closed due to serious environmental problems. The low-level waste disposal at these sites relied upon a shallow land-burial technique that did not perform

⁴⁶ The U. S. Nuclear Regulatory Commission recognized three classes of LLRW in its regulations of January 26, 1983 (10 CFR 61):46 Classes A, B, and C, depending upon the degree of radiation and the time during which exposure might adversely affect human health. Classes A & B require different packaging with Class B having the more stringent requirement and both classes of waste must decay to specified safe levels within 100 years. Class C wastes, mainly irradiated reactor parts, must meet a 500-year standard of protection with geological (deeper burial than Class A or B) and engineered (e.g., concrete vaults) barriers.

⁴⁷ M. English, *Siting Low-level Radioactive Waste Disposal Facilities: The Public Policy Dilemma* (New York: Quorum, 1992), 3.

⁴⁸ English, *Siting Low-level Radioactive Waste*.

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well. This experience prompted several states to require more stringent engineered barriers for future LLW sites.⁴⁹

The LLRWPA created a unique program whereby the federal government turned the civilian low-level problem over to the states. This strategy sought to avoid conflict between federal agencies and the states or public groups over disposal sites and technologies (e.g., shallow land burial versus engineered barriers). The idea was to make the states responsible for locating and operating their own sites. They were subject to federal oversight and regulation but otherwise the states would be in charge of low-level waste facilities. The Act envisioned the waste sites as potential revenue sources for states and local communities, and attempted to consolidate waste disposal at the regional level by encouraging “compacts” or multi-state agreements to jointly develop sites.

Few policies that so obviously failed have lasted so long. In two decades the program has not produced one new low-level waste site despite dozens of extraordinary efforts by states and compacts.⁵⁰ Meanwhile, the uncertainty about access to a disposal facility along with the steep increases in costs at the existing sites motivated waste producers to reduce the volume of wastes. These waste-reduction efforts have been so successful that it is now doubtful that the new sites envisioned under the 1980 federal LLW Act are needed. In 1995, 680 thousand cubic feet of wastes went to disposal sites, down from more than 2.6 million annually in 1984 and 1985.⁵¹

Attempts to develop new sites have been stopped by public opposition despite expert opinion and the evidence of risk assessments that no significant danger exists at numerous places. Efforts to impose an expert-driven, top-down risk assessment process failed for one program after the other. This was replaced by attempts by some states and compacts to find an incentive approach and offer benefit sharing, especially economic development and support for public services. Local public officials who supported these efforts were quick to learn that these trade-offs were politically untenable. States and compacts abandoned their programs during the 1990s. Ward Valley in California, Boyd County in Nebraska, and Sierra Blanco in Texas were the last to go.

Meanwhile, a private firm, Envirocare, opened a remote Utah site in 1987. Between 1993 and 1998, 14 million cubic feet of lightly radioactive wastes have been disposed of at this remote

⁴⁹ English, *Siting Low-level Radioactive Waste*.

⁵⁰ J. Weingart, *Waste is a Terrible Thing to Mind: Risk, Radiation, and Distrust of Government* (Princeton, NJ: Center for Analysis of Public Issues, 2001).

⁵¹ U. S. Nuclear Regulatory Commission, *NRC Information Digest: 1997 Edition*, NUREG-1350, vol. 9 (Washington, DC: U. S. Nuclear Regulatory Commission, 1997).

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facility under contracts with DOE that amounted to as much as \$250 million. Additional contracts for the next five years (1998 to 2003) are expected to provide \$350 million. How did a private developer open a site when public authorities could not? Part of the answer came in 1998 when *The Washington Post* reported that Larry Anderson, a former director of the Utah Radiation Control Division, the state official responsible for issuing the Envirocare license and exercising operations oversight, sued Khosrow Semnani, the owner of the facility. Anderson apparently approached Semnani in 1986 with an offer to serve as a “consultant” for a payment of \$100,000 and 5% of the profits. Semnani subsequently paid Anderson about \$600,000 but discontinued payments when Anderson left his position with the Utah State office, which, in turn, prompted Anderson’s suit. This, the *Washington Post* article, points out: “. . . raised questions about the validity of Envirocare’s license and the adequacy of the state’s response to the dump’s history of safety violations — which include chunks of radioactive material literally falling from boxcars and top managers scoring a perfect zero on radiation competency tests.”⁵² While a federal grand jury investigated and various courts considered litigation, DOE negotiated a deal with Semnani allowing him to retain his 100% interest in Envirocare but giving up his management control to his longtime vice president as his successor. In turn, Envirocare could bid on DOE contracts. The agreement was quickly followed by new business from DOE contractors. Accounts of how the Envirocare site was licensed and operated along with DOE’s special accommodations can hardly be expected to serve as a model for the siting of other low-level sites. Yet this is the only “successful” LLRW siting in recent decades.

⁵² J. Warrick, “Waste Dump Paid Utah Regulator.” *Las Vegas Review Journal* (from *The Washington Post*), 6 April 1998.

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Transuranic Wastes. The Waste Isolation Pilot Project (WIPP) in southern New Mexico is designed to store transuranic wastes more than 2,000 feet underground.⁵³ These wastes come from nuclear weapons production and are stored at federal facilities in 10 states.⁵⁴ Work at the site began in 1975 and in 1980 Congress authorized a “research and development facility for demonstrating safe disposal of radioactive waste from defense activities and program.”⁵⁵ The designation of WIPP as a “defense facility” means it did not come under Nuclear Regulatory Commission oversight while the designation of the project as a pilot program for research and development minimized the immediate responsibilities to meet national and state environmental regulation. These Congressional advantages were not entirely successful. Over the years, WIPP “evolved from a low-profile initiative to become highly disputed.”⁵⁶

The social-political responses to siting radioactive waste facilities are complex. Originally, the Town of Carlsbad solicited and supported the WIPP program as an economic development and employment opportunity to replace an abrupt decline of potash mining in the area and over the decades the town has been a staunch supporter. The State of New Mexico was less enthusiastic and served as the focus of public sector opposition to WIPP. Citizen advocacy groups opposed the project. Thus, after its promising start, it took 25 years before the first, long-awaited shipments of waste began, and then only after years of negotiation between government agencies, Congress, and the State of New Mexico on a long list of items.

As the long political process at WIPP proceeded, a clear case of nuclear stigmatization was litigated and substantiated in the case of the City of Santa Fe v. Komis. One segment of the transportation route along the interstate highway system was planned to go through New Mexico’s capital, Santa Fe, but this was avoided when the federal government agreed to construct a bypass for the waste transportation. One section of the bypass route required 43.4 acres of the property belonging to John and Lemonia Komis, leaving them the remaining 430 acres. The Komises refused to accept the city’s offer because it did not provide compensation for the decline in the value of their remaining land due to stigma arising from public fears about the

⁵³ National Research Council, Committee on the Waste Isolation Pilot Plant, Board on Radioactive Waste Management, *The Waste Isolation Pilot Plant: A Potential Solution for the Disposal of Transuranic Waste* (Washington, DC: National Academy Press, 1996). This report includes a short definition of transuranic waste and a more precise one at p. 155. The short definition is: “Transuranic waste – radioactive waste consisting of radionuclides with atomic numbers greater than 92 [uranium] in excess of agreed limits.” The limits are provided for in DOE Order 5820.2A and the EPA regulation 40CFR 191.

⁵⁴ National Research Council, *Waste Isolation Pilot Plant*.

⁵⁵ Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980. Public Law 164. 96th Cong., 1st sess., 29 December 1979.

⁵⁶ H. Jenkins-Smith, “Alternative Theories of the Policy Process: Reflections on Research Strategy for the Study of Nuclear Waste Policy.” *PS: Political Science & Politics*, June 1991, 157-166.

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transportation of transuranic wastes on the bypass. The property was condemned in 1988 and went to a jury trial in 1991. In November 1991 the jury awarded the Komises \$884,000, including \$337,000 for the stigma damage claim. The city appealed to the New Mexico Supreme Court where the jury award was upheld in August 1992.⁵⁷ Subsequently, the New Mexico Department of Transportation settled a similar claim related to the WIPP route bypass at Roswell, New Mexico.⁵⁸ The Komis case is notable because it awarded compensation to a property owner based upon survey interviews where respondents said they did not want to buy property or live near a radioactive transportation route.

High-Level Radioactive Wastes. The management, storage, and disposal of high-level nuclear wastes (HLNW) from nuclear power plants is considered one of the keys to public acceptability of nuclear power in the United States. Although significant amounts of HLNW have been produced by the nation's nuclear weapons complex, the great majority of radioactivity requiring management and disposal comes from civilian power reactors in the form of irradiated or "spent" fuel.

At the present time most civilian HLNW is stored at reactor sites in cooling pools that require continuous supervision. As existing pool capacity fills, some utilities are providing storage in casks that are passively air-cooled and utilize a system of shielding. This "dry cask" technique, which works best with fuel rods that have had some years of aging to reduce the heat and radioactivity, has been certified by the U. S. Nuclear Regulatory Commission as a safe storage technique for at least a hundred years.⁵⁹ However, residents near nuclear power plants using dry-cask storage are not convinced the technology is safe. They question the potential effects of extended storage, the ability of utilities to correct problems that may occur, the design of specific cask types, and the security provisions at individual facilities.⁶⁰

⁵⁷ "\$337,000 WIPP Road Land Award Upheld." *Santa Fe Journal*, 27 August 1992.

⁵⁸ A. H. Mushkatel K. D. Pijawka, "Nuclear Waste Transportation in Nevada: A Case for Stigma-Induced Economic Vulnerability," Report no. MRDB/RP0149 to the Nevada Nuclear Waste Project Office (Carson City, NV: NWPO, 1994).

⁵⁹ U. S. Nuclear Regulatory Commission, 10 CFR Part 51, "Consideration of Environmental Impacts of Temporary Storage of Spent Fuel after Cessation of Reactor Operations; and Waste Confidence Decision Review: Final Rules," *Federal Register* 55, no. 181 (18 September 1990).

⁶⁰ M. Sinclair, "Dry Cask Fact Sheets," mimeo (Midland, MI: Don't Waste Michigan, n.d.).

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For four decades, the federal government's goal for HLNW and spent fuel has been permanent disposal, a solution that would "close the fuel cycle" and provide assurances that nuclear power could generate electricity and deal with the potential hazards of long-term radioactive wastes. Many sites have been suggested and abandoned thus bringing into question the government's ability to locate, study, license, construct, operate, and safely dispose of HLNW. After several years of negotiation with the many interested parties, Congress passed the Nuclear Waste Policy Act of 1982 (NWPA).⁶¹

The NWPA attempted to address some long-standing problems revealed in the early failures by establishing a set of democratic principles and ethical rules to guide the process of selecting a repository site.⁶² Several principles were designed to produce an equitable outcome. The NWPA addressed geographic equity by mandating two repositories, one in the west, where DOE had already done some site studies, and one in the east, where most of the nuclear wastes are generated. The NWPA mandated that those who benefit from the repository pay for it and required fees charged on nuclear-generated energy to go into a Nuclear Waste Fund to finance repository development. Monetary compensation was authorized for those living near the repository. Other provisions of the NWPA were intended to ensure an equitable process of site selection. DOE was required to provide information about all of their activities associated with selecting and building the repository, including scientific data and analyses, to affected stakeholders such as state governments, Indian tribes, and the public. Program managers were to employ an objective selection process based on technical criteria. In addition, the decision process used to select or eliminate candidate sites was to be open to outside scrutiny, making it difficult to select a site on arbitrary or capricious grounds. DOE was to consult and cooperate with affected states and Indian tribes before making key decisions. (However, this provision did not give stakeholders authority to control the siting process.) Nuclear Waste Fund allocations were provided to affected states and Indian tribes to oversee DOE studies and conduct socioeconomic assessments. Importantly, the NWPA contained provisions to protect public health. It instructed the U. S. Environmental Protection Agency (EPA) to set radiation-exposure standards. DOE was to demonstrate how it would meet these standards, which would be used by the U. S. Nuclear Regulatory Commission (NRC) in deciding whether to grant a construction license. In addition, the

⁶¹ L. C. Carter, *Nuclear Imperatives and Public Trust: Dealing with Radioactive Waste* (Washington, DC: Resources for the Future, 1987).

⁶² Douglas Easterling and Howard Kunreuther, *The Dilemma of Siting a High-Level Nuclear Waste Repository* (Boston, Kluwer Academic, 1995); James Flynn, et al., *One Hundred Centuries of Solitude: Redirecting America's High-Level Nuclear Waste Policy* (Boulder: Westview, 1995); *Nuclear Waste Policy Act of 1982*, Public Law 425. 97th Cong., 2nd sess., 7 January 1983.

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NWPA permitted any state designated to host a repository to file a notice of disapproval—essentially a veto of the site. Although this provision exceeded previous state authority over the siting of a federal facility, it was still a weak power because Congress could vote to overturn a state veto.

The NWPA appeared to many observers as a reasonable political compromise, a good-faith effort to forge a successful siting process. The equity and public safety provisions were intended to ensure fairness in site selection and to make the eventual choice acceptable to those affected directly. And, indeed, NWPA appeared to have succeeded—at least to the extent of attracting, in 1982, the support of most congressional representatives from states then identified as potential repository host sites. The NWPA, which President Reagan signed into law on January 7, 1983, authorized the creation of the Office of Civilian Radioactive Waste Management (OCRWM) within DOE.

Once the program was put into effect, however, the NWPA's principles and goals began to unravel. Mandated schedules were missed and the expected dates for opening the repository slipped from 1998 to sometime in the second or third decade of the 21st century. Problems surfaced with DOE oversight of contractor work and data on sites was compromised.⁶³ As early as 1985, the NRC warned that the DOE quality-assurance plan did not meet regulatory requirements, an opinion reiterated in 1986.⁶⁴ Numerous requirements of the NWPA, such as the mandate that DOE negotiate cooperation and consultation agreements with potential host states, were not completed. DOE made a unilateral decision in 1986 to abandon the search for a second repository site in the east, claiming that the single western facility would meet the nation's needs. This came in the midst of a congressional election period and effected eastern states where public opposition was fierce. States and public-advocacy, community-based, and industry groups filed numerous suits against the program. In 1986 the U. S. General Accounting Office (GAO) quarterly reports to Congress began to include a section on litigation; at one time more than 20 cases, some of which grouped plaintiffs, were active.⁶⁵ By 1987 it was clear that the program was failing.⁶⁶

⁶³ U. S. General Accounting Office, *Nuclear Waste: Status of DOE's Nuclear Waste Site Characterization Activities*, GAO/RCED-87-103FS (Washington, DC: GAO, 1987).

⁶⁴ U. S. General Accounting Office, *Nuclear Waste: Repository Work Should Not Proceed Until Quality Assurance is Adequate*, GAO/RCED-88-159 (Washington, DC: GAO, 1988).

⁶⁵ U. S. General Accounting Office, *Nuclear Waste: Quarterly Report on DOE's Nuclear Waste Program as of September 30, 1987*, GAO/RCED-88-56FS (Washington, DC: GAO, 1988), Appendix I; also see GAO quarterly reports to the Senate Committee on Energy and Natural Resources from October 1985 to September 1987.

⁶⁶ Carter, *Nuclear Imperatives*; G. Jacob, *Site Unseen: The Politics of Siting a Nuclear Waste Repository* (Pittsburgh, PA: University of Pittsburgh, 1990).

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In the closing days of 1987, Congress passed amendments to the NWPAA, and over the objections of Nevada, selected Yucca Mountain, Nevada as the only site to be studied. Over the following years, Congress abandoned many of the original assurances to potential host states in attempts to salvage a failing program. In response the State of Nevada moved into open opposition to the repository program. This creates a serious problem for the federal government since states in the U. S. federal system have significant political power. Combined with the difficult scientific and technical problems the HLNW program faces, this means that the final outcome will remain in doubt for some time.⁶⁷

Looking Ahead: Unresolved Issues for the 21st Century. The last half of the 20th century saw the United States develop an awesome nuclear weapons system and the world's largest nuclear power industry. During the same time public attitudes toward nuclear science and technology shifted from support to suspicion and then to significant opposition. This shift developed along with nuclear stigmatization to create a social context that led to the gradual decline of nuclear power, continuous public concerns about the cleanup of old weapons facilities and questions about new waste-management programs and sites.

In addition, three problem areas remain unresolved: reprocessing, decommissioning, and the transportation of radioactive wastes. These activities can be expected to become public concerns and issues early in the 21st century.

Reprocessing. In the past reprocessing was seen as a way to close the nuclear fuel cycle and “provide another source of fuel to a growing industry and also largely relieve owners of individual power plants of the burden of storing spent fuel.”⁶⁸ It would use reprocessing techniques developed in the weapons’ program to recover uranium and plutonium from spent nuclear fuel. These resources would be recycled to fabricate mixed oxide (uranium and plutonium — MOX) fuel rods, which would then be sent to reactors as a new fuel source. There was support from scientists for a breeder reactor, which in creating more fuel (plutonium) than it consumed as uranium thereby creates an endless supply of fuel.⁶⁹ Historically, many scientists and nuclear experts thought that uranium was a scarce resource and a breeder reactor as a source of future fuel

⁶⁷ The social problems are given significant attention in a recent report from the National Academy of Sciences Committee on Disposition of High-Level Radioactive Waste Through Geological Isolation, *Disposition of High-Level Waste and Spent Nuclear Fuel: The Continuing Societal and Technical Challenges* (Washington, DC: National Academy Press, 2001).

⁶⁸ Walker, *Containing the Atom*, 24-5; also see Carter, *Nuclear Imperatives*, especially chap. 3.

⁶⁹ B. Cohen, *The Nuclear Energy Option: An Alternative for the 90s* (New York: Plenum, 1990), 226-31. For a more somber evaluation of past federal attempts to develop the breeder reactor with a focus on the Clinch River project see: L. Cohen and R. Noll, “The Clinch River Breeder Reactor,” Chapter 9 in *The Technology Pork Barrel* (Washington

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would be an economic necessity. As it has turned out, now and for the foreseeable future, there will be an excess supply of uranium and plutonium.⁷⁰

Also, there was the belief that the success of the weapons complex in reprocessing to produce plutonium for bombs could be transferred to the commercial fuel cycle. As Carter comments, “this was simply wrong.” It was wrong for technical, economic and political reasons. We know now that the weapons complex did not meet the minimum expectations of radioactive waste management although this was obscured for many years by the secrecy of “national security.” As for the economics of reprocessing, weapons production was not budgeted in terms applicable to the conditions in the private sector, even under the regime of a semi-monopoly electric power industry. The direct and indirect costs absorbed by the federal government under conditions of the Cold War were beyond anything a civilian industry could do. Also, the political and public opinion issues of producing plutonium within a high-security weapons complex were quite different from producing plutonium within a commercial industry. Reprocessing faced another problem since the process produces plutonium that can, at least technically, be used to make nuclear weapons. The Carter administration canceled work on the breeder reactor program in the late 1970s at least in part because of concerns that nuclear weapons proliferation might result from a plutonium economy.

There were, however, three major attempts over almost two decades to establish a civilian reprocessing capability. They failed on a number of dimensions. The first attempt at West Valley, New York started operations in 1966 and was closed in 1972. Built at a cost of \$35 million, it was designed to minimize capital investment. The history of West Valley problems and failures is long and bleak. Carter presents one anecdote, which is enlightening even if it is not typical.⁷¹ In early 1969 several fuel assemblies arrived from the Hanford N-reactor badly damaged, with some of the fuel rods ruptured along their entire length. When the rods were placed in the fuel storage pool, gross beta radiation in the pool shot up to more than 60 times what it should have been. The damaged fuel was hastily removed, put in scrap drums, and buried on site in a 50-foot-deep hole, encased in concrete. This problem is part of the current cleanup effort. Nuclear Fuel Services exercised its legal rights to withdraw from the project in 1976 and turned over responsibility for the site and the wastes to the State of New York, which subsequently got Congress to assign the site to the U.S. Department of Energy by Congress in 1980 (the West Valley Demonstration

DC: The Brookings Institute, 1991), 217-57; Carter, *Nuclear Imperatives*, pp. 117-18; E. Marshall, “Clinch River Dies,” *Science*, 222 (1983): 590-92.

⁷⁰ Carter, *Nuclear Imperatives*.

⁷¹ Carter, *Nuclear Imperatives*, 67.

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Project Act, PL 96-368). West Valley was the only commercial reprocessing plant to operate in the United States; it quickly became a cleanup site and work there continues to the present.

Two other serious commercial reprocessing attempts were made. In the early 1970s, General Electric Company designed a new process and built a plant to reprocess 300 tons of spent fuel per year at Morris, Illinois. When a cold run test (with nonradioactive materials) was conducted in 1974, major problems were uncovered. A thorough corporate review found that the transfer of the process from the laboratory to industrial operations would result in inevitable failures and the effort was halted. As Carter remarks, "General Electric and the State of Illinois were left with a white elephant, but at least it was not radioactive."

The final major reprocessing effort failed due to a lethal combination of technological, regulatory, and economic problems. Allied-General Nuclear Fuel Services began the project at Barnwell, South Carolina in the early 1970s and it was abandoned in 1983 when a final attempt to put together a workable package of funding and government support failed.

The costs of reprocessed uranium and plutonium simply could not compete with other sources of uranium as a fuel in the world nuclear power market nor provide the assurances of fail-safe control in an international plutonium market.

While the U. S. civilian-reprocessing efforts floundered and collapsed, other sources of plutonium produced considerable results. Albright et al. estimate that worldwide there are 1,300 metric tons of plutonium and 1,750 metric tons of weapons grade uranium-equivalent, often called highly enriched uranium (HEU).⁷² The military stockpiles of all grades of plutonium are estimated at 250 metric tons, with about 1,750 metric tons of HEU. Separated civilian stocks of plutonium, mostly processed in the United Kingdom, France, Belgium, and Russia, amount to about 120 metric tons. The majority of the world's plutonium is in unprocessed spent fuel. The potential problems with surplus plutonium and HEU have been the subject of extensive international negotiations about the best strategies for disposing of the stock of these materials.⁷³

As a result of weapons reduction agreements under the START II treaty between the United States and Russia, the United States in January, 1997 declared about 50 metric tons of plutonium as excess and announced a dual-track plan to dispose of this stock. This is only a start on the

⁷² D. Albright, F. Berkhout and W. Walker, *Plutonium and Highly Enriched Uranium 1996 World Inventories, Capabilities and Policies* (New York: SIORI and Oxford University, 1997).

⁷³ Matthew Bunn, "The Case for a Dual-Track Approach — and How To Move Forward from Here," in *Nuclear Materials Monitor* 1, no. 5 (Landsdowne, VA: Exchange Monitor Publications, 1997); for an interesting critique of the technical issues see: A. Makhijani, "Technical Aspects of the Use of Weapons Plutonium as a Reactor Fuel," *Science for Democratic Action* 5, no. 4 (February 1997).

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almost 2,000 metric tons of weapons grade plutonium and enriched uranium primarily held by the United States and Russia. The two tracks are: (1) blend the weapons grade plutonium with civilian uranium to create MOX fuel, which would then be burned in electric power reactors and disposed of as spent fuel; and (2) to mix the surplus plutonium with high-level wastes in a vitrification process and send the resulting combined waste product to disposal.⁷⁴

This program has engendered opposition from anti-nuclear activists who say that the program is designed to maintain the future options of fast breeder reactors and other forms of nuclear power, to subsidize the existing nuclear power industry by supplying MOX fuel at below cost, and to justify future reprocessing.⁷⁵ Other critics have focused on the proliferation issue and urged programs that will reduce any widespread use of plutonium in civilian reactors.⁷⁶ The mixing of civilian electric power and nuclear weapons materials would seem to provide another link for the deeper public concerns that link the risks of nuclear weapons and nuclear power.

Decommissioning Nuclear Power Plants. The final task at any nuclear power facility is to decommission it and clean up the radioactive wastes and residuals from the equipment, buildings, and site. This is a formidable challenge, with a familiar litany of problems: funding, public acceptance, short- and long-term site management, engineering and dismantling procedures, transportation of wastes and remains, cleanup standards, and regulation.

There appear to be three viable program options for decommissioning: (1) dismantle the facility promptly and remove the radioactive wastes; (2) provide interim on-site storage and management to allow radioactive decay and then remove the wastes; and, (3) provide for long-term on-site storage such as entombment.⁷⁷ In all cases, radioactive decontamination of the facility to some level is required. Entombment would maintain significant radioactive wastes on-site while the other two options require dismantlement and the transport of wastes to another site. About 115 commercial reactors will have to be decommissioned at some time in the future.

A number of commercial reactors have been taken out of service and designated for decommissioning. These plants divide into two classes, the early low-powered examples (such as Shippingport, Pennsylvania at 72 megawatts, Pathfinder, South Dakota at 62 megawatts, Fort St.

⁷⁴ Bunn, "Dual-Track Approach."

⁷⁵ P. Loeke, B. Joop and D. Bannink, *The MOX Myth: Risks and Dangers of the Use of Mixed Oxide Fuel*, WISE News Communiqué 469/470 (Amsterdam: WISE Amsterdam, 1997); Greenpeace, *Save Our Seas: Plutonium Reprocessing and the Contamination of the Seas*, brochure (Amsterdam: Greenpeace, 1997).

⁷⁶ A. Developi, "Fast Finish to Plutonium Peril," *The Bulletin of the Atomic Scientists* (September/October 1995): 20-21; Miller, "Reprocess the MOX Plan."

⁷⁷ C. Pollock, *Decommissioning: Nuclear Power's Missing Link*, Worldwatch paper 69 (Washington, DC: Worldwatch Institute, April 1986).

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Vrain, Colorado at 330 megawatts, and Peach Bottom I, Pennsylvania at 40 megawatts) and the later large plants (i.e., Rancho Seco, California, at 913 megawatts and Trojan, Oregon at 1,100 megawatts). The smaller plants have the advantage of being less contaminated and easier to take apart. For example, the Shippingport plant, which was decommissioned by the DOE for \$91.3 million, was contaminated with about 30,000 curies of radioactivity. It also contained a relatively small reactor vessel (153 tons and about 25 feet high) that was removed in one piece to a burial site on the Hanford, Washington reservation. In contrast, the Rancho Seco plant was contaminated with more than 9,000,000 curies and the reactor vessel may weigh up to 1,000 tons.⁷⁸ The General Accounting Office (GAO) looked at the lessons from Shippingport and concluded that other plants will be considerably more demanding.⁷⁹

Officials at the Sacramento Municipal Utility District, owners of the Rancho Seco facility, told GAO in 1990 that it would cost at least 10 times as much to decommission their plant as the amount DOE spent on Shippingport, that is, about \$1 billion. The attempt at decommissioning Rancho Seco is scheduled to begin about 2008, almost 30 years after the plant was taken out of service. However, considerable attention has been given to decommissioning costs and other estimates have been substantially less for comparable power plants.⁸⁰ It seems certain, however, that these costs will be substantial. For example, Commonwealth Edison operates the nation's largest nuclear power program with 13 units. In 1997, the firm estimated that it would cost \$4.6 billion to decommission these units (in 1997 dollars) and \$1.6 billion for low-level waste processing and burial of the 13 reactor units.⁸¹

In addition to the costs, the decommissioning of large reactors will increase the risk of worker and public exposure to radioactivity. This will be most acute for workers who must dismantle the large reactor vessels but the transportation of massive amounts of waste from the power-plant sites to appropriate waste-disposal sites will also present certain risks to the public. Pollock, for example, quotes a NRC estimate that it will take 1,363 truckloads of waste to remove 17,887 cubic meters of activated, contaminated, and radioactive wastes from a typical 1,100 megawatt pressurized water reactor.⁸²

⁷⁸ GAO, *Shippingport Decommissioning — How Applicable Are the Lessons Learned?* GAO/RCED-90-208 (Washington, DC: GAO, September 1990).

⁷⁹ GAO, *Usefulness of Information from Shippingport Decommissioning for Rancho Seco*, GAO/RCED-90-171 (Washington, DC: GAO, June 1990).

⁸⁰ A number of articles on decommissioning costs are contained in: M. Pasqualetti and G. Rothwell, eds., *Nuclear Decommissioning Economics: Estimates, Regulation, Experience and Uncertainty*, special nuclear decommissioning issue of *The Energy Journal*, 12 (Washington, DC: International Association for Energy Economics, 1991).

⁸¹ L. DelGeorge, Presentation to the National Research Council, Board on Radioactive Waste Management (17 July 1997).

⁸² Pollock, *Decommissioning*.

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Despite the engineering and economic analyses that have been applied to estimated decommissioning costs, the lack of experience with actually doing the work may conceal a number of costly factors that are not adequately accounted for in existing estimates. Robin Cantor points out some of the pitfalls and opportunities to learn from actual decommissioning experience.⁸³ Strauss and Kelsy conducted a survey of operating nuclear power plants and obtained estimates of decommissioning costs.⁸⁴ These cost estimates produced a mean value of \$211 per KW (1989 dollars) and a standard deviation of \$96/KW. At the extremes, four sites estimated costs of less than \$100/KW and four sites estimated costs of more than \$350/KW. Some of this difference is due to the various sizes and potential radioactive contamination of plants. Some is due to variations in what is included as decommissioning costs, such as whether costs of site remediation exceed the NRC trust-fund requirements. Future regulatory requirements can be expected to change over time with uncertain results for decommissioning costs. Projections of waste-transport and disposal costs are uncertain and may rise substantially. Cost estimates are an international problem; a study by the Organisation for Economic Co-operation and Development (OECD) laconically commented that costs could result from complex “political, institutional, technical, and economical factors.”⁸⁵

⁸³ R. Cantor, “Applying Construction Lessons to Decommissioning Estimates,” in Pasqualetti and Rothwell, *Nuclear Decommissioning Economics*, 105-17.

⁸⁴ P. Strauss and J. Kelsy, “State Regulation of Decommissioning Costs,” in Pasqualetti and Rothwell, *Nuclear Decommissioning Economics*, 55-72.

⁸⁵ Nuclear Energy Agency. Organisation for Economic Co-operation and Development, *Decommissioning of Nuclear Facilities: An Analysis of the Variability of Decommissioning Cost Estimates* (Paris: OECD, 1991).

In his review of past experience with decommissioning, Gene Fry found a large discrepancy between estimates to dismantle reactors and dismantlement experience.⁸⁶ Fry concludes: “Either available experience is misleading, or there is a vast body of underestimated dismantlement costs.”⁸⁷ In terms of funding decommissioning costs, Fry suggests that unless dramatic cost savings are discovered “fund collection for most reactors is too small and future ratepayers, stockholders, and taxpayers will be left paying for today’s errors.” James Hewlett argues that because interest accrues exponentially, if a reactor is retired early a substantial shortage of decommissioning funds will result.⁸⁸ If nuclear power plant owners are required to accept the costs of decommissioning and the regulatory agencies disallow transfer of those costs to ratepayers, then utilities may be encouraged to operate aging and troublesome plants simply to avoid serious economic losses. With increasing costs and fierce competition from other sources for electricity, Hewlett suggests the end result could be plants that are “too costly to run and simultaneously too costly to close . . . a situation to be avoided” (p. 290). There are several plants that are unlikely to operate for the 30 to 40 years that was expected when they were built and licensed. These early retirement plants, such as Rancho Seco and Trojan, are seriously underfunded and may require substantial funds from other sources — ratepayers, stockholders, or taxpayers — to complete decommissioning. Even then, unless the problems with disposal are solved there will be no place for them to send their wastes and on-site storage may be the default choice.

The costs of decommissioning are important, of course, but Martin Pasqualetti has cautioned that we should not lose sight of the potential social issues that “will become more important to decommissioning policy just as they did in matters of nuclear power planning, design, siting, and operation. Nuclear programs throughout the world have been transformed by public opinion and ensuing policy changes stressing costs, risks, equity, and the like.”⁸⁹

Transportation of Radioactive Wastes. Shipments of nuclear materials, such as reactor fuel, weapons and weapons components, and isotopes for medical or research purposes, take place regularly with little public notice or concern. Transporting radioactive wastes is difficult, especially spent fuel, which is highly radioactive. These wastes require extraordinary precautions

⁸⁶ G. Fry, “The Cost of Decommissioning U. S. Reactors: Estimates and Experience,” in Pasqualetti and Rothwell, *Nuclear Decommissioning Economics*, 87-104.

⁸⁷ Fry, “The Cost of Decommissioning,” 103.

⁸⁸ J. Hewlett, “Financial Implications of Early Decommissioning,” in Pasqualetti and Rothwell, *Nuclear Decommissioning Economics*, 279-91.

⁸⁹ M. Pasqualetti, “The Place of Economics in Decommissioning Policy,” in Pasqualetti and Rothwell, *Nuclear Decommissioning Economics*, 3-12; 8.

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to maintain their containment under a wide range of possible conditions, including highway and rail accidents.

Transportation removes the wastes from the security provided at well-regulated facilities and puts them into contact with a wide range of potential social activities, over which the waste managers have only modest or even little control. These social activities include everything from careless driving along truck routes or at train crossings to fanatical attacks upon shipment casks by terrorists or revolutionaries. The 1996 return of spent fuel from a small research reactor in Colombia to the United States relied on air transport to a Colombian port rather than risk guerrilla attacks on trucks. Even the prospect of army escorts was considered problematic and thought to risk being a provocation to an attack rather than prevention.⁹⁰ Certainly, transportation in the United States is not as risky as it is today in Colombia. Still, the rise of domestic and foreign terrorist activities in the United States over the past decade highlights a problem area that cannot be dismissed.

The largest radioactive waste transportation program in the United States involves wastes, mostly spent fuel, from 77 commercial nuclear power stations and 6 weapons-complex facilities. The shipping campaign would transport more than 85,000 metric tons of heavy metal (MTHM) over a period of about 40 years. With maximum reliance on rail transport, about 10,000 shipments will be required with hundreds of truck shipments from reactors without rail access. If only trucks are used, over 40,000 truck shipments would be required.⁹¹ If high-level wastes were shipped to Yucca Mountain, Nevada by rail about 100 miles of new rail access would have to be built at a cost of \$1 billion or more. Shipments would take place in more than 40 states,⁹² involving large numbers of interested parties — 199 state agencies with transportation authority, 140 state agencies concerned with emergency response to accidents or incidents, 33 state utility commissions, numerous public interest groups, and hundreds of cities, towns, and communities.⁹³

The case of HLNW transportation of this scope is expected to initiate public concern yet little is known about how people and communities will react. The Komis case in New Mexico signals the potential for impacts on property values, economic stability and growth, and quality of life. Such concerns may become powerful restraints on putting an efficient and acceptable HLNW

⁹⁰ H. Munera, M. Canal and M. Munoz, "Risk Associated with Transportation of Spent Nuclear Fuel Under Demanding Security Constraints: The Colombia Experience," *Risk Analysis* 17, no. 3 (1997): 381-89.

⁹¹ Bentz & Associates, *Technical and Institutional Considerations Regarding Near-Term (1998) Spent Fuel Transportation to an Interim Storage Facility*, Report to the Nevada Nuclear Waste Project Office (Carson City: NWPO, September 1995).

⁹² J. Williams, "Nuclear Solutions," *Forum for Applied Research and Public Policy* 14, no. 2 (Summer 1999): 103-07.

⁹³ Bentz & Associates, *Technical and Institutional Considerations*.

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program into effect.⁹⁴ State and local efforts to control waste shipments can be expected with all the problems of route selection, emergency-response preparations, and direct public opposition to specific shipments.

The problems associated with reprocessing, decommissioning, and waste transportation are capable of casting a long shadow over nuclear power for decades into the 21st century. The spread of the issues from these residual problems is nationwide, especially in the case of transportation, and offers little in terms of immediate benefits while presenting risks that can quickly erupt into public opposition.

Closing Comments. The problems confronting nuclear science and technology are clearly expressed in nuclear stigma, which functions as a composite evaluation of inherent hazards, the history of management, and the potential risks. The nuclear-stigma response runs wide and deep in American society. It is wide because concerns about nuclear facilities are shared across all segments of the population and for all forms of man-made radiation exposure. It is deep because there is a long history that supports public concerns. This history leads to an indictment of responsible organizations for failures to exercise good judgment, provide responsible administration, exercise fiduciary responsibility to public health and safety, and accept responsibility for adverse outcomes. The resulting public opposition undercuts expert and government prospects for future development of nuclear sciences and technologies. Yet the problems with management of nuclear programs and projects are not part of nuclear risk assessments and risk analysis except in the public's intuitive judgment, which underlies nuclear stigma.

New developments in communication technologies are transforming the roles of risk analysis and public decision-making. News of events as understood in the social amplification of risk seems headed toward a broad-based public and interactive availability. Motivated advocates will gain more and earlier leverage. This has the potential to focus public attention ever more effectively on decision processes and to provide the means for new involvements in policy and program choices. Technological stigma and other ways of framing information, especially those approaches that provide quick, affective, and widely held guidelines, such as moral values, will become more important and influential. In addressing nuclear stigma, society must focus on organizational performance. Science and technology must be, and be seen as, the servant of

⁹⁴ Paul Slovic et al., "Perceived Risk, Stigma, and Potential Economic Impacts of a High-Level Nuclear Waste Repository in Nevada," *Risk Analysis* 11 (1991): 683-96; Paul Slovic, James Flynn and Robin Gregory, "Stigma Happens: Social Problems in the Siting of Nuclear Waste Facilities," *Risk Analysis* 14, no. 5 (1994): 773-77.

human health and environmental preservation. Organizational goals must be recreated to these ends if management of inherently hazardous technologies is to achieve public acceptance and fulfill its potential contributions on behalf of mankind.

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The Social Geography of Risk Communication

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Abstract

Risk communication issues exist within complex societal structures with many overlapping and contending elements that can affect messages and responses. To address the significant contextual issues, we developed a conceptual framework entitled the Social Geography of Risk Communication. This framework builds on the past quarter century of work on risk issues and their social consequences but with a special orientation to the spatial conditions of communities, jurisdictions, and social spheres of communication and influence. One important objective is to identify the major arenas for social action and provide a means for analyzing communication patterns. It is within these arenas, as they display local issues and connections with other levels of society, that important responses to risk issues are formed and actions take place. Risk communication must understand the community context in order to address the primary social effects on public perceptions and behaviors.

In the social arenas, communication messages are understood in terms of the economic, social, and cultural surroundings. The meanings of the messages are constructed and reconstructed by people who receive them, often in ways that are not intended by senders. Moreover, any message sent must compete with risk messages from a variety of communicators. Government and industry jockey to become a credible source of information, as do consumer advocates, activists, and news reporters. Motivated stakeholders present various perspectives as they try to become a primary source of risk information and exercise influence over the decision process. Government and industry often use highly qualified scientists as basic risk information sources but often adversarial groups employ very capable experts.

1. Introduction

Social science research consistently shows that expert evaluations of the risks from low-dose radiation exposure are considerably different from those of the lay public.¹ This is important because lay risk evaluations are determinants of attitudes, preferences, and behaviors related to how nuclear facilities should be managed. The conclusions about the

¹ Paul Slovic, *The Perception of Risk* (London: Earthscan Publications, 2000).

potential hazards, the sources of evidence, interpretation of information, values applied to outcome and policy options, and confidence in organizational management are expressed in risk perceptions and displayed by social behaviors. These behaviors take place at several levels of society, often confrontationally within the context of local communities when specific programs or projects are proposed. At all social levels and among the many communities that make up our social-political society, the result has been considerable opposition to expert-recommended actions to manage radiation exposures.

Risk communication has been put forward as a means to bridge the gaps between expert and lay perspectives and thereby gain support for public radiation-control policies and programs. Experts tend toward recommendations expressed with quantified data and formal rational inferences, often using some baseline condition as a reference point. Thus, to justify low dose radiation exposure from the operation or remediation of nuclear facilities, reference is often made to natural background radiation. The rhetorical advantages of this are clear, at least within the expert ranks, since background radiation, including radon, raises only limited public concern and there is widespread public approval for the use of radioactive isotopes in basic research and in medicine. However, most industrial uses have been accepted only grudgingly as necessary (nuclear weapons) or as a *fait accompli* (existing nuclear power and radioactive waste sites). The primary disputes between experts and the public are with the industrialized sources of radiation, which are viewed from markedly different perspectives by both sides.

Scientific data exercises only a limited influence over public opinion even when specific cases are put into detailed scientific and risk terms. The public often misunderstands the nature of science itself. The inherent conditions of uncertainty and the inevitable development of new questions about the nature of radiation that result from scientific work seldom produce the clear, unambiguous, and final answers for lay people that would settle questions about the potential risks to human health and the environment. In addition, expert's science-laden recommendations do not directly address public concerns that arise from moral, ethical, or cultural values. On the contrary, these social-cultural value issues are often excluded from formal and informal discussion as a matter of policy. This results in a difficult communication situation. Society invests enormous time, resources, and effort into producing scientific and technical information to help

manage radiation risks only to have the best available advice rejected by individuals, groups, and communities for non-scientific reasons.

There is another side to this when scientific data are subordinated to schedule and/or budget goals or to political conditions by agencies that directly control the dominant scientific resources. In such cases, science data are often presented in ways that support administrative preferences, albeit without going through the process of defining the non-science values and potential options that are available. The case of scientific studies at the Yucca Mountain, Nevada site for a proposed high-level radioactive waste repository provides more than a decade of examples. When evidence from the exploratory studies showed that the criteria for qualifying the site as a repository could not be met, the regulations were changed and the standards for performance were adjusted to be less stringent. As these disappointing research results from the site accumulated, the project managers gradually abandoned the goal of reliance on geological isolation altogether and substituted claims that adequate protection of human health and the environment could be achieved with engineered barriers. In this way, the scientific data served not to assure the best choice of a repository site, or even a good site, but they were selectively used to comply with an outcome favored by powerful political forces.² The history of industrial development of nuclear technologies is replete with analogous cases, some where scientific data on exposures and consequences were suppressed for program reasons,³ others where they were denied for reasons of compensation liability,⁴ and still others where data were concealed for public relations reasons and to protect future development options.⁵

² Douglas Easterling and Howard Kunreuther, *The Dilemma of Siting a High-Level Nuclear Waste Repository* (Boston, Kluwer Academic, 1995); James Flynn et al., *One Hundred Centuries of Solitude: Redirecting America's High-Level Nuclear Waste Policy* (Boulder: Westview, 1995); James Flynn and Paul Slovic, "Yucca Mountain: A Crisis for Policy: Prospects for America's High-Level Nuclear Waste Program," in *Annual Review of Energy and the Environment*, vol. 20 (Palo Alto, California: Annual Reviews Inc.), 83-118.

³ U. S. Department of Energy, *Report of the Advisory Committee on Human Radiation Experiments* (Washington, DC: GPO, October 1995); S. Schwartz, "Four Trillion Dollars and Counting," *The Bulletin of the Atomic Scientists* (November-December 1995): 32-52.

⁴ H. Ball, *Justice Downwind: America's Atomic Testing Program in the 1950s* (New York: Oxford University, 1986); S. Udall, *The Myths of August: A Personal Exploration of Our Tragic Cold War Affair with the Atom* (New York: Pantheon Books, 1994).

⁵ A. Adler, "Public Access to Nuclear Energy and Weapons Information," chap. 2 in *Controlling the Atom in the 21st Century*, eds. D O'Very, C. Paine, and D. Reicher (Boulder, CO: Westview, 1994).

The selective use of science to achieve social and economic results raises questions about the place of risk communication. What potential roles can risk communication play to improve the management of radiation risks? The answer to this question must be based on understanding the current stigmatization of radiation, its development, and the present state of risk communication as a mediating force in public discourse. It is appropriate to recall that in the 1950s and 1960s there was widespread acceptance of nuclear technologies, from weapons complex facilities to nuclear power plants. This public acceptance declined and mutated into the widespread nuclear stigmatization we see in today's attitudes nuclear power and radioactive wastes.⁶ While the history of these years is easily forgotten in the press of current problems, the lessons should not be ignored. Some of that history is contained in the field of risk communication.

2. A Brief Overview of Risk Communication Development

The concept of chance and uncertainty in human affairs is deeply imbedded in the original myths of human cultures. It has long been recognized in the conduct of war, travel, commercial enterprises, and individual affairs. A history of the "story of risk" with an excellent account from the Renaissance to the present is contained in P. L. Bernstein's *Against the Gods: The Remarkable Story of Risk*.⁷ The developments of quantified approaches and methods for estimating risk have changed our understanding what risk is and who is responsible. In the last half century, such methods have led to risk assessment and risk analysis. The conditions presented by modern industrial technologies offer a stringent test for the use of risk assessment as a tool to gain public support for nuclear power or management of radioactive wastes.

Risk assessment to characterize the hazards of radioactivity was established in the 1970s, most notably with the work of Rasmussen.⁸ The problem of providing management and insurance against harms from nuclear power plants was addressed by the federal government in a number of ways, most directly with the creation of the Price-

⁶ James Flynn, *Nuclear Stigma* (Eugene, Oregon: Decision Research, 2002); James Flynn, "Nuclear Stigma," chap. 14 in *The Social Amplification of Risk*, ed. Nick Pidgeon, Roger Kasperson and Paul Slovic (London: Cambridge University Press, forthcoming 2003), 319-340.

⁷ (New York: John Wiley & Sons, Inc., 1996).

⁸ N. C. Rasmussen, *An Assessment of Accident Risks in U. S. Commercial Nuclear Power Plants* (Washington, D.C., U. S. Atomic Energy Commission, 1974).

Anderson Act of 1957, which instituted a combined industry-government liability and funding mechanism. The upper bounds of potential financial liability were based upon “worst case scenarios” for nuclear power plant accidents. The Act was scheduled for Congressional review in 1967.

In preparation for the Congressional hearings, the Atomic Energy Commission (AEC) commissioned a Brookhaven National Laboratory study to update the worst case effects that had been originally described in WASH-740. A new analysis was necessary because new and larger nuclear power stations were under construction and even larger ones were sited and under construction. The Brookhaven scientists would not estimate probabilities but did produce worst case estimates that the AEC felt would unnecessarily alarm the public and endanger the ongoing development of nuclear power. Attempts to provide the AEC with acceptable probability estimates for accidents were stymied by the lack of operating experience and data. In an AEC decision that Walker calls “inept as well as ill-advised” the AEC suppressed the Brookhaven work, creating for itself serious future problems.⁹ At the same time, the need to estimate nuclear power accident effects highlighted accident probability as critical data for nuclear power plant regulation.

In the summer of 1972, the AEC initiated the Rasmussen report.¹⁰ Subsequently, it was published in 1975 after the Nuclear Regulatory Commission (NRC) replaced the AEC as the federal nuclear regulatory agency. It then encountered severe criticism NRC disavowed the report in 1979.¹¹ The report did not achieve the necessary acceptance to continue endorsement by NRC but it did encourage sophisticated fault-tree analyses and other quantitative risk assessments as attractive potential data bases for probabilistic risk analysis.

⁹ J. S. Walker, *Containing the Atom: Nuclear Regulation in a Changing Environment 1963-1971* (Berkeley: University of California, 1992), 131. J. Samuel Walker, historian for the Nuclear Regulatory Commission, provides the best concise account of the subject. See chapters VI and VII.

¹⁰ D. Okrent, *Nuclear Reactor Safety: On the History of the Regulatory Process* (Madison, Wisconsin: The University of Wisconsin Press, 1981). Professor Norman Rasmussen from Massachusetts Institute of Technology was the study director along with Mr. Saul Levine from the AEC. The resulting report is contained in WASH-1400; U. S. Nuclear Regulatory Commission, *Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants*. (Washington, DC, U. S. Nuclear Regulatory Commission, 1975).

¹¹ Okrent, *Nuclear Reactor Safety*, 316-22.

The development of probabilistic risk assessment (PRA) as a basis for conducting risk analysis of complex technologies requires high levels of technical ability and further removes public involvement from regulatory decisions. It also creates an interesting regulatory condition for the future since public support, or at least acquiescence, is an integral part of regulation. As it turned out, once public health standards are coded in regulations and industry oversight, it is extremely difficult to ease them in response to improved operations, construction, or risk data because the public did not track well with the technical demands for setting standards based on PRA and it looks at efforts to relax such standards as imposing new and unacceptable risk conditions. At the same time, the nuclear power industry was aggressive in pursuing more economical conditions for operations, often arguing that new engineering, technical, and management conditions obviated the demands of regulations imposed in prior years.

The contribution of science to changing regulation standards has been limited because it can not demonstrate the safety of radiation exposure at low dose levels in ways that overcome politically and social adversaries. In lieu of definitive data showing a threshold or hormesis condition at specified low doses for the public, the linear no threshold (LNT) model was established as a conservative measure to minimize possible harm to members of the public.

The three optional models — linear no threshold, threshold, and hormesis imply overall policy objectives.¹² The LNT approach uses data from doses of radiation that produce measurable effects and then extrapolates to low doses in a straight line. Following this model, calculations to estimate population effects will show some mortality rates at any dose when the population is large enough. This assessment process has been linked to safety standards — for example, that specific conditions of radiation exposure not produce effects that estimate more than one death in a population of one million people. This sets a threshold not on the exposure but on the estimated consequences. Under these criteria, attempts to use other radiation models for estimating

¹² James Flynn and Donald G. MacGregor, "Commentary on Hormesis and Public Risk Communication: Is There a Basis for Public Discussions?" *Belle Newsletter* (October 2002): 28-30.

exposure to low dose radiation, such as arguments that exposure from nuclear power or nuclear waste sites are within the range of natural background radiation, are compromised and often rejected by the influential members of the public. By estimating human mortality as a mathematically calculated outcome for any dose of exposure, the LNT model supports concern about all sources of radiation including all levels of industrial and natural background sources.

For the operations of nuclear facilities, a somewhat different logic, a threshold model, is in effect for nuclear industry workers. In this case, at least theoretically, the risk is shared between informed workers and industry with the compensation of higher wages offsetting the increased risk to individual workers.

There are some radiation health experts who support a hormesis model that claims there are human health benefits from small doses of radiation. Widespread acceptance of this model would, of course, greatly change the regulatory standards for nuclear industrial facilities. To date, this model remains possible but not well-supported and it has been passed over in favor of the LNT model by both the National Council on Radiation Protection¹³ and the most recent National Academy of Sciences report.¹⁴ On the other end of the spectrum are claims that very low doses of radiation are proportionately more likely to produce cancer in humans.¹⁵ These advocates propose that efforts to establish threshold standards are motivated by the desire to save money in managing operations and the cleanup of nuclear sites.

To summarize the influence of radiation health science upon public understanding of risk assessment techniques and their application to regulation of radiation exposure, we can say it has been hampered by the scientific complexity and uncertainties addressed by risk analyses, the criteria used in creating and regulating radiation exposure standards, the

¹³ National Council on Radiation Protection and Measurements, *Evaluation of the Linear-Nonthreshold Dose-response Model for Ionizing Radiation*, NCRP Report No. 136 (Bethesda, Maryland, National Council on Radiation Protection and Measurements, 2001).

¹⁴ National Academy of Sciences, Committee on the Biological Effects of Ionizing Radiation, *Health Effects of Exposure to Low Levels of Ionizing Radiation: BEIR V* (Washington, D.C.: National Academy Press, 1990). Retrieved July 31, 2002 from the National Academy Press Web site: <http://www.nap.edu/books/0309039959/html/>. The report of BEIR VII is due out in 2003; BEIR VI addressed radon.

¹⁵ L. Moore, "Lowering the Bar," *Bulletin of the Atomic Scientists* (May/June 2002): 28-37.

history of past government management of radiation sources, and economic interests of advocates for less stringent standards in managing industrial radiation sources. Moreover, the goals, standards, and practical management issues addressed by public decision processes are sources of acute differences between experts and public advocates. An accommodation between the stakeholders will require tradeoffs that are seldom fully acknowledged and in many cases involve issues are often considered by regulators and other officials as too complex and technical for public debate. Thus the context for risk communication, assuming that information in a genuine communication effort would flow in both directions, from experts to the citizens and visa-versa, is difficult to put into practice. These conditions enforce a tendency to reduce the risk communication process to public relations, thus attempting to gain enough tactical advantage so that immediate issues can be resolved in a way that satisfies technical criteria and regulatory guidelines. The longer term costs, in regard to public trust and confidence in officials and their decision processes as well as the opportunity costs of cutting public education as short as possible in any specific case, are left to the future.

The “worst case” approach focused on the maximum possible losses from a major accident, which in addition to defining the maximum insurance claims, made a dramatic and memorable impact on public perceptions. Probabilistic risk analysis added the likelihood of accidents to the consequences and modified the insurance risk, at least in the view of experts. This modification proved to be difficult to communicate to the public and, it must be noted, it was not entirely convincing to the commercial insurance industry so that to this day the Price-Anderson Act is still in effect and in fact is well on its way to renewal in the current Congress. The acknowledgement that catastrophic consequences had to be considered, even if modified by calculations of probability, continues the concern with radiation exposure that has become associated with public perceptions of nuclear power. To this day, the image of major accidents exercises a major influence on public perceptions of nuclear power, the logic of probabilistic risk assessment notwithstanding.

The difficulties of communicating about radiation issues have led to many suggestions for increasing public understanding and support. The two primary goals of such efforts have been to properly educate and/or more simply to inform the public about

objective radioactive risk conditions. The search for ways to accomplish these goals has preoccupied the efforts of risk communication over the last quarter of the 20th century. A brief review of these efforts provides a necessary perspective on the nature of the risk communication problems.

3. Models for Risk Communication

The most basic model for risk communication contains: the sender of the risk message, the media used to distribute the message, and the message receiver. Each of these components has been examined to understand the communication challenges and opportunities. The early focus was on the information in the message. Later, this developed into interests in rhetorical strategies and to concerns with the social context for messages. Thus, Fischhoff more than a decade ago was able to construct the following outline of a risk communication history:¹⁶

- Give the public the facts
- Sell the public the facts
- Give the public more of what it has gotten in the past
- Give the public clear-cut, noncontroversial statements of regulatory philosophy
- Let the marketplace decide
- Put risk managers on the firing line
- Involve local communities in resolving their own risk management problems

He comments that “despite their flaws, these simple strategies all have some merit. It is important to give people the facts and to be persuasive when the facts do not speak for themselves or when existing prejudices must be overcome.” Still, as we move into the 21st century an effective role for risk communication remains to be developed. Only the last item, to involve the public, defines a cooperative, interactive process. It suggests that community positions are constructed through a series of communications, not all directed by the originator of the messages. This implies that both the originators of messages and

¹⁶ Baruch Fischhoff, “Judgment and Decision Making,” in *The Psychology of Human Thought*, ed. R. J. Sternberg and E. E. Smith (New York: Wiley, 1987), 153-187.

the responders have something to learn about each other as well as about the defined subject. How this might be done to good effect is not clear. The exhortation to involve local communities in resolving their own risk management problems has not achieved any dramatic breakthroughs nor can these problems be simply abandoned to local action. Local communities and their surrounding social units are not, by themselves the answer to risk management problems and can be more accurately described as arenas for consideration of risk issues rather than waiting answers with optimal social solutions. In terms of acceptability, costs, technical capabilities, and resources, local communities can more correctly be considered as part of the problem. The adversarial conditions exist even while risk communication attempts to develop a more comprehensive and effective understanding of the social problems and potential opportunities presented by host communities.

Table 1. Approaches to Communicating Risk

Approach	Reference	Strategy
1. Communication Process Approach	R. Lundgren and A. McMakin, <i>Risk Communication: A Handbook for Communicating Environmental, Safety, and Health Risks</i> (Columbus, Ohio and Richland, Washington: Battelle Press, 1998), chap. 2.	Message source sent through available channel to intended audience (with feedback if necessary).
2. National Research Council Approach	National Research Council, Committee on Risk Perception and Communication, <i>Improving Risk Communication</i> (Washington, D.C.: National Academy Press, 1989); National Research Council, Committee on Risk Characterization, <i>Understanding Risk: Informing Decisions in a Democratic Society</i> , eds. P. C. Stern and H. V. Fineberg (Washington, D.C.: National Academy Press, 1996).	An interactive exchange of information and opinion between experts and lay people.
3. Mental Models Approach	G. Gueter and A. L. Stevens, eds., <i>Mental models</i> (Hillsdale, New Jersey: Lawrence Erlbaum Associates, 1983); M. Granger Morgan, Baruch Fischhoff, Ann Bostrom, and Cynthia J. Atman, <i>Risk Communication: A Mental Models Approach</i> (New York: Cambridge University Press, 2002).	Compares mental model for audience with expert models for evaluating risks
4. Crisis Communication Approach	Lundgren and McMakin, <i>Risk Communication</i> , chap. 5.	Provides immediate action messages and directions
5. Convergence Communication Approach	E. M. Rogers and D. L. Kincaid, <i>Communications Networks: Toward a New Paradigm for Research</i> . (New York: Free Press, 1981).	Long term “cycling” of information between groups to slowly converge onto common ground
6. Three-Challenge Approach	K. E. Rowan, “Goals, Obstacles, and Strategies in Risk Communication: A Problem-Solving Approach to Improving Communication About Risks,” <i>Journal of Applied Communication Research</i> 19 (1991): 300-29.	Addresses the challenges of knowledge, process, and communication skills
7. Social Constructionist Approach	C. Waddell, “Defining Sustainable Development: A Case Study in Environmental Communication,” <i>Technical Communication Quarterly</i> 4 (1995) 201-16.	Considers the flow of information as modified by understanding, values, beliefs, and emotions.
8. Hazard Plus Outrage Approach	P. Sandman, “Hazard Versus Outrage in the Public Perception of Risk,” in <i>Effective Risk Communication: The Role and Responsibility of Government and Nongovernment Organizations</i> , eds. Vincent T. Covello, D. B. McCallum, and M. T. Pavlova (New York: Plenum Press, 1989).	Based on premise that risk communication often must address the condition of hazard + outrage

Source: Lundgren and McMakin, *Risk Communication*, chap. 2.

From the expert perspective, the basic problem is how to communicate with the lay people in communities about scientific evidence, instill confidence in the analyses, encourage trust in the policies and programs, and achieve public willingness to support specific projects. From the community perspective, the issue is how to gain recognition and influence for the community issues and gain amelioration of potential risks. Over past decades a series of conceptual approaches to risk communication have been developed. Lundgren and McMakin summarize eight approaches.¹⁷ As shown in Table 1, these approaches have become more complex as they have accommodated evidence of psychological, social, cultural, economic, and political factors. More complication is added as the power and variety of communication options develop, especially the many unscripted messages that now pass quickly among the general public through countless electronic messages and the development of ever more dramatic presentations by the news media.

This table points out the rather simple, linear and mechanistic descriptions of the 1960s and early 1970s, the movement of risk communication to incorporate work from social psychology and decision-making, and more recently the interest in sociological, cultural, and anthropological research.

The early models of risk communication lacked the ability to construct science-based messages that addressed public concerns and moderated public attitudes toward radiation exposure and its management. There were two serious limitations: The public was not given the information it wanted about decisions to be made on their behalf and decision-makers did not obtain appropriate understanding of public concerns. The result was a long series of contentious differences between radiation managers and the public expressed at the local, state and national levels. The early communication failures prompted the more recent models, which move toward inclusive approaches, taking account of a wider range of human social interactions that bear on the subject.

How well have these developing risk communication efforts worked? We really don't know. There is little evidence that significant improvements have been achieved in public risk perceptions, changes and adaptations to management plans or policies, public

¹⁷ Lundgren and McMakin, *Risk Communication*, chap. 2.

support or responses to management proposals. There have been very few attempts to measure the effects of specific risk communication strategies in different cases. Some initiatives with citizen task forces, advisory groups, and community representatives have been attempted but these tend to be carefully limited in their scope and purpose so there is little or no decision-sharing involved. Another block to realization of risk communication goals is identified in work on the social amplification of risk framework, which defines a complex, combative, and messy social condition with contending parties, messages and strategies for risk management policies and programs.¹⁸ This suggests there is little hope of imposing an integrated and effective communication presence in any community no matter how adeptly the public relations aspects are put into effect. Much more likely are conditions of multiple strategies and risk messages from many stakeholders and perspectives in conflict with each other. In these conditions, we find that science messages are seldom given the weight their author's envision as their due in public discussion, in many cases science messages are ignored and overwhelmed by issues based on social values. This can be seen with attempts over the last two decades to site nuclear waste facilities. When federal agencies have attempted to locate and develop high-level waste sites the responses at the community and state levels have inevitably been in opposition.¹⁹ The futile effort over two decades to locate low-level waste sites, undertaken by more than 20 states and multi-state (compact) programs shows how difficult it is to overcome public resistance at the community level.²⁰ In varying degrees these public responses apply to nuclear power and weapons production sites. Public concerns extend to transportation routes used for moving wastes and to atmospheric fallout that took place several decades ago.²¹

¹⁸ R. E. Kasperson et al., "The Social Amplification of Risk: A Conceptual Framework," *Risk Analysis* 8 (1988): 177-87; R. E. Kasperson, "The Social Amplification of Risk: Progress in Developing an Integrative Framework of Risk," in *Social Theories of Risk*, ed. Sheldon Krinsky and Dominic Golding (New York: Praeger, 1992), 153-78; Pidgeon, Kasperson, and Slovic, *The Social Amplification of Risk*.

¹⁹ L. C. Carter, *Nuclear Imperatives and Public Trust: Dealing with Radioactive Waste* (Washington, DC: Resources for the Future, 1987); Flynn et al., *One Hundred Centuries*.

²⁰ J. Weingart, *Waste is a Terrible Thing to Mind: Risk, Radiation, and Distrust of Government* (Princeton, NJ: Center for Analysis of Public Issues, 2001).

²¹ *City of Santa Fe v Komis*, 845 P.2d 753 (1992); "\$337,000 WIPP Road Land Award Upheld." *Santa Fe Journal*, 27 August 1992.

4. The Social Context for Risk Messages

As with any difficult risk management problem, the obvious question is “what can be done?” “How can some better risk communication process be found and put into place so that informed expert advice and opinion can enrich public discourse?” The scientific answer to such questions, from physical and social researchers alike, is to first understand the dynamics of the condition at issue and then examine actions that might modify the processes and their outcomes. Although the efforts to date have been fragmented, there is a baseline in studies about the perception of risk and the social amplification of risk. These areas of study have generated a substantial number of hypotheses about risk, its social contexts, and public behaviors.

The understanding that human risk attitudes, understanding, and behaviors are determined by beliefs and perceptions goes back at least to the 17th Century with the realization by natural philosophers (the scientists of their day) that human beings have no sources of wholly objective knowledge about the physical world. Knowledge about nature is mediated by individual intellectual capabilities and the social-cultural context. This includes the recognition that uncertainty is an inherent characteristic of human knowledge, which led to theories of probability and eventually provided the basis for risk assessment.²² The definition of risk perception as a social-psychological condition essential to risk management and risk communication has been studied for some time, including work has been done by Damasio,²³ and specifically in terms of risk perceptions by Slovic and his colleagues.²⁴ One point that has been documented in numerous studies is that experts and the public not only hold different views about the risks of radiation exposure but they construct those views and perception from different components they have available from science, the social context, political processes, and trust of managers.

²² P. L. Bernstein, *Against the Gods: The Remarkable Story of Risk* (New York: John Wiley & Sons, Inc., 1996).

²³ A. R. Damasio, *Descartes' Error: Emotion, Reason, and the Human Brain* (New York: Avon, 1994).

²⁴ Ellen Peters and Paul Slovic, “The Role of Affect and Worldviews as Orienting Dispositions in the Perception and Acceptance of Nuclear Power,” *Journal of Applied Social Psychology* 26 (1996): 1427-53; Ellen Peters and Paul Slovic, “The Springs of Action: Affective and Analytical Information Processing in Choice,” *Personality and Social Psychology Bulletin* 26 (2000): 1465-75; Slovic, *The Perception of Risk*.

Figure 1. A model of impact for unfortunate events. Adapted from Kasperson, “Social Amplification of Risk.”

Roger Kasperson and his colleagues initiated an important direction of social analysis with the formulation of the Social Amplification of Risk as a conceptual framework to describe public responses to risk information.²⁵ Figure 1 outlines this framework and shows a series of key social-cultural conditions. One outcome is the development of technological stigma for certain types of hazards and hazardous conditions. Stigmatization serves as a socially developed “sign” or “prompt” to guide risk evaluations and to serve as a warning about serious risks. It also functions as a feedback within the social amplification of risk framework to inform decision-makers about public acceptability.²⁶ Another important line of research considers the performance of organizations designated as risk managers, a matter that was included in the first wave of studies done on the social amplification of risk.²⁷

²⁵ Kasperson et al., “The Social Amplification of Risk”; Kasperson, “The Social Amplification of Risk.” The Social Amplification of Risk has been the subject of about a 100 articles and a forthcoming book, Pigeon et al., *The Social Amplification of Risk*.

²⁶ Robin Gregory, James Flynn, and Paul Slovic, “Technological Stigma,” *American Scientist* 83 (1995): 220-23; James Flynn, Paul Slovic, and Howard Kunreuther, eds., *Risk, Media and Stigma: Understanding Public Challenges to Modern Science and Technology* (London: EarthScan Publications Ltd, 2001); Terre Satterfield et al., “Risk Lived, Stigma Experienced,” in Flynn et al., *Risk, Media and Stigma*, 69-83; Flynn, “Nuclear Stigma.”

²⁷ William Burns et al., *Social Amplification of Risk: An Empirical Study* (Carson City, Nevada: Nevada Agency for Nuclear Projects Nuclear Waste Project Office, 1990); James Flynn, William Burns, C. K. Mertz, and Paul Slovic, “Trust as a Determinant of Opposition to a High-Level Radioactive Waste Repository,” *Risk Analysis* 12, no. 3 (1992): 417-29; James Flynn and Paul Slovic, “Nuclear Wastes and Public Trust,” *Forum for Applied Research and Public Policy* 8 (1993): 92-100.

Figure 2. Social geography of risk communication.

5. Social Geography of Risk Communication

The Social Geography of Risk Communication (SGRC) was developed as a framework to address risk communication issues as they are expressed within existing societal structures with their many overlapping and contending elements. This framework builds on past work on risk issues and their social consequences. Much of this earlier work focuses on individuals and responses from experimental studies in social psychology, which forms the basis for much of our understanding of risk perception. Considerable research by sociologists, economists, decision-analysts, anthropologists, and other social scientists have explored group, community, regional, and national responses to technological hazards and risks. The goal of research based upon the SGRC framework is to look at how group and community responses to risk conditions are created, expressed and modified. This leads to studies with a geographical awareness, an orientation to spatial conditions to identify social levels of interaction including communities, groups, lines of social interaction, and spheres of influence. The basic approach is shown in Figure 2. As a guide to research, the SGRC framework is used to identify the major arenas for social action. It is within these arenas that local issues, modified by the many societal connections, are incorporated into risk responses. Risk communication must be capable of understanding the community context in order to take account of the primary social effects on public perceptions and behaviors. It also must understand the broader societal forces that bear on community issues.

It is good to recall at this point how closely the purposes of risk communication are related to specific risk situations. A basic point is to recognize the purpose and objectives for initiating the risk communication. Lundgren and McMakin generalize to three motives for risk communication.²⁸ If the problem is to warn of personal health risks then the purpose will be to “increase awareness and change behavior” to minimize risk outcomes. If the issue is to implement a risk policy then the emphasis will be on “agreement about the way a risk is assessed or managed.” If the effort is to deal with a crisis, the purpose is “communicating to alert the audience and provide ways to minimize the risk.” The risks of radiation exposure can apply to any or all of these three forms of

²⁸ Lundgren and McMakin, *Risk Communication*.

risk. A fourth objective, coming from unofficial and perhaps even adversarial positions might be to prevent the implementation of a specific policy or program or to achieve major modifications in official plans to induce substantial changes in the proposed objectives.

The links between establishing objectives and changing behaviors become progressively less controllable and more problematic for risk communicators as the messages go to the more complex social contexts. This is true for proponents and opponents. In the social arenas, communication messages are sent to economic, social, and cultural surroundings where the meanings of the messages are constructed and reconstructed, often in ways that are not intended by those who sent them. The generation of risk messages with different presentations of facts and interpretations creates confusing conditions. Government and industry jockey to become credible sources of information, as do consumer advocates, activists and news reporters. Motivated stakeholders present various perspectives as they try to become a primary source of risk information. Government and industry often use highly qualified scientists as basic risk information sources but it also the case that very capable experts often work with and through alternative groups.

5.1 Communication Channels and the Social Context

Risk messages can be delivered directly through special publications, presentations, and personal contact. Face-to-face talk and explanations are an essential part of community life and an interactive method of communication. The dominant communications at the community level, however, involve the role of the news and communication media. This is for a number of reasons including the size of the audience, the social regard of the news media, the nature of the presentations, which can be quite dramatic, and the media's agenda-setting abilities. The structure and behavior of the news media assures that no risk communication will be presented to the public in the ideal form envisioned by the originators of messages. This means that the social context for those receiving the messages will exercise significant influence over the meaning derived by individuals and groups. This applies to the how the public views the legitimacy of facts, interpretations, and implications.

Risk communication involves intensely social behaviors. The parameters for risk identification, assessment, analysis and management are by their very nature public acts that require societal involvement. The contentious issues come when there are serious differences in risk perceptions and in preferences for strategies to respond to hazards. In these cases, not every opinion is, or should be, of equal value. Experience, knowledge, skill, and intelligence should outweigh casual responses to risks. At the same time, society at large recognizes that public opinion contains a validity that must be evaluated along with the technical details.²⁹ Of course health and public costs are important but equally society expects consideration of risks the public views as threats to social values, community functions, moral and ethical standards for process and outcomes, and vulnerabilities of individual economic or cultural possessions. The nonscientific social conditions that apply to public responses can vary widely from one location to another, from one group to another, and even within groups. Effective risk communication understands how expert perspectives and the much more diffuse public perspectives are used to construct risk judgments.

Another important task for risk communication is to gauge the consistency of judgments. Expert positions are built over time with basic standards for obtaining, measuring, and evaluating evidence. The public provides less structured responses and tends to develop its positions under the pressure of imposed conditions. The result is that public judgments are created in a social-cultural context that treats expert standards and processes as only one component. Thus risk communication must deal with social-cultural framing effects and their influence on attitudes, perceptions and behaviors.

²⁹ Paul Slovic, "Perception of Risk: Reflections on the Psychometric Paradigm," in *Social Theories of Risk*, eds. S. Krimsky and D. Golding (New York: Praeger, 1992), 117-52.

Even expert opinions are subject to debate and critical examination. The courts have found that evaluating expert testimony is not easy. The “gatekeeper” function assigned to judges is intended to eliminate “junk science” and provide a reasonable information base for juries and courts to make informed decisions.³⁰ In the broader social context no gatekeeper commands the authority to guide a community through the blizzard of risk information; rather many contenders aspire to influential roles in the public arena and often achieve them with some segment of the community. In many cases, important risk information is presented in terms of news events, entertainment, art, religion, business, existing ethical standards, citizen educational levels, or even local gossip. Where there are strong adversarial opinions, conflicting risk facts and analyses can reduce the role of science as an authoritative voice. The roles contending presentations for risk judgments play are often subtle and the influences on the public’s construction of preferences are largely unexamined.

Risk communications can be intended for individuals, groups, or communities. Within complex social settings, distinct audiences can be identified and communications designed to appeal to each, or with difficulty in contentious issues, to all. The social context can support or oppose the intent of the official risk management processes and decisions but in our current social-political world dominant control over risk messages is almost impossible. Modern democratic societies provide few legal restrictions on communication attempts and even these are difficult to enforce. Thus, each message must compete with other efforts that may present different data, appeal to different values and concerns, make contrary analyses, construct the issues in a variety of ways, recommend other strategies and actions, and appeal to alternative outcome goals.

The more analytic risk communicators recognize these social contexts are difficult to deal with. They recognize that many forces at work at various levels of society, public opinion is malleable, abundant strategies are available to individuals and interested groups, and the decision processes themselves are complex, often redundant, and time-consuming. These conditions define the need for conceptual frameworks to clarify key

³⁰ *Daubert v Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579, 113 S. Ct. 2786, 2796-99, 27 U.S.P.Q. 2d 200 (1993).

social conditions and improve understanding of the context and dynamics faced by risk communication. Without the clarity of good conceptual guides even the best-intended communications can be unproductive or even worse, counterproductive.³¹

Perception of Risk studies and the Social Amplification of Risk framework provide the important basic orientation for addressing the social-cultural interactions that come into play when public decisions are made. In a sense these areas of research bracket the subject of our paper; the perception of risk studies focus on individuals and social psychology while the social amplification of risk provides a categorization of key social conditions. Between these contributions to understanding risk and human behaviors are layers of social context. The purpose of the social geography of risk communication is to examine the social-psychological context of risk and decision making in key social-cultural arenas. What happens in these arenas is important if science is to exercise a more effective role in risk communication.

The most difficult social-psychological response is technological stigma, the stigmatization of places, products and technologies. Three major scientific areas get the bulk of adverse public responses: nuclear physics, chemistry, and more recently biology. Technological stigma is a social process that characterizes potential dangers, such as the storage of radioactive wastes, as morally unacceptable.³² Once socially established, stigmatization prejudices the acceptability of any exposure to the hazard at issue, discounting plans and attempts to manage, shield, or entomb the source of the danger.

Because individuals can articulate their perceptions if they are asked the right questions, most of our information about stigmatization comes from data provided by individuals. However, we also recognize that stigma marks and judgments conform to social values, they are created by social forces, and they are enforced by social units, such as communities. Technological stigma tends to cross social boundaries even while there are variations in the scope and power it displays from one place to another. At the community level, however, social, political, and economic factors can come together and achieve the mass and cohesion needed for effective societal actions at least in part

³¹ James Flynn, "How Not To Sell a Nuclear Waste Dump," *The Wall Street Journal* (15 April 1992), p. A20.

³² Gregory, Flynn, and Slovic, "Technological Stigma."

because social structures focus on controlling risk and responding to risk events. Proximity to a stigmatized condition creates a context of community responses.³³ In our industrialized society, modern technology makes it possible to distribute a specific kind of provocative risk condition in similar form to many communities thereby creating a matrix of risk concern across broad stretches of the contemporary social order. A prototypical example is found in transportation of hazardous materials such as radioactive wastes, toxic and volatile chemicals, and modern weapons of all kinds but especially those developed from modern biological production processes.

5.2 Research on Stigma and Risk Communication

The purpose of this research at Decision Research is to increase understanding of the issues and concerns involved in communicating about low dose radiation risks. We focused on four areas for our work. So at this point we will take a moment to put our community studies and the SGRC into the larger research context. First, we considered the historical background of public events that influences existing attitudes toward radiation hazards and we constructed a conceptual framework (the Social Geography of Risk Communication) to place our range of studies in a risk communication context. Second, we conducted a series of experimental studies in social psychology. Third, we conducted small group experiments on the potential to negotiate decisions about radiation exposure. Fourth, we examined community responses to existing sites that are associated with low dose radiation exposures.

The Social Geography of Risk Communication framework postulates that a complex web of connections exist within society spanning from the individual and various local geographical areas up through the national government. In the case of industrial sources of radiation, primarily from the nuclear weapons and nuclear power programs, the federal government is both a creator of the hazard and the final risk manager.

Risk communication for this topic is embedded in the social forces that people experience directly as well as the messages that come through national, regional, and local news sources. This context directly effects people's beliefs, attitudes, and

³³ Flynn et al., *Risk, Media and Stigma*.

preferences, which, in turn, influence decisions and behaviors.³⁴ Obviously no short term research project will answer all the questions involved. What we looked at were the issues, actors, and conditions we defined in conjunction with our experiences in social science research and our development of the social geography of risk framework. Our work concentrated on key social actors and a central set of research questions. These questions incorporate the wide range of information needed to answer the questions about, “How are decisions made when people, groups, and communities consider low dose radiation exposure?”

5.3 The Construction of Perceptions of Risk

At the individual level, risk decisions involve an important and subtle interaction between knowledge, cognition, values and emotion. Science is a primary source of risk knowledge and claims a major role in how this knowledge is to be understood and used. Personal values about a wide range of the human concerns, by scientists and experts as well as by lay people exercise significant influence on cognition and decision-making. These values are created within social-cultural experiences and include the explanations, rationales, and justification for risks and the subsequent decision-making processes. Acceptable evidence, explanations and decision-making vary across locations within the social geography framework. What is perceived as rational and necessary can be constructed from a variety of social-psychological materials. The study of how these decision preferences are constructed is basic to understanding people’s attempts to communicate.

5.4 Risk and Risk Management — An Emphasis on Trust & Distrust

The level of trust in other participants is an essential problem in community responses to risk management issues especially when the goal is to transcend individual and group perspectives and define social-level outcomes and strategies. At the most basic level, three conditions can define outcomes: When an authority has the standing to define the outcome; when some process of cooperation achieves agreement; or when a solution

³⁴ S. Kraus, “Attitudes and Prediction of Behavior: A Meta-analysis of the Empirical Literature,” *Personality and Social Psychology Bulletin* 21, no. 1 (1995): 58-75.

results from some combination of social power and cooperation. In the U.S. system, this last outcome often involves litigation through the court system.

The establishment of government as the manager of technological hazards during the 20th century and the dependence on a risk-based approach introduced science knowledge and interpretation into public controversies. This historical process included new levels of scrutiny of risk institutions and officials. In their proposals and decisions these organizations are expected to use the best scientific knowledge base, make clear and responsible inferences, develop accurate risk forecasts, and provide safety through specific programs. The public evaluations of these difficult tasks are reported in measures of trust and confidence. There are many uncertainties in each of these major areas of responsibility, which generates a wide range of opinions by individuals and stakeholder groups at every point. Risk communications under these conditions include substantive, procedural, and outcome factors, all of which are improved or damaged by the degree of trust and confidence achieved by risk management. In the end, risk management becomes a risk factor although this is usually expressed in non-risk terms, usually as concerns about organizational structure, authority, or individual deviant performances. Research that includes examination of risk management as a risk factor addresses one of the major difficulties in communication by clarifying the public and stakeholder perceptions, the risk implications of organizational performance, and the effects on program implementation.

Understanding the degree of individual and group credibility is important to examining the performance of risk communications. Standards of accountability and performance, although not identical for everyone, are applicable to all stakeholders and not only to the officially designated risk managers. Research in risk communication should recognize that the trust and confidence required of each important actor since judgments and behaviors on all sides are inevitably made based upon perceptions of trustworthiness.

5.5 Communities in Response — Case Studies and the Potential for Negotiations

Conflicting community positions on problems of radiation exposure, like many adversarial societal issues, require some form of negotiated settlement. This is the essence of political decision-making in democratic societies and applies to local health and environmental issues. In turn, negotiated processes require tradeoffs between stakeholders to reach accommodations that provide at least minimal acceptable results. Parties to negotiations must understand their own position and its reasons as well as learning about the positions of potential adversaries and allies. Yet when the scope of tradeoffs is defined to include moral, ethical, and social values as well as information from science on the probabilities and consequences to human health and the environment, the difficulties of negotiations are greatly increased. The inability of federal or state agencies to site low-level radioactive waste facilities show that programs that cannot be negotiated at the community level run the risk of failure.³⁵

The study of community experiences with radiation exposure issues provides a broad and deep information base for understanding the issues and responses by individuals, groups, and stakeholders. Both successful and unsuccessful attempts at program implementation, in many variations and permutations, are available for analysis. In addition to providing a data base for understanding the social interactions between risk managers and community residents, this line of research suggests options to improve both the processes and outcomes.

³⁵ U. S. General Accounting Office, *Low-level Radioactive Wastes: States are Not Developing Disposal Facilities* (Washington, D.C.: U.S. Government Printing Office, 1999), 104.

Two leading approaches to structuring tradeoff processes are negotiated dispute resolution³⁶ and value-based decision-making.³⁷ These two approaches emphasize shared decision-making and the development of a jointly constructed forum and process. The value-based process directly addresses some of major issues in radiation exposure by focusing on the social-psychological motives of participants that are often ignored with other approaches to decision making. This is especially important where technological stigma is present and the resulting high load of ethical, moral, and social issues can overwhelm scientific findings in adversarial confrontations.

Experimental research to evaluation of value-based decision-making in the cases of radiation exposure has been undertaken as part of this research program under the direction of Robin Gregory.³⁸ Another set of experimental studies were conducted on the role of emotion and affect in relation to radiation issues.³⁹ Detailed community studies were conducted over two years in three communities where radiation exposure involved significant public concern and involvement. These studies were completed for Brookhaven, New York,⁴⁰ Fernald, Ohio,⁴¹ and Rocky Flats, Colorado.⁴² In addition, separate community surveys were completed for two case study communities, Rocky

³⁶ Lawrence Susskind and Jennifer Thomas-Larmer, "Conducting a Conflict Assessment," in *The Consensus Building Handbook*, eds. Lawrence Susskind, S. McKernan, and Jennifer Thomas-Larmer (Thousand Oaks, California: Sage, 1999), 99-136; Lawrence Susskind, Paul F. Levy, and Jennifer Thomas-Larmer, *Negotiating Environmental Agreements: How to Avoid Escalating Confrontation, Needless Costs, and Unnecessary Litigation* (Washington, D.C.: Island Press, 1999).

³⁷ T. L. McDaniels and Robin S. Gregory, "A Framework for Structuring Cross-Cultural Research in Risk and Decision Making," *Journal of Cross-Cultural Psychology*, 22, (1991): 103-28; Ralph L. Keeney, *Value-focused Thinking: A Path to Creative Decisionmaking* (Cambridge, Harvard University, 1992); Ralph L. Keeney and H. Raiffa, *Decisions with Multiple Objectives* (New York: Cambridge University, 1993); Robin S. Gregory and Ralph L. Keeney, "Creating Policy Alternatives Using Stakeholder Values," *Management Science* 40 (1994): 1035-48; Robin S. Gregory and Paul Slovic, "A Constructive Approach to Environmental Valuation," *Ecological Economics* 21 (1997): 175-81; T. L. McDaniels, Robin S. Gregory, and D. Fields, "Democratizing Risk Management: Successful Public Involvement in Local Water Management Decisions," *Risk Analysis* 19, no. 3 (1999): 497-510.

³⁸ Robin S. Gregory and J. Arvai, *A Decision-focused Approach to DOE Cleanup Priorities* (Eugene, Oregon: Decision Research, 2002), 30.

³⁹ Ellen Peters, Bert Burraston, and C. K. Mertz, *An Emotion-based Model of Stigma Susceptibility: Cognitive Appraisals of Emotion, Affective Reactivity, and Worldviews in the Generation of Technological Stigma* (Eugene, Oregon: Decision Research, 2002).

⁴⁰ Thomas Webler, *Low Dose Risk Perception and Communication: A Case Study of the Tritium Controversy at Brookhaven National Laboratory* (Eugene, Oregon: Decision Research, 2002).

⁴¹ Seth Tuler, *Radiation Risk Perception and Communication: A Case Study of the Fernald Environmental Management Project* (Eugene, Oregon: Decision Research, 2002).

⁴² Theresa Satterfield and Josh Levin, *Risk Communication, Fugitive Values, and the Problem of Tradeoffs at Rocky Flats* (Eugene, Oregon: Decision Research, 2002).

Flats, Colorado and Fernald, Ohio.⁴³ Taken together, these studies address points that must be covered to “triangulate” on the real needs and subjects of risk communication.

The major context for risk communication is the existing societal structure with its many overlapping and contending elements. People live within a variety of social communities, some formal with traditional and legal parameters, others made up of professional, work or business, religious, social, and even recreational networks. It is not simply that differences exist; these communities often function as arenas where conflict is the main event. At the same time, formal societal structures often must address significant public issues in ways that include national, state, local, and community interests. Problems with low dose radiation exposure require cooperation at all levels but this is often hard to achieve.

Even when decision processes are the same for all parties involved, the many judgments and goals will introduce conflict that in turn challenges risk communication in its support of outcome choices. One example of a differing condition for individuals is the sources of information and the meanings assigned to this information. Another example is the differential influence of social, political, and cultural values on the interpretation of information and how it should be used in the decision process. For the public, the major information sources are television, newspapers, radio, and magazines. In contrast, official and expert stakeholders depend more on scientific reports and data, expert assessment, and institutional guidelines. Even when stakeholders are organized along the same decision timeline and they are involved jointly in an established process, the differences can be wide and agreement difficult. Communication messages in these cases have a forum but they must also have the insights, understanding and skills to bridge stakeholder differences and establish a basis for viable outcome decisions. The social geography of risk communication is a conceptual framework that seeks to organize the necessary understanding required in public decision processes. It approaches this task by identifying key components at different levels of society and then examining how these components are, and could be, involved in program and policy decisions.

⁴³ C. K. Mertz et al., *Community Surveys: Low Dose Radiation. Fernald, Ohio and Rocky Flats, Colorado* (Eugene, Oregon: Decision Research, 2002).

The research conducted during this project examined several components of expert-public communication conditions. We selected areas of study that would extend or initiate approaches to understanding communication research. The work on community case studies is a prime example. Although case studies are an established social science approach, there are few studies of community risk communication processes. Local conditions require careful evaluations since present and historical conditions create conditions that must be understood if communication is to serve its role in addressing radiation exposure issues. The Social Geography of Risk Communication framework directs attention to important community conditions and identifies a number of topics that have solid support from social science research as basic for radiation risk management in a public context.

6. Summary

The SGRC framework posits that communities have interactive social and geographical parameters that apply to specific risks, that these conditions can be defined for specific cases and usefully analyzed in terms of risk communication issues. In many cases geographical areas are defined by political boundaries, transportation routes, natural resource bases, and physical topography. Within these conditions, communities develop and carry on their full range of functions. Despite the reach of modern technology with its news, entertainment, travel, and business activities, physical proximity encourages distinctive human interactions including community-based values, senses of place and purpose, engagement in social relations, and shared responses to hazards and risks.

There are, of course, variations across all social groups and broader differences that become apparent as the social bonds are stretched both physically and emotionally. Taking these basic human conditions into account we can see that risk communications, based predominantly on scientific evidence and risk assessments, must speak to many topics arising from community reconstructions of official data by groups and individuals. Risk information, facts, and data will be judged in terms of social-cultural values, within community terms. Those terms include discussions that are motivated by affect and emotion as well as by the inferences drawn from unique experiences, beliefs, and aspirations that transcend the intentions of those who initiate risk discussion processes.

The heuristics individuals use for making choices and decisions have a corollary in communities. If it is efficient for individuals to use established patterns of perception and judgment when they view new dimensions of hazards or risks, it is likewise efficient for communities. This line of thought tends to put the importance of reputation and past experience into perspective. If an individual or agency has been untrustworthy in the past, it can expect to have problems with trust and confidence now and in the future. If hazards have long been described and viewed as risky in the past, they will have that presumption in the future. The community heuristic for evaluating radiation exposure, for example, is best described in terms of stigmatization, a mark or sign imposed and enforced by various social communities.

To communicate well requires knowing what communities are involved, how these communities listen to and respond to risk communications, how they judge the trust and credibility of involved people and institutions, and what sources exercise influence over the risk responses of the community. Rational thought and emotional responses are not necessarily contrary conditions. Indeed, both are needed for individuals to make socially acceptable decisions about behavior.⁴⁴ Perhaps this is the case with social judgments also. In any case, risk communication messages must address facts, values, and emotions if they hope to move toward socially acceptable traded-offs in evaluating radiation risks. The study and understanding we can find with community level research offers a path to improved risk communication.

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⁴⁴ Damasio, *Descartes' Error*.

Low Dose, Risk, Decisions, & Risk Communication

Perception of Radiation Exposure Part I: Perception of Risk and Judgment of Harm

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Abstract

Radiation exposure comes from a number of sources, some natural in origin and others human made. While the basic physics of radiation is relatively clear, its biological effects are not, particularly at low levels of exposure such as those associated with nuclear site remediation efforts. A set of empirical studies to assess how non-scientists perceive the potential harm associated with a range of radiation exposure sources found that perceptions of radiation exposure and its risks tend to follow qualitative considerations that reflect broader concerns about the harm that radiation may do and the potential problems of radiation risk management. Judgments of potential harm from radiation exposure were also influenced by the context of the exposure, such as natural background versus nuclear site. The results of the study pose a serious challenge to the viability of the notion of “natural background radiation” as a psychological benchmark or natural standard to which other exposures can be compared. While it remains an open question the degree to which these perceptions are amenable to change by more information about radiation and its effects, the study offers a caveat that the untutored notions of non-scientists about radiation and its effects do not contain at least some of the key concepts that radiation scientists rely upon in assessing and communicating the health risk of radiation exposure to one another.

Introduction

A significant technological feature of the 20th century was the systematic development and exploitation by some industrialized societies of the energy contained in the nucleus of the atom. Nuclear energy, first released in a military context near the end of World War II, rapidly found its way into civilian applications such as nuclear power and nuclear medicine. However, the relationship between nuclear energy and society has been one of mixed sentiments and unmet expectations. Once heralded as “energy too cheap to meter,” the nuclear power industry fell into decline after only a decade or so of successful operations, with some sites discontinuing operations even before reaching the tenure of their engineered lifespan. Large-scale weapons production efforts during the Cold War period left many areas of the U.S. contaminated by radioactive materials. While some of these areas have been at least partially remediated, most still retain an increment of radioactivity due to residual wastes that remain in their soils. In contrast to this somewhat dismal picture of nuclear energy in our modern age is the use of radioactive materials in other areas where clear and valued benefits are present. For example, nuclear medicine has proven to be a valuable tool in cancer detection and treatment. Some life-saving consumer products rely on nuclear materials, such as household smoke detectors. Nuclear materials are also used as part of the power generation systems for scientific exploration of space.

Thus, the picture of nuclear energy and its value to society is a complex one. While human use of nuclear energy has produced some of the most devastating social and environmental consequences in history, it has also proven to be of significant value in contexts such as medical diagnosis and treatment. Complicating the picture even more is the fact that radiation exposure results not only from human uses of nuclear materials, but also occurs naturally from such sources as solar radiation, geological sources such as uranium and radon gas, and cosmic radiation from deep space. Indeed, the human body itself is slightly radioactive, as is the food we eat and the air we breathe. Radiation is all around us, and has been since the beginning of geologic history.

While the basic physics of radiation is relatively clear, its biological effects are not. Though high doses of radiation (e.g., 100,000 mrem or more) lead to predictable and potentially serious biological and health consequences, the effects of much lower doses are less readily discerned. Recent advances in genetic research and molecular biology have presented science and society with an opportunity to make more precise determinations of the potential harm that might be caused by exposure to low doses of radiation, such as those associated with residual radioactivity in the soils

of former industrial sites. As new findings about the biological effects of low-dose radiation come to light, they will need to be communicated in terms of their implications for risk management.

However, the realities of risk communication are very often daunting, and are made complex by the pre-existing attitudes and beliefs that people have about risks in general and about radiation in particular. Failure to account for these in the design and implementation of risk communication programs is very likely to result in a lack of success (at best) or to exacerbate whatever social conflicts may already exist. This paper is an effort to inform risk communication (and, by implication, risk management) by elaborating the attitudes and beliefs non-scientists hold about radiation, and placing those views in the context of others sources of risk and harm to which members of society are exposed.

Methodology

The empirical basis for this research comes from a series of survey-type instruments administered to a group of 205 university-age adults (59.5% males and 40.5% females) in the winter of 2000. Though their average age was relatively young at slightly under 22 years (mean = 21.8 yrs.), they represent an educated group, having (for the most part) at least some formal coursework in the physical and natural sciences: 75.6% indicated that they had taken one or more science courses; 66.3% had taken at least one university-level course in biology, chemistry, or physics. While social and behavioral research that draws its data from university-age respondents is sometimes criticized for a failure to match a broader demography, the level of science education among university populations is likely to be higher than that of the population as a whole, leaving them in a potentially better position to appreciate the technical aspects of risk. To the degree that greater technical understanding of risk issues facilitates more positive attitudes toward risk sources and their management, they should be a more understanding and accepting group. To the degree that their attitudes are similar to those of the broader public is suggestive of the potential limits of education to influence risk attitudes.

Perception of Radiation Exposure, Part I

Figure 1. Perceived risk ratings for 36 risk items. * denotes radiation exposure items.

Defining Radiation

Radiation exposure comes from a number of sources, some natural in origin such as solar or geological sources, and others human-made, such as radiation from medical treatments or nuclear storage sites. In preparing research materials for this study, a general outline of radiation sources was drawn from U.S. Department of Energy publications, and particularly from a four-unit secondary school curriculum developed by U.S. DOE and titled *Science, Society, and America's Nuclear Waste* (U.S. DOE, 1992).

Perception of Risk

While risk communication generally focuses on a specific risk, the risks of life are experienced in a broader risk context. Respondents were asked to rate the risks “to you and your family” from 36 sources of hazard, some natural and others technological, using a four-point scale ranging from *no risk* (=1) to *high risk* (=4). Figure 1 shows the relative ranking of their ratings in terms of the percentage of respondents who gave either a *moderate* or *high* risk rating to each item.

Cigarette smoking received the highest risk rating, followed by stress, multiple sex partners, and second-hand smoke. Common risks to which people are exposed such as those associated with motor vehicle travel, bacteria in food, and pesticides occupied middle positions in the distribution of risk ratings. At the bottom were risks associated with blood transfusions, tap water, and vaccines.

Sources of radiation risks (marked with asterisks in Figure 1) were widely dispersed throughout the distribution of risk ratings. While suntanning, stored nuclear waste, and radon in homes ranked relatively high, other sources of radiation exposure ranked much lower, such as natural background radiation, nuclear materials used in space research, cosmic radiation and medical X-rays. Relative ratings for the 11 sources of ionizing radiation included in the set of 36 risk items can be seen separately in Figure 2.

Figure 2. Perceived risk ratings for 11 sources of radiation exposure.

Neither human-made nor natural sources of radiation exposure were consistently grouped in the distribution of risk ratings: the top three risk items (suntanning, stored nuclear waste, and radon in homes) contained both natural and human-made sources of ionizing radiation exposure, as did the bottom three risk items (medical X-rays, nuclear materials in space, and natural background radiation). It appears that respondents did not draw a clear distinction between radiation exposure resulting from human activities and radiation from natural sources as a consistent or significant basis for assigning their risk ratings.

With regard to natural background radiation, the rating for this as a category of exposure was the lowest of all of the radiation sources, and lower than would be expected given the relatively high ratings for its components. Respondents apparently did not think of natural background radiation in terms of its individual contributors, and gave much higher ratings to individual sources of radiation exposure that are part of the natural background than they gave to natural background as a category of exposure. For example, suntanning, radon, and cosmic radiation all received much higher ratings than did natural background radiation, of which they are a part.

For human-made sources of radiation exposure, risk ratings tended to be higher for industrial uses associated with the nuclear power generation fuel cycle (e.g., stored nuclear waste) and weapons development/production (e.g., nuclear weapons testing) than for uses of radiation associated with medical diagnosis (e.g., X-rays) and treatment (e.g., hospital radiation wastes). Previous research has suggested that perceptions of risk are inversely related to perceptions of benefit, which may explain the tendency for risk ratings of human-made sources of radiation to be lower for medically-related sources than industrial sources.

Overall, the data suggest that as a category of societal risk, non-scientists do not have a single, monolithic perception of radiation risks. Looking at perceptions of radiation exposure across a wide range of sources, some industrial, some medical, and some natural background, we see an equally wide range of judgments about the level of risk associated with these exposures. When individual elements of a category of radiation exposure (e.g., natural background radiation) are posed separately, their risk perception increases dramatically, suggesting that non-scientists do not have a measurement standard for radiation exposure by which they make consistent and accurate comparative judgments.

Perception of Radiation Exposure, Part I

Figure 3. Risk of very low exposures. * denotes radiation exposure items.

Perceived Risk of Low Exposures

One indication of public sensitivity to a risk issue is their reaction to low levels of exposure. For example, non-scientists' perceptions of chemical risks tend to be highly sensitive to even minute amounts of exposure, particularly if the chemical is known to be carcinogenic (MacGregor, Slovic, & Malmfors, 1999; Kraus, Malmfors, & Slovic, 1992). In the case of radiation, public exposures are almost uniformly at a low-level, with (perhaps) the exception of occupational exposures. Thus, non-scientists' perceptions of the risk associated with low-level exposures to radiation provides a measure of their concern about radiation, as well as a context for comparing perceptions of radiation exposure with other hazards experienced at a low-level of exposure.

Respondents were given a set of items that included both chemical and radiation hazards. The chemical hazards included consumer products (e.g., laundry detergent, cigarettes, caffeine, smoke detectors), pharmaceuticals (e.g., vitamins, valium, aspirin), industrial products (e.g., asbestos, motor oil), and environmental pollutants (e.g., carbon monoxide, lead). Radiation hazards included both human-made and natural sources of ionizing radiation (e.g., cosmic radiation, medical X-rays, nuclear power plants), as well as sources of non-ionizing radiation (e.g., microwave ovens, EMF). For each item, they were asked to judge the degree to which a very low exposure would be harmful to an average individual. Very low exposure was defined as: "an exposure that is substantially less (say 1/100) than the exposure level that has been approved by a regulatory agency or that would begin to cause concern to such an agency." Thus, low exposure was defined in terms of a small fraction of the exposure level that has already passed regulatory muster. Ratings were made on a five-category scale ranging from *no risk* (= 1) to *very high risk* (= 5). Figure 3 shows the distribution of ratings according to the percentage of respondents who gave a rating of *high* or *very high* risk to each item.

Overall, none of the risk items were rated as *high* or *very high* risk by the majority (50% or more) of respondents. Radiation from nuclear weapons testing topped the risk ratings with 38% giving it a high risk rating, and was followed by nicotine in cigarette smoke, stored radioactive waste, nuclear power plants, and rat poison. It appears that a significant portion of the respondents believed that exposure to these elements at even a tiny fraction of current regulatory levels constituted a high or very high risk.

Figure 4. Risk of very low exposures: ionizing radiation subset.

Other sources of ionizing radiation exposure received relatively low ratings. For example, suntanning was judged similar to EMF, and medical X-rays similar to microwave ovens, all of which were relatively low in the risk hierarchy. Of the sources of ionizing radiation, radiation from air travel was judged the lowest risk. Natural background radiation as a category of radiation exposure was also judged to be relatively low risk, on a par with Valium, oral contraceptives, and fluoride.

A slightly more detailed picture of ionizing radiation risks can be seen in Figure 4, which shows these 11 radiation sources separately.

Among sources of radiation exposure, natural background radiation was at the bottom of the risk ratings. Suntanning, stored nuclear waste, and radon in the home occupied the top positions. However, while natural background radiation received the lowest risk rating, the various components of natural background radiation included in Figure 2, such as cosmic radiation, radon in the home, and suntanning, all received much higher risk ratings. These results suggest that non-scientists do not have a model of natural background radiation that includes its various components and may be unlikely to think of radiation exposure from a variety of natural background sources in a common or consistent metric.

Perception of Radiation Exposure, Part I

Figure 5. Factors that cause cancer.

Causes of Cancer

Cancer is generally viewed as one of the more significant health effects of high levels of radiation exposure, and may also result from low doses of radiation as well. However, cancer may be caused by factors other than radiation exposure, some relating to environmental pollutants and some relating to lifestyle choices that individuals make. Respondents were given a number of factors that have been proposed as possible causes of cancer or have been linked to cancer in media reports. They were then asked to indicate how many cancers they thought were caused each year in the United States by each of these factors. Respondents made their responses on a four-category scale: *almost none* (= 1), *few*, *many*, *very many* (= 4). Figure 5 shows the distribution of responses to the 35 causes of cancer, ranked by the combined percentage of those who responded either *many* or *very many*.

Cigarette smoke inhaled by smokers received the highest ratings, followed very closely by radiation, inherited genetic susceptibility, chemicals, and suntanning. Although the results offer at least partial indication that respondents were sensitive to some lifestyle factors as notable causes of cancer (e.g., smoking, sedentary lifestyle), in other cases they were not. For example, fatty foods and alcohol received relatively low ratings. However, diet and tobacco may account for as much as 65% of cancer deaths (Doll & Peto, 1981). Longevity (living a long time) also received low ratings despite the trend that historical increases in cancer rates are also associated with increased life expectancy, and that in many cases cancer is a disease of the aged. Infections, estimated to cause approximately 10% of cancer deaths (Doll & Peto, 1981), fell relatively low in respondents' ratings, near those of food preservatives, medical X-rays, and prescription drugs. None of the respondents indicated that any cancers were the result of contact with someone who has cancer.

Some environmental factors, such as air and water pollution, were judged relatively high as cancer causes. However, other environmental factors, such as natural chemicals in fruits and vegetables, were not. Overall, the results indicated that respondents' judgments of the causes of cancer bore a moderate but inconsistent relationship to statistical realities.

Figure 6. Sources of radiation as a cause of harm. Items are ranked by responses to “nuclear industry sources of radiation.”

Harm From Radiation

The potential health effects of radiation that are more commonly mentioned in the media, and are more prevalent in the culture, are cancer and birth defects. However, non-scientists may utilize a variety of cues and information sources when they intuitively assess their health status, such as when they attempt to ascribe a causal factor to one or more symptoms that they experience (e.g., MacGregor & Fleming, 1996; Pennebaker, 1986).

Respondents were asked to judge the likelihood that each of 18 types of possible harm or illness could be caused by radiation. One group was instructed to base their ratings on “nuclear industry sources of radiation (e.g., nuclear power plants, nuclear waste, nuclear weapons).” A second group based their ratings on “medical sources of radiation” (e.g., x-rays, medical treatment) and a third group on “natural background sources of radiation” (e.g., cosmic radiation, uranium ores, radon). All three groups made their ratings on a four-category scale: *not likely* (= 1), *slightly likely*, *moderately*, or *very likely* (= 4). Figure 6 shows for each of the 18 items the percentage of respondents that gave either a *moderately* or *very likely* response for each of the three groups (sources). The 18 items in Figure 6 are ranked by responses to the “nuclear industry sources of radiation” group.

Table 1. Risk Management Scale Items

Item	Strongly disagree	Disagree	Agree	Strongly agree
The Department of Energy will provide full and prompt disclosure of the results and problems with the research they sponsor on the effects of radiation.	20.49%	58.54%	19.02%	1.95%
I believe radiation risks are adequately regulated.	8.78	55.61	32.20	2.93
Decisions about health risks should be left to the experts.	22.93	53.17	21.95	1.46
When testing nuclear weapons, the U.S. Government did everything they could to protect the public from radioactive fallout.	43.41	41.95	10.73	3.41

As might be expected, the types of harm that received the highest ratings were those relating to cancer, birth defects (including genetic damage), and fertility. Hair loss received a high rating, particularly for the medical sources group (82.3%) where an association with cancer treatment may have been particularly salient. However, a fairly large proportion of the natural background sources group (49.3%) also saw hair loss as an effect of radiation.

A notable trend in Figure 6 is the tendency of respondents in all three of the sources groups (and particularly the natural background group) to perceive all the forms of harm as caused by radiation, including mental illness, Alzheimer's disease, allergies, and tinnitus. For these forms of harm, approximately 1 in 5 or 6 respondents thought it moderately or very likely that the harm is caused by radiation, regardless of source. These results suggest that non-scientists have a limited mental model of the relationship between radiation exposure and health consequences, with the result that they have a relatively poor ability to discriminate between health outcomes that are caused by radiation and those that are not. The data in Figure 6 also suggest that when non-scientists are confronted with health conditions for which they have no ready explanation (causal understanding) that radiation may fit conveniently into their predispositions about the potential health impacts of a force they perceive to have a powerful influence on the human body. Other research has found that relatively simple mental models or intuitive theories may be used by non-scientists to infer a broad range of biological effects, particularly when such effects have causes unknown to them (e.g., MacGregor, Slovic, & Morgan, 1994).

Risk Management Worldviews

Many of the important public questions about radiation center around the management of its risks. Respondents were asked to respond to a set of four attitude statements relating to current risk management. Table 1 summarizes their responses.

Though approximately a third of respondents agreed that radiation risks are adequately regulated, the large majority did not believe so. Most (76.1%)¹ disagreed that decisions about health effect should be left to experts.

¹ Percentages for *strongly disagree/disagree* or *strongly agree/agree* categories combined as appropriate.

Table 2. Summary of Radiation Risk Scales

Scale Code	Scale Name	Scale Description	Reference	Scale Range	Scale Mean/s.d.	Alpha ^a
RP	Risk Perception Scale	Mean rating across 36 risk items	Figure 1	1 (almost no risk) to 4 (high risk)	2.4/0.5	.93
RPP	Radiation Risk Perception Scale	Mean rating across 11 radiation risk items.	Figure 2	1 (almost no risk) to 4 (high risk)	2.4/0.7	.87
LD	Perceptual Sensitivity to Low Dose Exposures	Mean across 11 low-dose ionizing radiation items	Figure 3	1 (no risk) to 6 (very high risk)	3.0/1.0	.91
CC	Radiation Causes of Cancer Scale	Mean rating across 4 radiation items as possible causes of cancer.	Figure 5	1 (almost none) to 4 (very many)	2.6/0.6	.66
HR	Harm From Radiation Scale	Mean across 18 health effects potentially caused by radiation.	Figure 6	1 (not very likely) to 4 (very likely)	2.4/0.6	.93
RM	Risk Management Scale	Mean across 4 risk management attitude items.	Table 1	1 (low confidence) to 4 (high confidence)	2.0/0.5	.67

^aCronbach's alpha is a measure of scale consistency.

The majority of respondents were inclined to disagree that U.S. DOE would provide “full and prompt disclosure of results and problems” with radiation research (79.1%). Respondents also generally disagreed that the U.S. Government took sufficient health-protective actions during nuclear weapons testing (85.3%). Overall, respondents were inclined to hold somewhat negative attitudes about the management of radiation risks.

Radiation Risk: Scale Intercorrelations

The relationship between perceptions of radiation risks, harm caused by cancer, and risk management attitudes discussed above can be seen more clearly in scale scores constructed by summing respondents’ responses across sets of items and correlating the resulting indices. Table 2 below shows the properties of six such scales: Risk Perception, Radiation Risk Perception, Radiation Causes of Cancer, Harm From Radiation, Low Dose Sensitivity, and Risk Management.

Across all six scales, the average scale value tended to be near the middle of the item response range. Scale consistency (Cronbach’s alpha) ranged from moderately high to very high, indicating a high degree of intrascale reliability. Lower scale consistency values tended to correspond to scales having fewer items, as would be expected.

Table 3. Radiation Risk: Scale Intercorrelations

Scales ^a	RP	RRP	LD	CC	HR	RM
RP	—	.90	.65	.47	.38	-.26
RRP		—	.63	.45	.33	-.19
LD			—	.50	.46	-.18
CC				—	.36	-.09
HR					—	-.28
RM						—

The intercorrelations between the six radiation risk scales can be seen in Table 3. The values in Table 3 are Pearson Product-Moment Correlations computed across respondents. The correlation between general risk perceptions (RP) and radiation risk perception (RPP) was the highest of the scale intercorrelations at .90; since the RPP items were a subset of the RP items such a high correlation is to be expected. Low dose sensitivity (LD) correlated moderately high with both risk perception scales (.65 & .62). Causes of cancer (CC) and harm from radiation (HR) correlated at lower levels with the risk perception and low dose sensitivity scales. Correlations of the risk management (RM) scale with the other five perception scales were the lowest of all, though only one of the scale correlations (−.09 with the CC scale) failed to achieve statistical significance ($p < .05$).

The scale intercorrelations indicate a relatively strong pattern of correspondence between perceptions of risk and judgments of health effects: higher perceptions of risk in general (and radiation risk in particular) were associated with a tendency to attribute radiation as a cause of cancer, and a tendency to judge radiation as a more likely cause of various types of physical and psychological harm. In addition, heightened perceptions of risk and judgments of harm were associated with lower confidence in traditional risk management practices, as reflected in lower scores (negative correlation) on the risk management (RM) scale. While these correlations were modest compared to the correlations between the various risk and harm scales, they were statistically significant in all but one case. Further research is needed to identify additional determinants of risk management attitudes.

Discussion and Conclusion

Given the myriad of sources of radiation exposure that exist in our natural and constructed environment, one might well expect that non-scientists would have developed at least general sense of their relative proportionality. Unfortunately, the research results presented in this paper tended to indicate that such an expectation is not reasonably met. For the most part, the non-scientists who participated in our studies perceived the risks of radiation exposure to be disproportional to the exposures that actually occur from a variety of sources, some natural and some human made. If there is a singular conclusion to draw from these results it may be that the typical non-scientist (even those with some university-level science coursework) does not have a composite view of radiation exposure that is decomposable into a metric by which the risk associated with different

radiation exposure sources can be quantitatively gauged, even in an ordinal sense. Rather, perceptions of radiation exposure and its risks tend to follow qualitative considerations that reflect broader concerns about the harm that radiation may do and the potential problems of radiation risk management.

From a risk communication perspective, perhaps the most serious challenge offered by these results is to the viability of the notion of “natural background radiation” as a psychological benchmark or natural standard to which other exposures can be compared. Indeed, it appears from the judgments of participants in these studies that natural background radiation is seen as a category of exposure separate and apart from its components. It remains an open question the degree to which these perceptions are amenable to change by more information about radiation and its effects, and further research is needed to assess the malleability of these perceptions. Nonetheless, the present study offers a caveat that the untutored notions of non-scientists about radiation and its effects do not contain at least some of the key concepts that radiation scientists rely upon in assessing and communicating the health risk of radiation exposure to one another. This (potential) disparity between the scientific and non-scientific communities needs to be addressed if low-dose science is to be communicated effectively outside its community of researchers.

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Low Dose, Risk, Decisions, & Risk Communication

Perception of Radiation Exposure

Part II: Communicating About Radiation Exposure and Health Effects

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Abstract

Communicating with non-scientists about radiation health risks is challenging in part because of the complexity of the subject matter and the relatively low level of knowledge about radiation held by the general public. Attempts to produce effective communications often rely on techniques that decompose the average annual radiation exposure received by a typical individual (i.e., approximately 360 mrem/yr) into exposure from various sources, including natural background sources (e.g., geologic, solar) and human-made sources (e.g., medical treatments, X-rays, nuclear fuels). The “radiation budget” approach attempts to cast human-made radiation as a relatively small subset of an individual’s total yearly exposure. In principle, this should lead them to regard such sources as of less concern than they would otherwise. In a set of empirical studies, we have been investigating what people infer about radiation exposure from various presentations of radiation exposure information, including the radiation budget portrayals that are often a part of radiation risk communication. Our results tend to show that non-scientists generally find these representations of radiation exposure interesting and informative, and are surprised to learn that the amount of radiation exposure from natural background is as high as it is. However, their concerns about radiation exposure from industrial sources, such as weapons fallout, nuclear waste storage, and nuclear power plant operations, are not attenuated by a broader awareness of sources of radiation. In depth studies of attitudes about radiation exposure reveal that some scientific concepts relating to the role of radiation as an integral part of how life as we know it has come about, do not seem plausible to non-scientists. The potential for radiation to have contributed to genetic diversity, for example, is not represented in non-scientists’ views about radiation. Our results to date suggest that non-scientists view radiation largely in terms of its potential for harm, and that more information about radiation exposure from background sources may only serve to increase concerns about radiation exposure.

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1. Introduction

Radiation is a ubiquitous part of our natural and constructed environment. Each day, people in virtually all locations, and from all walks of life, are exposed to radiation from a variety of sources, including terrestrial radiation from soils and rocks, cosmic radiation from space, radioactive materials in consumer products, and radiation from medical treatment and diagnosis. U.S. DOE sources place the average annual radiation exposure for individuals at approximately 360 millirem, with the largest portion of that exposure due to Radon in homes and places of work.

One of the challenges of managing the risks of radiation exposure is communicating about such risks with non-scientists. Although risk communication problems are endemic to a wide range of natural and technological hazards, and communicating about radiation risks shares many of these difficulties, radiation risk communication is potentially burdened with some unique problems. First, the public has long had a particularly heightened level of concern about radiation-related hazards, in part from historical concerns about nuclear power and the nuclear fuel cycle. Second, radiation (and radioactivity) itself is a complex topic, and non-scientists have relatively little technical background in the basic concepts of nuclear physics. Third, interpreting radiation exposure at low levels in terms of health effects is scientifically controversial owing to several factors, including a lack of clear scientific evidence of how low-dose exposures affect cellular biology. And, finally, any communication of radiation exposure and its health risks for the broad public must deal with biological concepts at the cellular level, for which most non-scientists have an equally impoverished knowledge base as they do for concepts in radiation.

The study reported here is directed toward understanding more about how non-scientists form viewpoints about radiation exposure and its potential health effects based on receiving information of different types and from different sources about radiation.

2. Method

The empirical basis for this research comes from a series of survey-type instruments administered to a group of 205 university-age adults (59.5% males and 40.5% females) in the winter of 2000. Though their average age was relatively young at slightly under 22 years (mean = 21.8 yrs.), they represent an educated group, having (for the most part) at least some formal coursework in the physical and natural sciences: 75.6% indicated that they had taken one or more science courses; 66.3% had taken at least one university-level course in biology, chemistry, or

physics. While social and behavioral research that draws its data from university-age respondents is sometimes criticized for a failure to match a broader demography, the level of science education among university populations is likely to be higher than that of the population as a whole, leaving them in a potentially better position to appreciate the technical aspects of risk. To the degree that greater technical understanding of risk issues facilitates more positive attitudes toward risk sources and their management, they should be a more understanding and accepting group. To the degree that their attitudes are similar to those of the broader public is suggestive of the potential limits of education to influence risk attitudes.

3. Sources of Radiation

Radiation exposure comes from a number of sources: some natural such as the sun and ore deposits in the Earth, and some from human activities such as medical technologies and industrial uses of radiation (e.g., nuclear fuels, weapons testing). A common approach to describing an individual's exposure to radiation is to express it in terms of a radiation budget, often measured in *millirems*. For example, the pie chart in Figure 1 shows the percent that each of a number of radiation sources contributes to an average individual's radiation exposure in the United States of 360 millirems per year. The pie chart shown in Figure 1 was taken from a set of educational materials entitled *Science, Society and America's Nuclear Waste* developed by the U.S. Department of Energy for use as a secondary school curriculum (U. S. DOE, 1992). It was intended to provide information about scientific and societal issues related to the management of spent nuclear fuel from generation of electricity at nuclear power plants and high-level radioactive waste from U.S. national defense activities.

Figure 1 depicts eight sources of radiation in terms of the percentage that each contributes to an average individual's annual exposure. A number of questions can be asked about how such displays of radiation are received by non-scientists: How do people's prior expectations about exposure from various radiation sources compare with what is shown in the pie chart of Figure 1? How are perceptions of risks from radiation related to this type of information presentation? What, if anything, is the significance of this type of comparative risk information for attitudes about radiation, its effects, and those who manage it?

Figure 1. Sources of radiation.

Table 1. Radiation Sources and Descriptions Given to Research Respondents

Label	Description
Cosmic	Radiation that comes from space.
Terrestrial	Geological sources of radiation contained in uranium ore, granite, and other radioactive mineral deposits
Radon	Radon is a colorless and odorless radioactive gas that is given off by uranium ore in the earth as its radioactivity decays.
Internal	Sources of radioactivity in the human body that come from natural elements in the foods we eat, such as potassium and carbon.
Medical X-rays	Source of radiation that comes from x-rays used by doctors and dentists to diagnose medical problems.
Nuclear medicine	Radiation used in the treatment of disease, such as cancer, as well as radiation from medical diagnostic techniques that use radioactive materials such as radiograms.
Consumer products	Radiation from radioactive materials used in some consumer products, such as smoke detectors, gas lantern mantles, and lawn fertilizers.
Other	Industrial and technological sources of radiation, including nuclear power plants, nuclear waste storage, nuclear waste transport, and fallout from nuclear weapons testing.

3.1 Study Design

A group of 205 research respondents (described previously) was presented with the pie chart shown in Figure 1 along with a set of definitions for each of the chart's segments, shown in Table 1. Respondents were asked to make a number of responses, including whether the amount of radiation from each source was smaller or larger than expected, the level of societal risk associated with each source, and their degree of agreement/disagreement with a set of attitudinal statements related to radiation risk management.

3.2 Expectations About Sources of Radiation Exposure

Respondents indicated for each of the eight categories of radiation sources how they compared with that they might have expected them to be before seeing the pie chart. They gave their responses on a five-category scale: much smaller than expected, smaller than expected, about the same, larger, much larger. Their responses are summarized in Table 2.

A substantial majority of respondents indicated they found Radon to be a larger source of radiation exposure than expected, followed at a distant second by Internal sources. However, Radon as a category of radiation exposure covered over 50% of the area of the graph, and its perception as larger than expected may simply reflect its dominance in the display. On the other hand, Internal sources was a much less dominant display element than Radon and yet it was judged by over half of the respondents as a larger exposure source than expected. Respondents may have been previously unaware (and subsequently surprised) that radiation exposure also comes from radioactivity in the human body due to natural elements, in which case the display provided (at least for some respondents) new information about a category of radiation exposure.

At the other end of the response distribution, Industrial sources and Nuclear Medicine were seen as smaller sources of radiation exposure than expected. Respondents tended to judge Consumer Products as either a smaller source of radiation than expected or about the same as expected.

These results suggest that at least for some of the categories of exposure shown in the pie chart (e.g., Radon), respondents' perceptions were potentially influenced by the relative dominance in the display of a given source. In other cases, however, (e.g., Internal sources, Nuclear

Table 2. Expectations About Sources of Radiation

Source of radiation	Percent <i>larger or much larger</i> than expected	Percent <i>smaller or much smaller</i> than expected
Radon	80.5%	2.9%
Internal	58.5	10.7
Cosmic	39.0	18.1
Medical X-rays	38.1	21.0
Terrestrial	34.2	16.6
Nuclear medicine	13.2	50.2
Consumer products	13.2	43.9
Industrial	3.4	50.2

Table 3. Perceived Societal Risk from Sources of Radiation

Source of radiation	Percent <i>moderate or high</i> <i>risk</i>	Proportion in pie chart
Radon	85.4%	55%
Medical X-rays	49.8	11
Internal	41.0	11
Cosmic	40.0	8
Nuclear medicine	40.0	4
Terrestrial	36.1	8
Consumer products	32.7	3
Industrial	24.4	1

medicine), the graph may have provided new information, either in the form of a category of exposure of which they were previously unaware, or a relative level of exposure that was lower than previously believed.

3.3 Perception of Societal Risk

Respondents were asked to indicate for each of the radiation sources “how much risk to society as a whole there is from exposure to each source of radiation.” These judgments were made on a four-category scale: No risk, slight, moderate, high risk. Responses are summarized in Table 3 in terms of the percentage indicating either *moderate* or *high* risk.

Radon was judged to have the highest level of societal risk, followed at some distance by the various medical and natural sources, with Industrial sources the lowest. In general, the aggregate risk judgments very closely followed the distribution of area in the pie chart, matching the relative area assigned to each source almost perfectly. Thus, while respondents were more or less informed relative to their expectations by the amount of radiation exposure coming from each of the sources (see Table 2), the translation of their perceptions of the graphic information into a judgment about risk tended to be framed by how the information was represented in the display format. From the perspective of informing risk judgments, the information value of the pie chart was largely contained in the relative ranking implied by the relative sizes of the pie segments.

What is the relationship between expectations about exposure and societal risk? When people are “surprised” by the technical content of a radiation risk communication does it influence perception of risk of radiation? Table 4 shows the correlation coefficients between expectation judgments and risk judgments for each of the radiation sources.

The correlations between expectation judgments and perceived risk were quite low, approaching zero in most cases. Respondents who were surprised that the amount of radiation from a given source was either smaller or larger than expected did not tend to give risk judgments that were particularly low or high, a result that again highlights the strong framing effect of the exposure display on risk judgments.

Table 4. Correlations of Radiation Expectations with Societal Risk

Source of radiation	Correlation
Cosmic	-.027
Medical X-rays	.004
Internal	-.009
Consumer products	-.035
Terrestrial	.038
Radon	.038
Nuclear medicine	.038
Industrial	-.161*

* $p < .05$; $df = 199$

Table 5. Attitudes About Radiation Sources Information

Item	Strongly Disagree	Disagree	Agree	Strongly Agree	Scale Correlations
Radiation exposure from the nuclear fuel cycle is not significant in the overall picture as portrayed by the pie chart.	7.32%	49.27%	36.10%	5.85%	-.21**(LD) -.20**(RP) -.20**(RRP) .20**(RM)
There are important sources of radiation exposure that are not included in the pie chart.	6.83	41.95	44.88	3.41	-.18**(RM)
The sources of radiation exposure shown in the pie chart are so different that they can't be compared.	6.83	62.44	26.34	2.44	--
Background sources of radiation (i.e., cosmic, terrestrial, internal, radon) are natural and shouldn't be compared to human-made sources in the pie chart.	5.85	63.41	28.29	0.98	-.15*(LD) -.15*(RP) -.16*(CC)
The representation of radiation exposure shown in the pie chart is informative and helpful to me in thinking about radiation risks.	1.95	27.80	51.71	17.07	.29*** (CC) .14* (HR) .20** (RM)

* $p < .05$. ** $p < .01$. *** $p < .001$.

3.4 Attitudes About Sources of Radiation Information

Respondents were asked to indicate their agreement/disagreement with a number of attitudinal items relating to the information portrayed in the pie chart, including its helpfulness, completeness, and comparability. Responses to these items are shown in Table 5. Also shown in Table 5 are the correlations of attitudinal responses to the radiation sources information with a series of six radiation risk perception scales. The correlation coefficients shown in Table 5 are computed across respondents. Summary details of the scales are shown in Table 6. A more complete description of the scales is available in MacGregor, Flynn, Slovic, and Mertz (2001).

For the most part, respondents found the pie chart and exposure information helpful and informative (68.7%). Respondents who scored higher on the Causes scale (CC) tended to find the presentation more helpful, suggesting that individuals who are more likely to perceive radiation as a cause of cancer may find information such as that presented in the pie chart more informative to them. Likewise, respondents who had higher scores on the Harm scale (HR) also found the information more helpful, again suggesting that people who have greater concerns about consequences of exposure to radiation may find comparative exposure information more salient. Respondents tended to be split regarding whether or not important sources of radiation were not included in the display.¹

With regard to the comparative value of the information in the pie chart display, most respondents disagreed that the various sources of radiation couldn't be compared (69.2%). When asked specifically about comparing background sources of radiation (e.g., cosmic, terrestrial) with medical and industrial sources, respondents again disagreed (69.2%) that such comparisons shouldn't be made. Respondents who scored higher on the Exposure (LD), Risk (RP), and Causes scales tended to be more likely to disagree than otherwise, suggesting that psychological sensitivity to radiation exposure, risk and harm may have enhanced the meaningfulness and/or relevance of the comparisons provided in the display. This relationship was somewhat stronger in the case of radiation exposure from the nuclear fuel cycle: though the majority of respondents (56.6%)

¹ In a follow-on study, respondents who indicated that they thought important sources of radiation were omitted were asked to indicate what sources they thought were missing. Responses tended to reflect a desire for greater detail in some of the categories, such as consumer products where all products containing radioactive materials were not identified in the information presentation. The result suggests that when people encounter new categories of radiation exposure in the context of risk messages, they may view risk communication as less complete unless extra effort is made to describe the sources of exposure in greater detail.

Table 6. Summary of Radiation Risk Scales

Scale Code	Scale Name	Scale Description	Alpha ^a
RP	Risk Perception Scale	Mean rating across 36 risk items	.93
RPP	Radiation Risk Perception Scale	Mean rating across 11 radiation risk items.	.87
CC	Radiation Causes of Cancer Scale	Mean rating across 4 radiation items as possible causes of cancer.	.66
HR	Harm From Radiation Scale	Mean across 18 health effects potentially caused by radiation.	.93
LD	Perceptual Sensitivity to Low Dose Exposures	Mean across 10 low-dose ionizing radiation items	.91
RM	Risk Management Scale	Mean across 4 risk management attitude items.	.67

^aCronbach's alpha is a measure of scale consistency.

Table 7. Inferences About Risk and Risk Management

Item	Strongly disagree	Disagree	Agree	Strongly Agree	Scale Correlations
The risk to society from each of the sources of radiation in the pie chart is directly proportional to their percentages.	15.12%	54.63%	25.37%	2.44%	.18**(RM)
Society should spend greater effort to protect people from natural background radiation (i.e., cosmic, geological, radon)	13.17	42.93	36.59	5.85	.21**(LD) .14*(RRP) .16*(CC)
The amount of harm to humans from exposure to each of the radiation sources shown in the pie chart is directly proportional to their percentages.	12.68	54.63	31.22	0.49	.16*(RM)
The purpose of the radiation exposure to me matters more than the amount.	6.34	40.98	43.90	7.80	--

* $p < .05$. ** $p < .01$.

disagreed that radiation from the nuclear fuel cycle was insignificant, the tendency toward disagreement was greater among those who were more sensitive to low-dose radiation exposure (LD scale), had higher perceptions of risk in general (RP scale), and had higher perceptions of radiation risks in particular (RPP scale).

Taken together, these results suggest that the type of information presentation about radiation sources provided to respondents was perceived as helpful and useful, and that the notion of a comparative budget of exposure from a number of sources is at least informative in principle. However, attitudes about the information and its potential meaning are moderated by other more general attitudes about risk, as well as attitudes about exposure to radiation and the harm that it can potentially cause.

3.5 Attitudes About Risk and Risk Management

A question to ask of any risk communication approach is what do people infer about the risk and its management from the content of the communication. Respondents were asked to indicate their views about the relative harm associated with the various sources of radiation exposure shown in the pie chart, as well as whether exposure to natural background radiation should be stringently managed. These responses are summarized in Table 7.

Respondents were given two items relating to the relationship between amount of radiation exposure associated with each of the sources in the pie chart display and the harm done or risk to society. In general, respondents tended to disagree that damage from radiation exposure was proportional to the percentages shown in the display, both in terms of “amount of harm to humans” (67.3%) and in terms of “risk to society” (69.8%). These responses conflict somewhat with those given in a separate portion of the task where respondents indicated the risk to society associated with each radiation source, and for which a high positive correlation was observed between perceived social risk and proportion of radiation associated with each source (see Table 3). However, the data in Table 3 is from all respondents, not just those who disagreed with the proportional risk concept. For those who *disagree* that risk is proportional to exposure, are their risk ratings less correlated with display features than those who agree? This can be examined by looking at the relationship between societal risk ratings for each of the eight exposure sources against the proportions shown in the pie chart separately for those who disagree ($n = 143$) and those who agree ($n = 57$) with the “risk to society” item shown in Table 7.

Table 8. Relationship Between Proportionality Hypothesis and Societal Risk Ratings

Source	Contribution	Percent <i>moderate</i> or <i>high</i> risk	
		Disagree (<i>n</i> =143)	Agree (<i>n</i> =57)
Radon	55%	83.9% (1)	93.0% (1)
X-rays	11	48.3 (2)	54.4 (2)
Internal	11	42.0 (5)	38.6 (3)
Cosmic	8	44.1 (3)	28.1 (6.5)
Terrestrial	8	37.1 (6)	31.6 (5)
Nuclear medicine	4	43.4 (4)	33.3 (4)
Consumer products	3	34.3 (7)	28.1 (6.5)
Industrial	1	25.9 (8)	17.5 (8)

Table 8 shows the societal risk ratings for both groups of respondents: those who agreed with the proportionality concept and those who disagreed. Also shown are the ranks of the societal risk ratings for both groups.

Though some differences are observed in the rankings of the societal risk ratings for the two groups, particularly for Internal and Cosmic radiation sources, the risk ratings are remarkably alike. Both groups of respondents tended to see the highest levels of societal risk associated with Radon and X-rays, and the lowest with Industrial sources of radiation exposure, in keeping with the proportions shown in the pie chart. Those who disagreed that societal risk is proportional to the percentages shown in the display, when asked as an attitude item, did not reflect that view in their societal risk judgments in a manner that was clearly discernible from those who agreed. We speculate that while in the abstract people may not view risks of radiation as proportional to exposure, graphic displays of the type used in this study exert a very powerful framing effect on perceptions and judgments of risk that may, under some circumstances, overwhelm underlying attitudes about risk, or at least may seem to on a “local” and (very likely) temporary basis. These results suggest that risk communicators need to be cautious about what may (or may not) appropriately be inferred regarding new or changed attitudes about perceived risks of, for example, radiation when those attitudes are based on responses people give to information displays that have a high framing potential.

Respondents also tended to agree that the purpose of radiation exposure matters more than the amount (51.7%, see Table 6), a result consistent with other research that has identified an inverse relationship between perceptions of benefit or value and perceptions of risk (e.g., Alhakami & Slovic, 1994; Finucane, Alhakami, Slovic, & Johnson, 2000). However, a substantial (though minority) portion of respondents (47.3%) disagreed that purpose matters. Again, the effect of the display may have been to frame the issue of radiation exposure almost entirely in terms of risk, thereby amplifying that aspect of radiation.

With regard to risk management, respondents were asked to indicate whether society should expend greater effort to protect people from natural background radiation, including geological and cosmic sources. Though most respondents disagreed that such effort should be expended (56.1%), a large proportion did agree (42.4%). Those who scored more highly on the LD scale, the RRP scale and the CC scale were more likely to agree, suggesting that stronger

Table 9. Attitudes About Sources of Information About Radiation Exposure

Item	Strongly disagree	Disagree	Agree	Strongly Agree	Scale Correlations
The representation of radiation exposure shown in the pie chart is biased and reflects what the nuclear industry would like people to believe.	5.37%	47.32%	40.98%	3.90%	-.17*(RM)
Given the representation of radiation exposure shown in the pie chart, the source of this data, The National Council on Radiation Protection and Measurements, is probably a pro-nuclear industry group.	4.88	40.49	46.34	6.34	.17*(RRP)

* $p < .05$.

attitudes about exposure to radiation and its risks is associated with a greater desire for risk management, even when the sources of radiation exposure are natural background. This result suggests that looking to natural background radiation levels as benchmarks for regulatory standards may be problematic, and prone to acceptance difficulties, particularly among those who are more concerned about radiation exposure and its potential harm. Furthermore, it appears from these data that the notion of radiation as a “natural” property of the environment is not appreciated, at least in a way that would permit the use of natural background exposure levels as a ready referent against which radiation from human activities can be judged comparable and (by implication) acceptable.

3.6 Trust in Information About Radiation Exposure

How people use information and the level of credibility they give it is partly influenced by their perceptions of where that information comes from and/or the institutions that have provided it. Respondents were asked to indicate their views about what interests the information display might have been designed to serve, and their beliefs about the source to which the information was attributed in the materials they received for evaluation. Their responses are shown in Table 9.

Many respondents tended to view the representation of radiation exposure in the pie chart as biased toward a nuclear industry perspective (52.7%), though a sizeable (but not majority) proportion disagreed (44.9%). The actual information for the pie chart came from a document published by *The National Council on Radiation Protection and Measurements*. When asked if this was probably an industry group, the majority of respondents (52.7%) agreed, with agreement more likely from those who scored higher on the RRP scale. Given the long and turbulent social history of nuclear energy and its uses, including the institutional problems that have plagued the nuclear industry over the years, it is not surprising that some skepticism (and even cynicism) is observed in people’s beliefs about where information about radiation might have come from and the intents and purposes that might be behind making comparisons between industrial sources of radiation exposure and natural background. We suspect that most people are insufficiently aware of the meaning and function of various groups involved in radiation management, such as The National Council, that operate in the broad public interest. If there is a lesson in the responses shown in Table 8, it may be that in the domain of radiation risk communication, people are primed and predisposed to assume risk representations to be biased and even the most august and intentionally neutral societal organizations to be compromised.

Table 10. Judged Plausibility of Conjectures About Radiation: Effects on Biological Diversity, Adaptation, and Plant Genetics

Conjectures	Not Plausible	Slightly Plausible	Moderately Plausible	Very Plausible	Scale Correlations
The diversity of species we observe on Earth today is partially due to the exposure of organisms to natural background radiation.	21.57%	50.49%	14.71%	13.24%	
Human evolution and adaptation are in part the result of exposure to natural background radiation.	20.59	43.63	20.59	14.71	.14*(HC) .16*(CC)
Radiation in the environment causes genetic mutations in plants.	4.9	33.82	31.86	28.43	.15*(HC) .23*** (CC)

Note. $df = 199$. * $p < .05$. *** $p < .001$.

4. Plausibility of Radiation Conjectures

As radiation science moves forward to deepen our understanding of how radiation exposure affects people and their health, experts will continue to be faced with the problem of communicating their new science to the public. While on the one hand radiation has been part of Earth's environment for millennia, the ability to gain insights into its effects on humans at the cellular level has been very recent. However, the picture that appears to emerge from laboratory studies of the effects of cellular-level exposure to radiation is unclear and sometimes contradictory to broad public notions about radiation and its possible harm. These contradictions can make it more difficult for the scientific community to communicate effectively with non-scientists, particularly when scientific hypotheses are at odds with what the public believes is plausible or reasonable. For example, radiation health effect research directed toward establishing a threshold level of exposure below which health effects do not occur may be looked upon harshly by a skeptical public who may believe that radiation exposure at any level causes meaningful and significant damage.

To gain a better understanding of how non-scientists may view a number of proposals relating to (a) the potential role of radiation in biological evolution and adaptation, and (b) the potential outcomes of radiation health effect research, respondents were given a set of conjectures to evaluate in terms of their plausibility. Plausibility was defined as "how seemingly valid or likely to be true." Respondents rated each conjecture on a four-category scale: not plausible, slightly, moderately, very plausible.

4.1 Effects of Radiation on Evolutionary Factors

Table 10 summarizes plausibility ratings for three conjectures pertaining to the role of radiation in biological evolution. These include the role of radiation in contributing to species diversity, human adaptation, and the potential effects of radiation on plant genetics.

Table 11. Judged Plausibility of Conjectures About Radiation and Its Effects: Biological Effects on Humans of Low-Dose Exposures

Conjectures	Not plausible	Slightly plausible	Moderately plausible	Very plausible	Scale correlations
For some individuals, there is a <i>threshold</i> level of exposure to radiation below which they are not at risk.	44.12	41.67	10.29	3.92	-.19**(RRP)
A very small exposure to radiation has a long-term health benefit.	44.12	41.67	10.29	3.92	
A very small exposure to radiation protects against the harmful health effects of a large exposure.	39.71	45.10	12.75	2.45	
When the human body is exposed to a very small amount of radiation, its natural adaptive response provides more benefit than the harm that is done by the exposure.	29.41	47.06	20.59	2.94	-.15*(RRP)
There is a <i>threshold</i> level of exposure to radiation, below which no one is at risk.	27.45	44.61	18.63	8.82	.14*(HC) .14*(RM)
A given dose of radiation distributed over time has a lower health effect than the same dose received all at once.	23.04	45.10	23.53	7.35	

Note. *df* = 199. **p* < .05. ***p* < .01

A context that is sometimes used to explain radiation and its effects is that of the naturally occurring radiation in the environment and its potential role in shaping human evolution (e.g., Hall, 1984)². Notions that life has evolved in the context of exposure to radiation from background sources, such as solar and geological radiation, may be of potential value in developing radiation risk communication approaches, but only if non-scientists view these ideas as plausible. However, respondents in the present study gave these conjectures only marginal ratings of plausibility. Almost three-quarters of the respondents (72.06%) thought the conjecture that the diversity of species is partly due to radiation exposure was either not or only slightly plausible. Only about a quarter of respondents (27.95%) indicated that it was either moderately or very plausible. A higher percentage (35.3%) found the conjecture that human evolution and adaptation are partly the result of background radiation either moderately or very plausible. However, respondents tended to find it either moderately or very plausible (60.29%) that radiation in the environment causes genetic mutations in plants, the item judged most plausible of the three shown in Table 10. Across all three conjectures, the modal response tended to be *slightly plausible*, suggesting an unwillingness of the part of respondents to be completely skeptical, but at the same time not committing high degrees of belief to any of the conjectures. Plausibility judgments were only moderately correlated with radiation risk scales.

² Eric Hall's "Radiation and Life" has been developed for the Internet. A Google keyword searching using the search phrase "Eric Hall Radiation and Life" yielded 4,270 returns. While some of these were pages within pages, the ubiquity and prevalence of Hall's basic tutorial on radiation in the electronic information environment is noteworthy.

4.2 Effects of Low-Dose Radiation Exposure on Humans

Recent research on low-dose radiation exposure has identified a number of potential cellular-level effects that have significant implications for radiation risk management. These include the possibility of a threshold effect, a hormetic effect, and an inoculation effect. Respondents were asked to rate a set of conjectures relating to these effects. Table 11 summarizes their judgment.

With regard to threshold effects, respondents were generally skeptical that a threshold effect exists, but were more optimistic that one may exist for some individuals (43.14%) than they were that one exists below which “no one is at risk” (27.45%). However, in neither case did respondents tend to see a threshold effect as more than slightly plausible.

Conjectures about the potential hormetic effects of small amounts of radiation exposure were generally seen as even less plausible than those about threshold effects. Indeed, the conjecture deemed *not plausible* by the largest percentage of respondents was that proposing a small amount of radiation exposure has a long-term health benefit (44.12%). Almost equally implausible was that proposing an inoculation effect, whereby a small exposure protects against the effect of a larger exposure (39.71%). Framing the inoculation conjecture in terms of an adaptive response by the body that provides more benefit than harm in the small exposure case improved plausibility slightly, but not enough to tip the balance away from skepticism toward believability. Likewise, respondents did not tend to see as plausible the conjecture that small, protracted doses of radiation received over time are less harmful than the same dose received all at once.

Respondents conjecture ratings were made without any additional background information, and we may conjecture that had they received more relevant information upon which to base their plausibility judgments, some or all of the conjectures in Tables 9 and 10 may have been given a more positive endorsement. Certainly experimental manipulations along these lines are in order before strong statements can be made about what people deem reasonable or unreasonable about the effects of radiation exposure. However, communications about radiation risks very often take place in an environment where people have relatively little background information, or where the information is dense and difficult to assimilate. Furthermore, how people interpret information is in part a function of their prior beliefs, which often provide the framework within which they integrate or reject new concepts. From this perspective, the results shown in Tables 9 and 10 suggest that at least university-aged individuals with some background and exposure to science do not readily

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accept as plausible some of the hypotheses about the positive value of radiation that form some of the views of the scientific community.

Table 12. Interpretation of a Newspaper Passage About Radiation Exposure

Item	Strongly disagree	Disagree	Agree	Strongly agree	Scale correlations ^a
Radiation always causes cancer in everyone exposed, no matter how small the exposure.	35.78%	54.90%	8.33%	0.98%	.16*(LD) .20**(RP) .17*(RRP) .22**(HR)
There is a high probability that someone exposed to radiation will get cancer, no matter how small the exposure.	14.71	52.94	27.94	3.92	.30****(LD) .26****(RP) .23**(RRP) .22**(HR) .17*(CC)
There is a very low probability that someone exposed to radiation will get cancer.	12.75	57.84	26.96	1.96	-.21** (LD) -.32****(RP) -.31****(RRP) -.28****(HR) -.16*(CC) .25***(RM)
There is a high probability that someone exposed to radiation will get cancer, but only if the exposure is massive.	8.33	43.63	38.73	8.33	.17*(RM)
Whether or not a person get cancer from radiation depends on how much they are exposed.	2.94	24.51	62.75	8.82	-.19**(LD)
Some people exposed to radiation get cancer, while other people do not, even when the exposures are the same for both groups of people.	2.45	12.75	67.65	17.16	-.15*(LD) -.17*(RP) -.16*(RRP)
Radiation has been proven to cause cancer in animals.	1.96	13.24	59.80	24.51	-.14*(RM)

^adf = 200. *p < .05. **p < .01. ***p < .001. ****p < .0001.

5. Evaluations of Media Expressions of Radiation Risks

Media reports of environmental health and safety often use expressions such as “exposure,” “contamination,” or “causes” as part of conveying or communicating a risk. In the context of chemical risks, even relatively simple concepts such as “exposure” can have a multiplicity of meanings to non-scientists (MacGregor, Slovic, & Malmfors, 1999).

5.1 “Radiation Can Cause Cancer”

Respondents were asked to evaluate a number of statements that might appear in a newspaper report regarding the potential risks of radiation. In the first task, they were told to imagine that they had read a short newspaper article about radiation which stated that “radiation can cause cancer.” They were then given a number of possible meanings of this statement and asked to indicate their degree of disagreement or agreement with each. Their responses are summarized in Table 12.

Most respondents disagreed that radiation always causes cancer no matter how small the exposure (90.68%).³ They also tended to disagree that there is a high probability radiation exposure will lead to cancer even if the exposure is small (67.65%). There was a lesser inclination to disagree that exposure has a high probability of causing cancer if the exposure is massive (51.96%). When asked whether the amount of exposure effects whether or not a person gets cancer, there was relatively high agreement (71.57%). They also tended to agree that even when exposures are the same for different people, some will get cancer while others will not (84.81%).

However, interpretations of the various statements were, in some cases, quite strongly related to prior views and attitudes about radiation risks. Those who were more sensitive to radiation exposure and to risk were more likely to agree that there is a high probability someone exposed to radiation will get cancer, no matter how small the exposure. Inversely, they were more likely to disagree that there is a very low probability that someone exposed to radiation will get cancer. These individual differences in interpretation may be due to systematic individual differences in how people interpreted the meaning of “high” and “low” probability in statements in which it appeared. Indeed, when the term “massive” was included in a statement about “high probability,” correlations with prior views about risk and exposure dropped considerably.

³ Percentages in text are *agree* or *disagree* response categories combined.

Table 13. Interpretation of “Exposure To Radiation Can Cause Cancer” in a Newspaper Context

“Exposure means:”	Strongly Disagree	Disagree	Agree	Strongly Agree	Scale Correlations ^a
Contact with a large enough amount of radiation to cause cancer.	12.75%	38.24%	33.33%	14.22%	
A miniscule, tiny amount of contact.	12.25	56.86	24.02	6.86	.16*(LD) .20**(RRP) .16*(CC)
A massive contact.	11.27	51.47	31.86	5.39	
A contact large enough to cause cancer.	8.82	37.25	41.18	11.76	
Any contact, no matter how small.	3.92	22.55	51.96	21.57	.19**(LD) .19**(RP) .19**(RRP) .25*** (CC)
Coming in contact with radiation	1.47	11.76	59.31	27.45	.18**(RP) .18**(RRP) .26*** (CC)

^a $df = 200$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Thus, non-scientists appeared to be sensitive to the amount of radiation exposure as a determinant of whether people do or do not get cancer, and sensitive to individual differences in the health effects of radiation even when exposures are the same for different individuals. However, the use of probabilities to convey the degree of risk appears (at least from these results) to introduce additional interpretive problems. What constitutes a “high” or “low” probability in people’s minds regarding the possibility of cancer from radiation exposure is open to personal interpretation. Though explicit probabilities could be given as a context, even numerical representations of uncertainty are themselves often interpreted in light of the consequences to which they are attached and the framework within which they are portrayed (e.g., Slovic, Monahan, & MacGregor, 1999).

5.2 “Exposure to Radiation Can Cause Cancer”

A second task explored the meaning of “exposure” in the context of radiation by asking respondents to imagine a newspaper article in which it was stated that “exposure to radiation can cause cancer.” They were then asked to express their disagreement/agreement with a number of possible meanings of the term “exposure” in this context. Table 13 summarizes their responses.

Agreement was very high that exposure means any contact with radiation (86.76%). Respondents tended to disagree that exposure means a miniscule or tiny amount of contact (69.11%). However, over 30% of the respondents did agree with the “miniscule” interpretation. Though the majority of respondents disagreed with the interpretation of exposure as a massive contact (62.74%), a large percentage agreed (37.25%). Thus, the interpretation of exposure was neither uniformly a very small amount nor a very large one. Much stronger agreement was observed for the interpretation that exposure means any contact, no matter how small (73.53%).

Respondents were generally more equivocal when exposure was cast in terms of its relationship to cancer. They were only slightly more inclined to agree than disagree that exposure means contact large enough to cause cancer (53% vs. 46%). Slightly elaborating the statement to say contact with a large enough amount of radiation to cause cancer tipped the balance slightly toward disagreement (51% to 47%). Comparing responses to the two statements in a cross tabulation showed that 85.1% of the respondents were consistent across both statements (agreeing with both or disagreeing with both), while 14.9% were not.

Table 14. Inferences From a Newspaper Passage: "People in Oregon Are Exposed to Radiation That Can Cause Cancer"

Item	Directly Stated	Strongly Implied	Weakly Implied	Neither	Scale Correlations ^a
Many people are exposed.	24.27%	29.13%	27.18%	18.45%	
The exposure to radiation is serious.	19.42	47.57	23.30	9.71	.19*(RRP)
You, personally, are at risk.	18.45	35.92	32.04	13.59	-.27**(LD)
The exposure will probably result in cancer among those people who were exposed to the radiation.	12.62	35.92	33.98	17.48	
The exposure was unavoidable.	11.65	25.24	29.13	33.01	
The radiation is potent.	11.65	33.98	38.83	15.83	-.27**(LD)
The exposure to any one person is large.	3.88	21.36	36.89	37.86	.27**(RM)
The exposure to any one person is frequent.	4.85	22.33	31.07	41.75	
There are many different sources of exposure to radiation involved.	3.88	13.59	25.24	57.28	

^a $df = 99$. * $p < .05$. ** $p < .01$.

Scale correlations were highest for the statement that exposure means any contact, no matter how small: those who were more sensitive to radiation risks were also most inclined to agree with this interpretation of exposure. However, for both statements relating radiation exposure to cancer, scale correlations were below significance.

Overall, the results show that there was little consistency in how people interpreted the meaning of the term “exposure” in this context. While most respondents did interpret exposure to mean some contact, the *amount* of contact implied by the term exposure was not consistently seen as either very large or very small. When the exposure was linked to a health consequence, in this case cancer, responses were equivocal, suggesting that some people may have interpreted exposure in its strict, toxicological sense, while others interpreted exposure in terms of the consequences it may produce. From these results, it appears that non-scientists may impute meanings to relatively simple phrases that are part of the communication of risk.

5.3 Inferences About Exposure

The results in Table 12 and 13 suggest that people go beyond the information given when they interpret relatively simple phrases used as part of risk communication. To explore this hypothesis further, respondents were given the following brief passage that might appear in a newspaper:

“People in Oregon are exposed to radiation that can cause cancer.”

The statement was relatively ambiguous, with no mention of the sources of radiation exposure, the time frame over which they occurred, or who in Oregon might or might not be at risk. In the strictest sense, the statement is completely consistent with exposures to natural background sources, and does not state that the exposure has actually been demonstrated to cause cancer.

After reading the passage, respondents were asked to indicate for each of a number of statements whether the statement was directly stated, strongly implied, weakly implied or neither stated nor implied by the passage. Their responses are summarized in Table 14.

Looking across the range of responses in Table 14, a striking feature is the variability of responses to the various statements. For every statement, at least some individuals responded in each of the four categories, indicating that a wide range of inferences were drawn from the relatively simple passage. The statement that received the highest percentage of *directly stated* responses was that many people are exposed. However, even this statement had an approximately equal distribution of responses across four categories, with about a quarter rating it *strongly implied*

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and a quarter rating it *weakly implied*. Relatively large percentages responded *strongly implied* to inferences that the exposure to radiation is serious (47.57%), they personally are at risk (35.92%), the exposure will probably result in cancer to those exposed (35.92%), and the radiation is potent (33.98%). Even frequent exposure was seen as at least weakly implied (31.07%), as was many different sources of exposure to radiation involved (25.24%). Scale correlations with responses to the various statements were quite low, suggesting that the inferences people drew from the passage were not generally related to views about radiation risks.

Table 15. Inferences from a Newspaper Passage: "People in Oregon Are Contaminated by Radiation That Can Cause Cancer"

Item	Directly stated	Strongly implied	Weakly implied	Neither	Scale correlations ^a
Many people are contaminated.	25.74%	45.54%	20.79%	6.93%	
The contamination by radiation is serious.	19.80	58.42	17.82	3.96	-.24*(CC)
You, personally, are at risk.	14.85	51.49	25.74	7.92	
The radiation is potent.	14.85	35.64	36.63	12.87	
The contamination will probably result in cancer among those people who were contaminated by the radiation.	13.86	23.76	44.55	17.82	
The contamination was unavoidable.	6.93	29.70	25.74	36.63	
The contamination of any one person is frequent.	4.95	31.68	40.59	22.77	-.22*(CC)
The contamination of any one person is large.	1.98	31.68	37.62	28.71	-.23*(HC) -.20*(CC)
There are many different sources of radiation contamination involved.	1.98	19.80	30.69	47.52	-.22*(RRP)

^a*df* = 99. **p* < .05.

In some media presentations, the concept of exposure is implied by the more negative term “contamination.” A second group of respondents was given the same newspaper passage above, but expressed as follows:

“People in Oregon are contaminated by radiation that can cause cancer.”

A similar set of statements to those in Table 14 was provided for evaluation, with contamination as the focus rather than exposure. Table 15 summarizes responses to these items.

Overall, responses were similar to those made when the content of the message was exposure. For all of the items, at least some individuals gave responses in each of the four categories provided, some indicating that inferences were directly stated, others that they were implied. Again, the strongest inference (directly stated) was that many people are contaminated, while the weakest inference was that many different sources of radiation contamination are involved. Correlations between risk scales and item responses were generally low. It appears from these results that shifting from the relatively value-free term “exposure” to the more negative term “contamination” did relatively little to change the inferences that people drew from the newspaper passage.

The results from evaluations of both newspaper passages suggest that non-scientists have a tendency to go beyond information given in a risk communication context to make inferences about what the meaning or importance of a communication might be. These inferences may conflict with what experts or scientists intend to be communicated.

6. Attribution of Health Effects

Risk assessment approaches, such as epidemiology, applied to community or regional health issues sometimes lead to determinations of higher health risks for an area, but a non-specific conclusion as to the cause. Media reports of risk assessment results very often leave those who receive them in the position of having to draw at least tentative conclusions for themselves, based on their beliefs about what the causes of a health effect might be. Even in cases where experts have some ideas of what causal factors might be operating in a given instance, and where multiple causal options are reported to the public, the public can still be left with competing explanations for a health effect. How they make attributions about the possible causes for a reported health effect in a community provides a basis for understanding the reasoning processes that accompany risk communication.

Table 16. Attributions for Health Effects Presented in the Context of a Newspaper Report: Differences in Exposure to Environmental Hazards

	Not important	Slightly Important	Important	Very important	Scale correlations
Differences in exposure to human-made radiation in the environment.	0.49%	5.39%	37.75%	55.39%	.23**(RP) .15*(RRP) -.15*(HC) .22**(CC) -.14*(RM)
Differences in exposure to carcinogenic chemicals.	0.49	4.41	39.71	54.90	.16*(RP) -.18*(RM)
Differences in air quality.	3.43	20.59	47.55	28.43	.19**(LD) .25*** (RP) .18**(RRP) .15*(CC)
Differences in water quality.	5.39	31.37	40.20	21.08	.27***** (LD) .33***** (RP) .28***** (HC) .26***** (CC) -.20** (RM)
Differences in exposure to natural background radiation.	9.31	35.78	37.25	17.65	.34***** (LD) .29***** (RP) .26*** (RRP) .23** (HC) .34***** (CC)

df = 199. **p* < .05. ***p* < .01. ****p* < .001. *****p* < .0001.

Respondents were presented with the following brief newspaper report regarding a fictitious community in Oregon:

SALEM -- The Oregon Health Division announced today that a higher number of cancer cases was found in Mayville, Oregon. The Oregon Health Division stated that the number of cancer cases in Mayville was 15% higher than other towns of its size in the state. A study is currently underway to determine why this might be occurring.

Respondents were asked to imagine that they had read the above report in a newspaper, and to rate how important each of fourteen possible factors might be in accounting for why Mayville has more cancer cases than other towns. Ratings were made on a four-point scale: not important, slightly, important, very important. The fourteen factors included differences in exposure to environmental hazards, as well as lifestyle and demographic differences between Mayville and other communities.

Table 16 summarizes respondents' responses to five factors relating to differences in exposure to environmental hazards, including human-made radiation, background radiation, air & water pollution, and carcinogenic chemicals. The items shown in Table 16 are presented in the order of the percentage of *very important* ratings each item received.

All five difference factors tended to receive ratings of either *important* or *very important*. Most important among the five factors were differences in exposure to human-made radiation (55.39% *very important*) and to carcinogenic chemicals (54.90% *very important*). These were followed by air quality and water quality. Natural background radiation was also perceived as important, but at a lower level than the other four.

Table 17. Attributions for Health Effects Presented in the Context of a Newspaper Report: Differences in Personal, Demographic, and Methodological Factors

	Not Important	Slightly Important	Important	Very Important	Scale correlations
Differences in how well the studies were done to determine the number of cancer cases in various communities in Oregon.	2.94%	15.69%	37.25%	44.12%	
Differences in lifestyles (e.g., diet, exercise) of residents.	1.47	19.12	45.10	34.3	
Differences in genetic makeup of residents.	3.92	20.10	46.57	29.41	.15*(RP) .17*(CC)
Differences in the kinds of occupations in various communities in Oregon.	11.27	27.45	37.25	24.02	.21**(RP) .18*(HR) .22**(CC)
Differences in the quality of health care in Oregon communities.	10.78	35.78	35.29	15.69	
Differences in the average age of residents.	11.76	31.86	44.12	11.76	-.16*(RRP)
Differences in stress levels.	14.71	40.20	34.31	10.78	.15*(LD) .20**(RP) .19**(HC)
Differences in the proportion of males and females in Oregon Communities.	17.65	40.69	31.86	9.31	
Chance	23.04	47.55	24.51	4.41	.17*(CC)

df = 199. **p* < .05. ***p* < .01.

Correlations between importance ratings and the various risk-related scales tended to be relatively high, particularly for exposure to natural background radiation and for water quality. Respondents who perceived higher risks in general and higher risk due to radiation exposure, those who were exposure sensitive, and those who saw greater cancer risk were also most likely to give higher importance ratings to natural background radiation in accounting for health effect differences between Mayville and other communities. A similar pattern of correlations occurred for water quality. In the case of human-made radiation, the correlations were slightly weaker. Overall, the correlational results suggest that attributions for health effect differences are related to perceptions of risk and risk management. However, looking only at natural versus human-made radiation, the links between risk perception factors and attributions were stronger for natural background than for human-made radiation. This suggests that prior views about risk in general, and even the risks of radiation exposure play a relatively weak role in effecting how people attribute differential health effects on a geographical basis to human-made radiation.

Table 17 summarizes responses to nine factors relating to differences in demographic characteristics and lifestyle tendencies of people who live in Mayville versus other communities. Also included among these factors were one relating to how well studies are done, as well as the role of chance.

Compared with the set of environmental factors in Table 16, the importance ratings of the factors in Table 17 were generally lower. The most important factor was how well the studies were done to determine the number of cancer cases, followed by differences in the lifestyles of residents in Mayville compared to other communities. Genetic differences between residents was also seen as important, as well as average age of residents. Other differences such as stress levels, quality of health care, and gender proportions were seen as important, but less so than other factors. The factor deemed least important of the set was “chance.”

Correlations between importance ratings and the various risk scales tended to be weaker for the factors in Table 17 than for the environmental factors in Table 16. Thus, prior views about risk in general and radiation risks in particular exerted a lesser influence over accounting for differential health effects in terms of demographic and lifestyle types of factors than over accounting for health effects in terms of environmental factors, including exposure both to carcinogenic chemicals and to radiation.

From the perspective of risk communication, the prospects for using “natural background radiation” as a context within which to cast other types of radiation exposure gain little vitality from these results. As a factor in explaining health effect differences between communities, it received the most variable ratings of the five environmental factors, suggesting that people may not attribute it a consistent meaning. The results tend to suggest that whatever meaning people give “natural background radiation” is somewhat tied to general ideas about the risks of radiation and the consequences of radiation exposure, and that human-caused radiation is a much more salient explanation for health effects than natural background, even in the absence of specific information that sources of human-made radiation exposure are present.

7. Discussion and Conclusions

The interpretation of a complex science, such as radiation health physics, requires comprehension of a myriad of concepts and ideas. Developing such a knowledge base is, for a non-scientist, a significant task. For the most part, the awareness that the broad public has of radiation and its potential effects is gleaned from the images and ideas that form the basis of public controversy about human uses of radiation, and particularly industrial uses such as nuclear power and weapons. A deeply structured and articulated awareness of radiation and its role in life as we experience it does not generally exist among even somewhat educated individuals, as the results presented above have shown. Rather, people (and even university-educated people) who are not a part of the scientific community have a scattering of concepts that they use to form judgments about the hazardousness of radiation. Even when multiple factors are made available to which health effects can be attributed, strong impressions about the relationship between radiation and cancer appear to largely determine attributions of causality.

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Low Dose, Risk, Decisions, & Risk Communication

Public Perception of Nuclear Materials In Space Research

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A REPORT
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Abstract

The electrical power requirements of many deep space missions necessitate the use of nuclear materials onboard spacecraft to achieve mission goals. For spacecraft operating at distances too far from the sun for solar power to be feasible, such as the Cassini mission to Saturn and upcoming missions to Mars, Radioisotope Thermal Generators (RTG's) provide a reliable source of power by converting heat from a solid mass of decaying plutonium into electrical energy. While RTG's have been used in the U.S. space program for decades, their recent use on the Cassini mission to Saturn drew significant public attention. Though public perception of nuclear power has generally been negative, not all uses of nuclear energy are perceived the same. For example, medical uses of radiation tend to be viewed in a more positive light. When people are asked to rate the risks of nuclear materials used in space research, they tend to view these risks as relatively low compared to other societal risks. Even in the context of other sources of radiation exposure, the hazardousness of nuclear materials in a space research context is perceived similar to X-rays used in medical research. However, in rating the risks of radiation exposure from a number of sources, ratings for "natural background radiation" as a category of radiation risks are much lower than risk ratings of its separate components such as suntanning, cosmic radiation, and radon in homes. These results suggest that risk communicators exercise caution in using the general context of "natural background radiation" as a reference against which to draw comparisons with other sources of radiation exposure such as those from industrial and/or scientific uses of radioactive materials.

1. Background

The electrical power and internal heating requirements of many deep space missions necessitate the use of nuclear materials onboard spacecraft both to achieve mission goals and to meet cost efficiency standards. For spacecraft operating at distances too far from the sun for solar power to be feasible, such as the Cassini mission to Saturn and upcoming sample return missions to Mars (e.g., Mars 2001), Radioisotope Thermal Generators (RTG's) provide a reliable source of power by converting the heat from a solid mass of decaying plutonium dioxide (PU-238) into electrical energy through solid-state thermoelectric converters.¹ The RTG onboard the Cassini mission uses 10.8 kg (about 24 lb) of plutonium dioxide encased in a highly ruggedized container. Some missions utilize Radioisotope Heating Units (RHU's) to provide local heating (approx. 1 watt) for critical electronic components, and use approximately 2.7 g (about 0.1 oz) of plutonium dioxide. Both RTG's and RHU's are designed, constructed and tested to maintain their structural integrity even if exposed to an accident during launch or reentry from Earth orbit.

While radioisotope power systems have been used in the U.S. space program since 1961, their recent use on the Cassini mission to Saturn drew both public attention and special interest group activism. Concerns were expressed prior to the Cassini launch and during the period between launch and near-Earth flyby that the RTG onboard the spacecraft could, in the event of accidental re-entry, disintegrate in the Earth's atmosphere, thereby exposing the world's population to radiation should the containment holding the plutonium dioxide also fail. The history of space research is marked by incidents in which mission launch aborts or orbital reentry accidents have turned attention to the safety of radioisotope power systems. For example, a 1964 launch vehicle failure resulted in the destruction of a SNAP-9A² radioisotope power system, resulting in the dispersal of plutonium in the upper atmosphere. Following a 1968 mission launch aborted shortly after takeoff at Vandenberg AFB in California, the plutonium heat sources for a SNAP-19B2 power system were found intact in 300 feet of water off the California coast. The heat sources were recovered and reused in the next space mission. The SNAP-27 power source onboard the

¹ RTG's and RHU's used in the U.S. space program are designed and constructed by the U.S. Department of Energy. Both RTG's and RHU's are elements of Radioisotope Power Systems.

² Systems for Nuclear Auxiliary Power (SNAP) devices are early versions of RTG's and were used in the US space program through the 1975 Viking 2 mission to Mars.

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Apollo 13 lunar excursion module reentered the atmosphere and disintegrated over the south Pacific Ocean near the Tonga Trench in approximately 25,000 feet of water, with no subsequent indication that nuclear fuel was released (Furlong & Wahlquist, 1999). The most recent mission failure involving an RTG was the Russian Mars 96 unmanned spacecraft that failed to achieve orbit and re-entered the atmosphere somewhere near the border of Northern Chile and Argentina. The fate of the 7 ounces of plutonium onboard is unknown.

For approximately the past 40 years, public perception of the nuclear fuel cycle and industrial uses of radiation has generally been negative. For example, the nuclear power industry was essentially brought to a standstill by the difficulties the industry faced in convincing the public that nuclear energy was safe. Though there has never been a radiation-related death from a nuclear power plant accident, the public views radiation from operating nuclear power plants as a threat. Research on public perception of nuclear power and the nuclear fuel cycle suggests that public attitudes about nuclear power are not so much based on the track record of the technology (e.g., average annual fatalities) as on the perceived consequences of a catastrophic accident should it occur (e.g., Slovic, 1992; Slovic, Flynn, Mertz, Mays, & Poumadère, 2000). Also contributing to the negative perception of nuclear power has been broad public distrust and lack of confidence in organizations that manage and regulate nuclear energy and its risks.

However, public perception of nuclear energy and radiation is not uniformly negative. For example, medical uses of radiation tend to be viewed in a positive light, largely because in a medical context nuclear energy is perceived in terms of its benefits. At least some of the benefits of medical uses of radiation are not obtainable by other means, such as radiation treatments for cancer and X-rays for diagnosis. In addition, the medical profession and medical institutions are seen as more trustworthy and accountable than are industrial users of nuclear energy. Moreover, non-scientists perceptions of risk may be inversely related to their perceptions of benefit: the greater the perceived benefit, the less the perceived risk (Alhakami & Slovic, 1994; Finucane, Alhakami, Slovic, & Johnson, 2000).

The question of how non-scientists perceive the risk associated with the use of nuclear materials in space research has received some research attention. Maharik & Fischhoff (1992) examined the perceptions of experts and lay activists of the risks associated with the use of

Table 1. Responses to Survey Item: “Using Nuclear Materials to Make Electricity Onboard Spacecraft Does Not Pose a Significant Risk to People On Earth.”

	Strongly disagree	Disagree	Agree	Strongly agree	No answer
All respondents	2.9%	38.9%	45.8%	3.0%	9.5%
Sex of respondent					
Male	3.6%	31.9%	53.9%	4.9%	5.7%
Female	2.1	46.8	36.5	0.8	13.8
Respondent age					
18 to 29	2.7%	34.2%	56.3%	3.9%	2.9%
30 to 54	3.2	43.3	41.1	2.2	10.2
55 & over	2.5	35.2	45.9	3.8	12.6
Education					
HS or less	2.8%	47.8%	35.8%	1.4%	12.2%
Some college	4.6	41.7	42.3	3.5	7.9
College grad	2.0	24.1	57.6	5.9	10.5

nuclear energy sources in space. They found that while lay activists used many of the same concepts as experts when they think about such risks, they tended not to reason in specific terms about the effects of radiation exposure associated with accidental release of radioactive materials.

From a risk perspective, nuclear materials (such as those used in RTG's) potentially constitute a source of radiation exposure (albeit relatively small), and there is no potential for a catastrophic accident such as a core meltdown or nuclear explosion. Thus, nuclear materials used in the context of space research (and under even the worst case scenario) constitute a potential amount of radiation exposure similar to that resulting from radioactive fallout or residual nuclear materials in soils from industrial site contamination, both of which are contributors to the overall background radiation to which the public is exposed and both of which are managed as adverse radiation risks. However, public sensitivities to nuclear risks are less related to the amount of radiation exposure than to the context in which the exposure occurs. This report presents the results of research relating to public perception of the use of nuclear materials in space research, relative to other types of societal risk and hazards as well as to other sources of radiation to which the public is or may be exposed.

1.1 Nuclear Materials In Space Research: Results from a National Survey of Risk

A national survey of public attitudes about risk and related issues was conducted in 1997 by Decision Research of Eugene, Oregon.³ The survey was a stratified random sample of household members over 18 years of age in the U.S. surveyed by telephone from September 27, 1997, through February 3, 1998.⁴ Among the items included in the survey were several relating to planetary exploration. One item asked: "Using nuclear materials to make electricity onboard spacecraft does not pose a significant risk to people on earth." Respondents were given four response options: strongly disagree, disagree, agree, strongly agree. Table 1 shows responses tabulated according to characteristics of respondents.

³ The survey consisted of a number of risk-related topics. Results from various components of the survey have appeared in other publications, including Slovic et al., 2000; Finucane, Slovic, and Mertz, 2000; and Finucane, Slovic, Mertz, Flynn, and Satterfield, 2000.

⁴ A total of 1204 completed interviews were obtained, for an overall response rate of 46.8%. The mean age of survey respondents was 43.5 years, with 45% males and 55% females. A general sample as well as an ethnic oversample were weighted to the 1997 U.S. population as a whole in terms of race and gender. The average interview length was approximately 35 minutes.

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Overall, survey respondents were slightly more inclined to agree that nuclear materials onboard spacecraft do not pose a significant risk to people on Earth (48.8%) than to disagree (41.8%). A fairly large portion (9.5%) gave no answer to the question. However, male respondents were much more likely to agree that there is no significant risk (58.8%) than were female respondents (37.3%). Other surveys of public risk attitudes have found a similar difference across a broad range of risks, with a tendency for females to exhibit higher levels of perceived risk than males (e.g., Finucane, Slovic, Mertz, Flynn, et al., 2000; Flynn, Slovic, & Mertz, 1994; Neil, Slovic, & Hakkinen, 1993).

Younger respondents, particularly those in the 18-to-29 age group, were more likely to agree that there is no significant risk (60.2%) than were older respondents. Those in the youngest age group were also much less inclined to respond with *no answer*, while older respondents tended to give *no answer* approximately 10% or more of the time. Those respondents who were college graduates also tended toward agreement that there is no significant risk (63.5%) compared with those having only some college (45.8%) or high school only (37.2%). Thus, younger and more educated respondents were those more likely to see nuclear materials onboard spacecraft as not a significant risk to people on Earth.

Results from this single question posed to survey participants are not, of course, sufficient to draw firm conclusions about how nuclear materials in space research are perceived. The question itself is open to a number of interpretations, including the meaning of *not significant* and *risk*. Moreover, at least some respondents may have little or no knowledge about nuclear materials onboard spacecraft or the reasons for nuclear materials being there. While some of these respondents may have given *no answer*, others may have responded based on other perceptions or associations to the term *nuclear* included in the survey item. Nonetheless, the results do at least tentatively suggest that people are not overwhelmingly inclined to view nuclear materials onboard spacecraft as a risk of major concern. Furthermore, how nuclear materials used in the context of space research are perceived may depend in no small part on characteristics of the population of respondents, including their gender, age, and education level. For example, research in risk perception has documented a “white male” effect, whereby white males exhibit lower perceptions of risk across a broad range of risks and hazards than do white females, as well as both males and

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females of non-white ethnic groups (Finucane, Slovic, Mertz, Flynn, et al., 2000). The attenuated risk perceptions of white males may be linked to both real and perceived opportunities for control over exposure to risks, as well as a gender-related tendency to discount risk, though further research is needed to identify the specific factors that cause the effect. Age differences may also play a role in risk perception, particularly if a risk is seen as having immediate and personal consequences. Thus, retired individuals concerned about their financial welfare may express greater concern about technological risk and hazards that have the potential to effect contributors to wealth, such as property values. Technological activities that use nuclear materials may, in their view, pose a threat if a perceived potential exists for accidents, or even normal operations, to result in pollution or contamination that effects the economic value of property in a region, such as areas that are associated with space mission launch sites and ranges. Indeed, older individuals may express less concern about the personal, long-term health effects of radiation exposure than about the potential economic impact resulting from the perceptions of others.

Table 2. Responses To Survey Item: "I Would Consider Joining an Environmental Group Dedicated To Protecting the Environments Of Other Planets."

	Strongly disagree	Disagree	Agree	Strongly agree	No answer
All respondents	6.1%	49.9%	37.8%	3.2%	2.9%
Sex of respondent					
<i>Male</i>	7.2%	49.2%	37.4%	3.1%	3.1%
<i>Female</i>	4.9	50.8	38.2	3.4	2.6
Respondent age					
<i>18 to 29</i>	8.9%	40.7%	44.1%	3.8%	2.5%
<i>30 to 54</i>	5.5	49.1	40.2	2.8	2.4
<i>55 & over</i>	5.2	60.1	27.2	3.7	3.8
Education					
<i>HS or less</i>	3.8%	46.7%	43.8%	2.8%	2.9%
<i>Some college</i>	8.1	47.4	36.2	4.1	4.2
<i>College grad</i>	10.5	51.8	32.9	2.6	2.3

A potential source of concern about nuclear materials aboard spacecraft is their fate once the mission is completed. Though missions can be designed that ultimately send a spacecraft on a trajectory into the sun, thereby disposing of its nuclear component(s), other missions have as their endpoint a surface landing, thereby creating the potential for a nuclear “forward contamination” problem. As yet, this issue has not surfaced significantly in the public arena. However, to obtain some sense of general public sentiment toward protecting the environments of other planets, respondents were asked the following item: “I would consider joining an environmental group dedicated to protecting the environments of other planets.”⁵ Table 2 summarizes responses to this item according to characteristics of respondents.

A moderately high percentage (41%) indicated that they would consider joining the proposed environmental group. Females were no more likely than males to consider joining. However, younger respondents, particularly in the age range 18 to 29 were much more likely to consider joining (47.9%) than were respondents in the oldest age group (30.9%). This difference may be owing to the stronger environmental orientation of younger members of the population.

The (significant) positive endorsement to this survey item, though framed in terms of a behavioral intention, can also be interpreted in terms of its attitudinal implications. From an attitudinal perspective, a positive response suggests that “other planets” can be perceived as needing protection, particularly in terms of environmental impacts. Moreover, respondents who were inclined to endorse the statement may have also perceived that environmental groups are in some way an appropriate or relevant mechanism for helping insure that other planets are not damaged or harmed by exploratory activities. On a broader scale, attitudes about the environments of other planets may be based on themes or concepts that people apply to their concerns about environmental quality on Earth. Thus, risk of contamination of the surface of another planet by nuclear materials used as part of a space exploration mission, may be conceptualized and perceived in the same way as if the same form of contamination were to occur somewhere on our planet. In the context of biological protection, MacGregor, Slovic, and

⁵ Of the total survey sample, only 6.2% ($n = 27$) indicated that they were a member of an environmental organization.

Figure 1. Perceived risk ratings for 36 risk items.

Race (1998; see also Race & MacGregor, 2000) found that members of the general public expressed relatively strong views about the need for protection of other planets from biological contamination. Though planetary protection programs conducted as part of space missions in search of life elsewhere must, for environmental protection *and* scientific reasons, deal with both the forward and backward contamination problem, we know relatively little about how non-scientists view the need for planetary protection relating to nuclear materials. More research is needed along these lines to help inform the development of space policies relating to the entire life-cycle of nuclear fuels and materials used in space missions.

1.2 Perceptions of Radiation Risks in a Societal Context

A second perspective on perception of radiation risks comes from a study of university-age students conducted in February, 2000. A convenience sample of 207 individuals, average age 21.8 years, completed a set of survey-type questionnaires relating to radiation and radiation risk management. The sample was comprised of 39.5% males and 59.5% females. Among the questionnaires was one that asked respondents to rate 36 items in terms of the risks each poses to “you and your family.” Responses were made on a four-category scale: *no risk* (= 1), *slight*, *moderate*, or *high risk* (= 4). Eleven of the items were sources (or potential sources) of exposure to ionizing radiation, including an item “nuclear materials used on space missions.” Figure 1 summarizes responses in terms of the percentage of *moderate* or *high* risk ratings for each of the 36 items.

Figure 2. Perceived risk ratings for 11 sources of radiation exposure.

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Cigarette smoking received the highest risk rating, followed by stress, multiple sex partners, and second-hand smoke. Common risks to which people are exposed such as those associated with motor vehicle travel, bacteria in food, and pesticides occupied middle positions in this distribution. At the bottom were risks associated with blood transfusions, natural background radiation, tap water, and vaccines. “Nuclear materials used in space missions” was generally rated relatively low in risk, and similar to Medical X-rays, Storms & floods, and Cellular phones. However, 25.4% of respondents gave it a moderate or high rating. Figure 2 presents the same ratings as Figure 1, but only for the 11 items comprising sources of exposure to ionizing radiation.

Among sources of radiation exposure, nuclear materials used in space missions was very near the bottom of risk ratings, with only natural background radiation occupying a lower position. Suntanning, stored nuclear waste and radon in the home occupied the top positions. Although “Natural background radiation” received the lowest risk ratings, various components of natural background radiation included in Figure 2, such as Cosmic radiation, Radon in the home, and Suntanning all received much higher risk ratings. These results offer a word of caution against suggesting that natural background radiation can be used as a standard against which to gauge the perceptual significance of a specific industrial application, such as nuclear materials on space missions.

In the context of a broad spectrum of societal risks, as well as in the context of specific sources of exposure to ionizing radiation, the perception of risks associated with the use of nuclear materials in space missions is quite low. However, we cannot conclude that this perception is based on knowledge and awareness, or on a clear understanding of radiation exposure and its biological effects. We have no empirical results to date that indicate how much the public is aware of the use of nuclear materials in space research, or how they would see themselves as exposed to possible risks if their awareness increased. Previous research has shown that people’s perceptions of exposure to hazards, such as chemicals, can be highly sensitive to the way in which information is presented to them, and that even very small amounts of exposure to materials believed to be hazardous can lead to inferences of great harm (MacGregor, Slovic, & Malmfors, 1999).

Perhaps the fairest conclusion that can be drawn at this point regarding perception of nuclear materials in space research is that the public is not as sensitized to this aspect of human uses of radiation as a matter for concern as they are to other uses of radiation. Further research is needed to determine how changes in the information environment might influence these perceptions.

1.3 Implications for Risk Communication

As the use of RTG's and RHU's in deep space missions becomes a matter of greater public awareness, the need to develop approaches for communicating with the public about the purposes of these devices, the measures taken to assure their quality (e.g., safety, containment), and the potential risks associated with their failure will take on greater importance. Though research pertaining to public perceptions of nuclear materials in space research is at this point scanty, some preliminary observations regarding communication issues can be made.

In looking at perceptions of radiation exposure across a wide range of sources, some industrial, some medical, and some natural background, we see an equally wide range of judgments about the level of risk associated with these exposures. As a category of exposure, "natural background radiation" is of relatively little concern compared to human-activity sources such as nuclear waste storage. However, when individual elements of natural background radiation are posed separately, their risk perception increases dramatically. One question that can be asked with regard to the present results is how well people are prepared to recognize the separate components of natural background radiation. For example, cosmic radiation and radon, both components of natural background radiation, may not be associated in the public mind with the background. The pattern of results observed in this study suggests they are not. Thus, the non-scientist's mental representation of natural background radiation may not conform to that of the scientific community, with the result that a radiation expert's use of the concept "natural background" may include sources of radiation exposure that people do not associate or group together. Moreover, contributions to background radiation made by anthropogenic sources (e.g., nuclear power plants, weapons testing) may not be categorized as part of the background at all, but rather as special or unusual hazards. Communicators should be very cautious about using the natural background as a comparative context against which to illustrate the potential risks of

radiation exposure from RTG's and/or RHU's, particularly if the exposure is portrayed in the context of a spacecraft accident.

Research on public perception of radiation risks available thus far suggests that attitudes about radiation are strongly conditioned on beliefs and values concerning the purpose to which the radioactive materials are put. This "purposive categorization" of radiation exposures (and risks) is perhaps most obvious in the area of medical applications, where people generally have low concerns about radiation exposure, even when the levels are much higher than that associated with other purposes such as nuclear power plants. While some research suggests that the public has a positive perception of space research in general, and sees value in planetary exploration (MacGregor et al., 1998; Race & MacGregor, 2000), it is not clear how strongly these attitudes lend support to the use of RTG's. Thus, people may have concerns about particular aspects of space research (e.g., use of nuclear materials) that are not observed in their general beliefs about the benefits of space science. Once again, communicators are cautioned against drawing comparisons between RTG's and other purposive uses of radioactive materials, since alternative contexts may not be comparable in terms such as the benefits they are intended to achieve, or the level of control that people perceive themselves as having over exposure to risk.

Spacecraft and the various subsystems that enable their operation are complex and resilient to complete public understanding, even by non-scientists who earnestly endeavor to learn more about them. Recognizing this, communicators often resort to the use of probabilistic statements to convey the level of risk associated with, for example, RTG's. However, though probabilities are meaningful to those who are well-versed in the technicalities of risk assessment, their meaning to the public may be much less potent. Public concerns about technological risk and hazards, including those potentially associated with the use of RTG's, is often determined more by perception of consequences than by the probability of their occurrence. In these contexts, communicators are advised to use probabilities cautiously and to have low expectations about the potential success they will achieve. Communicators should be especially cautious of using low probabilities of accident resulting in exposure as a basis for assigning "reasonableness" or "rationality" to public views and concerns.

Much research remains to be done on how non-scientists perceive the use of nuclear materials in space research. Previous research in other areas of public reaction to technological risk management suggests that trust and confidence in organizations that deal with risks or that manage technologies that expose people to risks and hazards is at least as strong a determinant of public perception of technology as are characteristics of the technology itself. Indeed, it would not be inaccurate to say that perception of technology *is* perception of the organizations and institutions that manage it. Future research will look toward perception of the actions that organizations take to insure that technology is safe, including both the technical and engineering processes typically associated with design, construction, and testing, as well as management procedures that insure against oversights and recreancy.

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An Emotion-Based Model of Stigma Susceptibility

Cognitive Appraisals of Emotion, Affective Reactivity, and
Worldviews in the Generation of Technological Stigma

A REPORT

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Low Dose Radiation Research Program

Abstract

Results of an experiment ($N = 198$) indicate that stigma responses to radiation sources are created by an interaction between how individuals feel (an affective response) and what they think (a cognitive process) about the stigmatized object. Results of linear recursive modeling and structural equation models supported the hypotheses. Radiation sources that scored higher on a measure of stigma were considered in the analyses (i.e., nuclear power plants, radioactive waste from nuclear power plants, radiation from nuclear weapons testing). Individual differences in negative reactivity and worldviews were associated with the strength of negative emotion towards stigmatized radiation sources. The inclusion of emotional appraisals greatly increased the prediction of negative emotion. The model fit better as hypothesized with perceived risk as a function of negative emotion rather than vice versa; individual differences in affective reactivity and worldviews had only indirect effects on perceived risk. Finally, a measure of stigma was associated with negative emotion and, to a lesser extent, with risk perceptions. A theory of *stigma susceptibility* is proposed in which affective reactions and cognitive worldviews activate predispositions to appraise and experience events in systematic ways and result in the generation of negative emotion, risk perceptions, and stigma responses. Risk communication about stigmatized objects may benefit from a more complete understanding of how emotional belief systems are constructed and the routes through which they affect responses and behaviors.

The present study examines the interaction between two psychological systems — emotion and cognition — and their joint influence on perceptions and acceptability of risks, with particular emphasis on perceptions of radiation sources. We examine how individual differences and emotional appraisals relate to negative emotion as well as how negative emotion and risk perceptions relate to a measure of stigma.

1.1 Risk Perception, Cognition, Emotion, and Affect

People respond to hazards according to their perceptions of the risks they pose. The public's top risk concerns, however, do not agree with those of the experts (Roberts, 1990), leaving government and industry groups with the difficult task of choosing between the rationality of science and the “rival rationality” of the public (Slovic, 2000). The policies of federal agencies then appear to reflect the public's views rather than those of their own scientists. What the public perceives, why they perceive it that way, and how they will subsequently behave is a matter of great import to industries and governments trying to assess and implement technologies.

Most psychological studies on risk perception have focused on the cognitive forces that shape risk attitudes and behaviors (e.g., Slovic, Fischhoff, & Lichtenstein, 1979; See Slovic, 2000 for a review). Research following a psychometric paradigm, for example, has led to a taxonomy for hazards useful for understanding and predicting responses to risks (Slovic, 1987). Specifically, this work suggests that the risk perceptions of laypeople are based on a range of complex and richer considerations than the one variable — the number of lives at stake — on which the experts focus. Risk perceptions are characterized along two dimensions — *dread risk*, as defined by the extent of perceived lack of control, feelings of dread, perceived catastrophic potential, and the inequitable distribution of risks and benefits; and *unknown risk*, or the extent to which a hazard is judged to be unobservable, unknown, new, and delayed in producing harmful impacts. These simplified cognitive maps appear useful in explaining public reaction to specific technologies. For example, hazards such as nuclear power and DNA technology tend to be judged high on both the dread risk and unknown risk factors. An accident in either of these domains will likely produce a high degree of concern as well as social impacts that extend far beyond the original cost of lives lost or equipment damaged. In the present paper we examine a cognitive appraisal theory of emotion and argue that risk perceptions are primarily emotional

Figure 1. A model of the affect heuristic explaining the risk/benefit confounding observed by Alhakami and Slovic (1994). Judgments of risk and benefit are assumed to be derived by reference to an overall affective evaluation of the stimulus item. Source: Finucane et al. (2000).

phenomena with the emotions inextricably linked to how we think about technologies and what is communicated to us about those technologies.

Recent psychological work has identified affect and emotion as key ingredients in risk perceptions. Loewenstein et al. (2001), for example, argued that risk perceptions are feelings that also include a cognitive, thinking component. Affect is defined in the present paper as pleasant or unpleasant feelings towards an external stimulus (e.g., a city or a consumer good). These feelings persist over time as enduring dispositions strongly related to stimuli. Individuals differ in the extent and speed with which they attach affect to objects (Damasio, 1994; Peters, 1998; Peters & Slovic, 2000). This affect may induce subtle (or not so subtle) moods, but it is different from a mood manipulation induced as an independent variable in laboratory studies (e.g., Isen, 1997). Whereas mood has no object or has only fleeting objects, affect is a relatively stable property of the psychological experience of a stimulus for an individual. Affect may become associated with an object through careful thought, but also through experiential processes such as conditioning (Staats & Staats, 1958), familiarity (Zajonc, 1980), and priming (Hess, Waters, & Bolstad, 2000). Affect is different from emotion in that emotions such as fear, anger, and happiness are generally thought to be derived, in part, from these feelings of pleasantness or unpleasantness. In addition, however, emotions appear to be derived from other cognitive appraisals of the environment that include an appraisal of affect, but also include other dimensions such as predictability and coping potential (e.g., Smith & Ellsworth, 1985; Karasawa, 1995).

Support for the relationship between affect and risk perceptions comes from a variety of sources. Whereas risk and benefit tend to be positively correlated in the world, they are negatively correlated in people's minds (and judgments). This inverse relationship between perceived risk and perceived benefit of an activity (e.g., using pesticides), however, appears to be linked to the strength of positive or negative affect associated with that activity (Alhakami & Slovic, 1994). Their results imply the use of an "affect heuristic" (See Figure 1, Slovic et al., 2002); people appear to base their judgments of an activity or a technology not only on what they think about it but also on how they feel about it. If they like an activity, they appear to judge risks as low and benefits as high; if they dislike it, they may judge the opposite—high risk and low benefit. Under this model affect comes prior to, and directs, judgments of risk and benefit.

Figure 2. Model showing how information about benefit (A) or information about risk (B) could increase the global affective evaluation of a technology such as nuclear power and lead to inferences about risk and benefit that are affectively congruent with the information input. Similarly, information could decrease the global affective evaluation as in C and D, resulting in inferences that are opposite those in A and B. Source: Finucane et al. (2000).

Finucane et al. (2000) provided further tests of this model and demonstrated that giving information about benefit changed the perception of risk and vice-versa (see Figure 2). For example, information stating that benefit is high for a technology such as nuclear power led to more positive overall affect that, in turn, decreased perceived risk (Figure 2A). They also tested and supported the hypothesis that less deliberation, as a result of time pressure, greatly increased the inverse relationship between perceived risks and benefits. These two experiments are important because they demonstrate that affect influences judgment directly and is not simply a response to a prior analytic evaluation. They are also important because they illustrate the balance between the affective and deliberative systems. As deliberation decreased (through time pressure), emotional considerations carried greater weight in judgments.

Emotions appear to play a large role in reactions to risk. For example, we appear to be sensitive to the possibility rather than the probability of strongly-affective risky events (Loewenstein et al., 2001). Rottenstreich and Hsee (2001) demonstrated that attractiveness and subjects' willingness to pay to receive or avoid a strongly affective good, such as a kiss from a favorite movie star or an electric shock, was not influenced much by large changes in the probability of the good; at the same time, responses to less affective goods were quite influenced by probability. In addition, greater risk is communicated through the use of frequency data (the number of people at risk) than through a percentage format (the percent of people at risk) (Hoffrage et al., 2000). The greater impact of frequencies compared to percentages may be due to the greater affective images elicited by the frequency than the percentage format (Slovic, Monahan, & MacGregor, 2000).

Questions remain, however, concerning what an emotion or affect is and how they relate to cognition. Sunstein (2001), for example, suggests that affect may be simply a rough assessment of risks and benefits that can be influenced by the availability heuristic. It seems perfectly plausible and even likely that affect as well as emotion contain this rough assessment given that they seem to have developed through evolution to allow us to react quickly and appropriately to hospitable and inhospitable circumstances. However, they also appear to be more than that. Emotion and affect towards an object appears to be produced in a variety of ways that are important to risk perception. We agree with Sunstein that they may be the result, in part, of a rough estimate of risks and benefits, but also that they are produced by cognitive appraisals of

emotion, mood states, affective reactivity, and worldviews. We will treat each of these possible sources briefly in turn.

Risk Perceptions and Cognitive Appraisal Theories of Emotion. Cognitive theories of emotion contend that people's cognitive appraisal or interpretation of events or circumstances determines the quality of emotion (Karasawa, 1995; Frijda, 1986, Roseman, 1984; Scherer, 1984, Smith & Ellsworth, 1985). These theories propose a direct and causal link between specific cognitions and emotions. Cognitive emotion theorists assume that the appraisal is conducted along a small number of dimensions that discriminate the emotions. Specifically, Karasawa (1995) reviewed the literature and suggested five major appraisal dimensions that were in common across most appraisal theorists: pleasantness (positive versus negative affect), certainty (certain versus uncertain), causation (by self, other, or chance), coping potential, and importance. Appraisals are presumed to be relatively effortless and automatic processes that are sensitive to events related to survival (e.g., loss, threat, injustice) as well as to opportunities (e.g., forming attachments). Appraisal theories are special in that they are the only theoretical attempt to explain how an emotion such as fear or anger is generated. Some excellent work by Lerner and Keltner (2000, 2001) highlights the benefits of examining risk perceptions in an emotion-specific manner. They predicted and found that fear and anger had opposite effects on risk perception. Whereas fearful people expressed pessimistic risk estimates and risk-averse choices, angry people expressed optimistic risk estimates and risk-seeking choices.

To the best of our knowledge, cognitive appraisal theory has not been linked to emotions towards specific objects and, instead, has focused on individuals who differ in their tendencies towards specific discrete emotions (Lerner & Keltner, 2000) or has focused on eliciting a specific emotion such as fear or anger and examining its antecedents (Smith & Ellsworth, 1985). In the context of risk perceptions of radiation sources as well as other technologies, the picture is complicated, however, by the fact that people often experience mixed emotions about a technology. For example, they may feel angry, fearful, and sad about radiation from a nuclear power plant. With mixed emotions, the cognitive appraisals also will be mixed. In the present experiment, we identify cognitive appraisals that are consistent across mixed emotional reactions and examine their impact on risk perceptions.

Risk Perceptions and Mood. In earlier studies, Johnson and Tversky (1983) found that the negative (or positive) affect generated by a news story influenced subsequent estimates of risk perceptions, regardless of the similarity between the depicted event and the other events. They presented college-student subjects with three brief, newspaper-style stories about a tragedy involving the death of an undergraduate student. They found that reading about a tragic (fortunate) event increased (decreased) frequency estimates across causes of death and argued that negative and positive moods induced by the newspaper stories produced global changes to risk perceptions.

DeSteno, Petty, Wegener, & Rucker (2000) provided evidence that generalization is not limited to positive or negative moods but functions in an emotion-specific manner related to the informational value of the emotion. Specifically, they demonstrated that sadness and anger, two distinct, negative emotions, differentially biased likelihood estimates of sad and angering events. In addition, they showed that when the source of the emotion was made salient, a reversal of the bias occurred for individuals who tended to expend greater cognitive effort. Like the studies by Lerner and Keltner (2000), the DeSteno et al. findings suggest that risk perceptions also may operate in an emotion-specific manner. We will not consider mood itself further in the present paper, but will focus on the importance of emotional appraisals to risk perception.

Risk Perceptions and Affective Reactivity. Gray (1981, 1982) hypothesized that two general motivational systems underlie behavior and affect: a behavioral inhibition system (BIS) and a behavioral activation system (BAS). The negative reactivity of the BIS, in particular, may be important to risk perceptions. According to Gray, the BIS is sensitive to signals of punishment, nonreward, and novelty. It inhibits behavior that may lead to negative or painful outcomes. In past studies, individuals high in negative reactivity perceived greater risk than did individuals low in negative reactivity when judging the same situation (Gasper & Clore, 1998). Those individuals high versus low in negative reactivity also seem to place greater disutility on high-loss options as evidenced by them learning more quickly to avoid choosing those options (Peters & Slovic, 2000; Peters & Mauro, 2000). Individuals with high BIS sensitivity appear to react more to negative-emotion-provoking situations (and express more negative emotion), but they also appear to learn to take action to avoid those situations in the future.

Activities and technologies also can differ in the extent to which they elicit a negative reaction. Nuclear objects appear to carry strong associations with our society's early experiences with radiation and nuclear war. Nuclear things were "conceived in secrecy and revealed to the world in horror." As a result, the concept of negative emotion is indissolubly linked with the learning of avoidance behavior characteristic of high-risk situations. Negative reactivity is expected to influence the elicitation of negative emotion and the potential for higher risk perceptions.

Risk Perceptions and Worldviews. Worldviews (generalized attitudes toward the world and its social organization) have been shown to orient or guide people's responses in complex situations (Dake, 1991, 1992). Dake argues that people's identities and worldviews are mediated by their social relations and the extent to which social prescriptions govern their behavior. Individuals can differ in terms of beliefs about right and wrong, belief about where control emanates, beliefs about responsibilities to others, beliefs about the extent to which rules are needed to control behavior, and beliefs about whether these rules should be different across society. Several researchers have related worldviews (i.e., egalitarian, hierarchical, and individualistic worldviews) to affect and risk perceptions of nuclear power. Peters and Slovic (1996) found worldviews to be instrumental in determining a person's risk attitudes and perceptions and suggested that they might be one system for assessing value. Jenkins-Smith (1993) concluded in his studies on worldviews that rather than being passive receivers of information, "people actively impute significance and value to signals in systematic ways" (p. 2). Although a relation has been found between worldviews and affective evaluations of nuclear power, worldview theory has not been related to negative emotion or negative emotion appraisals in past studies. Based on this past research, we will examine whether information about risks may be filtered and interpreted through worldviews such that negative emotion appraisals are systematically related to them.

1.2 Risk Perceptions and Stigma

In this paper we examine not only risk perceptions of various radiation sources but also the extent to which each radiation source appears to be stigmatized. Researchers have not agreed yet on a precise definition of technological stigma. Kasperson, Jhaveri, and Kasperson (2001) defined it as “a mark placed on a person, place, technology, or product, associated with a particular attribute that identifies it as different and deviant, flawed, or undesirable” (p. 19). While stigma can be defined in terms of market impacts (e.g., on the local economy, real estate prices), a wholly economic viewpoint overlooks the “complex interplay of psychological, social and political forces” (Gregory et al., 1995, p. 222) that produces stigma. Stigma certainly has a strong negative emotional component. People are fearful of stigmatized objects and places; they can be angry about them as well. We do not just feel a stigma response, however. We also have distinct thoughts about stigmatized objects that may relate to more general cognitive structures with which we seem to organize our world (e.g., worldviews, Dake, 1991; Peters & Slovic, 1996). Fischhoff (2001) characterized stigma as reflecting “a moral statement of what constitutes unacceptable behavior” (p. 367). In the present paper we take this definition of stigma as something that is disgraceful and unacceptable, and we examine a model of the possible emotional and cognitive prerequisites for the generation of a stigma response.

Figure 3. Emotion-based model of stigma susceptibility.

Emotion-Based Model of Stigma Susceptibility. In the proposed theory, stigma responses are generated by the activation of negative emotion through emotional appraisals. These appraisals, as described earlier, are due to interpretations of events and circumstances (e.g., linked to a radiation source) and are the building blocks of emotion. We also propose, however, that information relevant to the appraisals is filtered first through individual characteristics (i.e., affective reactivity and cognitive worldviews). For this proposed theory, we draw upon recent claims that affective reactivity and cognitive worldviews bias subsequent information processing (e.g., LeDoux, 1996; Panksepp, 1998; Dake, 1991; Gray, 1990; Carver & White, 1994; Peters & Slovic, 1996) and upon evidence that emotions such as fear and anger are defined by a set of central dimensions (Smith & Ellsworth, 1985). Both affective reactivity and worldviews are expected to activate cognitive predispositions to appraise events in systematic ways that can result in the generation of negative emotion, risk perceptions, and, ultimately, stigma responses. We call this process *stigma susceptibility*. Stigma susceptibilities are goal-directed processes through which information about events are interpreted and result in the generation of an emotion and its subsequent motivations and action tendencies. The stigma-susceptibility hypothesis asserts that cognitive appraisals of emotion and the potential for stigma responses are influenced not only by events in the world around us, but also by our individual proclivities. Thus, two persons can be witness to the same series of events, but appraise them quite differently due to individual or cultural differences, and experience qualitatively-different emotions and their ensuing action tendencies. Likewise, two events, alike in some ways but different on particular dimensions important to the appraisal process, can occur and activate different appraisals, resulting in different emotional experiences. The appraisals, however constructed, will determine the quality of the emotion felt; the negative emotion will determine the extent of perceived risk and stigma. Risk perception and negative emotion, thus, are thought to be highly related but not synonymous. See Figure 3.

Stigma responses also reflect an evaluation that some object or activity is too risky. Several theories of risk now posit that risk perceptions are influenced by interactions of affect and cognition (Johnson & Tversky, 1983; Loewenstein, 1996; Loewenstein, Weber, Hsee, & Welch, 1999; Lopes, 1987; Mann, 1992; Slovic et al., in press). Thus, risk is modeled as being impacted by negative emotion and having a direct impact on stigma. We believe that this combination provides a parsimonious (although preliminary) model of the generation of a stigma response.

Hypothesized Relations Between Individual Differences and Emotional Appraisals. The BIS has been related to the experience of negative feelings and therefore it may influence cognitive appraisals integral to the generation of negative emotion. Questions remain, however, about the types of information to which it is sensitive. The experience of fear and anger, central to responses towards stigmatized radiation sources, has been characterized along a number of appraisal dimensions with fear and anger sharing some similar appraisals (events that result in fear or anger are appraised as less pleasant, more important, requiring more coping, and as caused by another more than the self). Activation of the BIS might make interpretations along some or all of these dimensions more likely. BIS theory has been silent on the specific appraisal dimensions that might be influenced, but Gray (1990) has long been a proponent of the inseparability of cognitive and emotional systems. He argues that all the basic cognitive processes have arisen, through evolution, in relation to the handling of emotional information, and, as a result, are likely to be closely related to the emotion systems. Animal studies of the BIS have indicated that activation of this system results in the inhibition of ongoing activities, increased arousal, and increased attention to environmental cues. As a result, one might expect that increased activation of the BIS would be related to increased unpleasantness, increased importance of the object (related to the increased attention) and an increase in the perception that others rather than self cause the event and are responsible and have control over its impact on the individual's life (thus, the individual cannot control but can avoid the negative events).

Worldviews have not been associated with emotion appraisals prior to the present research, but it has been hypothesized and found that affect and attitudes toward technologies such as nuclear power were systematically related to worldviews. For example, Peters & Slovic (1996) found that individuals high (vs. low) in egalitarianism reported more negative affect towards nuclear power and were less likely to support that technology. Cultural theory suggests that worldviews help people interpret the world in such a way as to maintain their system of beliefs and moral codes (Dake, 1992). As a result, worldviews are expected to act to filter information that leads to appraisals of negative emotion and stigma responses. In the present research, we included the worldview measures (hierarchy/fatalism, individualism, and egalitarianism) used in past research (Peters & Slovic, 1996).

High vs. low hierarchs are hypothesized to foster the view that nature is robust to a point and that sustainable development is the rational environmental strategy. Fatalism is confounded with hierarchy in the scale used in the present study. High vs. low fatalists are hypothesized to be resigned to stringent controls on their behavior and to have a “why bother?” attitude towards risks such as those represented in the stigmatized set. Because fatalists are resigned and hierarchs have been shown to trust the government and experts, it is hypothesized that individuals scoring high vs. low on this scale will perceive the stigmatized objects as more positive, less important, and requiring less coping in the future. High vs. low egalitarians, on the other hand, tend to have higher risk perceptions and may be particularly susceptible to stigma responses to the stigmatized radiation sources in the present study. Because they frame risk-related issues in ethical terms and tend not to trust the government or experts, they may be more likely to have anger responses as well as fear responses to these radiation sources (anger is an ethical statement). Individuals scoring high versus low on this scale were expected to view these radiation sources as more unpleasant, more important, and requiring more coping. Individualists value decisions stemming from personal judgment so high vs. low scores on this factor may be associated with greater self — rather than other — responsibility and control (causation). High versus low individualists tend to believe that people will produce the abundance that would make up for any hazards that are created in the process. As a result, high versus low scores on this scale also are expected to be associated with less importance of these radiation sources, as requiring less coping, and as more pleasant since the technologies are merely serving their purpose in a free market economy.

In the present experiment, we examine whether responses to stigmatized radiation sources may be created by an interaction between how individuals feel (an affective response) and what they think (a cognitive process) about the stigmatized object. While generally characterized as an “extreme case of either [a] risk-avoidance or negative-imagery process” (Easterling, 1997, p. 638), stigma appears to have a strongly negative emotional component and to be associated with distinct thoughts about the risks and what they mean. In the present paper we examine one possible model of the emotional and cognitive prerequisites of stigma. Stigma is operationalized as “a moral statement of what constitutes unacceptable behavior” (Fischhoff, 2001, p. 367), and, specifically, as a belief that something is disgraceful, unacceptable in general, and unacceptable under any imaginable circumstances.

2. Methodology

Final study participants ($N = 198$) responded to a series of 15 objects and activities including radiation sources (nuclear power plants, radiation from nuclear weapons testing, radioactive waste from nuclear power plants, sun-tanning, radiation therapy for cancer control, radiation to prevent bacteria in food (i.e., food irradiation), radiation from air travel, microwave ovens, medical x-rays, natural background radiation, and cosmic radiation) and other miscellaneous objects thought to be associated with particular emotion states (death of your favorite pet, spring break this year, final exams this term, a series of thefts or crimes in your neighborhood). The non-radiation items were added to provide context and were not analyzed further. The radiation sources were thought a priori to consist of both stigmatized and non-stigmatized sources. For each object or activity, participants provided ratings on 17 scales designed to tap into feelings, emotional appraisals, risk perceptions, and stigma. At the end of the task, participants provided self-report ratings of affective reactivity and worldviews.

All stimuli were rated on 9 scales designed to represent specific emotion appraisals (PLEASANTNESS: I feel bad or good about it; PREDICTABILITY: its aftereffects are unpredictable or predictable; CAUSATION: others are responsible/have control over its impact on my life and I am responsible/have control over its impact on my life; COPING POTENTIAL: it will require a lot or a little effort from me in the future and I can or cannot adjust to whatever happens; and IMPORTANCE: it is not at all or very important). Participants also responded to two discrete emotions — how ANGRY and AFRAID they were about each item as well as rating how RISKY each item was for the American public. Participants responded to five stigma items including how DISGRACEFUL, IMMORAL/MORAL, UNACCEPTABLE/ ACCEPTABLE, AND STIGMATIZED each item appeared to be. Participants were also asked if they could IMAGINE A SITUATION in which the item might become acceptable if it was not already. Two of the items (STIGMATIZED and IMMORAL/MORAL) were dropped from further analyses due to the large number of non-responses. Each of the items is shown in Appendix A; all items were assessed on 5-point scales. Finally, participants responded to items on negative and positive affectivity scales (BIS negative reactivity, Carver & White, 1994; Big-5 extraversion for positive reactivity, Saucier, 1994; see Appendix B for items), and worldview scales (Peters & Slovic, 1996). The survey took approximately 40 minutes to complete.

Table 1. Means for Stigma, Perceived Risk, Negative Emotion, and Pleasantness for Each Stimulus Item

Stimulus items	Stigma	Perceived risk	Negative emotion	Pleasant-ness	Cognitive appraisals of emotion			Predicta-bility
					Import-ance	Coping	Causation	
Stigmatized radiation sources (used in subsequent analyses)								
radioactive waste from nuclear power plants		3.0	2.8	-1.6				1.7
radiation from nuclear weapons testing		2.9	2.7	-1.6				1.7
nuclear power plants		2.9	2.3	-0.8				2.0
Means for stigmatized radiation sources	1.9	2.9	2.6	-1.3	2.2	0.8	4.7	1.8
Non-stigmatized radiation sources and other items								
a series of thefts or crimes in your neighborhood		2.3	2.6	-1.4				1.5
radiation to prevent bacteria in food (i.e., food irradiation)		2.2	1.8	-0.3				1.7
sun-tanning		2.4	1.1	-0.3				2.8
radiation therapy for cancer control		2.2	1.4	0.6				1.9
final exams this term		1.0	1.6	-0.4				2.3
radiation from air travel		1.9	1.6	-0.7				1.7
spring break this year		0.9	0.3	1.4				2.3
medical x-rays		1.3	0.9	0.4				2.5
cosmic radiation		1.3	1.0	-0.3				1.5
microwave ovens		1.3	0.8	0.5				2.2
death of your favorite pet		1.0	2.2	-1.6				2.1
natural background radiation		1.1	0.8	-0.1				1.7
Means for non-stigmatized radiation sources	0.3	1.6	1.0	0.1	1.6	-0.8	-0.7	2.1
Significant difference between stigmatized and non-stigmatized radiation sources	t = x; p < x	t = x; p < x	t = x; p < x	t = x; p < x	t = x; p < x	t = x; p < x	t = x; p < x	t = x; p < x

3. Results

Before further analyses, summary variables were constructed. A single measure of stigma was calculated from the average of responses to Disgraceful, Unacceptable, and Cannot imagine ever acceptable ($\alpha = .xx$).¹ Negative Emotion was calculated from the average of Angry and Fearful ($\alpha = .xx$). As predicted and shown in Table 1, the three radiation sources thought a priori to be stigmatized were rated as significantly higher than the other radiation sources on the measure of stigma (stigma mean for the top 3 radiation sources = 1.9; for the other radiation sources = 0.3; $p < .xx$). Stigmatized radiation sources were perceived as higher in risk, greater in negative emotion, and more unpleasant than non-stigmatized radiation sources.

Summary variables also were constructed for 2 of the 5 appraisals. CAUSATION consists of the average of “others are responsible,” “others have control,” the reverse of “I am responsible,” and the reverse of “I have control.” As a result, a higher CAUSATION score would indicate a belief that others cause the impact of the technology on the subject’s life while lower scores suggest a belief that the subject causes its impact. COPING refers to the perception of how much coping will be required; it consists of the average of “it will require a lot of future effort” and the reverse of “I can adjust to the situation.” As a result, higher scores indicate a belief that possible situations produced by the radiation source will require more coping in the future.

The stigmatized and non-stigmatized radiation sources differed on cognitive appraisals as expected based on the elicited emotion. Stigmatized sources were perceived as less pleasant, more important, requiring greater coping, and as being caused by others rather than the self. The two types of sources did not differ on predictability of their aftereffects. This finding also is expected because subjects were both more fearful and more angry about stigmatized versus non-stigmatized sources. Because appraisal theories hypothesize greater predictability of aftereffects in the presence of more anger and less predictability in the presence of more fear, the impact of more fear *and* anger on predictability should cancel out.

¹ Results of an earlier pilot study guided the design of the final study. Anger and fear were found to best represent feelings towards the sources thought to be stigmatized; we also found that we needed a direct measure of stigma. Results of the pilot study ($N = 51$) were quite similar to the present ones.

Table 2. Correlations of Individual Differences in Negative Reactivity and Worldviews with Perceptions of Radiation Sources¹

	Stigmatized radiation sources				Non-stigmatized radiation sources			
	Worldviews				Worldviews			
	Negative reactivity (BIS)	Hierarchical / Fatalistic	Individualistic	Egalitarian	Negative reactivity (BIS)	Hierarchical / Fatalistic	Individualistic	Egalitarian
Stigma	.20	-.35	-.40	.36			-.19	
Risk perception	.16	-.30	-.35	.30		-.15		.15
Negative emotion	.18	-.32	-.33	.32				.16
Pleasantness	-.17	.33	.45	-.33		.28	.45	-.21
Importance		-.17	-.18	.18			.14	
Coping		-.18	-.23	.21				
Causation	.23	-.21	-.24		.15			
Predictability								

¹Correlations are shown if they are significant at least at the .05 level.

Also as expected, individual differences in worldviews as well as negative reactivity were associated with ratings of the stigmatized radiation sources. Individuals high versus low in negative reactivity perceived greater stigma, greater risk, more negative emotion, and less pleasantness. The Hierarchical/Fatalist measure related similarly to the Individualist measure and the reverse of the Egalitarian measure. Participants high versus low on the former and middle scales and low versus high on the latter scale perceived less stigma, lower risk, less negative, and more pleasantness concerning the stigmatized sources. As can be seen in Table 2, associations with the non-stigmatized sources were less consistent and were always smaller than those with the stigmatized sources (there was one exception — the correlation between Individualism and Pleasantness was identical, $r = .45$, for both types of radiation sources).

Figure 4. Hypothesized path model.

3.1 Stigma Susceptibility — Structural Equation Models

Overview of Model Results. Radiation sources that scored higher on a measure of stigma were considered in further analyses (i.e., nuclear power plants, radioactive waste from nuclear power plants, radiation from nuclear weapons testing). In general, the results of structural equation models supported the hypotheses. Individual differences in negative reactivity and worldviews were associated with the strength of negative emotion towards stigmatized radiation sources. The inclusion of emotional appraisals greatly increased the prediction of negative emotion. As hypothesized, the model fit the data better with perceived risk as a function of negative emotion rather than vice versa; risk perception was related only indirectly to individual differences in affective reactivity and worldviews. Finally, stigma itself was associated with negative emotion and, to a lesser extent, with risk perceptions. The model fit the responses of both males and females. Some gender differences did exist and may provide clues into what underlies gender differences in risk perceptions.

The Hypothesized model shown in Figure 4 did not fit the data adequately, as indicated by the various fit indices (NFI = .90, CFI = .94) and the chi-square test statistics [χ^2 (37, $N = 198$) = 92.92, $p = .00$]. Two modifications to the Hypothesized Model were needed in order to provide an adequate fit — two paths were added, from Pleasantness to Risk and from Pleasantness to Stigma. Figure 5 contains the Modified Model. The resulting model adequately fits the data, as indicated by the various fit indices (NFI = .96, CFI = .99) and the chi-square test statistics [χ^2 (35, $N = 198$) = 40.31, $p = .25$]. Note that adding the path from Pleasantness to Stigma increases the explained variation of Stigma from 59% to 66% but renders the path from Risk to Stigma non-significant.

Figure 5. Modified path model.

As can be seen in Figure 5, individual differences in worldviews were correlated with one another. Hierarchy/Fatalist scores correlated positively with Individualism scores ($r = .48$, $t = 6.11^2$, $p < .01$) and negatively with Egalitarianism scores ($r = -.33$, $t = -4.34$, $p < .01$). Individualism and Egalitarianism scores also correlated negatively ($r = -.25$, $t = -3.37$, $p < .01$). Individual differences in Negative Reactivity did not correlate significantly with any of the worldview measures.

² These t-values are actually critical ratios; our analyses were conducted with AMOS which uses an estimated standard error rather than the actual standard error in calculations.

Table 3. Error Covariances for Modified Path Model

	e4	e5	e6	e7
e4	—			
e5	–.33*	—		
e6	–.39*	.27*	—	
e7	–.22*	.15*	.50*	—

* $p < .05$

Because we were measuring objects that were feared and that angered, appraisals shared by fear and anger were expected to correlate. As a result, we allowed the errors of the Appraisal measures to covary. Table 3 contains the correlated errors for the measures of Appraisal. Because increases in anger and fear should have opposite effects on Predictability, we did not correlate it with the other measures in Figure 3 nor did we include it in any further analyses.

The Individual Difference measures combined to explain 25% of the variation in Pleasantness. Both Individualism ($\beta = .37, t = 5.26, p < .00$) and Egalitarianism ($\beta = -.21, t = -3.42, p < .00$) significantly predicted Pleasantness, while the Hierarch/Fatalist ($\beta = .05, t = 0.74, p > .10$) and Negative Reactivity ($\beta = -.09, t = -1.50, p > .10$) measures did not.

Negative Reactivity ($\beta = .19, t = 2.82, p < .01$) and Individualism ($\beta = -.22, t = -3.21, p < .01$) combined to explain 8% of the variance in Causation. Egalitarian ($\beta = .15, t = 2.20, p < .05$), Individualism ($\beta = -.18, t = -2.32, p < .05$), and Hierarch/Fatalist ($\beta = -.01, t = -0.18, p > .10$) scores combined to explain 7% of the variation in Coping. Although none of the paths were significant, Hierarch/Fatalist scores ($\beta = -.06, t = -0.73, p > .10$), Individualism ($\beta = -.12, t = -1.46, p > .10$), Egalitarian ($\beta = .13, t = 1.72, p < .10$), and Negative Reactivity ($\beta = .07, t = 1.16, p > .10$) combined to explain 6% of the variance in Importance.

The Appraisal measures combined to explain 56% of the variance in Negative Emotions. Coping ($\beta = .34, t = 5.73, p < .00$) and Pleasantness ($\beta = -.33, t = -5.95, p < .00$) had the strongest relationship with Negative Emotions followed by Importance ($\beta = .22, t = 3.92, p < .00$) and Causation ($\beta = .12, t = 2.26, p < .05$). Negative Emotions ($\beta = .71, t = 14.69, p < .00$) and Pleasantness ($\beta = -.35, t = -6.48, p < .00$) combined to explain 70% percent of the variation in Risk. Negative Emotions ($\beta = .71, t = 14.69, p < .00$), Pleasantness ($\beta = -.35, t = -6.48, p < .00$), and Risk ($\beta = .11, t = 1.41, p > .10$) combined to explain 66% percent of the variation in Stigma.

Figure 6. Alternative stigma model.

Alternative Stigma Model

Figure 6 is the Alternative Stigma Model and only differs from the previous model (Figure 5) in one way; the path from Negative Emotions to Risk has been reversed so that Risk predicts Negative Emotions. The Alternative Stigma Model does not adequately fit the data, as indicated by the various fit indices (NFI = .92, CFI = .95) and the chi-square test statistics [χ^2 (35, $N = 198$) = 80.73, $p = .00$].

The path from Risk ($beta = .63$, $t = 13.26$, $p < .00$) to Negative Emotions is strong and increases the explained variation of Negative Emotions from 52% to 72%. In the context of the Risk, the paths from Importance ($beta = .16$, $t = 3.26$, $p < .01$) and Coping ($beta = .19$, $t = 4.01$, $p < .00$) to Negative Emotions remained significant but were smaller in magnitude than in the previous model (Figure 5). In the context of Risk, the paths from Pleasantness ($beta = -.10$, $t = -1.91$, $p < .10$) and Causation ($beta = .02$, $t = 0.39$, $p > .10$) to Negative Emotions became non-significant.

The explained variation of Risk drops from 70% (Figure 2) to 37% (in Figure 6). The path from Pleasantness ($beta = -.61$, $t = -10.85$, $p < .00$) to Risk was quite strong. The Modification Index indicates that adding paths from Coping and Causation to Risk would significantly improve the fit of the model to the data.

Table 4. Direct, Indirect, and Total Effects in Linear Recursive Models

Dependent variable	Predetermined variable	Total effect	Standardized beta values			
			Indirect effects via:			
			Appraisals	Negative emotion	Risk	Direct effect
Pleasantness Adj R ² = .26	Negative reactivity	-.12	—	—	—	-.12
	Egalitarianism	-.21**	—	—	—	-.21**
	Individualism	.34****	—	—	—	.34****
	Hierarch/Fatalism	.09	—	—	—	.09
Causation Adj R ² = .05	Negative reactivity	.23***	—	—	—	.23***
	Egalitarianism	—	—	—	—	—
	Individualism	—	—	—	—	—
	Hierarch/Fatalism	—	—	—	—	—
Coping potential Adj R ² = .07	Negative reactivity	—	—	—	—	—
	Egalitarianism	.16*	—	—	—	.16*
	Individualism	-.16*	—	—	—	-.16*
	Hierarch/Fatalism	-.05	—	—	—	-.05
Importance Adj R ² = .05	Negative reactivity	.11	—	—	—	.11
	Egalitarianism	.12	—	—	—	.12
	Individualism	-.10	—	—	—	-.10
	Hierarch/Fatalism	-.08	—	—	—	-.08
Negative emotion Adj R ² = .58	Negative reactivity	.14*	.10	—	—	.04
	Egalitarianism	.21**	.13	—	—	.08
	Individualism	-.19**	-.18	—	—	-.01
	Hierarch/Fatalism	-.16*	-.08	—	—	-.08
	Pleasantness	-.28****	—	—	—	-.28**
	Causation	.10*	—	—	—	.10*
	Coping potential	.34****	—	—	—	.34****
	Importance	.20***	—	—	—	.20***
	Negative emotion	—	—	—	—	—
Risk Adj R ² = .70	Negative reactivity	.12	.10	.03	—	-.01
	Egalitarianism	.19**	.12	.05	—	.02
	Individualism	-.23**	-.19	.00	—	-.04
	Hierarch/Fatalism	-.12	-.07	-.04	—	.01
	Pleasantness	-.34****	—	-.20	—	-.14**
	Causation	.16**	—	.07	—	.09*
	Coping potential	.26****	—	.23	—	.03
	Importance	.10	—	.14	—	-.04
	Negative emotion	.69****	—	—	—	.69****
Stigma Adj R ² = .67	Negative reactivity	.16**	.10	.01	.00	.05
	Egalitarianism	.23***	.13	.04	.01	.06
	Individualism	-.25***	-.20	.00	.00	-.05
	Hierarch/Fatalism	-.16*	-.07	-.04	.00	-.05
	Pleasantness	-.43****	—	-.14	-.01	.28****
	Causation	.09	—	.05	.01	.03
	Coping potential	.29****	—	.17	.00	.12*
	Importance	-.01	—	.10	.00	-.11*
	Negative emotion	.48****	—	—	.05	.43****
	Risk	.08	—	—	—	.08

* $p < .05$; ** $p < .01$; *** $p < .001$; **** $p < .0001$

3.2 Linear Recursive Models

The result of a different statistical technique — linear recursive modeling — confirmed the general results of the structural equation models. This technique relies on a series of regression analyses constructed so that the total, direct, and indirect effects of each variable on the others in the model can be calculated.

As indicated in Table 4, higher scores in Egalitarianism and lower scores in Individualism were associated with appraisals of less Pleasantness. No individual difference related to the Predictability appraisal; individuals high versus low in negative reactivity appraise others rather than the self as causing whatever happens with the radiation source. Higher scores in Egalitarianism ($p < .05$) and lower scores in Individualism ($p = .06$) were associated with greater coping being needed. No individual difference measure was associated significantly with the Importance appraisal.

The individual difference measures each had a significant total effect on negative emotion, as expected, but most of the effects were indirect through the appraisals to that there were no significant direct affects of individual differences on negative emotion. As hypothesized, however, 4 of the 5 appraisals provide direct explanatory power of the experience of negative emotion towards stigmatized radiation sources (the fifth appraisal, certainty, was predicted to have no effect because participants felt both anger and fear, and there are opposing predictions about certainty on the experience of anger and fear).

In terms of risk perceptions, higher Egalitarian scores and lower individualistic scores were associated with higher risk perceptions; these effects were indirect through the emotional appraisals. The emotional appraisals had some direct effects on risk perceptions as well as indirect effects through negative emotion. Similar to the SEM results, decreased Pleasantness ratings were associated directly with increased risk perceptions ($beta = -.14$). Negative emotion had a very large effect on risk perceptions ($beta = .69$).

Stigma ratings were influenced indirectly (mostly through the appraisals) by each of the individual difference measures; these measures provided no significant direct influences, however. The biggest predictors of stigma ratings were pleasantness (i.e., affect) and negative emotion (the betas of the direct effects were $-.28$ and $.43$, respectively). Risk perceptions did not add significantly to the prediction of stigma after taking into account the other variables.

3.3 Gender Differences in Stigma Model

In order to test for gender differences we ran the Modified Model (Figure 5) as a stacked model in which parameters for males and females were estimated simultaneously. The Stacked Model fits the data, as indicated by the fit indices (NFI = .92, CFI = .99) and the chi-square test statistics [χ^2 (70, N females = 91; N males = 107) = 79.52, p = .20].

Of the Individual Difference measures that were used to predict the Appraisal measures, the path from Individualism to Importance ($\beta = -.29$ females, $\beta = .02$ males, $t = 2.00$) differed significantly by gender. For females, higher Individualism scores were associated with lower ratings of the importance of these radiation sources to their lives; these variables were unrelated for males. The path from Coping to Negative Emotions ($\beta = .18$ females, $\beta = .45$ males, $t = 2.07$) also differed significantly by gender. Feeling that the stigmatized radiation sources would require greater coping was more predictive of Negative Emotions for males than females. No other paths differed significantly between the gender.

There were significant gender differences for the variances of Negative Emotions ($D = .76$ females, $D = .46$ males, $t = -2.33$), and Pleasantness ($D = .28$ females, $D = .44$ males, $t = 2.16$). In other words, the model explained the data for males better than females.

The correlations of Individualism with Hierarch/Fatalist ($r = .36$ females, $r = .56$ males, $t = 2.23$), and Individualism with Egalitarianism ($r = -.05$ females, $r = -.39$ males, $t = -2.60$) differed significantly by gender. Finally, the correlations between the error terms of Pleasantness (e4 with e5) and Causation ($r = -.17$ females, $r = -.39$ males, $t = -2.18$) differed significantly by gender.

4. Conclusion

Results of the present experiment supported our hypotheses that radiation-related stigma responses may be created by an interaction between how individuals feel (an affective response) and what they think (a cognitive process) about the stigmatized object. While generally characterized as an “extreme case of either [a] risk-avoidance or negative-imagery process” (Easterling, 1997, p. 638), stigma appears to have a strongly negative emotional component and to be associated with distinct thoughts. People were fearful of and angry about stigmatized

objects and places. These fear and anger responses were associated with individual differences, emotional appraisals, and risk perceptions as hypothesized.

We proposed a new theory of stigma susceptibility in which stigma responses are generated by an activation of risk perceptions (of potential hazards or threats) and negative emotion (fear and anger). The negative emotion results from tendencies to feel negative affective reactions and to hold particular worldviews as well as from emotional appraisals of the object itself. We proposed and supported an hypothesis that individual differences in negative reactivity and worldviews activate cognitive predispositions so that events are experienced in systematic ways that result in the generation of negative emotion and stigma responses. We call this process *stigma susceptibility*. Stigma susceptibilities are goal-directed processes through which information about events are interpreted and result in the generation of an emotion and its subsequent motivations and action tendencies. The stigma-susceptibility hypothesis asserts that emotional appraisals and the potential for stigma responses are influenced not only by events in the world around us, but also by our individual proclivities. Thus, two persons can witness the same series of events, but appraise them quite differently due to individual or cultural differences. As a result, they will experience qualitatively-different emotions and will tend to behave differently. The appraisals, however constructed, will determine the quality of the emotion felt, the perceived risks, and the stigma response.

Results of structural equation models as well as linear recursive models supported the hypotheses. Radiation sources that scored higher on a measure of stigma were considered in the analyses (e.g., radioactive waste from nuclear power plants, radiation from nuclear weapons testing). Participants rated these stigmatized radiation sources as being higher in negative emotional reactions (fear and anger), greater in perceived risk, and more unpleasant than non-stigmatized sources. Individual differences in negative reactivity and worldviews were associated with the strength of negative emotion towards stigmatized radiation sources. The inclusion of emotional appraisals greatly increased the prediction of negative emotion. Perceived risk was a function of negative emotion, but not of individual differences in affective reactivity or worldviews as has been found in past studies. Finally, stigma itself was associated with negative emotion and, to a lesser extent, with risk perceptions. When a path was added from affect (or pleasantness) to stigma, risk perceptions no longer added significant explanatory power to the perception of stigma.

Not all of our predictions were supported. For example, we expected that higher individual difference scores of negative reactivity would be associated with less perceived Pleasantness (i.e., greater negative affect), particularly because higher negative reactivity scores were associated with fewer high-loss choices in previous experiments (Peters & Slovic, 2000). We were surprised that this relation was nonsignificant after taking into account the other variables (although the direct correlation between Pleasantness and negative reactivity was significant). Greater negative reactivity scores were associated with increased perceptions that others rather than the self were responsible for the radiation sources. It may be that negative reactivity leads to a more specific appraisal of “I can’t control this and therefore I must avoid it” more than it does to the more general appraisal of negative affect.

The amount of variance in the appraisals that was predicted by the individual differences, while significant, was fairly small (ranging from 6% to 25%). Pleasantness, or affect, was explained the best by far. This finding suggests that the factors underlying and creating these emotional appraisals are influenced by individual differences but, not surprisingly, that situational differences also likely play a major role.

The appraisals themselves predicted negative emotion quite well. Fifty-seven percent of the variance in negative emotion was predicted by the four hypothesized appraisals; 70% and 66% of the variance in risk perceptions and stigma, respectively, were predicted by the model. Affect, or pleasantness, appears to play a particularly important role. It provided significant independent explanatory power of negative emotion as hypothesized, but also independently, it provided additional explanatory power for risk perceptions and stigma, over and above the power provided by negative emotion. Affect appears to play a fundamental role in risk perceptions and stigma responses.

The same model predicted male as well as female responses although male responses were predicted somewhat better. Although we expected that negative emotion might have predicted risk perceptions more for females than males based on past research findings of women being more emotional (Doherty et al., 1995), the data did not support the hypothesis. However, some significant gender differences did emerge at the level of individual differences and emotion appraisals. Specifically, as Individualism scores for women increased, their perceptions of the radiation sources’ importance declined; no such relation existed for men. The perception of more

coping being needed, however, was associated with greater negative emotion more for men than women. These findings will need to be explored further in future research.

These results suggest several important conclusions. First, stigma responses appear to be inextricably linked with emotional responses that can be predicted, in part, by specific appraisals of the technology. Technologies may be different in their susceptibility to these appraisals. Second, some individuals appear to be more susceptible to the generation of stigma responses, due either to individual differences in affectivity or worldviews or to differences in appraisals. Risk communication about stigmatized objects may benefit from a more complete understanding of how emotional belief systems are constructed and the routes through which they affect responses and behaviors. Third, cognitive appraisal theories of emotion appear to be linked to individual differences. Finally and fourth, these same appraisal theories appear to be applicable to affective reactions of specific stimuli (as opposed to being applicable only to full blown emotion states). The application of appraisal theories in this manner should help theorists to gain a greater understanding of the impact of emotion on risk perceptions and the processes that underlie phenomena such as gender differences in risk perception.

Fischhoff (2001) characterized stigma as a moral statement. He suggests three routes to reducing stigma: 1) moral persuasion, 2) convincing people that their general stigma rules do not apply to a specific situation, and 3) convincing people that while their general stigma rule applies in principle, it does not apply in practice. Stigma, as an emotional response, leads us to alternative routes to reducing stigma: 1) changing the affective associations with a specific situation, 2) changing the emotional appraisals of the technology and/or the situation within which it is appraised, and 3) influencing media presentations of the emotional appraisals in order to amplify or attenuate the appraisals and resulting emotion, risk perceptions, and stigma.

Future research should examine the relationship between how the media portray technologies on each of the appraisal dimensions and how those technologies are perceived. Experiments could also attempt to alter the appraisals directly.

Low Dose, Risk, Decisions, & Risk Communication

An Emotion-Based Model of Stigma Susceptibility

Appendix A Sample Items from Each of the Scales Used

Appraisals

GOOD/BAD. For each situation or thing listed below, **please make a quick intuitive rating of how good or bad you feel about it** by circling a number from -2 = very bad to +2 = very good.

VERY BAD				VERY GOOD	
-2	-1	0	+1	+2	

PREDICTABLE / UNPREDICTABLE. Sometimes we feel like a situation or a thing will continue as expected; it's predictable. Other times, however, we feel as if we don't know what might happen; it's unpredictable. How predictable or unpredictable are the aftereffects of each of the following situations or things? For each one, please make a quick intuitive rating of how predictable or unpredictable you feel its aftereffects are by circling a number from 0 = very unpredictable to 4 = very predictable.

VERY UNPREDICTABLE			VERY PREDICTABLE		
0	1	2	3	4	

OWN INFLUENCE OR CONTROL. How much influence or control do you have over how much each of the following situations or things impacts your life? For each one listed below, **please indicate how much influence or control you have over its impact on your life** by circling a number from 0 = have no influence or control to 4 = have lots of influence or control.

**I HAVE NO
INFLUENCE OR
CONTROL**

**I HAVE LOTS OF
INFLUENCE OR
CONTROL**

0

1

2

3

4

SELF RESPONSIBLE. Overall, how responsible are you for the impact on your life of each situation or thing listed below? **Please make a quick intuitive rating of how responsible you are for the impact of each one on your life** by circling a number from 0 = not personally responsible at all to 4 = personally very responsible.

**NOT
PERSONALLY
RESPONSIBLE AT
ALL**

**PERSONALLY
VERY
RESPONSIBLE**

0

1

2

3

4

OTHERS' INFLUENCE OR CONTROL. How much influence or control do you have over how much each of the following situations or things impacts your life? For each situation or thing listed below, **please make a quick intuitive rating of the extent to which others influence or control the impact of each one on your life** by circling a number from 0 = have no influence or control to 4 = have lots of influence or control.

**OTHERS HAVE
NO INFLUENCE
OR CONTROL**

**OTHERS HAVE
LOTS OF
INFLUENCE OR
CONTROL**

0

1

2

3

4

OTHERS RESPONSIBLE. Overall, how responsible are others for the impact on your life of each situation or thing listed below? For each situation or thing listed below, **please make a quick intuitive rating of how much other individuals are responsible**

or not responsible for its impact on your life by circling a number from 0 = others are not responsible at all to 4 = others are very responsible.

**OTHERS NOT
RESPONSIBLE AT
ALL**

**OTHERS VERY
RESPONSIBLE**

0 1 2 3 4

ADJUST TO SITUATION. How well do you think you could adjust to the aftereffects (both good and bad) of what might happen? For each situation or thing listed below, **please make a quick intuitive rating of how well you could adjust to what could happen with each one** by circling a number from 0 = could not adjust at all to 4 = could adjust very well.

**COULD NOT
ADJUST AT ALL**

**COULD ADJUST
VERY WELL**

0 1 2 3 4

FUTURE EFFORT REQUIRED. Overall, how much of your effort (mental or physical) might each situation or thing require in the future? For each one listed below, **please make a quick intuitive rating of the extent of effort each one might require from you in the future** by circling a number from 0 = very little effort to 4 = a lot of effort.

**VERY LITTLE
EFFORT**

**A LOT OF
EFFORT**

0 1 2 3 4

IMPORTANCE. How important do you feel each situation or thing will be in your life? For each one listed below, **please make a quick intuitive rating of how important or unimportant each one will be in your life** by circling a number from 0 = not important at all to 4 = very important.

**NOT IMPORTANT
AT ALL**

VERY IMPORTANT

0 1 2 3 4

Negative Emotions

ANGRY. For each situation or thing listed below, **please make a quick intuitive rating of how angry you feel about it** by circling a number from 0 = not at all angry to 4 = very angry.

NOT AT ALL
ANGRY

VERY ANGRY

0 1 2 3 4

AFRAID. For each situation or thing listed below, **please make a quick intuitive rating of how afraid you feel about it** by circling a number from 0 = not at all afraid to 4 = very afraid.

NOT AT ALL
AFRAID

VERY AFRAID

0 1 2 3 4

Risk Perception

RISKY. For each situation or thing listed below, **please make a quick intuitive rating of how risky you feel it is to the American public** by circling a number from 0 = not at all risky to 4 = very risky.

NOT AT ALL
RISKY

VERY RISKY

0 1 2 3 4

Measures of Stigma

DISGRACEFUL. For each situation or thing listed below, **please make a quick intuitive rating of how disgraceful you feel it is** by circling a number from 0 = not at all disgraceful to 4 = very disgraceful.

NOT AT ALL
DISGRACEFUL

VERY
DISGRACEFUL

0 1 2 3 4

An Emotion-Based Model Appendix A: Sample Items from Each of the Scales

IMMORAL/MORAL. For each situation or thing listed below, **please make a quick intuitive rating of how moral or immoral you feel it is** by circling a number from -2 = very immoral to +2 = very moral. If the moral/immoral rating is not applicable to it, please circle "9" in the far right column.

VERY IMMORAL			VERY MORAL		Not Applicable
-2	-1	0	+1	+2	9

UNACCEPTABLE/ACCEPTABLE. For each situation or thing listed below, **please make a quick intuitive rating of how acceptable or unacceptable you feel it is** by circling a number from -2 = very unacceptable to +2 = very acceptable.

VERY UNACCEPTABLE			VERY ACCEPTABLE	
-2	-1	0	+1	+2

IMAGINE A SITUATION? For those situations or things listed below that seem unacceptable to you, can you imagine any social or economic situations under which it would become acceptable? For each situation or thing below that you find unacceptable, **please indicate whether you can imagine some situation in which it could become acceptable to you** by circling a number from 0 = can imagine no situations to 3 = can imagine many situations. If it is acceptable already, please circle "9" in the far right column.

NO IMAGINEABLE SITUATIONS		MANY IMAGINEABLE SITUATIONS		ACCEPTABLE ALREADY
0	1	2	3	9

STIGMATIZED. For each situation or thing listed below, **please make a quick intuitive rating of how stigmatized you feel it is** by circling a number from 0 = not at all stigmatized to 4 = very stigmatized.

NOT AT ALL STIGMATIZED			VERY STIGMATIZED	
0	1	2	3	4

Low Dose, Risk, Decisions, & Risk Communication

An Emotion-Based Model of Stigma Susceptibility

Appendix B Negative Reactivity (BIS) and Positive Reactivity (Extraversion) Items

BIS items (1 = *strongly disagree* to 4 = *strongly agree*)

If I think something unpleasant is going to happen, I usually get pretty “worked up.”

I worry about making mistakes.

Criticism or scolding hurts me quite a bit.

I feel pretty worried or upset when I think or know somebody is angry at me.

Even if something bad is about to happen to me, I rarely experience fear or nervousness. (r)

I feel worried when I think I have done poorly at something.

I have very few fears compared to my friends. (r)

Extraversion items

(1 = *extremely inaccurate self-description* to 9 = *extremely accurate self-description*)

Bashful (r)

Bold

Energetic

Extraverted

Quiet (r)

Shy (r)

Talkative

Withdrawn (r)

Ionizing Radiation:

A Tutorial on Sources and Exposures

Version 2.0

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Ionizing Radiation:

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This tutorial was compiled and edited by Donald MacGregor of Decision Research, Eugene, Oregon, USA. He received valuable assistance from several colleagues, including James Flynn, Paul Slovic, and Carrie Goodwin. In addition, the following technical experts have provided helpful commentary and review. Their contribution to the tutorial is very much appreciated.

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About Decision Research

Decision Research is a private, nonprofit research institute that conducts research on social response to environmental impacts and technological change. Support for the Institute's research activities comes from the National Science Foundation and other federal agencies, and from private foundations such as the Sloan Foundation and the Annenberg Foundation. Research projects undertaken by Decision Research are in the public interest and contribute to national policies for managing environmental health and safety risks. For more information about Decision Research, visit www.decisionresearch.org.

What is the purpose of this tutorial?

Radiation is a part of the environment in which we live, and comes from sources that are both natural as well as human-made. Although the physics of radiation provides a very rich body of knowledge about radiation and its sources, the biological effects of radiation are not as well understood, particularly at low doses. In a society that places a strong value on public involvement in environmental decisions, a need exists to better understand how to inform the public about radiation and its effects. Our research on risk communication focuses on how people receive, evaluate, and form positions on scientific information and its relationship to low-dose radiation exposure.

This tutorial was developed as part of an ongoing series of studies about how views and attitudes concerning radiation exposure are influenced by information presented in an educational format. The research seeks to understand more about the role of education in risk communication and how new findings from the science of low-dose radiation exposure are received by nonscientists.

Radiation is inherently a complex subject area with many barriers to understanding by nonscientists. Volumes can (and have) been written on the physics and health physics of radiation. The goal of this tutorial is to make the essence of radiation science accessible to lay readers within a reasonable time frame for reading and comprehension. Its length reflects a trade-off between the depth needed to communicate fundamental concepts, and the brevity needed to maintain readers' interest and attention. For purposes of our research, it is important that the tutorial present a background on radiation exposure and health effects that is consistent with what radiation scientists consider to be the essential education that nonscientists need to understand low-dose radiation exposure risks.

Notes. Throughout this tutorial, words that first appear in **bold** are further defined in the accompanying Glossary, which appears at the back of this notebook. You are welcome to refer to the Glossary at any time.

Please only write on the **blue response pages** in this notebook, not on the pages of the tutorial.

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Introduction

What Is Radiation?

Radiation is the movement of energy through space. For example, when you feel heat or warmth, you are actually experiencing the transfer of energy from some source to your body. As your body absorbs the energy, usually in the form of infrared radiation, you experience the feeling of heat.

Radiation is everywhere — in, around, and above the world we live in. We can think of it as the natural energy force that surrounds us. Radiation (the movement of energy through space) allows us to gain the benefits of light and heat from the sun. Human-made radiation in the form of electromagnetic waves is the basis for the transmission of radio and television signals. Cellular telephones rely on radiation as a carrier of information for communication.

In general, radiation is divided into the two broad categories of **ionizing radiation** and **non-ionizing radiation**. Ionizing radiation is called ionizing because it can knock **electrons** out of **atoms** and **molecules**, creating electrically charged particles called ions. Material that ionizing radiation passes through absorbs energy from the radiation, and through the process of **ionization** can change its chemical composition. You may recall from basic chemistry that the properties of a chemical are determined by its atomic and/or molecular composition. Changing the atomic or molecular structure of a chemical, such as by changing the number of electrons, changes what the chemical is and does.

There are two general forms of ionizing radiation: particles and rays. The most common types of particle radiation are **alpha particles** and **beta particles** emitted or radiated from some types of materials, both natural and human-made. Particle radiation is ionizing because the particles have sufficient mass and energy to at least partially break apart atoms that they strike.

Ionizing radiation also occurs in the form of rays. This type of radiation is pure energy without mass or charge. **Gamma rays** and **X-rays** are part of the electromagnetic energy spectrum (shown on page 3). The low end of the energy spectrum is *non-ionizing radiation*. This includes radio waves, microwaves, and visible light. At the high end, electromagnetic energy is ionizing.

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Ionizing radiation can be used for many beneficial purposes. For example, ionizing radiation in the form of X-rays is produced by X-ray machines, which are very useful for medical diagnosis. However, ionizing radiation can also cause serious, negative health effects. That is why ionizing radiation is one of the most intensively studied subjects in modern science. Most of our attention in this section will be focused on ionizing radiation — what it is, where it comes from, and some of its properties. All of our lives, perhaps without knowing it, we have reaped the benefits associated with non-ionizing radiation. For example, radio and television waves provide news and entertainment in the home, microwaves ease some cooking tasks, the light from electric light bulbs takes away the night, and the ultraviolet from grow lights brings an artificial sun indoors for our flowering plants. These are some forms of non-ionizing radiation.

*The gamma rays and X-rays emitted by radioactive materials are waves of pure energy. Like all electromagnetic waves, they travel at the speed of light and their energies are determined by their frequencies. Alpha and beta particles are not part of the **electromagnetic spectrum**. They travel at much less than the speed of light and their energies are functions of their velocities and masses. Source: Hall (2000).*

Types of Ionizing Radiation

Scientists have identified three distinct types of radiation. They were named after the first three letters of the Greek alphabet: α (alpha), β (beta), and γ (gamma).

Alpha particles are helium nuclei (2 protons, 2 neutrons).

Beta particles are speedy electrons.

Gamma radiation is a high-energy photon.

Source: Particle Data Group (2000).

How do the types of ionizing radiation differ?

Because it can knock electrons from the atoms and molecules in its path, ionizing radiation can cause chemical and/or physical changes in human tissue. However, the various types of ionizing radiation differ widely in their abilities to penetrate tissue and deposit energy in our bodies through ionization.

What are some properties of alpha particles?

Alpha particles, for instance, are relatively large and carry a double positive charge (helium nucleus). They are not very penetrating and can be stopped by a piece of paper. They travel extremely short distances in human tissue but deposit all their energies along their short paths, with the potential of doing a relatively large amount of damage along these paths.

What are some properties of beta particles?

Beta particles (electrons) are extremely small compared to alpha particles and carry a single negative charge. They are more penetrating than alpha particles, but can be stopped by thin aluminum metal. They travel much longer distances in human tissue and deposit much less energy along their paths.

What are some properties of gamma rays and X-rays?

Gamma rays and X-rays, having no mass or electrical charge (electromagnetic radiation), can travel extremely long distances in human tissue compared to particle radiation (alpha and beta). They deposit much less energy in our bodies along their paths, but can damage internal organs.

What Are Neutrons?

Neutrons are neutral atomic particles that carry no electric charge. They are produced in nuclear chain reactions (e.g., nuclear reactors, the nucleus of the sun), and can be highly penetrating.

Source: Hall (2000).

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How is ionizing radiation measured?

The basic unit for measuring radiation received is the *rad* (radiation absorbed dose). One rad equals the absorption of 100 **ergs** in every gram of tissue exposed to radiation. (An erg is an extremely small amount of energy. For example, it would take about 13.6 million ergs to raise a pound weight one foot.)

To show biological effect, rads are converted to **rems**. The rem (radiation equivalent man) is adjusted to take into account the type of radiation absorbed and the likelihood of damage from the different types of radiation. Exposures are normally in fractions of a rem, so the commonly used unit of exposure is the **millirem** (mrem).

$$1 \text{ millirem} = \frac{1}{1000} \text{ of a rem}$$

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Blue Response Page

Please Write Your Responses
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Before continuing, please complete the following brief quiz about the material you just read. You may review the material to help you answer the items.

Quiz #1

1. Which of the following is a form of ionizing radiation? [Check one box.]

- ☐₁ Microwaves
- ☐₂ Beta particles
- ☐₃ High-voltage power lines
- ☐₄ Visible light
- ☐₅ None of the above

2. People are exposed to ionizing radiation only from nuclear materials used by industry such as nuclear power reactors. [Check one box.]

- ☐₁ True
- ☐₂ False

3. Non-ionizing radiation is less harmful because it travels slower than the speed of light. [Check one box.]

- ☐₁ True
- ☐₂ False

4. Alpha particles are a form of ionizing radiation that penetrates human tissue very readily. [Check one box.]

- ☐₁ True
- ☐₂ False

5. Compared to alpha and beta particles, gamma rays distribute their energy over a longer path. [Check one box.]

- ☐₁ True
- ☐₂ False

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Sources of Ionizing Radiation

What Are Some Natural Sources of Ionizing Radiation?

There are a variety of pathways by which people are exposed to ionizing radiation. Cosmic radiation, immersion in and inhalation of indoor and outdoor air, exposure to radiation from rocks and soil, and ingestion of food and drink are most important.

Ionizing radiation sources originate from both natural and human-made sources.

The main natural sources are:

- **radon** and its **decay products** in the indoor atmosphere
- cosmic (radiation from outside the earth)
- the rocks and soils around us (and building material made of, e.g., granite), and
- the radioactive materials from the natural chemicals in our bodies.

The radiation from rocks and soil is often referred to as **terrestrial radiation**. The sum of the exposures from **cosmic radiation**, natural materials in the body, terrestrial radiation, and the radiation from radon in the atmosphere is called **natural background radiation**.

What Are Some Human-made Sources of Ionizing Radiation?

The main sources of exposure to human-made radiation are the X-rays and the radioactive **isotopes (radioisotopes)** used in medical practice. Other human-made sources include nuclear industry facilities, **fallout** from weapons testing, and consumer products, such as lantern mantles used for camping and household smoke detectors. Still other human-made sources are those related to technology. One example is ash from coal-fired power plants that contains the radioactivity originally present in the coal, but in more concentrated form. Other examples are increased terrestrial radiation from disturbing earth during construction and road building, and fertilizers made from **phosphates**.

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Ionizing Radiation Exposures

The average American is exposed to about 360 millirem of ionizing radiation per year. This average exposure comes from all sources, including natural sources, medical sources, and commercial and industrial sources.

The table below shows how much each source of ionizing radiation contributes to our average annual exposure. The exposure from radon and its decay products is listed under natural sources, although its effect is influenced by housing and building design. Also under natural sources are the sum of the exposures from cosmic radiation, terrestrial radiation, and internal radiation (e.g., through **potassium** and carbon in the body).

Radon is a radioactive gas that results from the decay of natural radioactive materials in the earth, such as **uranium**. Today's emphasis on energy efficiency has resulted in better-insulated but less well-ventilated buildings, thereby increasing the likelihood of higher indoor radon concentrations.

Ionizing Radiation Exposure in the United States		
Source	Estimated average annual whole-body exposure of the U.S. population (in millirems)	Percentage of average annual radiation exposure (360 millirems) from each source
<i>Natural sources</i>		
Radon	200	55%
Cosmic & terrestrial	58	16
Internal (body)	40	11
<i>Medical</i>		
Diagnostic X-rays	39	11%
Nuclear medicine	14	4
<i>Commercial & industrial</i>		
Consumer products	11	3%
Occupational exposures	<1	<0.05
Nuclear power fuel cycle	<1	<0.05
Weapons testing	<1	<0.05
Total	360 mrem	100%

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Before continuing, please complete the following brief quiz about the material you just read. You may review the material to help you answer the items.

Quiz #2

6. Which of the following is **not** a source of natural background radiation?
[Check one box.]

- ☐₁ Cosmic radiation
- ☐₂ Beta particles
- ☐₃ Uranium ore
- ☐₄ Coal ash

7. Most of the radiation exposure that people receive is from natural background sources. [Check one box.]

- ☐₁ True
- ☐₂ False

8 Radon is: [Check one box.]

- ☐₁ A source of non-ionizing radiation produced as a by-product of water treatment systems.
- ☐₂ A chemical used in household smoke detectors.
- ☐₃ A harmless gas found in swamps and estuaries that glows in the dark.
- ☐₄ A by-product of natural radiation decay in rocks and soils.

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Cosmic Radiation

Effect of Elevation, in Feet, on Cosmic Radiation Exposures (millirems per year)

0 (sea level)	26
500	27
1,000	28
2,000	31
4,000	39
6,000	52
8,000	74
10,000	107

Source: BEIR III (1980).

What is the average exposure from cosmic radiation?

Cosmic radiation originates outside the Earth's atmosphere and is composed of highly penetrating radiation of all sorts, both particles and rays. At sea level, the average annual exposure from cosmic radiation is 26 millirem, about 7% of an individual's total annual exposure who lives at that altitude. The table at left shows the effect of elevation on cosmic radiation exposures.

Because the atmosphere shields the earth from cosmic radiation, cosmic radiation exposure rises with increasing elevation. Therefore, passengers on a jet airplane receive additional radiation exposure from cosmic radiation during the flight. According to the National Council on Radiation Protection and Measurements, cosmic exposure at 39,000 feet is 0.5 millirem per hour. So a person taking a five-hour flight would receive about $2\frac{1}{2}$ millirems of additional radiation exposure from cosmic sources

Terrestrial Radiation (Natural Materials in the Earth)

What is the average U.S. exposure from terrestrial radiation?

The average exposure to an individual in the United States from terrestrial radiation is about 28 millirem per year. However, terrestrial exposures vary. On the coastal plains of the Atlantic and Gulf regions the average exposure is 16 millirem per year. In a region on the eastern slopes of the Rocky Mountains where Denver is located, the average terrestrial radiation exposure is 63 millirem per year. For the rest of the country, it is about 32 millirem per year, with little variation.

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Radon

How Much Radon Is in Our Air?

Radon concentration is measured in terms of picoCuries per liter of air. A picoCurie (pCi) is a unit of radioactivity that is 1 millionth of a millionth of a Curie. The USEPA considers indoor Radon levels above 4.0 pCi/L (10 times the free air average) to warrant action to reduce the concentration. This can include sealing basement floors and improving ventilation.

On average in the United States, the amount of Radon in the free air is 0.4 pCi/L. The average concentration of Radon in U.S. homes is 1.3 pCi/L, or about three to four times the amount in the free air.

Many new homes are designed with Radon abatement in mind, and utilize construction techniques that prevent Radon from entering living spaces.

What we know about the health effects of Radon comes largely from studies of underground miners, who work in environments with relatively high Radon levels. Based on such studies, the USEPA has set its action level at 4.0 pCi/L.

What is Radon?

Radon is a colorless and odorless gas that is a common element in our everyday environment. It comes from the breakdown or decay of natural radioactive materials (primarily uranium and radium) in rocks and soils. Radon and its decay products can enter buildings through their foundations and accumulate. For example, homes that are in a location where such gasses are prevalent may have relatively high concentrations of Radon. People are exposed to the ionizing radiation of Radon when they inhale the air in homes or buildings. In the United States, the majority of the radiation received by the general public is associated with natural Radon exposure.

How are people exposed to Radon?

Two factors influence the amount of Radon exposure that an individual receives. One factor is the location where a person lives. Not all locations in the United States emit the same amount of Radon gas. Some areas of the country have relatively large amounts of Radon, while others have relatively little. Even two houses, for example, side-by-side, may be built on ground that differs markedly in the amount of Radon being emitted. As a general guide, the map on the right shows average Radon in the atmosphere throughout the United States. Radon levels are relatively low in the southeastern states and the western parts of the northwest, including northern California. Levels are highest in the Rocky Mountain states, the plains states, and some parts of the northeast. The Radon levels shown in the map are free-air levels measured over relatively large areas. For any particular location on the map, such as a city block or homesite, the actual amount of radon may be higher or lower than is shown.

A second factor that influences the amount of Radon exposure an individual receives is how their home (and/or work location) is constructed and the amount of time they spend indoors. On average, the concentration of Radon in homes across the United States is about three to four times the amount in the free air. This is because Radon gas can seep up through cracks or gaps in foundations and build up in the interior. The amount of accumulation varies depending on (a) the amount of Radon at the location of the building, (b) the way the building is constructed (particularly its foundation), and (c) the amount of ventilation in the building. Homes with less ventilation will have greater Radon concentrations, all other factors being equal. The only way to know the amount of Radon in a home or building is through testing. The U. S. Environmental Protection Agency (USEPA) has set regulatory standards for the amount of Radon in homes and offices that is considered safe. The actual amount of Radon exposure that any

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particular individual receives also depends upon how much time they spend indoors.

How important to my health is Radon exposure?

Radon accounts for approximately 55% of the total ionizing radiation exposure that the average individual receives on a yearly basis, and is the largest source of radiation exposure for most people. It is estimated that Radon contributes to between 7,000 and 30,000 lung **cancer** deaths each year, or approximately 1 in every 7 cases of lung cancer is the result of Radon exposure. Smokers are at higher risk of developing Radon-induced lung cancer than nonsmokers.

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Radioactivity in Food

How much exposure does our food contribute?

Potassium and carbon in the food we eat contribute about 19 millirem to the average annual internal exposure of 39-40 millirem. The main contributor to the exposure (about 18 millirem) is from potassium-40, a radioactive isotope of naturally occurring potassium. Slightly more than 1 millirem is contributed by radioactive carbon-14 in our food.

How does radioactivity become part of our food?

Like uranium and **thorium**, potassium-40 was present when the Earth was formed. Unlike potassium-40, radioactive carbon-14 is continuously formed by the action of cosmic radiation on our atmosphere.

Each gram of natural potassium has a very small amount of radioactive potassium-40. Average soil contains about 1.5% natural potassium and is the source of potassium in our food. Carbon-14 in the atmosphere becomes incorporated in the natural carbon of growing things that are the source of carbon in our food.

How much potassium and carbon are in our bodies?

The body maintains a natural potassium content of about 0.2% by weight and a carbon level of about 23%. Small amounts of the potassium and carbon in the food we eat are used to maintain these levels, and the rest is eliminated.

Why Do We Need Potassium and Carbon?

Why is potassium important to health?

Potassium is important for healthy body function. It helps maintain fluid pressure and balance within cells. It is also important in normal muscle and nerve response and in maintaining heart rhythm. Even a temporary potassium deficiency can result in serious upsets of body functions. Bananas and oranges are both high in potassium.

Why is carbon important?

Carbon is also important. Not counting the small amounts of minerals in the body (such as potassium, sodium, calcium, iron, etc.), the main chemical components of the body, by percent of body weight, are oxygen (61%), carbon (23%), hydrogen (10%), and nitrogen (2.6%). Carbon makes up 45% of the carbohydrates we eat for energy, 55% of the fat we eat and the body fat

used up in exercise, and 50% of the protein that builds our muscles. Most of the carbon we eat reacts in our bodies with the oxygen we breathe and is exhaled as carbon dioxide (CO₂).

This provides the heat and energy we need to perform our daily work. That's what we mean when we say we "burn" calories during exercise.

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Human-made Sources

What are some exposures to human-made sources?

The figure below gives the annual exposures from some important human-made sources of ionizing radiation. The number given is the exposure in millirem per year to the individual receiving the highest normal exposure. For comparison purposes, the figure includes the average annual exposure to an individual in the United States from natural radiation sources (300 mrem/year).

The exposure of 870 millirem per year from smoking deserves a special explanation. This is the maximum exposure from smoking one pack of cigarettes a day, estimated by the National Council for Radiation Protection and Measurements. It is not a statistical average individual exposure. The radiation exposure from smoking comes from the natural radioactive materials contained in tobacco leaves. These radioactive materials become part of the smoke from burning tobacco, and are inhaled when cigarettes are smoked. Smokers who smoke more than one pack per day receive a proportionally larger amount of radiation exposure.

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Ionizing Radiation and High-Level Waste

At a nuclear power plant, what protects workers and the environment from exposure to radiation from spent fuel?

Fission is the creation of radiation through chain reactions and intense heat. It also creates waste and a residual source of radiation in the form of **spent fuel** rods that are part of a fuel assembly. When the radioisotopes in a spent fuel assembly undergo **radioactive decay**, they release both alpha and beta particles and gamma rays. While the metal in the fuel rods making up the fuel assembly will stop alpha and beta particles, it will not stop gamma rays. Therefore, fuel assemblies are stored in deep pools of water at the power plant sites to protect workers from the ionizing gamma rays coming from the fuel assemblies. Workers also use shielding and remote handling when working with a spent fuel assembly outside the pool.

How do shielding, distance, and time protect workers from radiation?

Shielding is the primary method of protecting workers and other people from a source of radiation. However, it is also true that the further one is from a source of radiation, the less radiation one receives. Reducing the time of exposure to a radiation source also will result in a lower exposure. Radiation workers not only use shielding to protect themselves, but they also wear radiation monitors to measure the amount of radiation they receive during their work periods.

How are people and the environment protected from ionizing radiation during disposal?

After 10 years of storage, the nuclear fuel will have lost 90 – 95% of its radioactivity. The remaining 5% – 10% radioactivity in the waste takes much longer to decay, even thousands of years. Workers would still use shielding and remote operation to handle a spent fuel assembly. To protect people and the environment, workers enclose spent fuel assemblies in a heavy shielded **cask** for storage. The federal government has created programs to develop permanent disposal facilities where the spent fuel assemblies will be placed in disposal containers and then in the **geologic repository** deep underground. These facilities will be designed to isolate the wastes and prevent radioactive contamination of the environment.

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**Please turn the
page and calculate
your radiation
exposure**

Blue Response Page

Please Write Your Responses
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Calculate Your Radiation Exposure: Tables

On average, people living in the United States are exposed to approximately 360 millirems of radiation each year. However, many factors influence the amount of radiation exposure that a particular individual receives. The form on the next page will help you calculate your personal radiation exposure.

Please follow the instructions on the following page, referring to the Tables on this page as needed. You may use your calculator.

Item 1. Cosmic Radiation

sea level – 100 feet = 26 millirems
 100 – 500 feet = 27 millirems*
 (*includes Eugene elevation at 422 feet)
 500 – 1,000 feet = 28 millirems
 1,000 – 2,000 feet = 31 millirems
 2,000 – 3,000 feet = 35 millirems
 3,000 – 4,000 feet = 41 millirems
 4,000 – 5,000 feet = 47 millirems
 5,000 feet plus = 55 millirems + 10 millirems for each additional 500 feet
 (for example, 6,550 feet = 55 + 30 mrem, for a total of 85 mrem)

Item 6. Occupational Exposure

Underground mining: 700 millirems
 Airline flight crew: 670 millirems
 Industry, including construction or factory: 240 millirems
 Medicine: 150 millirems

Item 8. Living Situation*

Write in the score for each of the following in the boxes provided, total your score, and enter it as Item 8, your Living Situation Score, on the following page.

*If you have a smoke detector your score is increased by 0.01 mrem — an amount too small to change your Total Radiation Exposure score.

If you live in a stone, brick, concrete, or adobe building, enter 7 here

If you cook and heat with natural gas, enter 2 here

If you watch TV, enter 1 here

Add all three amounts and write the sum here.

It is your Living Situation Score.

Item 3. Terrestrial Radiation

Write the number corresponding with the region in which you (mostly) live:

UT, CO, AZ, NM: 67 millirems

TX, OK: 46 millirems

Other western, Midwestern, eastern, & central states (e.g., OR, WA, CA, MN, IL, PA, NY): 32 millirems

Atlantic and Gulf states

(e.g., LA, GA, FL, MD, NJ): 16 millirems

Item 7. Medical Diagnosis

Write in the score for each of the following in the boxes provided, total your score, and enter it as Item 7, your Medical Diagnosis Score, on the following page.

If you received at least one diagnostic X-ray in the past year, enter 40 here

If you received any dental X-rays in the past year, enter 10 here

If you received at least one thyroid scan in the past year, enter 590 here

Add all three amounts and write the sum in the boxes provided. **You may use your calculator.**

This is your Medical Diagnosis Score.

Calculate Your Radiation Exposure

1. Cosmic Radiation	Refer to the Cosmic Radiation Table on the preceding page. Write the number for your elevation in the space provided.	1. My Cosmic Radiation Score _____
2. Radon Gas	Write the U.S. average of <i>200 millirems</i> in the space provided.	2. My Radon Score _____
3. Terrestrial Radiation	Refer to the Terrestrial Radiation Table on the preceding page. Write the Terrestrial Radiation Score for your region in the space provided.	3. My Terrestrial Radiation Score _____
4. Radiation in Food	Write the U.S. average of <i>40 millirems</i> in the space provided.	4. My Radiation in Food Score _____
5. Transportation of Nuclear Materials and Fallout from Nuclear Weapons Testing	The U.S. average for each of these two sources of radiation exposure is $\frac{1}{2}$ millirem (<i>0.5 mrem</i>), for a total of 1 millirem of radiation exposure due to both of these sources. Please write 1 in the space provided.	5. My Nuclear Transportation/Fallout Score _____
6. Occupational Exposure	Refer to the Occupational Exposure Table on the previous page. If your occupation is on the list, write its score in the space provided.	6. My Occupational Exposure Score _____
7. Medical Diagnosis	Refer to the Medical Diagnosis Table on the previous page. Follow the instructions for calculating your Medical Diagnosis Score, then write it in the space provided here.	7. My Medical Diagnosis Score _____
8. Living Situation	Refer to the Living Situation Table on the previous page. Follow the instructions provided and write your Living Situation Table score in the space provided.	8. My Living Situation Score _____
9. Air travel	Add <i>1 millirem for every 1,000 miles</i> you traveled by air in the past year.	9. My Air Travel Score _____
10. Smoking	If you smoke, add <i>870 millirems for every pack per day that you smoke</i> . (For example, 1 pack/day = 870 mrem; $\frac{1}{2}$ pack/day = 435 mrem.)	10. My Smoking Score _____

Using your calculator, add numbers one through 10.
This is your **Total Radiation Exposure**.

My Total Radiation Exposure Is: _____

Blue Response Page

Please Write Your Responses
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Before continuing, please complete the following brief quiz about the material you just read. You may review the material to help you answer the items.

Quiz #3

9. Which of the following activities is least likely to result in increasing a person's exposure to ionizing radiation? [Check one box.]

- ☐₁ Road construction
- ☐₂ Cigarette smoking
- ☐₃ Scuba diving
- ☐₄ Flying in an airplane

10. The average annual exposure of an individual to cosmic radiation is approximately what percentage of their average total exposure to ionizing radiation? [Check one box.]

- ☐₁ Greater than 75%
- ☐₂ Approximately 50%
- ☐₃ About 10%
- ☐₄ Less than 1%
- ☐₅ None of the above

11. On average, people living in the United States are exposed to about the same amount of ionizing radiation no matter where they live. [Check one box.]

- ☐₁ True
- ☐₂ False

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Please Write Your Responses
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Please complete the following brief quiz about the material you just read. You may review the material to help you answer the items.

Quiz #3 continued

12. People are exposed to ionizing radiation by consumer products that contain radioactive materials. [Check one box.]

☐₁ True

☐₂ False

Do each of the following increase, decrease, or have no effect on a person's exposure to ionizing radiation? [Check one box for each item.]

	<u>Increase exposure</u>	<u>Decrease exposure</u>	<u>No effect on exposure</u>
13. Traveling in an airplane	☐ ₁	☐ ₂	☐ ₃
14. Moving to a lower altitude	☐ ₁	☐ ₂	☐ ₃
15. Stopping smoking	☐ ₁	☐ ₂	☐ ₃
16. Eating bananas	☐ ₁	☐ ₂	☐ ₃
17. Having a chest X-ray	☐ ₁	☐ ₂	☐ ₃
18. Wearing sunscreen	☐ ₁	☐ ₂	☐ ₃
19. Heating food in a microwave oven	☐ ₁	☐ ₂	☐ ₃
20. Using an electric blanket	☐ ₁	☐ ₂	☐ ₃

21. Moving farther away from a source of ionizing radiation has an effect on the amount of radiation one receives. [Check one box.]

☐₁ True

☐₂ False

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Biological Effects of Ionizing Radiation

What Are the Biological Effects of Ionizing Radiation?

Because ionizing radiation is high energy radiation which can knock electrons out of atoms and molecules, it can damage human tissue. The effects of ionizing radiation on the body depend on many things. First and most important, how much radiation energy was absorbed by the body? Second, what type of radiation was it? Third, what kind of cells—and how many of them—were exposed, and how long was the exposure?

The damage done by radiation results from the way it affects *molecules* essential to the normal function of body cells. Four things may happen when radiation strikes a cell:

- 1 It may pass through the cell without doing any damage.
- 2 It may damage the cell, but the cell repairs the damage.
- 3 It may damage the cell so that it not only fails to repair itself but reproduces itself in damaged form over a period of years. Over time, incompletely or incorrectly repaired cells may produce delayed health effects such as cancer or genetic **mutations** or birth defects in babies exposed prior to birth.
- 4 It may kill the cell. The death of a single cell may not be harmful, but serious problems occur if so many cells are killed in a particular organ that the organ can no longer function properly.

Longer and greater amounts of exposure to radiation increases the chance that damage will occur. However, if enough time passes between exposures, a higher total exposure may be tolerated than if the total exposure is received all at once. This effect is similar to the body's response to non-ionizing solar radiation —too much sun can cause a severe sunburn, but short exposures and sun block can limit the sun's burning effect on the skin.

Distributing exposures to ionizing radiation over longer periods of time allows some of the damaged cells to be repaired by the body, helping to reduce the overall effect. Because alpha and beta particles are not very penetrating, they mainly damage skin and surface organs. However, they can affect internal organs if substances giving off alpha and beta radiation are swallowed or inhaled.

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Gamma rays and X-rays have similar properties, but gamma rays are generally more energetic. Their biological effects are similar. Their paths in living tissue are long. This means their energy is deposited over a longer path, is less likely to cause damage, and is more likely to be repaired. But because they can penetrate the body more deeply, they can affect internal organs.

There are two categories of effects from ionizing radiation: **somatic effects** and **genetic effects**. Somatic effects appear in the exposed person. They result from radiation damage to body cells that are *not* reproductive cells. They can occur soon after the exposure or they can take a number of years to become obvious. Somatic effects cannot be inherited.

Genetic effects may appear in children conceived after a parent has been exposed to radiation if that parent's egg or sperm cells were affected. Some genetic defects may be inherited.

What Are Some Effects of Acute Radiation Exposures?

Large exposures in short periods of time (**acute exposures**) produce injuries within weeks or even hours. The severity depends on the amount of radiation received. For example, 100,000 to 400,000 millirem (350 to 1,000 times natural background exposure levels) could cause **radiation sickness**, resulting in any and/or all of the following effects:

<i>Within hours or weeks:</i>	Nausea, headache, loss of appetite, changes in blood cells
<i>Within succeeding weeks:</i>	Loss of hearing, hemorrhaging, diarrhea, effects on the central nervous system

At these exposure levels, prompt medical treatment gradually restores the patient's health in most cases.

Even larger exposures can destroy bone marrow cells. (This happened to some victims of the Chernobyl **nuclear reactor** accident in the Soviet Union in 1986). An exposure of 400,000 to 500,000 millirem within a short period of time, if left untreated, has a 50% chance of causing death in a person. An exposure of 500,000 millirem is about 1,400 times the 360 millirem exposure the average American receives from all sources in a year.

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Based on the cancer death rate of groups of people exposed to **large** amounts of ionizing radiation, we know that such exposures can cause cancer. The most significant groups are:

- survivors of the atomic bombs dropped on Japan;
- U.S. *radiologists* who were exposed when using ionizing radiation from the 1920s through the 1940s to diagnose and treat medical problems;
- people given high X-ray exposures to treat a disease of the spine in the early days of radiation treatments.

Exposure to small amounts of radiation (1,000 millirem or less) produces no immediate observable effects. Larger exposures received over weeks or months may not produce visible symptoms. There is a slight risk, however, that a delayed effect (primarily cancer) could develop 10 to 40 or more years later. It's also possible (but even less likely) that damage to a reproductive cell could have occurred.

What Are the Effects of Low-Dose Radiation Exposures?

No direct data exists to estimate the human health risk resulting from low levels of ionizing radiation, such as the radiation we receive from our natural environment. Although scientists agree on the health effects of high levels of ionizing radiation exposure, there is uncertainty about the effects of low doses of radiation. This is because we cannot observe directly the effects on individuals of low doses of radiation exposure and can only infer such effects by looking at whole populations of people over time. However, such studies are complicated by the fact that the health effects that are observed may be due to other factors (e.g., diet, lifestyle, genetic predispositions) that are unrelated to radiation exposure and that cannot be completely controlled for.

To estimate the risk of human health of low-dose radiation exposure, scientists have used a number of methods for making use of the data and information they have. At present, three different models have been proposed that relate the amount of radiation exposure to a health effect, most commonly cancer. A model is simply a way of describing how differences in the amount of radiation to which an individual is exposed correspond to differences in effects on the human body. Models of this type are usually depicted in terms of a graph, where each point on a line shows the relationship between the amount of exposure and the risk of a health effect.

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Linear, No-Threshold (LNT) Model

Cancer risk versus radiation exposure: A straight line drawn to low exposure through data of high exposures is believed to estimate the effects of low exposures of alpha radiation. The effects of low exposures of beta, gamma, or X-ray radiation could be 2 to 10 times less than would be predicted by the straight line.

The LNT model assumes that because we have no direct data about the health effects of low-dose radiation exposures, conclusions have to be made on the basis of information we have gathered about health effects (particularly cancer) from high exposures. As you can see in the LNT graph above, risk of cancer death increases as exposure to radiation increases.

The straight line drawn through the high-exposure data down to zero is assumed to show the cancer risk from different levels of radiation exposure, based on observations of health effects at high levels of exposure. Thus, the health risk at low levels of exposure is estimated on the basis of data in the high-level exposure region. According to the LNT model, the health risk associated with radiation exposure is proportionally smaller as the amount of radiation exposure decreases, with zero risk occurring at zero exposure.

The LNT model assumes that the effect of radiation depends only on the amount of energy deposited within the cell. Since less radiation exposure means less energy deposited within a cell (or collection of cells), then less effect or damage should occur. This assumption also means that no amount of radiation is without effect. However, this assumption disregards any cellular responses that may defend or protect against harmful effects of radiation.

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Threshold Model

An alternative to the LNT model is the threshold model, shown in this graph.

In the threshold model, the health effect of radiation decreases with decreasing radiation exposure to a point below which smaller amounts of radiation exposure have no observable effect. In other words, there is a “threshold” below which radiation exposure has no observable health effects.

Scientific evidence for the threshold model comes from studies that indicate an “adaptive response” by cells when they are exposed to small amounts of radiation. A similar adaptive response also appears to occur from exposure to toxic chemicals. In the case of radiation, the adaptive response is assumed to arise from the induced repair to DNA (genes) damaged by radiation energy, though scientific evidence to support this conclusion is not yet available. However, an adaptive response by cells exposed to low-level radiation does not always occur, and the nature and presence of the adaptive response appears to depend on many factors, including age, sex, genetic background, type of cell, and the timing of radiation exposure.

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Hormesis Model

A third model that relates radiation exposure to health effects is based on the concept of *hormesis*. The term *hormesis* is derived from the Greek word *hormain*, which means “to excite or to stimulate.” The hormetic effect of small amounts of chemicals or substances for which large amounts are detrimental to health can be seen in a number of cases. For example, research indicates that while consuming large amounts of alcohol daily is bad for health, a small amount consumed daily may be more beneficial than none at all. Small amounts of vitamins improve human health, but large amounts can be toxic.

Some research has found that small amounts of exposure to radiation results in a stimulating effect on cells. Evidence for the hormesis model comes from a number of sources, including studies that appear to show a stimulating effect of small amounts of radiation on various organisms such as some plants and insects, as well as chick and salmon embryos.

However, the meaning and interpretation of the hormetic effect is unclear. Some scientists argue that cell stimulation is of beneficial value and leads to positive health effects. Their conclusions are often based on *epidemiological* studies: studies of populations of people exposed to differing amounts of radiation. For example, people living in the central plateau of the United States (e.g., Idaho, Colorado) and who are exposed to greater background radiation from cosmic and geologic sources tend to have lower cancer rates than people living in the southeastern gulf states (e.g., Louisiana, Mississippi). This observation is taken by some scientists to indicate a beneficial health effect of small radiation doses. However, epidemiological studies have great difficulty accounting for factors other than radiation that may influence cancer rates, such as life style factors (diet, smoking), genetic predispositions, and the like. Because epidemiological studies cannot adequately control for these factors, they cannot be taken to prove a cause-effect relationship between very low doses of radiation exposure and health effects.

Other scientists who have studied hormesis argue that the stimulation of the cells by very low doses of radiation could be associated with repair mechanisms that are activated to compensate for cell damage, in which case the beneficial value of cell stimulation by radiation may be accompanied by some residual genetic injury. At present, research is underway to increase our knowledge about what happens within cells when they are exposed to very small amounts of radiation. Results from this research will provide a clearer picture of whether radiation hormesis is beneficial or not.

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How Do We Resolve the Differences in These Models and the Evidence Supporting Them?

At present, the most commonly accepted model that relates radiation exposure to health effects is the linear, no-threshold model. You will recall that this model assumes

- 1** all radiation exposure results in some damaging effect on the body,
- 2** the body makes no adaptive response to radiation exposure, nor does it have any mechanism for repairing damaged cells, and
- 3** health effects of low levels of radiation exposure are predicted from health effects at high levels of exposure.

While there is scientific evidence that puts these assumptions in doubt, the linear no-threshold model has generally served as a health-protective safety guide for how much radiation exposure people can be allowed in contexts such as occupational settings and nuclear site cleanup.

Some scientists hold the view that we should abandon the linear, no-threshold model because it is overly cautious and the present state of our knowledge about the health effects of very low doses of radiation is sufficient to conclude that there is a threshold below which we can safely be exposed to radiation. They point to the virtual impossibility of scientifically identifying health effects in populations of people who are exposed to very small amounts of radiation (such as a few millirems) above the background radiation level of approximately 300 millirems to which everyone is exposed. They claim that the linear, no-threshold model imposes enormous economic costs on society to reduce radiation exposure from industrial activities for which no health effect can be shown, such as nuclear site cleanup, to levels very near the natural background.

Other scientists, however, claim that the linear, no-threshold model cannot be rejected simply because it is economically costly. They point to the lack of scientific research showing that there are no health effects at very low levels of radiation exposure, and believe that until research is available showing there are no health effects we cannot reject the linear, no-threshold model and should continue to use it.

The concept of hormesis has tended to provoke scientific debate about whether or not low levels of radiation exposure are actually beneficial to health. Though the balance of scientific opinion is generally tipped in the direction of either no or small negative health effects at low exposure levels, the hormesis theory is currently receiving considerable research attention. The concept of hormesis is more consistent with the

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threshold model than with the linear, no-threshold model, in that the threshold model implies a lower limit on negative health effects with very small exposures. Positive health effects are not precluded by the threshold model, but they are precluded by the linear, no-threshold model.

To summarize, current standards for radiation protection in both occupational and nonoccupational environments are guided by the linear, no-threshold model by which some damage to cells is assumed to occur no matter how small the radiation exposure. Although this model may be overly protective and there is scientific evidence to suggest that cellular repair systems exist that may limit the potential for negative health effects at very low exposure levels, there is no absolute proof that negative health effects do not occur with very small exposures.

Effects of Ionizing Radiation on the Unborn

Many genetic and environmental factors affect development of babies before birth. For this reason, it is difficult to say with certainty how radiation exposure affects an unborn child. Therefore, information gathered from animal studies is generally used to estimate these effects.

Animal studies have shown that large exposures can result in a very wide range of results — from no observable damage to malformations of major organs of the body, slowed growth, damage to the central nervous system, and even death. Effects vary depending on the stage of development at the time of exposure and the level of exposure. Since no equivalent experimental studies are conducted on humans, the major sources of information about effects on humans are survivors of the atomic bombs in Japan and patients exposed during medical diagnosis or treatment. The most commonly reported abnormalities are defects to the central nervous system and slowed growth.

Rapidly dividing cells are especially sensitive to radiation. So, before birth and during infancy when children grow rapidly, medical exposures to radiation carry a risk. Scientists generally agree that exposure to ordinary diagnostic X-rays is not likely to be harmful. Nevertheless, it is important to balance benefits of exposure to radiation against risks. It is wise for a woman of childbearing age to determine whether or not she is pregnant before being exposed to radiation above background levels. This precaution can help avoid unnecessary risk.

Birth Defects: A Fact of Life

How common are birth defects?

Approximately 10 percent of all children born (100,000 out of a million) have some genetic defect. These defects range from those so mild they are never noticed to those that are severe and even fatal. Spontaneous defects occur when unknown factors cause cells to not work properly. Defects may also occur because cells are affected by something in the environment, including ionizing radiation.

Have genetic defects from radiation been observed in humans?

Hereditary genetic defects can result from egg or sperm cells that have been damaged before conception occurs, usually because one or both parents were exposed to radiation before an effected child was conceived. These genetic effects of ionizing radiation are different than genetic effects resulting from radiation exposure to the fetus that could result if the mother was exposed to ionizing radiation while she was pregnant. No hereditary defects caused by ionizing radiation have been observed in humans, even among Japanese survivors of the atomic

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bombs. However, there is enough data from animal studies of large radiation exposures (most often using mice) to suggest that such effects may result under extreme exposure conditions.

What Are the Causes of Cancer Deaths?

Each year, approximately 2,400,000 deaths occur in the United States from all causes, including diseases and accidents. Cancer from various causes accounts for about 23% of all deaths (about 550,000 deaths annually). The table below shows a breakdown of cancer deaths according to the source of the cancers. Most cancers result from lifestyle decisions, such as diet and smoking. Other cancers result from environmental factors, including chemicals in air, water, and food, as well as radiation in the natural environment.

As you already know, the average annual radiation exposure for people living in the United States is about 300 millirem from natural sources. It is generally accepted among scientists that from one to three percent of all cancer deaths could be the result of this yearly exposure, most of which is from radon (see pages 11–12).

Cancer Deaths Attributable to Various Sources

(adapted from Doll & Peto, 1981)

Source	Percent of cancer deaths
Diet (range: 10% – 70%)	35%
Tobacco (range: 25% – 40%)	30%
Infection	10%
Sexual lifestyle (range: 1% – 13%)	7%
Occupation	4%
Alcohol	3%
Natural environment (including background radiation)	3%
Pollution	2%
Medical care	1%
Food additives	1%
Industrial products	1%
Unknown	3% *
<hr/>	
Total	100%

* Sources of some common cancers of unknown causes (e.g., prostate, bone marrow, lymph tissue).

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Blue Response Page

Please Write Your Responses
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Before continuing, please complete the following quiz about the material you just read. You may review the material to help you answer the items.

Quiz #4

22. *The human body is capable of repairing cell damage caused by low levels of exposure to ionizing radiation. [Check one box.]*

☐₁ True

☐₂ False

23. *Exposure to 100 millirems of radiation can cause radiation sickness. [Check one box.]*

☐₁ True

☐₂ False

24. *One of the more serious problems of large exposures to ionizing radiation is that somatic effects can lead to birth defects through inheritance. [Check one box.]*

☐₁ True

☐₂ False

25. *Gamma rays cause biological damage because they are frequently emitted by materials that are swallowed or inhaled. [Check one box.]*

☐₁ True

☐₂ False

26. *When gamma rays strike a cell, they: [Check one box.]*

☐₁ Always cause at least some damage because of their high energy level.

☐₂ Kill the cell they strike as well as surrounding cells.

☐₃ May pass through a cell without causing damage.

☐₄ Inhibit the natural repair mechanism of cells.

You may write on this page.

Blue Response Page

Please Write Your Responses
On This Page

Please complete the following quiz about the material you just read. You may review the material to help you answer the items.

Quiz #4 continued

27. *The longer the pathway that ionizing radiation takes through the body, the less damage is done to individual cells along the way. [Check one box.]*

☐₁ True

☐₂ False

28. *Acute health effects from ionizing radiation are immediately observable, even from exposures to natural background radiation. [Check one box.]*

☐₁ True

☐₂ False

29. *Even though humans have been exposed to natural background radiation for centuries, scientists are still uncertain about the health effects of low-dose exposures to ionizing radiation. [Check one box.]*

☐₁ True

☐₂ False

30. *In general, the effects of ionizing radiation on the unborn: [Check one box.]*

☐₁ Are predictable in humans based on studies of survivors of atomic bomb explosions.

☐₂ Always result in slower growth rates.

☐₃ Are confounded with other environmental effects not involving radiation.

☐₄ Are limited because rapidly dividing cells are not particularly sensitive to radiation.

31. *What is the amount of radiation exposure the average individual in the United States receives in a year? [Check one box.]*

☐₁ 1,400 millirems

☐₂ 400,000 millirems

☐₃ 360 millirems

☐₄ 35 millirems

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Blue Response Page

Please Write Your Responses
On This Page

Please complete the following quiz about the material you just read. You may review the material to help you answer the items.

Quiz #4 continued

32. *The human body is capable of repairing cell damage caused by low levels of exposure to ionizing radiation. [Check one box.]*

☐₁ True

☐₂ False

33. *Exposure to 100 millirems of radiation can cause radiation sickness. [Check one box.]*

☐₁ True

☐₂ False

34. *When gamma rays strike a cell, they: [Check one box.]*

☐₁ Always cause at least some damage because of their high energy level

☐₂ Kill the cell they strike as well as surrounding cells

☐₃ May pass through a cell without causing damage

☐₄ Inhibit the natural repair mechanism of cells

35. *The longer the pathway that ionizing radiation takes through the body, the less damage is done to individual cells along the way. [Check one box.]*

☐₁ True

☐₂ False

36. *Acute health effects from ionizing radiation are immediately observable, even from exposures to natural background radiation. [Check one box.]*

☐₁ True

☐₂ False

37. *Even though humans have been exposed to natural background radiation for centuries, scientists are still uncertain about the health effects of low-dose exposures to ionizing radiation. [Check one box.]*

☐₁ True

☐₂ False

You may write on this page.

Blue Response Page

Please Write Your Responses
On This Page

Please complete the following quiz about the material you just read. You may review the material to help you answer the items.

Quiz #4 continued

Listed below are a number of concepts and statements relating to radiation exposure and health. For each one, check the health effect model to which it best applies.

[Check one box for each item.]

	<i>Linear No-Threshold <u>Model</u></i>	<i>Threshold <u>Model</u></i>	<i>Hormesis <u>Model</u></i>	<i>Doesn't apply to any model</i>
38. All radiation exposure results in some damaging effect on the body.	☐ ₁	☐ ₂	☐ ₃	☐ ₄
39. Exposure to radiation stimulates cell repair with a positive effect on health.	☐ ₁	☐ ₂	☐ ₃	☐ ₄
40. Small amounts of radiation exposure have no observable effects.	☐ ₁	☐ ₂	☐ ₃	☐ ₄
<hr style="border-top: 1px dotted black;"/>				
41. Health effects of low levels of radiation exposure are predicted from health effects at high levels of exposure.	☐ ₁	☐ ₂	☐ ₃	☐ ₄
42. Most health-protective model used in regulating radiation exposure	☐ ₁	☐ ₂	☐ ₃	☐ ₄

43. Imagine that a local community was developing a standard for radiation protection in an area near an abandoned uranium mine. They established a radiation exposure level that was consistent with the average of the natural background radiation in their state, on the assumption that they would not be able to determine any health effects at that level or below. Which of the following best describes how they made their decision? [Check one box.]

- ☐₁ They used a linear, no-threshold model
- ☐₂ They used a threshold model
- ☐₃ They based their decision on the concept of hormesis
- ☐₄ None of the above

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Blue Response Page

Please Write Your Responses
On This Page

Please complete the following quiz about the material you just read. You may review the material to help you answer the items.

Quiz #4 continued

44. *Given the three models you read about that relate radiation exposure to health effects, which one makes the most sense to you as a way of managing radiation exposure? [Check one box.]*

☐₁ Linear, no-threshold model

☐₂ Threshold model

☐₃ Hormesis

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Glossary

acute exposure - Large or small exposure received over a short period of time.

alpha particle - A positively charged particle emitted in the radioactive decay of certain radioactive atoms. An alpha particle is identical to the nucleus of the helium atom.

atom - The smallest part of a chemical element that has all the chemical properties of that element.

background radiation - The natural radioactivity in the environment. Background radiation consists of cosmic radiation from outer space, radiation from the radioactive elements in rocks and soil, and radiation from radon and its decay products in the air we breathe.

beta particle - A negatively charged particle that is emitted by certain radioactive atoms. A beta particle is identical to the electron.

cancer - An abnormal mass of new tissue growing uncontrollably on or in the body; a disease in which such growths form.

cask - A special container used to store radioactive materials including radioactive waste.

cosmic radiation - Energetic particles and rays from space that strike the Earth at nearly the speed of light.

decay product - The isotope produced by the decay of a radioactive isotope.

electromagnetic spectrum - The complete range of frequencies of electromagnetic waves from the lowest to the highest, including radio infrared, visible light, ultraviolet, X-ray, gamma ray, and cosmic radiation waves.

electron - A subatomic particle with a negative charge. The electron circles the nucleus of an atom.

erg - An extremely small amount of energy. Example: to raise a pound weight one foot would require about 13.6 million ergs.

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Glossary, cont.

fallout - The slow descent of minute particles of radioactive debris in the atmosphere following a nuclear explosion. (*American Heritage Dictionary*, Second College Edition.)

gamma ray - Gamma radiation emitted during the radioactive decay of certain radioactive materials.

genetic effect - Effect that can be transferred from parent to offspring.

geologic repository - An underground facility for the long-term storage of nuclear waste.

ionization - The production of ions from neutral atoms or molecules by some process. For example, exposure to ionizing radiation.

ionizing radiation - Radiation that has enough energy to remove electrons from substances that it passes through, forming ions.

isotope - Atoms of the same element that have equal numbers of protons but differing numbers of neutrons.

millirem - A unit of radiation exposure equal to one-thousandth of a rem.

molecule - The smallest unit into which a chemical compound containing two or more atoms can be divided and still keep all of its chemical characteristics.

mutation - A permanent, transmittable change in the characteristics of an offspring that makes it different from its parents.

neutron - A subatomic particle that appears in the nucleus of all atoms except hydrogen. Neutrons have no electrical charge.

non-ionizing radiation - Low energy radiation such as radio and television waves.

nuclear reactor - A device in which a fission chain reaction can be initiated, maintained, and controlled.

phosphates - A chemical salt usually obtained from rocks and bones, and generally used in fertilizers.

potassium - A chemical element used in making glass and fertilizer, and an essential chemical element for proper body functioning.

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Glossary, cont.

radiation - Energy that moves through space in the form of particles or electromagnetic waves.

radiation sickness - Sickness that results from high exposure to radiation received in a short time. Common symptoms include: nausea, fatigue, vomiting, loss of teeth and hair, and in more severe cases damage to blood-forming tissue and decrease in red and white blood cells. In most cases, prompt medical treatment gradually restores patient's health. A radiation dose of 400,000 mrem results in death of about 50% of those so exposed.

radioactive decay - The spontaneous giving off of an alpha or beta particle or a gamma ray by a radioisotope.

radioisotope - A naturally occurring or artificially created radioactive isotope of a chemical element.

radon - A radioactive noble gas that is the result of the natural decay of radioactive elements in soil and rocks.

rem - A unit of exposure to ionizing radiation; an estimate of the health risk that exposure to ionizing radiation could have on human tissue.

somatic effect - Effect of radiation limited to the exposed individual.

spent fuel - Fuel that has been used in a nuclear reactor and then withdrawn. Spent fuel is thermally hot and highly radioactive.

terrestrial radiation - The portion of natural radiation (background) that is emitted by naturally occurring radioactive materials in the Earth.

thorium - A radioactive metallic chemical element used in mantels for gas lanterns.

uranium - A naturally occurring radioactive element with the atomic number 92 and an atomic weight of approximately 238.

X-ray - Electromagnetic radiation used in medical diagnosis.

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Low Dose, Risk, Decisions, & Risk Communication

Communicating About Radiation Exposure: Effects of Science Education on Radiation Decisions

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Low Dose, Risk, Decisions, & Risk Communication

Low-Dose Radiation Science: Communication Challenges

- Long legacy of radiation, but limited knowledge.
- Radiation science is opaque to non-scientists.
- Generally negative perceptions.
- (Im)plausibility of science concepts.
- Simple concepts, but complex perceptions.
- Strong "context effect" – purpose matters.
- Negative views of risk management institutions.

Low Dose, Risk, Decisions, & Risk Communication

Low Dose, Risk, Decisions, & Risk Communication

Study Questions

- How are views and attitudes concerning radiation exposure and its management influenced by information presented in an educational format?
- How well can non-scientists learn radiation science concepts?
- What can be accomplished in terms of science communication with "minimal resources?"
- Can science education influence the "context effect" in radiation risk perception?

Low Dose, Risk, Decisions, & Risk Communication

Low Dose, Risk, Decisions, & Risk Communication

“Ionizing Radiation: A Tutorial on Sources and Exposures” Bibliographic & Reference Resources (partial)

- **U. S. Department of Energy. Office of Civilian Radioactive Waste Management. (1992).** Science, society, and America’s nuclear waste: Ionizing radiation.
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Low Dose, Risk, Decisions, & Risk Communication

"Ionizing Radiation: A Tutorial on Sources and Exposures" Tutorial Outline

- **Physics of Radiation**

- Ionizing vs. non-ionizing radiation
- Quiz #1

- **Sources of Ionizing Radiation**

- Overview of Sources
- Quiz #2
- Natural Background Sources
- Human-made Sources
- Ionizing Radiation and High-Level Waste
- Compute Personal Radiation Exposure
- Quiz #3

Low Dose, Risk, Decisions, & Risk Communication

"Ionizing Radiation: A Tutorial on Sources and Exposures" Tutorial Outline

- **Biological Effects of Radiation**

- Effects of Acute Radiation Exposures
- Effects of Low-Dose Radiation Exposure

- **Models of Radiation Health Effects**

- Linear, No-Threshold (LNT) Model
- Threshold Model
- Hormesis
- Differences Between Models
- Evidence Supporting Models

- **Effects of Ionizing Radiation on the Unborn**

- **Birth Defects**

- Quiz #4

Low Dose, Risk, Decisions, & Risk Communication

Distribution of accuracy scores for all tests combined

Low Dose, Risk, Decisions, & Risk Communication

"Which model makes the most sense to you as a way of managing radiation exposure?"

Low Dose, Risk, Decisions, & Risk Communication

Changes in perception of risk from "low exposures to radiation."

****p<.0001
***p<.001
**p<.01

DECISION
RESEARCH

Low Dose, Risk, Decisions, & Risk Communication

Likelihood of harm caused by Nuclear Industry (NI) and Natural Background (NB) sources of radiation: pre/post change scores

DECISION
RESEARCH

Low Dose, Risk, Decisions, & Risk Communication

Attitudes about risk management: pre/post change scores

Low Dose, Risk, Decisions, & Risk Communication

Implications for low-dose science communication

- Non-scientists can learn radiation principles vis-à-vis a tutorial approach.
- Perceptions of radiation & its management change in response to tutorial.
- How can tutorial approach be embedded with low-dose problem areas?
 - Public outreach (e.g., web-based)
 - Community advisory groups, task forces
 - EIS process, enhancements
 - Media outreach
- Potential of health-effect models as a consolidating framework for low-dose science education and communication.

Low Dose, Risk, Decisions, & Risk Communication

Research Directions

- What are the effective elements of tutorial-based radiation science education?
- How well are concepts retained over time?
- Utilization of concepts in radiation risk decision making.
- How can tutorial approach be embedded in public communication and outreach efforts?

Low Dose, Risk, Decisions, & Risk Communication

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Low Dose, Risk, Decisions, & Risk Communication

A Decision-Focused Approach to DOE Cleanup Priorities

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Abstract

This exploratory study compares two approaches for involving stakeholders in choices about the cleanup of contaminated sites. Both approaches have as their goal informing non-expert members of the public about key elements of decisions relating to the cleanup of contaminated sites. The first approach focuses on technical information and seeks to improve the available knowledge base so that participants can make choices informed by the best available scientific data. This approach is similar in intent to many of the science-based initiatives in decision making now being undertaken by EPA, DOE and other federal or state agencies. The second approach, in contrast, focuses on values-based information and seeks to improve stakeholders' ability to make difficult choices in the light of required tradeoffs across a variety of technical and non-technical concerns. The results demonstrate that although both approaches help to increase participants' level of knowledge, a values-based approach is more successful in meaningful involvement of lay participants in program choices that have historically been viewed as primarily technical problems.

Proposed Continuation Of Work

The results of this initial, exploratory study are helpful in outlining an improved approach for involving stakeholders in site cleanup decisions. However, as is typical with experimental studies we present results based on small sample sizes (which means that some key distinctions between the two approaches are difficult to demonstrate), by using scenarios with limited information to characterize the consequences of cleanup alternatives, and by asking volunteer subjects to evaluate hypothetical cleanup problems. The results would be more meaningful, we believe, if a second study were conducted at an actual DOE cleanup site, with the participation of technical experts in the design of the cleanup options, and with adult participants who live in the community and, as a result, will be more directly affected by cleanup decisions.

1. Introduction

A key objectives of the U. S. Department of Energy (DOE) is to support improvements in environmental quality by aggressively cleaning up the legacy of radiation-contaminated sites due to past production of nuclear weapons and materials. The report, *Accelerating Cleanup: Paths to Closure*, discusses how the agency intends to meet this objective (DOE, 1998). The report also outlines how the DOE plans to accelerate and finish the job of cleaning up the nations' radiation- contaminated sites while being sensitive to concerns of the agency's stakeholders such as the cleanup workforce, surrounding communities, regulatory agencies, and the general public. A key element of this plan involves fostering a better understanding among all stakeholders — DOE and scientific experts included — of the technical requirements for meeting the agency's cleanup objectives consistent with the associated cost, environmental quality, and temporal constraints. A central aspect of fostering this broader understanding is the inclusion in the cleanup process of techniques for ensuring an enhanced responsiveness to the concerns of stakeholders by allowing meaningful participation in setting cleanup priorities and in executing cleanup plans.

Despite its obvious appeal, achieving the goal of fostering a broader understanding of DOE cleanup priorities through the meaningful involvement of stakeholders is not an

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easy task. This cautionary tone is consistent with the perspective of the broad literature on stakeholder participation and dispute resolution (Susskind & Cruikshank, 1987). It is also consistent with the decidedly mixed real-world results from recent initiatives to clean up or store nuclear wastes. A good example is the effort to involve states in the management of long-term storage of commercial low-level radioactive wastes. Despite the expenditure of a great deal of money (more than \$600 million) and numerous suggestions as to how to organize and promote public consultation processes, none of the efforts to establish a regional compact have been successful (U.S. General Accounting Office, 1999; Weingart, 2001). Spent fuel from nuclear power plants continues to be stored on-site or in temporary storage facilities and issues of transportation and future site cleanup repeatedly raises questions about the viability of public policies and programs (Flynn et al., 1992).

In our view, positive progress with stakeholder involvement in DOE cleanup programs could be achieved with an approach that permits participants to think (and feel) carefully about the different pros and cons of policy options and then, once their own priorities are in order, to be involved meaningfully in the development of a recommended alternative. In consequential decision contexts such as the cleanup or storage of radioactive wastes, meaningful involvement goes well beyond inviting a cross section of people to receive and respond to technical information about a specific problem (Gregory 2000; Arvai, Gregory & McDaniels, 2001). There must also be mechanisms in place to improve the participants' ability to recognize and make difficult choices about how the cleanup effort should proceed. Clearly, informing these difficult choices involves the careful consideration of the technical components of a cleanup problem and the anticipated consequences of different cleanup actions. A second and equally important aspect of informing choices, however, is the inclusion of stakeholder values in a way that facilitates the creation of cleanup options that will clearly address those concerns of most importance.

Our objective in this exploratory study was to compare two alternative approaches for involving stakeholders in choices about the cleanup of contaminated sites. Both approaches inform non-expert members of the public about key elements of decisions

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relating to the cleanup of contaminated sites. The first approach focuses on the presentation of technical information and seeks to improve the available knowledge base so that participants can make choices that are informed by the best available scientific data. This approach is similar in intent to many of the science-based initiatives in decision making now being undertaken by EPA and other federal or state agencies as well as DOE (DOE, 1993; EPA, 2000; Graham, 2000). The second approach, in contrast, provides scientific data but focuses on the presentation of values-based information and seeks to improve the ability of participants to make difficult choices in the light of required tradeoffs across a variety of technical and non-technical concerns. Thus, although the content of the scientific information conveyed to participants in the two conditions is nearly identical, the form in which it is presented and, consequently, the decision-aiding assistance provided to participants is quite different.

2. Methods

2.1 Context

The context for this experiment is the cleanup of Federal Superfund sites contaminated with low dose radiation. Specifically, participants were asked to provide input to decisions about how public funds should be allocated to the cleanup of three hypothetical sites in the Pacific Northwest. These sites were

- a former nuclear weapons facility,
- an irrigation-tunneling project with radon emissions, and
- a storage depot for farm fertilizers containing trace amounts of radioactivity.

All subjects were provided with short written descriptions of each of the three sites as well as a map depicting the locations of the three sites in relation to the hypothetical town of Larkspur. Participants were told to assume that they lived in the town and planned to continue doing so. They were then asked to help allocate \$30 million in cleanup funds across the three sites; this was said to be the spending level proposed for year five of an anticipated eight-year cleanup effort. In order to avoid a bias in favor of completing the cleanup at the cheapest of the three sites, participants were instructed that completely cleaning up any site would not be possible even if the entire \$30 million budget were to be spent at that one location.

Table 1. Experimental Design

Science-based	Values-based
Introduction	Introduction
Initial self-rating	Initial self-rating
Background information	Background information
<ul style="list-style-type: none"> • Radiation • 3 contaminated sites • Ongoing cleanup efforts • The town of Larkspur 	<ul style="list-style-type: none"> • Radiation • 3 contaminated sites • Ongoing cleanup efforts • The town of Larkspur
Summary table (Table 2)	Summary table (Table 2)
Specific Information	Specific Information
<ol style="list-style-type: none"> 1. Specific radiation levels in soil by particle type (α, β, Γ, X) and severity (millirem) 2. Specific radiation levels in water by particle type (α, β, Γ, X) and severity (millirem) 3. Human health effects by ailment and severity 4. Environmental health effects by type, severity, and ecosystem 	<ol style="list-style-type: none"> 1. General environmental effects by indicator species 2. General human health effects in terms of illness or death 3. Values components (economic costs of monitoring, tourism losses, unsightliness) 4. Magnitude of soil and water contamination (x “normal”)
Summary table (Table 3)	Summary table (Table 4)
No intervening value-structuring task	Intervening value-structuring task: Modified swing-weighting approach
Choice Task 1 — no uncertainty	Choice Task 1 — no uncertainty
Intervening self-rating	Intervening self-rating
Choice Task 2 — with uncertainty	Choice Task 2 — with uncertainty
Intervening self-rating	Intervening self-rating
Choice Task 3 — direct allocation	Choice Task 3 — direct allocation
Final self-rating	Final self-rating
Close and payment	Close and payment

2.2 Design

This experiment made use of a workbook prepared in two versions, which are referred to as the science-based and the values-based conditions (Table 1). Both versions of the workbook consisted of 23 pages and provided specific information to subjects about the human and environmental health risks of radiation as well as the principal issues and problems associated with cleanup at the contaminated sites. Additional material was included in the form of color-coded charts and tables presented on the wall of the room where the study took place; these allowed participants to study the detailed characteristics of different clean-up options at their own pace. Subjects recorded answers in the workbooks to a series of closed-ended questions. Individuals worked one-at-a-time under the supervision of a trained facilitator at the laboratory of Northwest Survey and Data Services in Eugene, Oregon. Both workbooks required approximately one hour, on average, to complete. The experiment included a computer-based task (described in more detail below) involving an automatically-updating spreadsheet that showed participants the implications of their allocation decisions.

The experiment had a multi-part design with one independent variable (the science-based or values-based structure) and several dependent variables. The dependent variables used for judging the quality of stakeholder input included participants' self-ratings of their knowledge level, their level of comfort with their decisions, and their perception of how well their stated choices reflected their concerns. Participants were asked these questions at several different times over the course of the study so that we could compare their initial and final responses and also test for the effectiveness of particular interventions.

Table 2. Background Information About Each of the Three Contaminated Sites

	Abandoned nuclear weapons factory	Irrigation tunnel project	Former fertilizer depot
Level of soil contamination within 100 m of site (millirem/year): *average annual human exposure = 360 millirem/year	3600	1800	720
Level of water contamination within 100 m of site (millirem): *normal “background” level = 28 millirem	240	120	48
Average number of people who venture onto site per year:			
Visitors (authorized and unauthorized)	500	10	1000
Cleanup personnel	225	40	40
Regular personnel/staff	15	5	75
Percent of site remaining to be cleaned after Year 5:	50%	70%	65%
Proximity of site to Town of Larkspur:	5 Miles North	3 Miles West	0.5 Miles South
Total size of site:	14 acres	1 acre	2.5 acres
Total cost to complete cleanup as of Year 5:	\$80,000,000	\$45,000,000	\$35,000,000
Projected time to finish cleanup at current rate of work (in years):	7	4	2
Intended purpose of the site (post-cleanup):	Wildlife Refuge	Rangeland	Storage Warehouse

Note. This information was presented in both the science-based and values-based conditions.

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Both the science-based and values-based conditions shared four common elements. These elements were, 1) background information about radiation, the contaminated sites, the ongoing cleanup efforts, and the town of Larkspur, 2) more detailed information about the human and environmental health risks of radiation, 3) closed-ended self-rating questions, and 4) a series of three choice tasks (Table 1). The information about the three contaminated sites was further broken down into information dealing with radiation levels in surrounding soils and water, the expected number of people who would be entering each site, the percentage of the site remaining to be cleaned, the proximity of each site to the town, the remaining cleanup costs, and the amount of time remaining to complete the cleanup effort (Table 2). Providing all participants (in both conditions) with the data shown in this table ensured that all participants would have access to the same basic information about the cleanup options.

Table 3. Specific Information About Each of the Three Contaminated Sites Presented Only in the Science-Based Condition

	Abandoned nuclear weapons factory	Irrigation tunnel project	Former fertilizer depot
Level of soil contamination within 100 m of site (millirem): *average annual human exposure = 360 millirem/year	3600	1800	720
<i>Level of contamination (millirem) from:</i>			
Alpha particles	450	575	25
Beta particles	1750	1150	450
Gamma rays	1050	75	245
X-rays	350	0	0
Level of water contamination within 100 m of site (millirem): *normal “background” level = 28 millirem	240	120	48
<i>Level of contamination (millirem) from:</i>			
Alpha particles	5	10	10
Beta particles	135	92	33
Gamma rays	70	18	5
X-rays	30	0	0
Environmental Health Impacts (measured as the number of animals/plants with radiation-related abnormalities per 100 sampled) within 1 square miles of site on:			
Plants	20	7	2
Terrestrial Vertebrates	30	17	2
Aquatic Vertebrates	5	2	0
Health Effects (measured as the mean number of radiation-related illnesses/deaths per 1000 workers and visitors to the site over the total 8 year cleanup time):			
Respiratory infections	10	6	25
Non-fatal cancers	10	5	15
Radiation sickness	2	0	0
Non-fatal bone disease	5	4	5
Genetic effects	5	2	5
Radiation-related deaths	4	1	0

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Both the values-based and science-based workbooks provided specific information about the status of cleanup activities at each of the three contaminated sites. However, the way in which this information was presented varied between the two different treatments. In the science-based condition, subjects were presented only with technical information relating to the level of contamination and the human and environmental health risks at each of the three sites (Table 3). This information had been pre-tested for comprehension and completeness as part of earlier risk-communication studies conducted earlier by colleagues working on this DOE-sponsored research (MacGregor & Flynn, 2002). In the present study, subjects were presented with information that described contamination levels by radiation type and severity in millirems (e.g., alpha particles, beta particles, gamma rays, and x-rays), risks to human health (frequency of respiratory ailments, cancers, radiation sickness, genetic effects, and fatalities among people visiting and working at each site), and environmental risks (frequency of radiation-related defects in plants and terrestrial and aquatic organisms).

Table 4. Specific information about each of the three contaminated sites presented only in the values-based condition.

	Abandoned nuclear weapons factory	Irrigation tunnel project	Former fertilizer depot
Overall environmental risks within 1 square mile of site: (0 = <i>no risk</i> ; 5 = <i>moderate risk</i> ; 10 = <i>extreme risk</i>)	7	4	1
Percent of alder affected within 1 square mile of site	20%	7%	2%
Percent of deer affected within 1 square mile of site	30%	17%	2%
Percent of brook trout affected within 1 square mile of site	5%	2%	0%
Risk of radiation-related illnesses to humans: (0 = <i>no risk</i> ; 5 = <i>moderate risk</i> ; 10 = <i>extreme risk</i>)	4	2	10
Percent of workers and/or visitors falling ill	3.2%	1.7%	7.0%
Risk of radiation-related deaths to humans: (0 = <i>no risk</i> ; 5 = <i>moderate risk</i> ; 10 = <i>extreme risk</i>)	3	1	0
Percent of workers and/or visitors dying	0.04%	0.01%	0.0%
Annual costs of managing the Larkspur drinking water supply	\$1,000,000	\$2,000,000	\$250,000
Annual costs to the Larkspur economy from reduced tourism due to contamination:			
Summer Tourism (camping, fishing, etc.)	\$750,000	\$5,500,000	\$0
Percent Decline	3%	22%	0%
Winter Tourism (skiing, snowshoeing, etc.)	\$1,500,000	\$15,000,000	\$0
Percent Decline	4%	36%	0%
Judged unsightliness (“ugliness”) of site: (0 = <i>not at all unsightly</i> ; 5 = <i>moderately unsightly</i> ; 10 = <i>extremely unsightly</i>)	8	6	2
Level of soil contamination within 100 m of site (x normal level): *average annual human exposure = 360 millirem/year	10.0 x	5.0 x	2.0 x
Level of water contamination within 100 m of site (x normal level): *normal “background” level = 28 millirem	10.0 x	5.0 x	2.0 x

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In the values-based condition, information related to the severity of contamination at each of the three sites was linked explicitly to societal values and to personal objectives for the cleanup activities (Table 4). For example, human health risks were described in terms of the general severity of anticipated effects (i.e., using scales from 1 [low severity] to 10 [high severity]) and were not subdivided by the type of ailment, as was the case in the science-based treatment. Environmental risks were presented using 10-point scales that addressed anticipated changes in the levels of indicator species in each of the three communities (alder, deer, and brook trout). Other aspects of the site cleanup activities were linked to the costs of ongoing monitoring, to losses of tourism-related revenues due to the radiation contamination and ongoing cleanup operations, and to the unsightliness of the cleanup at the sites.

An additional component of the values-based workbook was the inclusion of a values structuring task, which was introduced to help participants think through difficult tradeoffs associated with allocating the year 5 cleanup funds. Participants were asked to consider the six different values-based components noted above and to decide which of these concerns was relatively more or less important to them. These participants employed a modified swing-weighting approach (von Winterfeldt & Edwards, 1986) in which each individual was provided with the range of anticipated effects, showing the worst and best levels for each value objective. They were asked to rank these six areas of concern, selecting the value they would most like to improve (i.e., “swing”) from the worst to the best possible level, then to select the second most-important value, and so forth. Using this approach, all six value categories were ranked from most to least important.

Subjects in both conditions were then asked to make choices for three different tasks. The first and second tasks asked each person to choose their preferred allocation of funds across the three sites. A list of five prepared alternatives allowed funding allocations of either \$5, \$10, or \$15 million for each site. The anticipated outcomes of these funding allocations were scaled according to these allocations and were reflected as changes in the attributes that were presented as part of the second summary table in both the science-based (Table 3) and values-based (Table 4) condition. The difference between the first

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and second choice tasks was that the latter task introduced uncertainty about the magnitude of effects so as to increase its realism. This was done by having each anticipated outcome shown as a range of possible consequences. To help facilitate easier comparisons across the alternatives during both of these choice tasks, the five alternatives along with the current status of each site were presented side-by-side on 3' x 5' tables affixed to the walls of the room where the study took place.

The third choice task asked subjects to directly allocate funds themselves using a computerized, self-updating computer model in which the anticipated outcomes of the cleanup effort (described for the science-based and values-based conditions) were updated in real-time depending on the size of the desired allocation. This allowed subjects to immediately see the anticipated effect of their choices and to then change the allocations in order to improve the balance (that is, make the relative allocations more compatible with their preferences) across the sites.

At the close of the allocation tasks, subjects were asked to provide affective judgments for each of the three contaminated sites. Recent findings in judgment and choice research acknowledge the importance of emotions and affect — the feeling states that people experience, such as happiness or sadness, and the qualities associated with a stimulus or event, such as its perceived goodness or badness — as key elements in how individuals form judgments and make decisions (Loewenstein, 1996; Slovic et al, in press). In this study we elicited affective judgments across two dimensions, valence and arousal for each of the three contaminated sites where valence was measured with a seven-point scale from very good to very bad (using “indifferent” as a midpoint) and arousal was measured with a seven-point scale from very calm to very upset (with “indifferent” again a midpoint).

Each workbook ended as it began, with a series of closed-ended self-rating questions where responses were provided on seven-point Likert scales. Both of the middle choice tasks also were followed by similar closed-ended self-rating questions. Three specific questions were only asked at the termination of both the science-based and values-based condition. These questions asked for participants' opinions about the quality and level of distortion of the information that was presented to them as well as its usefulness in terms

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of informing their cleanup choices; the exact wording all of the self-rating questions is shown in Table 5.

We anticipated that participation in either the science-based or values-based conditions would lead to subjects making more informed choices as measured by their accumulated level of knowledge, comfortable with their decisions, and how well their decisions reflected their concerns. However, we predicted that the allocation choices made by subjects in the science-based conditions would reflect their affective judgments more strongly than those in the values-based condition. In both conditions, we also studied how subjects' affective reactions to the three different sources of contamination influenced their choices in terms as measured by the desired intensity of the cleanup effort and the size of the funding allocation for a particular contaminated site. We hypothesized that subjects in the values-based condition would make choices about the cleanup of the sites that more closely reflected their stated priorities about how cleanup efforts should proceed.

Table 5. Closed-ended self-rating questions used in both the science-based and values-based conditions

Question 1. Asked at start; after choice task 3:

Do you think policy decisions about the cleanup of contaminated soils as part of the Superfund program should be based just on public input or should they be made just by technical experts?

1	2	3	4	5	6	7
Just public input		Both public & expert input			Just expert input	

Question 2. Asked at start; after choice task 1; after choice task 3

How would you characterize your level of knowledge about radiation risks? (very little knowledge; moderate amount of knowledge; a lot of knowledge)

Question 3. Asked at start; after choice task 3

How comfortable are you with the prospect that your participation in this study could have an influence on federal cleanup policies for contaminated sites? (not at all comfortable; moderately comfortable, very comfortable)

Question 4. Asked at start; after choice task 1; after choice task 3

To what extent do you trust risk managers working for the government to do a good job on the cleanup of contaminated soils? (I don't trust them at all; moderate amount of trust; I trust them very much)

Question 5. Asked at start; after choice task 1; after choice task 3

To what extent do you trust risk managers working for private companies to do a good job on the cleanup of contaminated soils? (I don't trust them at all; moderate amount of trust; I trust them very much)

Question 6. Asked after choice task 1; after choice task 3

How comfortable would you be with this choice if the money really were to be spent according to your choice of alternatives? (not at all comfortable; moderately comfortable; very comfortable)

Question 7:

Version 1 asked after choice task 1

How well does your choice on the previous page match with what you believe would be the ideal allocation of funds for the cleanup of the contaminated sites in year five? (not at all well, moderately well; very well)

Version 2 asked after choice task 3

How well do you feel that the choices you made today about funding allocations reflect what you really care about when it comes to the cleanup of contaminated sites? (not at all well, moderately well; very well)

Question 8. Asked after choice task 3

To what extent do you feel that the information presented to you today was distorted to suit the needs of the government managers in charge of cleaning up the contaminated sites in your community? (not at all distorted; moderately distorted, very distorted)

Question 9. Asked after choice task 3

In your view, how would you judge the quality of the information that was presented to you today? (very low quality, average; very high quality)

Question 10. Asked after choice task 3:

How useful did you find the information that was presented to you today to be for making your choices about the Superfund cleanup of the contaminated sites? (not very useful; moderately useful, very useful)

Note. Subjects' answers were expressed on seven-point Likert scales as shown after question 1. Scale end and mid-point(s) for the other questions appear in parentheses. The time at which the question was asked — at the start, after choice task 1, after choice task 2, or at the end of the workbook after choice task 3 is also indicated.

2.3 Subjects

The subjects in this study were paid adult volunteers recruited from the city of Eugene, OR. Fifty five subjects participated, half in the science-based condition and half in the values-based condition. Subjects were reminded that there were no right or wrong answers to any of the questions and that their responses, although anonymous, would help to provide insight to government decision makers about an important and problematic series of public policy questions.

2.4 Data Analysis

Analyses were carried out on the data obtained from the closed-ended questions in subjects' completed workbooks in both the science-based and values-based conditions. The samples (25 subjects in the science-based condition and 25 subjects in the values-based condition) are relatively small but not unusual for an exploratory study of this type. Descriptive statistics were used to summarize and compare subjects' responses to the closed-ended self-rating questions. For questions that were asked only twice over the course of the experiment, 1-tailed paired-sample t-tests were used for within-subject comparisons and two-sample t-tests were used for between-subject comparisons. Repeated measures for analyses of variance were used for within-subject questions that were asked three times.

Table 6. Summary of Within-Condition Comparisons of Participants' Responses to Closed-Ended Questions Asked at Three Points During the Science-Based and Values-Based Conditions

Question	Science-Based							Values-Based						
	$\bar{x}_{\text{Start}}$	SE _{Start}	$\bar{x}_{\text{Mid}}$	SE _{Mid}	$\bar{x}_{\text{End}}$	SE _{End}	<i>p</i>	$\bar{x}_{\text{Start}}$	SE _{Start}	$\bar{x}_{\text{Mid}}$	SE _{Mid}	$\bar{x}_{\text{End}}$	SE _{End}	<i>p</i>
1. Public or experts? ^b	4.48	0.18	—	—	4.60	0.19	0.57	4.48	0.16	—	—	4.52	0.13	0.74
2. Level of knowledge? ^a	3.32	0.32	4.84	0.27	4.48	0.24	«0.01*	3.56	0.28	4.40	0.25	4.28	0.27	«0.01*
3. Comfort giving policy advice? ^b	5.48	0.34	—	—	4.84	0.28	0.06	5.40	0.33	—	—	4.60	0.38	0.02
4. Trust in government? ^a	4.00	0.25	3.92	0.22	4.16	0.27	0.41*	3.12	0.36	3.44	0.23	3.72	0.27	0.11*
							0.58**							0.04**
5. Trust in private companies? ^a	2.96	0.30	3.12	0.33	3.12	0.34	0.59*	3.08	0.33	3.24	0.31	3.24	0.28	0.71*
6. Comfort with choice? ^b	—	—	4.88	0.31	3.92	0.22	0.03	—	—	5.20	0.31	4.40	0.26	«0.01
7. Choice reflects what matters? ^b	—	—	4.84	0.29	5.44	0.24	0.02	—	—	3.88	0.33	4.96	0.27	«0.01
8. Distortion of information ^c	—	—	—	—	2.40	0.21	—	—	—	—	—	3.28	0.34	0.03
9. Quality of information ^c	—	—	—	—	5.16	0.28	—	—	—	—	—	4.64	0.29	0.19
10. Usefulness of information ^c	—	—	—	—	5.36	0.26	—	—	—	—	—	5.20	0.27	0.67

Note. Unabridged questions appear in Table 5.

^aRepeated measures ANOVA for within-subject comparisons. ^bPaired-sample t-test for within-subject comparisons. ^c2-sample t-test for between-subject comparisons.

p*-level reflects the comparison of means at the start and end of each condition. *p*-level represents results from a paired-sample t-test comparing means at the start and end each condition.

3. Results

Participants in the science- and values-based conditions were very similar in their judgments about their desired level of public and expert participation for choices about site cleanup (Table 6, Item 1). At the start of both conditions, subjects' expressed preference for the level of expert and public input was 4.48, coinciding with a fairly equal blend of public and expert input. These levels changed little by the end of the workbooks, with a mean rating of 4.52 in the values-based condition and 4.60 in the science-based condition. Neither of these differences is statistically significant.

Responses to the self-rating questions showed that subjects in both the science- and values-based conditions felt more knowledgeable after completing their respective workbooks relative to when they started (Table 6, Item 2). For subjects in the values-based condition, their mean initial knowledge level of 3.56 rose to 4.40 after the first choice task, and then fell to 4.28 following the third choice task (which introduced uncertainty into the consequence estimates). From beginning to end, these participants' mean level of knowledge rose by 0.62 points, a statistically significant difference at a significance level of 0.05 as revealed by the repeated measures ANOVA.¹ Subjects in the science-based condition began with a base level of knowledge of 3.32, which rose by a statistically significant margin to 4.84 after the first choice task and then fell to 4.48 following the third choice task; the comparison of initial and final knowledge levels is again significant. Overall, the mean reported knowledge level of the values-based participants increased 17% as compared to a 35% increase for the science-based subjects. However, comparisons between the value- and science-based participants' initial, intermediate, or final ratings are not significantly different.

When asked how comfortable they were with their selected alternatives after choice tasks 1 and 3, participants in both the *science* and values-based groups felt less comfortable with their choices after the introduction of uncertainty as part of the third choice task (Table 6, Item 6). In the values-based condition, subjects' comfort with their choice of alternatives fell from 5.20 after choice task 1 to 4.40 after choice task 3. In the

¹ Unless otherwise noted, all statistical comparisons are reported at the .05 probability level.

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science-based condition, subjects' comfort with their choice of alternatives fell from 4.88 after choice task 1 to 4.48 after choice task 3. Both differences were statistically significant across tasks (and within conditions) but were not significant between conditions. Similar responses were obtained in the self-rating question asking participants about their comfort level with giving policy advice to a government agency such as DOE (Table 6, Item 3). Subjects' mean comfort levels in the values-based condition fell from 5.40 at the start of the workbook to 4.60 at the end. For participants in the science-based condition, mean comfort levels fell from 5.48 at the start to a mean level of 4.84 at the end. The difference in the values-based condition is statistically significant ($p = 0.02$), although the difference in science-based condition is not ($p = 0.06$).

One of the key questions asked of participants in both conditions was their level of trust in the ability of risk managers working for the government to do a good job cleaning contaminated soils (Table 5, Question 5). The values-based participants show a steady increase in their expressed level of trust after choice tasks 1 ($\bar{x} = 3.25$), 2 ($\bar{x} = 3.44$), and 3 ($\bar{x} = 3.72$). A repeated measures ANOVA reveals no significant difference between these means ($p = 0.11$), due largely to the small sample size. A paired-sample t-test comparing means after choice task 1 and choice task 3 revealed a statistically significant difference at the 0.04 level (Table 6, Item 5). Participants in the science-based condition, on the other hand, show a more erratic pattern, with expressed mean levels of trust declining following choice task 2 (from $\bar{x} = 4.00$ to $\bar{x} = 3.92$) and then increasing after task 3 ($\bar{x} = 4.16$). Neither of these differences is statistically significant using repeated measures ANOVA or a paired-sample t-test comparing means after choice task 1 and choice task 3. No difference was observed for either condition with respect to subjects' expressed mean level of trust in the private companies responsible for the cleanup effort at the three sites (Table 6, Item 6).

In terms of their feelings about how much the information presented to them was distorted to suit the needs of government managers (Table 5, Question 8), subjects in the values-based condition judged the level of distortion to be higher ($\bar{x} = 5.20$) than their counterparts in the science-based condition ($\bar{x} = 2.40$). This difference was significant ($p = 0.03$; Table 6, Item 8). However, no significant difference was observed for subjects'

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judgments about the quality of information or its usefulness for informing cleanup choices (Table 6, Items 9 and 10).

Another key question asked of participants following choice tasks 1 and 2 was in regards to how well their choices about the cleanup of contaminated sites in their community reflected what mattered to them (Table 5, Question 7). For subjects in the values-based condition, mean responses increased from 3.88 to 4.96, a statistically significant difference at the $p < 0.01$ level (Table 6, Item 7). Subjects in the science-based condition also show an increase in terms of how well the later allocations, which followed the introduction of additional information, reflected their values. This difference, from 4.84 at the start to 5.44 at the end, is statistically significant ($p = 0.02$).² In terms of absolute increases, however, the mean rating for participants in the values-based condition increased more than twice as much (28% as compared to 12%) over the course of the tasks introduced in the workbook.

² The reader will note that the initial ratings for the science-based participants are significantly higher (4.84 vs. 3.88, $p = .03$) than those of the values-based participants. This result is puzzling — this question was asked at the very start of the questionnaire, before the introduction of any differences between conditions — and appears to be an artifact of the relatively small sample sizes. It is noteworthy that by the second ratings, completed toward the end of the study, there was no significant difference in the two mean ratings; the ratings of values-based participants had increased enough more than the science-based participants that they had, in effect, “caught up” and the difference was no longer significant.

Table 7. Summary of Affect Ratings Across the Valence (A) and Arousal (B) Dimensions in Both the Science-Based and Values-Based Conditions

A

Condition	Valence					
	$\bar{x}_{\text{Nuclear}}$	SE	$\bar{x}_{\text{Fertilizer}}$	SE	$\bar{x}_{\text{Tunnel}}$	SE
Science-Based	6.36	0.19	4.52	0.26	2.28	0.28
Values-Based	6.08	0.17	5.08	0.22	2.16	0.24

B

Condition	Arousal					
	$\bar{x}_{\text{Nuclear}}$	SE	$\bar{x}_{\text{Fertilizer}}$	SE	$\bar{x}_{\text{Tunnel}}$	SE
Science-Based	6.08	0.22	4.28	0.22	2.48	0.30
Values-Based	6.32	0.22	4.44	0.28	3.02	0.23

Note. Answers represented on 7-point Likert scales from 1 = *very good* to 7 = *very bad* (midpoint = *indifferent*) for valence and 1 = *very calm* to 7 = *very upset* (midpoint = *indifferent*) for arousal.

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For both conditions, subjects' highest affect ratings across the valence and arousal dimensions corresponded to the abandoned nuclear weapons factory, followed by the fertilizer depot and the tunneling project, respectively (Table 7). Mean funding allocations also were compared to subjects' affect ratings for each of the three sites. In the science-based condition, we observed a steady increase in the size of subjects' desired funding allocation as affect ratings across both dimensions — valence and arousal — increased (Figures 1A and 1B). In contrast, no such trend was observed for subjects in the values-based condition. However, values-based subjects' mean funding allocations could be well correlated with the sites where the anticipated outcomes reflected the priorities identified during the values structuring task (Figure 1C).³

³ Comparing subjects' identified priorities with their funding allocations was possible only for subjects' responses in the values-based condition because only they completed the modified swing-weighting task.

4. Discussion

Our objective for this experiment was to study two approaches for involving non-expert stakeholders in what historically have been considered technical choices, to be addressed by experts. We believe that both approaches tested in this experiment represent significant improvements over those typically employed in most stakeholder involvement processes. The science-based treatment was unusual in terms of the high quality and extensive information provided to subjects, leading to more informed participants. The values-based approach was unusual in that it tied the same technical information to prioritized values (including both individual and societal objectives) so as to foster clearer, more consistent tradeoffs. Both conditions provided relevant information about the decomposed problem, thereby aiding in cognitive processing associated with the workbook tasks, and provided immediate feedback to participants about the consequences of their allocation choices through a self-updating computer program, which afforded opportunities for learning.

Both the science- and values-based approaches show promise in terms of meaningfully engaging stakeholders in helping to set cleanup priorities. For example, both the science-based and values-based approaches resulted in a significant increase in subjects' accumulated level of knowledge, comfort with their choices, and a feeling that their decisions reflect "what matters" (Table 6, Items 2, 4, and 7). These results are consistent with both workbooks providing subjects with more information than is commonly made available through public participation efforts. In addition (and of critical importance), participants in both conditions were provided with a helpful structure for interpreting data. This involved presenting alternatives that could be evaluated across several different attributes, reducing subjects' cognitive demands by implementing a step-by-step approach for analyzing a complex problem, enhancing evaluability by allowing for a side-by-side comparison of the alternatives (for choice tasks 1 and 2), and providing real-time updates of the various attributes of the alternatives that would change depending on the size of subjects' funding allocations (in choice task 3).

Presenting information in a way that is conducive to making complex choices and involves people in a meaningful way may also account for subjects' increased trust in the

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capabilities of risk managers in government agencies (Table 6, Item 6). This is a major problem for many federal agencies involved in waste cleanup activities, including DOE; low levels of trust and a corresponding decline in confidence have been highlighted as an impediment to the progress of cleanup activities and, at a deeper level, “call into fundamental question the bond between those who govern and those who are governed” (DOE, 1993: 3). The results of this study (Table 6, item 6) show moderate increases in trust for the science-based subjects but significant beginning-to-end increases in trust for the values-based participants. These results are supported by those of other values-based risk communication initiatives (e.g., Arvai et al. 2001). They also are consistent with, and help to explain, the finding of the current study (see Table 6, item 1) that important public policy decisions, effecting a diverse group of stakeholders, ought to include about an equal blend of expert and public input.

The results of this study also highlight several differences in the design and outcomes of the science-based and values-based approaches. Subjects’ mean responses to the last three self-rating items shows that participants in the values-based condition felt that the information presented to them was more distorted to meet the needs of government decision makers than did participants in the science-based condition (Table 6, Item 8). This result appears to reflect the dominant societal paradigm concerning the key role of science in solving difficult technical problems such as those common to radioactivity and the cleanup of contaminated sites (Jasanoff, 1990). Clearly, these problems have at their roots complex technical principles and therefore require a detailed science base.

In this context, it is significant that participants in the values-based condition reported a far-larger increase in the extent to which the information helped to make choices about cleanup options that reflected what really matters to them (28% vs. 12% for the science participants). This result is consistent with experimental evidence that people—including both experts and non-experts—often have difficulty when asked to make complex decisions (Slovic et al., 1976). The between-subject comparison suggests that at least a part of this difficulty stems from the fact that people tend not to place technical information in the larger context where they need help to define what matters. As a result, participants may have found it uncomfortable to make difficult choices involving science-science tradeoffs as part of the evaluation of alternatives.

Figure 1. Subjects' mean funding allocations with respect their affect ratings of valence (A) and arousal (B) as well as values-based subjects' priority ratings (C). Error bars reflect standard error. Answers represented on 7-point Likert scales from 1 = *very good* to 7 = *very bad* (midpoint = *indifferent*) for valence and 1 = *very calm* to 7 = *very upset* (midpoint = *indifferent*) for arousal.

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For example, people in the science-based condition of our experiment were presented with information that forced them to make tradeoffs between various complex technical attributes of the alternatives (e.g., tradeoffs between reducing α or β particles and Γ or X rays, tradeoffs between saving terrestrial vertebrates, aquatic vertebrates, or plants, and tradeoffs between a wide variety of frightening illnesses or death). These types of exclusively technical tradeoffs are extremely difficult to make and may represent a form of “constitutive incommensurability” (Tetlock, 2000), where individuals believing they are asked to make tradeoffs among attributes that *all* seem critically important. This is akin to subverting some morally significant values in favor of others and, understandably, creates a conflict that leads to tradeoff avoidance. Evidence for this comes from results showing how participants in the science-based condition made their direct allocation choices (choice task 3). Increases in the mean allocation size were commensurate with increases in mean affect ratings across both the valence and arousal dimensions. On the other hand, the relationship between affect and allocation in the values-based condition was more erratic (Figure 1A and 1B). Overall, affective responses to the three contaminated sites were a more important driver of subjects’ choices in the science-based condition.

In contrast, the magnitude of subjects’ allocations in the values-based condition increased proportionally with the priority they assigned to addressing key attributes of the contamination (Figure 1C). For example, individuals who identified illnesses to humans as their number one concern during the modified swing-weighting task also allocated, on average, the most funds to the site where this was the most significant problem — in this case the former fertilizer depot. Similarly, individuals who identified the costs of monitoring the town’s water supply to be their number one concern tended to allocate the most funds to the site of the irrigation tunneling project. The final priority-allocation relationship (Figure 1C) was established by calculating the mean funding allocations for all sites with the attributes corresponding to a particular priority rating (1 through 6).

In our opinion, choices about the cleanup of radioactive wastes (along with many other important public policy choices) that are reflective of subjects’ carefully considered priorities are more thoughtful and, hence, of higher quality than choices based primarily

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on affect. Although we acknowledge the important role that affect plays in helping to simplify certain types of choices, we contend that complex choices that involve uncertain risks, benefits and large expenditures of resources (like those common to the cleanup of contaminated sites) ought to proceed based on more thoughtful, deliberative modes of judgment. In this respect, the values-based conditions appear to have outperformed the science-based workbooks.

The values-based condition also has the ability to democratize the risk-assessment process by allowing non-experts to participate more meaningfully. This is because the decision-aiding structure of the values-based condition permits non-experts to more capably contribute in areas reflecting their own “expertise” (e.g., objectives relating to community stability and pride, quality of life, economic and recreation opportunities, and the like) (McDaniels, Gregory & Fields, 1999). Moreover, structuring decisions in this way helps to address (and, in some cases, to resolve) issues of tradeoff avoidance because as the different attributes of a given alternative become more tractable, tradeoffs between them seem less objectionable. As a result, choices become easier and participants can begin to follow the mental and affective linkages leading from their own values to the selection of alternatives, which in turn increases their trust in the evaluation and allocation process.

Whereas it is proper for science information to come from technical experts, community and public stakeholders are the experts in terms of their own values. Thus, participatory decision-making processes should work to identify, structure, and meaningfully incorporate these values. Technical analyses are required to address the magnitude and incidence of consequences, but value judgments are needed to identify the sources of concern. Creating a more informed populace is an important objective of public participation processes, but it should be remembered that it is in turn a means to a more fundamental objective: helping non-experts and experts alike to make choices about preferred cleanup alternatives that more closely reflect their primary concerns.

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Low Dose, Risk, Decisions, & Risk Communication

A Decision-Focused Approach to DOE Cleanup Priorities

Appendix A Science-Based Survey Instrument

10/8/02 – S

START TIME _____ END TIME _____

The study in which you are about to participate is part of a research project sponsored by the federal government. The information that will be presented to you is modeled after actual scientific evidence but the context is hypothetical. Nevertheless, your responses may influence government policies about contaminated site cleanup, so please answer each question thoughtfully and with care.

In several cases we will first ask you a question relating to cleanup of contaminated sites, then provide you with more information, and then ask you the same question again. You may find that your answers change or they may stay the same – the choice is entirely up to you and there is no single “right” answer. In all cases, the information we provide you with will be as accurate as possible, reflecting the current state of scientific knowledge.

A FEW QUESTIONS BEFORE WE BEGIN...

Before we begin, please tell us a little about yourself.

1. What is your gender?

_____ Female

_____ Male

2. Please check the category that corresponds with your age.

_____ 18-25

_____ 26-35

_____ 36-45

_____ > 46

3. Do you currently live near a site that has received the Superfund designation from the U.S. Government?

_____ Yes

_____ No

_____ Don't know

INTRODUCTION

Many communities in the United States have problems with soils that are contaminated because of earlier manufacturing or industrial activities. Communities with severe cases of contamination receive the Environmental Protection Agency's *Superfund* designation, which provides targeted funding allocated by Congress and also puts the community on a fast-track list of sites designated for cleanup.

Approximately 500 sites in the United States are currently undergoing cleanup as part of the Superfund program. The nature of the contamination varies from site to site. For example, some sites have been contaminated by hazardous chemicals while others have been contaminated by radiation. Both types of risk can lead to serious adverse effects on human health or the natural environment, depending on the type and duration of exposure. Several Superfund sites are located in the Pacific Northwest.

The intent of the Superfund Program is to clean up all of America's contaminated sites over time. But, depending on the source of the contamination, the costs involved, and the dangers posed to human or environmental health, some sites will be cleaned up sooner than others. Also, cleanup means different things at different sites: some locations will be extensively cleaned so that future residential or agricultural development can occur, and other sites will be cleaned less fully so that they can be used as rangeland or for other less intensive purposes. So in the short-run, choices need to be made regarding what sites to clean up first, how much cleanup to do, and what types of restrictions (if any) should be placed on future uses.

You have been asked to participate in this study so that you can help the US Environmental Protection Agency to decide on priorities for the ongoing Superfund cleanup in the Pacific Northwest. Funding for this study, which is being conducted by independent, university-affiliated researchers based in Eugene, Oregon, comes from the U.S. Environmental Protection Agency and the U.S. Department of Energy.

Imagine that three sites in your community have received the Superfund designation because of problems with soils contaminated by radiation. Assume that you are middle-aged with a family and a secure job in the community that you like. Although you definitely plan to continue living in the community, you agree with many of your neighbors that the soil-based contamination at these three sites is a problem and that some type of cleanup at these sites is necessary.

Assume that cleanup work has been ongoing at all three of the contaminated sites in your community for the past four years, as part of an initial five-year allocation of federal and state funds that was paid to cover costs associated with the cleanup. The final year of the initial phase of the cleanup is scheduled to begin January 1, 2002. As a result, choices will need to be made very soon about how to spend the remainder of the money allocated for the first phase of the cleanup of the three contaminated sites. Phase 2 of the cleanup – a three-year allocation of funds – to complete the cleanup effort is slated to begin in the spring of 2003.

PLEASE ANSWER THE FOLLOWING QUESTIONS...

Please answer the following questions about radiation risks and the cleanup of contaminated soils. Use the seven-point scale that is shown just under each question and circle the response number that best represents your views. There are no right or wrong answers; we want to know *your* views.

1. Do you think policy decisions about the cleanup of contaminated soils as part of the Superfund program should be based just on public input or should they be made just by technical experts?

1	2	3	4	5	6	7
Just public input			Public and expert input			Just expert input

2. How would you characterize your level of knowledge about radiation risks?

1	2	3	4	5	6	7
Very little knowledge			Moderate amount of knowledge			A lot of knowledge

3. To what extent do you have a sense of the issues that matter most to you when thinking about radiation risks?

1	2	3	4	5	6	7
Not at all well			Moderately well			Very well

4. How much have you thought about radiation risks as a source of potential harm to humans or to the environment?

1	2	3	4	5	6	7
Very little thought			Moderate amount of thought			A lot of thought

A Decision-Focused Approach Appendix A: Science-Based Survey Instrument

5. Compared to other human or environmental risk management issues such as global warming or a loss of biodiversity, how important to you are issues related to radiation exposure through soil contamination?

1	2	3	4	5	6	7
Not at all important			Moderately important			Very important

6. How comfortable are you with the prospect that your participation in this study could have an influence on federal cleanup policies for contaminated sites?

1	2	3	4	5	6	7
Not at all comfortable			Moderately comfortable			Very comfortable

7. To what extent do you trust risk managers working for the government to do a good job on the cleanup of contaminated soils?

1	2	3	4	5	6	7
I don't trust them at all			Moderate amount of trust			I trust them very much

8. To what extent do you trust risk managers working for private companies to do a good job on the cleanup of contaminated soils?

1	2	3	4	5	6	7
I don't trust them at all			Moderate amount of trust			I trust them very much

9. Do you believe that the goal of the EPA Superfund program, which is to clean up the three contaminated sites to a designated safe level, will be achieved successfully?

1	2	3	4	5	6	7
No			Maybe			Yes

A Decision-Focused Approach Appendix A: Science-Based Survey Instrument

10. When you think about the following places or programs, to what extent do they make you feel good or bad?

- a. A factory that manufactures nuclear weapons

1	2	3	4	5	6	7
Very Good			Indifferent			Very Bad

- b. An irrigation tunnel that supplies water to local farms

1	2	3	4	5	6	7
Very Good			Indifferent			Very Bad

- c. A warehouse for the storage of farm fertilizers

1	2	3	4	5	6	7
Very Good			Indifferent			Very Bad

- d. A federally funded program to cleanup contaminated sites

1	2	3	4	5	6	7
Very Good			Indifferent			Very Bad

11. When you think about the following places or programs, to what extent do they make you feel calm or upset?

- a. A factory that manufactures nuclear weapons

1	2	3	4	5	6	7
Very Calm			Indifferent			Very Upset

- b. An irrigation tunnel that supplies water to local farms

1	2	3	4	5	6	7
Very Calm			Indifferent			Very Upset

- c. A warehouse for the storage of farm fertilizers

1	2	3	4	5	6	7
Very Calm			Indifferent			Very Upset

- d. A federally funded program to cleanup contaminated sites

1	2	3	4	5	6	7
Very Calm			Indifferent			Very Upset

WHY IS RADIATION A CONCERN?

Because of the energy that it emits, radiation poses a potential human health and environmental risk. This energy can disrupt the structure and function of plant and animal cells. In some cases, the cells can repair the damage done by radiation. However, radiation may also damage cells so that they fail to repair themselves and reproduce in the damaged form, which can lead to several illnesses including radiation sickness and cancers. In the extreme, radiation may kill cells. Longer exposures and larger radiation doses increase the chance that cell damage will occur.

In spite of these risks, it is worth noting that we, as well as the environment around us, are constantly exposed to radiation. It is in the air we breathe and in the things around us. Some of the main natural sources are:

- cosmic radiation
- the rocks and soils around us
- radon and its decay products in rocks and in the atmosphere, and
- the radioactive materials naturally present in our bodies.

Some prominent human-made sources of radiation include materials used:

- at nuclear industry facilities and weapons facilities
- in the manufacture of consumer products such as lantern mantles used for camping and household smoke detectors.

Another common human-made source of radioactivity is ash from coal-fired power plants, which contains the radioactivity originally present in the coal but in a more concentrated form. Other examples of radiation sources are increased terrestrial radiation from disturbing earth during tunnel construction and road building, and fertilizers made from phosphates.

Besides the health and environmental risks associated with radiation, it can be used for many beneficial purposes. For example, the main sources of human-made radiation are X-rays and the radioactive isotopes (radioisotopes) used in the diagnosis and treatment of many injuries and illnesses.

THE TOWN OF LARKSPUR

The town of Larkspur (a hypothetical town based on real events) is located in the Pacific Northwest. It is a medium sized town with approximately 27,000 residents. At present, the economy of Larkspur is mainly natural resource-based with many jobs in the town tied to the timber industry and agriculture. Tourism also plays a major role in the economy of Larkspur. Just north of the town is the Jefferson State Park. The park is a popular tourist destination that offers cross-country skiing, snow-shoeing, and snowmobiling in the winter as well as camping and hiking during the summer months.

RADIATION IN YOUR COMMUNITY

The three sites of soils-based radiation exposure that have been identified in and around Larkspur are:

- an abandoned nuclear weapons factory
- an irrigation tunneling project, and
- a storage warehouse for road maintenance equipment that once served as a storage depot for farm fertilizers.

The locations of these sites are shown on the accompanying map.

Map 1. The Town of Larkspur and Surrounding Areas.

1. The Abandoned Nuclear Weapons Factory:

Built in 1954 and operated by the United States government, this factory produced warheads for nuclear missiles deployed on American submarines. The factory – five miles north of Larkspur – was decommissioned in 1990 at the end of the cold war. Seven of the fourteen buildings that made up the factory have been demolished. The seven buildings that remain will be demolished and all of the contaminated soils on the 14-acre site will be remediated as part of the Superfund cleanup. The source of radioactivity at this site is soils that have been contaminated with uranium used in the weapons manufacturing process.

The level of contamination in the soils and water at this site is ten times the normal background radiation level. This elevated radiation level poses a high risk to human and environmental health. The cleanup of this site began 4 years ago and approximately 50% of the site has been cleaned to date. It is estimated that it will take another seven years before the cleanup is complete at a cost of \$80 million.

On average, 740 people visit the site each year. Of these 740 people, 15 comprise inspectors and salvage operators who are overseeing the demolition of the buildings and the cleanup of the site. Another 225 people are members of the Superfund cleanup crews. The remaining 500 people, primarily day-hikers, are unauthorized visitors who enter the site despite warnings. The plan is for the cleaned site to form part of a nature preserve on the Amon River by the year 2011.

2. The Irrigation Tunneling Project:

Funded by the State and Larkspur County, work began in 1998 on a 15-mile irrigation tunnel linked to the Amon River to support local farms. The project was completed in September 2000 and the irrigation tunnel now provides water for 130 farms in the area. The main source of contamination is approximately 9,000 tons of soil rich with the radioactive material radon that was excavated as part of the tunneling project and currently is stored on site near the tunnel entrance.

The level of contamination in the soils and water at this site is five times the normal background radiation level. Tests of soil samples show that the level of radiation is 1800 millirem. Tests of water samples indicate a radiation level of 120 millirem. The cleanup of this site began four years ago and approximately 50% of the site has been cleaned to date. It is estimated that it will take another four years to complete the cleanup at a cost of \$50 million. The plan is to use the cleaned site as agricultural rangeland for cattle.

An average number of 55 people visit this site each year. Of these 55 people, 5 work in the pump house that regulates water flow in the tunnel. Another 40 people are members of the Superfund cleanup crew. The remaining 10 people are unauthorized visitors to the site who enter the site despite warnings. This soil is currently sitting in a one-acre repository approximately three miles west of the town of Larkspur.

3. The Former Fertilizer Depot:

The farm fertilizer storage depot in southwest Larkspur was owned and operated by a large agricultural supply company from 1971, when it was built, until 1992, when the company was sold and the warehouse was closed. In 1994, the warehouse was converted so that it could house road maintenance and construction equipment owned by the town. The main source of contamination at this site is soils contaminated by radioactivity associated with phosphates contained within the fertilizers that used to be kept here.

The level of contamination in the soils and water at this site is twice the normal background radiation level. Tests of soil samples show that the level of radiation is 720 millirem. Tests of water samples indicate a radiation level of 48 millirem. The cleanup of this site began four years ago and approximately 65% of the site has been cleaned to date. It is estimated that it will take another two years to complete the cleanup at a cost of \$35 million. Once cleaned, the warehouse will still be used to store construction and road maintenance equipment.

An average number of 1,115 people visit this site each year. Of these 1,115 people, 75 work for the town and regularly use the equipment now stored in the warehouse. Another 40 people are members of the Superfund cleanup crew. The remaining 1,000 people are authorized visitors to the site who assist the regular town personnel (e.g., maintenance crews, contractors, etc.). This 2.5-acre site is located approximately half a mile south of the town of Larkspur.

Table 1 on the following page summarizes the information about the three sites:

Table 1. Background information about three contaminated sites near Larkspur.

	Abandoned Nuclear Weapons Factory	Irrigation Tunnel Project	Former Fertilizer Depot
Level of soil contamination within 100 m of site (millirem/year): <i>*average annual human exposure = 360 millirem/year</i>	3600	1800	720
Level of water contamination within 100 m of site (millirem): <i>*normal "background" level = 28 millirem</i>	240	120	48
Average number of people who venture onto site per year:			
Visitors	500	10	1000
Cleanup personnel	225	40	40
Regular personnel	15	5	75
Percent of site remaining to be cleaned after Year 5:	50	70	65
Proximity of site to Town of Larkspur:	5 Miles North	3 Miles West	0.5 Miles South
Total size of site:	14 acres	1 acre	2.5 acres
Total cost to complete cleanup as of Year 5:	\$80,000,000	\$45,000,000	\$35,000,000
Projected time to finish cleanup at current rate of work (in years):	7	4	2
Intended purpose of the site (post-cleanup):	Wildlife Refuge	Rangeland	Storage Warehouse

THE CLEANUP

Cleanup activities are currently underway at each of these three sites. As shown on the map, none of the three sites are located directly in the town of Larkspur. But plants and terrestrial and aquatic organisms living in or near Amon River in the vicinity of the three sites are exposed to radiation associated with the contamination. Also, workers at, and visitors to, each of the sites are exposed to heightened levels of radiation.

Approximately \$30 million remains for the last year (Year 5) of Phase 1 of the cleanup effort for the contaminated sites in your community. Because of the sizes of the affected areas, their degree of contamination, and the costs involved, *completely* remediating *all* of the contaminated areas in your community will not be possible at this time. As a result, the authorities in charge of planning the clean up would like your input regarding the priorities for the clean up effort.

INFORMATION TO HELP INFORM YOUR CHOICES

In order for sound decisions to be made about the cleanup effort in Year 5, it is important that people be given accurate information about the impacts of cleanup efforts. The starting place is to look to the quality of the scientific information, which describes the current state of knowledge about nature of the contamination as well as the prognosis for the cleanup. In fact, this focus on getting detailed and accurate information would be true for any tough decision you might need to make. For example, if you were shopping for a new car, you might look for information that describes the size of the engine, amount of horsepower, fuel economy, and seating capacity.

In the case of contaminated soils near the town of Larkspur, scientists have determined the following technical facets of the problem to be of importance when making decisions about the cleanup of the contaminated sites:

1. A Breakdown of Radiation Contamination by Type

Because it can knock electrons from the atoms and molecules in its path, radiation can cause chemical and/or physical changes in human and animal tissue. The basic unit for measuring radiation is the *rad*. To show biological risk, rads are converted to *rems*. The rem is a unit that has been adjusted to take into consideration the type of radiation absorbed and the likelihood of damage from the different types of radiation. Exposures are normally measured in fractions of a rem, so the commonly used unit of exposure is the *millirem (mrem)*.

$$\begin{aligned}1 \text{ millirem} &= 0.001 \text{ rem} \\1000 \text{ millirem} &= 1 \text{ rem}\end{aligned}$$

It is important to note that different types of radiation (alpha particles, beta particles, gamma rays, and X-rays) differ widely in their abilities to penetrate tissues and deposit energy through ionization. Keep in mind though, that all types of radiation can cause human and environmental health problems depending on the time of exposure and the number of people exposed.

Alpha Particles

Alpha particles are relatively large and carry a double positive charge. They are not very penetrating and can be stopped by a piece of paper. They travel extremely short distances but deposit all of their energy along their short path, doing a relatively large amount of damage.

Beta Particles

Beta particles are extremely small compared to alpha particles and carry a single negative charge. They are more penetrating than alpha particles, but can be

stopped by thin aluminum metal. They travel much longer distances in tissues and deposit much less energy along their paths. Hence, they are less harmful than alpha particles.

Gamma Rays and X-Rays

Gamma rays and X-rays, having no mass or electrical charge, can travel extremely long distances in human tissues compared to alpha and beta rays. They deposit much less energy along their paths but can do large amounts of damage to internal organs. They are the most harmful of all of the radiation types.

2. Human Health Effects by Type

Clearly, exposure to radiation can be a human health risk. As noted above, the energy associated with radiation can disrupt the structure and function of cells. These damaged cells may fail to repair themselves and may, in turn, reproduce in the damaged form. The reproduction of damaged cells can lead to several illnesses including radiation sickness and cancers. In the extreme, radiation may kill cells. Although there is some disagreement about the underlying model, many scientists think that human health effects are directly related to the level of radiation dosage (that is, as the dosage goes up, adverse health effects also go up).

Human health risks are measured based on the mean number of radiation-related illnesses or deaths per 1000 workers and visitors to the site over the total 8 year Superfund cleanup time. Human health experts have identified six primary forms of radiation-related human health risks. They are:

Respiratory Infections

By breathing in radioactive particles, humans are at risk of low to medium level respiratory infections. Patients suffering from these infections typically exhibit difficulty in breathing accompanied by wheezing and a dry cough. If left untreated, these infections may ultimately lead to a condition that may be fatal.

Non-Fatal Cancers

Prolonged exposure to low levels of radiation may lead to certain non-fatal cancers provided the cancers are detected in their early stages. These include a variety of skin cancers and Non-Hodgkin's lymphoma. Typically, treatment of these cancers involves a surgical procedure or chemotherapy treatments.

Radiation Sickness

Acute exposures to radiation may result in radiation sickness. Within a few hours or weeks, radiation sickness manifests itself with the patient suffering from nausea, headaches, loss of appetite, or abnormalities in blood cells. Within

succeeding weeks, symptoms include a loss of hearing, hemorrhaging, diarrhea, and effects on the central nervous system. In most cases, prompt medical treatment gradually restores the patient's health.

Non-Fatal Bone Disorders

Prolonged exposure to radiation may result in a decrease in bone density. If radiation exposure is halted and the disorder is treated in its early stages, the reduction in bone density may be reversed.

Genetic Defects

Rapidly dividing cells are especially sensitive to radiation. Thus, genetic effects affect the development of babies before birth. Studies on animals indicate that exposure to radiation can result in effects that range from no observable damage to malformations of major organs of the body, slowed growth, damage to the central nervous system. In cases where radiation-related genetic effects do not lead to death, affected individuals usually endure permanent disabilities.

Radiation-Related Deaths

Radiation-related disorders that go untreated or exposure to large amounts of radiation can result in death. For example, large exposures to radiation may result in the destruction of bone marrow cells and blood cells. In these cases, fatal forms of bone cancer and leukemia may result.

3. Environmental Impacts by Type

Besides the obvious risks to human health, radiation also poses a risk to the natural environment. The effects of radiation can be most clearly seen in plants, terrestrial organisms, and aquatic organisms.

Plants

Radiation in all forms can be harmful to most plant species. The effects on plants associated with exposure to radiation include a wide variety of phenomena. These include, but are not limited to stunted growth, lower densities of plants per unit area, the presence of tumors, and a decrease in the density of foliage. The effects of radiation on plants are estimated by determining the number of plants with radiation-related abnormalities per 100 sampled within 1 square mile of the source of contamination.

Terrestrial Organisms

Radiation is harmful to most species of terrestrial organisms (organisms that live on land). These organisms include bacteria, insects, reptiles, and mammals. The

effects of radiation on these organisms include, but are not limited to unusually high juvenile mortality, impaired growth, lower densities of organisms per unit area, the presence of radiation-related tumors, and abnormal blood counts. The effects of radiation are estimated by determining the number of terrestrial organisms with radiation-related abnormalities per 100 sampled within 1 square mile of a source of contamination.

Aquatic Organisms

As is the case with terrestrial organisms, radiation in the form of alpha particles, beta particles, gamma rays, and X-rays is also harmful to aquatic organisms (organisms that live in water for all or part of their lives). The effects of radiation on these organisms are the same as those seen in terrestrial organisms. Here too, the effects of radiation on plants are estimated by counting the number of aquatic organisms with radiation-related abnormalities per 100 sampled within 1 square mile of the source of contamination.

4. Cleanup Resources Remaining

Finally, when making choices about the cleanup of contaminated sites, it is important to consider the percentage of the site that has been cleaned up to date, the total cost to complete the cleanup, and the time before the cleanup will be finished at the current rate of work. Clearly, spending more on the cleanup of one site will result in a faster rate of work and therefore, the cleanup of the site over a shorter time period. Conversely, spending less on a particular site will decrease the rate of work, thereby making the cleanup take longer.

Table 2 presents more detailed information on a number of key impacts that have been noted to be of concern with respect to the cleanup of the contaminated sites in your community. Different levels of impact are shown for each of the three different sites, depending on the level of effort and associated expenditures. Please read this information very carefully.

A Decision-Focused Approach Appendix A: Science-Based Survey Instrument

Table 2. Summary of scientific knowledge about three contaminated sites near Larkspur.

	Abandoned Nuclear Weapons Factory	Irrigation Tunnel Project	Former Fertilizer Depot
Level of soil contamination within 100 m of site (millirem): *average annual human exposure = 360 millirem/year	3600	1800	720
Level of contamination (millirem) from:			
Alpha particles	450	575	25
Beta particles	1750	1150	450
Gamma rays	1050	75	245
X-rays	350	0	0
Level of water contamination within 100 m of site (millirem): *normal "background" level = 28 millirem	240	120	48
Level of contamination (millirem) from:			
Alpha particles	5	10	10
Beta particles	135	92	33
Gamma rays	70	18	5
X-rays	30	0	0
Environmental Health Impacts (measured as the number of animals/plants with radiation-related abnormalities per 100 sampled) within 1 square miles of site on:			
Plants	20	7	2
Terrestrial Vertebrates	30	17	2
Aquatic Vertebrates	5	2	0
Health Effects (measured as the mean number of radiation-related illnesses/deaths per 1000 workers and visitors to the site over the total 8 year cleanup time):			
Respiratory Infections	10	6	25
Non-Fatal Cancers	10	5	15
Radiation Sickness	2	0	0
Non-Fatal Bone Disease	5	4	5
Genetic Effects	5	2	5
Radiation-Related Deaths	4	1	0
Percent of site remaining to be cleaned after Year 5:	50%	70%	65%
Projected time to finish cleanup at current rate of work (in years):	7	4	2
Total cost to complete cleanup:	\$80,000,000	\$45,000,000	\$35,000,000

TIME TO CHOOSE – TASK 1

In a moment, you will be shown five different alternatives for approaching the fifth year of the first phase of the cleanup. Each alternative involves an allocation of a fixed amount of funds to continue the cleanup at each of the three contaminates sites near Larkspur. Recall, the budget for the final year is \$30 Million.

The size of the allocation of funds for a given site affects the scientific parameters associated with the contamination. For example, allocating \$15 Million for the cleanup of the abandoned nuclear weapons factory will reduce the level of soil based contamination from 3600 millirem to 3060 millirem by the end of year five of the cleanup. Similarly, allocating \$5 Million to the former fertilizer depot will decrease the level of contamination in the Amon River from 48 millirem to 34 millirem.

On the basis of what you now know about the three sites and the types of risks that are involved, we would now like you to select your preferred alternative for the allocation of funds across all three sites in Year 5 of the cleanup. Read over the alternatives carefully and select the alternative that you like the best by writing the number that corresponds with your choice in the space below. Then, please answer the question that follows this task.

My choice is Alternative _____

How comfortable would you be with this choice if the money really were to be spent according to your choice of alternatives?

1	2	3	4	5	6	7
Not at all comfortable			Moderately comfortable			Very comfortable

HOW DO YOU FEEL ABOUT YOUR CHOICE?

Please answer the following questions that relate to the choice you made on the previous page. We know that you answered some of these same questions before. Still, we'd like you to answer them again. Some of your answers may have changed compared to your earlier responses and some may have stayed the same. Either is fine – we want to know *your* views as of this point in time. Use the seven-point scale that is shown just under each question and circle the response number that best represents your views. Again, there are no right or wrong answers; we want to know *your* views. Please don't look back at your previous responses.

1. How would you now characterize your level of knowledge about radiation risks?

1	2	3	4	5	6	7
Very little knowledge			Moderate amount of knowledge			A lot of knowledge

2. To what extent do you feel that you've identified the issues that matter most to you when thinking about radiation risks?

1	2	3	4	5	6	7
Not at all well			Moderately well			Very well

3. Was the information presented to you about radiation risks and cleanup issues sufficient for you to be able to achieve a comprehensive understanding of the problem and what to do about it?

1	2	3	4	5	6	7
Not at all sufficient			Moderately sufficient			Very sufficient

4. How well does your choice on the previous page match with what you believe would be the ideal allocation of funds for the cleanup of the contaminated sites in year five?

1	2	3	4	5	6	7
Not at all well			Moderately well			Very well

IT'S A COMPLEX PROBLEM – TASK 2

One of the troubling and more complex aspects of cleaning up contaminated sites is the uncertainty that typically accompanies the cleanup effort. This uncertainty can take many forms including:

- uncertainty about the magnitude of current risks
- effectiveness of the cleanup effort
- uncertainty about the timing of the cleanup

The presence of uncertainty means that scientists may disagree about the magnitude of risks or about the effectiveness of cleanup actions. In fact, some scientists believe that in the early stages of the cleanup, some aspects of the contaminated sites will actually become worse before they get better (for example, the amount dust associated with the early stages of the cleanup may result in a higher number of illnesses among workers). This uncertainty can be expressed as a range of possible outcomes associated with each concern. For example, allocating \$10 Million for year 5 of the cleanup of the irrigation tunneling project means that the cleanup of the entire site could be finished sooner than expected (in two years) or later than expected (in four years) – depending on which scientist you asked.

Here are the same 5 alternatives for cleanup that you saw before. The difference is that they now include uncertainty depicted by the ranges of values present for each concern. As before, the budget for the final year is \$30 Million (this money already has been allocated, so it is not subject to uncertainty!). Read over the alternatives carefully. Then, select the alternative that you like the best. You may select a different alternative or stick with your prior choice: it's up to you. As before, please answer the question that follows this task.

My choice is Alternative _____

How comfortable would you be with this choice if the money really were to be spent according to your choice of alternatives?

1	2	3	4	5	6	7
Not at all			Moderately			Very
Comfortable			comfortable			comfortable

HOW DO YOU FEEL ABOUT YOUR CHOICE?

Please answer the following questions that relate to the choice you made on the previous page. We know that you answered some of these same questions before but we'd like you to answer them again because some of your answers may have changed while some may have stayed the same. Either is fine – we want to know *your* views as of this point in time. Use the seven-point scale that is shown just under each question and circle the response number that best represents your views. Again, there are no right or wrong answers; we want to know *your* views. Please don't look back at your previous responses.

1. Given the uncertainty associated with the contaminated sites and their cleanup, do you think differently about the problem?

1	2	3	4	5	6	7
Not at all differently			Somewhat differently			Very differently

2. Given the uncertainty associated with the contaminated sites and their cleanup, to what extent do you trust risk managers working for the government to do a good job on the cleanup of contaminated soils?

1	2	3	4	5	6	7
I don't trust them at all		Moderate amount of trust				I trust them very much

3. Given the uncertainty associated with the contaminated sites and their cleanup, to what extent do you trust risk managers working for private companies to do a good job on the cleanup of contaminated soils?

1	2	3	4	5	6	7
I don't trust them at all		Moderate amount of trust				I trust them very much

12. Given the uncertainty associated with the contaminated sites and their cleanup, do you believe that the goal of the EPA Superfund program in Larkspur, which is to clean up the three contaminated sites to a designated safe level, will be achieved successfully?

1	2	3	4	5	6	7
No			Maybe			Yes

A DIRECT ALLOCATION OF FUNDS – TASK 3 (ON COMPUTER)

We'd now like to give you the opportunity to directly allocate the \$30 Million worth of funds for year five of the cleanup to the three contaminated sites.

Keeping the scientific information in mind, use the computer to allocate the amount funding of your choice to each of the three contaminated sites. As you do this, notice that the magnitude of risks or estimates about the effectiveness of cleanup actions varies depending on the amount of money that you choose to spend each site.

After you have finished, please write the amount of your desired allocation of funds for each of the three contaminated sites in the spaces provided below.

Site	Nuclear Weapons Factory	Irrigation Tunneling Project	Former Fertilizer Depot
Allocation	\$ _____	\$ _____	\$ _____

SOME FINAL QUESTIONS...

1. Suppose that we were to come back to you again in two or three weeks and ask you to complete these same three tasks. Do you think your answers would be the same?

_____ Yes _____ No
(please check one)

2. How well do you feel that the choices you made today about funding allocations reflect what you really care about when it comes to the cleanup of contaminated sites?

1	2	3	4	5	6	7
Not at all well			Moderately well			Very well

3. How useful did you find the information that was presented to you today to be for making your choices about the Superfund cleanup of the contaminated sites?

1	2	3	4	5	6	7
Not at all useful			Moderately useful			Very useful

4. In your view, how would you judge the quality of the technical/scientific information that was presented to you today?

1	2	3	4	5	6	7
Low quality			Medium quality			High quality

5. To what extent do you feel that the information presented to you today was distorted to suit the needs of the government managers in charge of cleaning up the contaminated sites in your community?

1	2	3	4	5	6	7
Not at all distorted			Moderately distorted			Very distorted

6. How would you now characterize your level of knowledge about radiation risks?

1	2	3	4	5	6	7
Very little knowledge			Moderate amount of knowledge			A lot of knowledge

7. How frustrating did you find it to complete the 3 allocation tasks in this workbook?

1	2	3	4	5	6	7
Not at all frustrating			Moderately frustrating			Very frustrating

A Decision-Focused Approach Appendix A: Science-Based Survey Instrument

8. Do you think policy decisions about the cleanup of contaminated soils as part of the Superfund program should be based just on public input or should they be made just by technical experts?

1	2	3	4	5	6	7
Just public input			Public and expert input			Just expert input

9. Compared to other human or environmental risk management issues such as global warming or a loss of biodiversity, how important to you are issues related to radiation exposure through soil contamination?

1	2	3	4	5	6	7
Not at all important			Moderately important			Very important

10. How comfortable are you with the prospect that the choices you made today could have an influence on federal cleanup policies for contaminated sites?

1	2	3	4	5	6	7
Not at all comfortable			Moderately comfortable			Very comfortable

11. To what extent do you trust risk managers working for the government to do a good job on the cleanup of contaminated soils?

1	2	3	4	5	6	7
I don't trust them at all			Moderate amount of trust			I trust them very much

12. To what extent do you trust risk managers working for private companies to do a good job on the cleanup of contaminated soils?

1	2	3	4	5	6	7
I don't trust Them at all			Moderate amount of trust			I trust them very much

13. Do you believe that the goal of the EPA Superfund program in Larkspur, which is to clean up the three contaminated sites to a designated safe level, will be achieved successfully?

1	2	3	4	5	6	7
No			Maybe			Yes

A Decision-Focused Approach Appendix A: Science-Based Survey Instrument

Did your choice of alternative in Task 2 differ from your choice in Task 1 (after you received information about the problem that was more “uncertain”)? Please explain why or why not.

This image shows a blank sheet of white paper with horizontal ruling lines. The lines are evenly spaced and extend across the width of the page. There are no margins, text, or other markings on the paper.

If applicable, please tell us, in as much detail as possible, about your thought processes when you completed Task 3 (on the computer) and directly allocated funds for year 5 of the Superfund cleanup.

[illegible]

Low Dose, Risk, Decisions, & Risk Communication

A Decision-Focused Approach to DOE Cleanup Priorities

Appendix B Values-Based Survey Instrument

10/10/02 – V

START TIME _____ END TIME _____

The study in which you are about to participate is part of a research project sponsored by the federal government. The information that will be presented to you is modeled after actual scientific evidence but the context is hypothetical. Nevertheless, your responses may influence government policies about contaminated site cleanup, so please answer each question thoughtfully and with care.

In several cases we will first ask you a question relating to cleanup of contaminated sites, then provide you with more information, and then ask you the same question again. You may find that your answers change or they may stay the same – the choice is entirely up to you and there is no single “right” answer. In all cases, the information we provide you with will be as accurate as possible, reflecting the current state of scientific knowledge.

A FEW QUESTIONS BEFORE WE BEGIN...

Before we begin, please tell us a little about yourself.

1. What is your gender?

_____ Female

_____ Male

2. Please check the category that corresponds with your age.

_____ 18-25

_____ 26-35

_____ 36-45

_____ > 46

3. Do you currently live near a contaminated site that has received the Superfund designation from the U.S. Government?

_____ Yes

_____ No

_____ Don't know

INTRODUCTION

Many communities in the United States have problems with soils that are contaminated because of earlier manufacturing or industrial activities. Communities with severe cases of contamination receive the Environmental Protection Agency's *Superfund* designation, which provides targeted cleanup funding allocated by Congress and also puts the community on a fast-track list of sites designated for cleanup.

Approximately 500 sites in the United States are currently undergoing cleanup as part of the Superfund program. The nature of the contamination varies from site to site. For example, hazardous chemicals have contaminated some sites while others have been contaminated by radiation. Both types of risk can lead to serious adverse effects on human health or the natural environment, depending on the type and duration of exposure. Several Superfund sites are located in the Pacific Northwest.

The intent of the Superfund Program is to clean up all of America's contaminated sites over time. But, depending on the source of the contamination, the costs involved, and the dangers posed to human or environmental health, some sites will be cleaned up sooner than others. Also, cleanup means different things at different sites: some locations will be extensively cleaned so that future residential or agricultural development can occur, and other sites will be cleaned less fully so that they can be used as rangeland or for other less intensive purposes. So in the short-run, choices need to be made regarding what sites to clean up first, how much cleanup to do, and what types of restrictions (if any) should be placed on future uses.

You have been asked to participate in this study so that you can help the US Environmental Protection Agency to decide on priorities for the ongoing Superfund cleanup in the Pacific Northwest. Funding for this study, which is being conducted by independent, university-affiliated researchers based in Eugene, Oregon, comes from the U.S. Environmental Protection Agency and the U.S. Department of Energy.

Imagine that three sites in your community have received the Superfund designation because of problems with soils contaminated by radiation. Assume that you are middle-aged with a family and a secure job in the community that you like. Although you definitely plan to continue living in the community, you agree with many of your neighbors that the soil-based contamination at these three sites is a problem and that some type of cleanup at these sites is necessary.

Assume that cleanup work has been ongoing at all three of the contaminated sites in your community for the past four years, as part of an initial five-year allocation of federal and state funds that was paid to cover costs associated with the cleanup. The final year of the initial phase of the cleanup is scheduled to begin January 1, 2002. As a result, choices will need to be made very soon about how to spend the remainder of the money allocated for the first phase of the cleanup of the three contaminated sites. Phase 2 of the cleanup – a three-year allocation of funds – to complete the cleanup effort is slated to begin in the spring of 2003.

PLEASE ANSWER THE FOLLOWING QUESTIONS...

Please answer the following questions about radiation risks and the cleanup of contaminated soils. Use the seven-point scale that is shown just under each question and circle the response number that best represents your views. There are no right or wrong answers; we want to know *your* views.

1. Do you think policy decisions about the cleanup of contaminated soils as part of the Superfund program should be based just on public input or should they be made just by technical experts?

1	2	3	4	5	6	7
Just public input			Public and expert input			Just expert input

2. How would you characterize your level of knowledge about radiation risks?

1	2	3	4	5	6	7
Very little knowledge			Moderate amount of knowledge			A lot of knowledge

3. To what extent do you have a sense of the issues that matter most to you when thinking about radiation risks?

1	2	3	4	5	6	7
Not at all well			Moderately well			Very well

4. How much have you thought about radiation risks as a source of potential harm to humans or to the environment?

1	2	3	4	5	6	7
Very little thought			Moderate amount of thought			A lot of thought

A Decision-Focused Approach Appendix B: Values-Based Survey Instrument

5. Compared to other human or environmental risk management issues such as global warming or a loss of biodiversity, how important to you are issues related to radiation exposure through soil contamination?

1	2	3	4	5	6	7
Not at all important			Moderately important			Very important

6. How comfortable are you with the prospect that your participation in this study could have an influence on federal cleanup policies for contaminated sites?

1	2	3	4	5	6	7
Not at all comfortable			Moderately comfortable			Very comfortable

7. To what extent do you trust risk managers working for the government to do a good job on the cleanup of contaminated soils?

1	2	3	4	5	6	7
I don't trust them at all			Moderate amount of trust			I trust them very much

8. To what extent do you trust risk managers working for private companies to do a good job on the cleanup of contaminated soils?

1	2	3	4	5	6	7
I don't trust them at all			Moderate amount of trust			I trust them very much

9. Do you believe that the goal of the EPA Superfund program, which is to clean up the three contaminated sites to a designated safe level, will be achieved successfully?

1	2	3	4	5	6	7
No			Maybe			Yes

A Decision-Focused Approach Appendix B: Values-Based Survey Instrument

10. When you think about the following places or programs, to what extent do they make you feel good or bad?

- a. A factory that manufactures nuclear weapons

1	2	3	4	5	6	7
Very Good			Indifferent			Very Bad

- b. An irrigation tunnel that supplies water to local farms

1	2	3	4	5	6	7
Very Good			Indifferent			Very Bad

- c. A warehouse for the storage of farm fertilizers

1	2	3	4	5	6	7
Very Good			Indifferent			Very Bad

- d. A federally funded program to cleanup contaminated sites

1	2	3	4	5	6	7
Very Good			Indifferent			Very Bad

11. When you think about the following places or programs, to what extent do they make you feel calm or upset?

- a. A factory that manufactures nuclear weapons

1	2	3	4	5	6	7
Very Calm			Indifferent			Very Upset

- b. An irrigation tunnel that supplies water to local farms

1	2	3	4	5	6	7
Very Calm			Indifferent			Very Upset

- c. A warehouse for the storage of farm fertilizers

1	2	3	4	5	6	7
Very Calm			Indifferent			Very Upset

- d. A federally funded program to cleanup contaminated sites

1	2	3	4	5	6	7
Very Calm			Indifferent			Very Upset

WHY IS RADIATION A CONCERN?

Because of the energy that it emits, radiation poses a potential human health and environmental risk. This energy can disrupt the structure and function of plant and animal cells. In some cases, the cells can repair the damage done by radiation. However, radiation may also damage cells so that they fail to repair themselves and reproduce in the damaged form, which can lead to several illnesses including radiation sickness and cancers. In the extreme, radiation may kill cells. Longer exposures and larger radiation doses increase the chance that cell damage will occur.

In spite of these risks, it is worth noting that we, as well as the environment around us, are constantly exposed to radiation. It is in the air we breathe and in the things around us. Some of the main natural sources are:

- cosmic radiation
- the rocks and soils around us
- radon and its decay products in rocks and in the atmosphere, and
- the radioactive materials naturally present in our bodies.

Some prominent human-made sources of radiation include materials used:

- at nuclear industry facilities and weapons facilities
- in the manufacture of consumer products such as lantern mantles used for camping and household smoke detectors.

Another common human-made source of radioactivity is ash from coal-fired power plants, which contains the radioactivity originally present in the coal but in a more concentrated form. Other examples of radiation sources are increased terrestrial radiation from disturbing earth during tunnel construction and road building, and fertilizers made from phosphates.

Besides the health and environmental risks associated with radiation, it can be used for many beneficial purposes. For example, the main sources of human-made radiation are X-rays and the radioactive isotopes (radioisotopes) used in the diagnosis and treatment of many injuries and illnesses.

THE TOWN OF LARKSPUR

The town of Larkspur (a hypothetical town based on real events) is located in the Pacific Northwest. It is a medium sized town with approximately 27,000 residents. At present, the economy of Larkspur is mainly natural resource-based with many jobs in the town tied to the timber industry and agriculture. Tourism also plays a major role in the economy of Larkspur. Just north of the town is the Jefferson State Park. The park is a popular tourist destination that offers cross-country skiing, snow-shoeing, and snowmobiling in the winter as well as camping and hiking during the summer months.

RADIATION IN YOUR COMMUNITY

The three sites of soils-based radiation exposure that have been identified in and around Larkspur are:

- an abandoned nuclear weapons factory
- an irrigation tunneling project, and
- a storage warehouse for road maintenance equipment that once served as a storage depot for farm fertilizers.

The locations of these sites are shown on the accompanying map.

Map 1. The Town of Larkspur and Surrounding Areas.

1. The Abandoned Nuclear Weapons Factory:

Built in 1954 and operated by the United States government, this factory produced warheads for nuclear missiles deployed on American submarines. The factory – five miles north of Larkspur – was decommissioned in 1990 at the end of the cold war. Seven of the fourteen buildings that made up the factory have been demolished. The seven buildings that remain will be demolished and all of the contaminated soils on the 14-acre site will be remediated as part of the Superfund cleanup. The source of radioactivity at this site is soils that have been contaminated with uranium used in the weapons manufacturing process.

The level of contamination in the soils and water at this site is ten times the normal background radiation level. This elevated radiation level poses a high risk to human and environmental health. The cleanup of this site began 4 years ago and approximately 50% of the site has been cleaned to date. It is estimated that it will take another seven years before the cleanup is complete at a cost of \$80 million.

On average, 740 people visit the site each year. Of these 740 people, 15 comprise inspectors and salvage operators who are overseeing the demolition of the buildings and the cleanup of the site. Another 225 people are members of the Superfund cleanup crews. The remaining 500 people, primarily day-hikers, are unauthorized visitors who enter the site despite warnings. The plan is for the cleaned site to form part of a nature preserve on the Amon River by the year 2011.

2. The Irrigation Tunneling Project:

Funded by the State and Larkspur County, work began in 1998 on a 15-mile irrigation tunnel linked to the Amon River to support local farms. The project was completed in September 2000 and the irrigation tunnel now provides water for 130 farms in the area. The main source of contamination is approximately 9,000 tons of soil rich with the radioactive material radon that was excavated as part of the tunneling project and currently is stored on site near the tunnel entrance.

The level of contamination in the soils and water at this site is five times the normal background radiation level, which is considered to pose a low to moderate risk to human and environmental health. The cleanup of this site began four years ago and approximately 50% of the site has been cleaned to date. It is estimated that it will take

another four years to complete the cleanup at a cost of \$45 million. The plan is to use the cleaned site as agricultural rangeland for cattle.

An average number of 55 people visit this site each year. Of these 55 people, 5 work in the pump house that regulates flow rates in the irrigation tunnel. Another 40 people are members of the Superfund cleanup crew. The remaining 10 people are unauthorized visitors to the site who enter the site despite warnings. This soil is currently sitting in a one-acre repository approximately three miles west of the town of Larkspur.

3. The Former Fertilizer Depot:

The farm fertilizer storage depot in southwest Larkspur was owned and operated by a large agricultural supply company from 1971, when it was built, until 1992, when the company was sold and the warehouse was closed. In 1994, the warehouse was converted so that it could house road maintenance and construction equipment owned by the town. The main source of contamination at this site is soils contaminated by radioactivity associated with phosphates contained within the fertilizers that used to be kept here.

The level of contamination in the soils and water at this site is twice the normal background radiation level. This elevated level of radiation poses a low environmental risk but poses a extreme risk to human health in terms of radiation related illnesses due to the large number of workers and visitors to this site. An average number of 1,115 people visit this site each year. Of these 1,115 people, 75 people work for the town and regularly use the equipment now stored in the warehouse. Another 40 people are members of the Superfund cleanup crew. The remaining 1,000 people are authorized visitors to the site who assist the regular town personnel (e.g., maintenance crews, contractors, etc.).

The cleanup of this site began four years ago and approximately 65% of the site has been cleaned to date. It is estimated that it will take another two years to complete the cleanup at a cost of \$35 million. Once cleaned, the warehouse will still be used to store construction and road maintenance equipment. This 2.5-acre site is located approximately half a mile south of the town of Larkspur.

Table 1 on the following page summarizes the information about the three sites:

Table 1. Background information about three contaminated sites near Larkspur.

	Abandoned Nuclear Weapons Factory	Irrigation Tunnel Project	Former Fertilizer Depot
Level of soil contamination within 100 m of site (x background): *average annual human exposure = 360 millirem/year	10 x	5 x	2 x
Level of water contamination within 100 m of site (x background): *normal "background" level = 28 millirem	10 x	5 x	2 x
Average number of people who venture onto site per year:			
Visitors	500	10	1000
Cleanup personnel	225	40	40
Regular personnel	15	5	75
Percent of site remaining to be cleaned after Year 5:	50	70	65
Proximity of site to Town of Larkspur:	5 Miles North	3 Miles West	0.5 Miles South
Total size of site:	14 acres	1 acre	2.5 acres
Total cost to complete cleanup as of Year 5:	\$80,000,000	\$45,000,000	\$35,000,000
Projected time to finish cleanup at current rate of work (in years):	7	4	2
Intended purpose of the site (post-cleanup):	Wildlife Refuge	Rangeland	Storage Warehouse

THE CLEANUP

Cleanup activities are currently underway at each of these three sites. As shown on the map, none of the three sites are located directly in the town of Larkspur. But, plants, wildlife, and fish living in or near the Amon River in the vicinity of the contaminated sites are exposed to radiation associated with the contamination. Also, workers at, and visitors to, each of the sites are exposed to heightened levels of radiation.

Approximately \$30 million remains for the last year (Year 5) of Phase 1 of the cleanup effort for the contaminated sites in your community. Because of the sizes of the affected areas, their degree of contamination, and the costs involved, *completely* remediating *all* of the contaminated areas in your community will not be possible at this time. As a result, the authorities in charge of planning the clean up would like your input regarding the priorities for the clean up effort.

INFORMATION TO HELP INFORM YOUR CHOICES

In order for informed decisions to be made about the cleanup effort in Year 5, it is important that people be given accurate information about the cleanup efforts. The starting place is to look to the issues that people in the community say that matter most to them – their values. In fact, this focus on values would be true for any tough decision you might need to make. For example, if you were shopping for a new car, you might look for features that make you and your family feel like you are doing your part for the environment while at the same time making you feel safe.

In the case of contaminated soils near the town of Larkspur, people in the community have identified the following facets of the problem to be of importance when making decisions about the cleanup of the contaminated sites:

1. Environmental Risks

Radiation can be harmful to many species of plants, wildlife, and fish. For example, exposure to radiation may result in stunted growth, a lower number of animals or plants in an affected area, the presence of tumors and deformations, and reductions in the overall populations of these species. In general terms, risks to plants, wildlife, and fish are considered to be negligible when scientists cannot find any affected plants or animals within 1 square mile of the contaminated site. Risks are considered to be moderate when approximately 15% of the plants and animals sampled show signs of radiation-related problems. Risks are considered to be extreme when about 30% or more of the plants, animals, and fish sampled show signs of radiation-related problems. For environmental risks, an overall – or general – risk factor (on a 10-point scale) can be determined for all plants, wildlife and fish living near the contaminated sites. It's also possible to assign a risk factor for plants, wildlife, and fish in the following way:

Plantlife – Scientists can examine certain trees, alder in particular, for signs of radiation related problems. An extreme risk to plant life is roughly equivalent to finding 30% of the alder examined within 1 square mile of the contaminated site exhibiting radiation-related effects.

Terrestrial Wildlife – A good indicator of the effects of radiation on wildlife is to look at its effects on the resident deer population near Larkspur. Risks to wildlife are judged as being extreme when approximately 35% or more of the deer population within 1 square mile of the contaminated site exhibits radiation-related problems.

Fish – Brook trout provide one of the best indicators of radiation related effects on fish in the Amon River. Risks to fish are judged as being extreme when approximately 25% of the brook trout sampled within 1 square mile of the contaminated site exhibit radiation-related effects.

2. Human Health Risks

Large doses of radiation or prolonged exposure poses a risk to human health. As noted above, the energy associated with radiation can disrupt, damage, or destroy the structure and function of cells. One way of determining the magnitude of human health risks from radiation is to look at the number of radiation-related illnesses and deaths among people who work at or visit contaminated sites.

In the case of radiation-related illnesses, risks from radiation are considered to be extreme when 7% of the people who work at or visit a contaminated site fall ill. For radiation related deaths, radiation risks are considered to be extreme when 2% of the people who work at or visit a contaminated site die as a result of their exposure to radiation.

3. Costs of Managing the Larkspur Drinking Water Supply

When the Superfund sponsored cleanup of the contaminated sites near Larkspur began, there was concern about the safety of the town's water supply. These concerns arose despite the fact that the drinking water supply for Larkspur comes from an area 30 miles north of Larkspur and upstream from each of the three contaminated sites, thereby virtually eliminating the risk that the drinking water supply for town will become contaminated. Nevertheless, the town has instituted more strict water testing procedures as part of its water management guidelines. These stricter testing procedures will remain in place over the course of the Superfund cleanup. Currently, the town spends \$3,250,000 per year on the new tests of the drinking water supply, with the monies spent coming from increased property taxes. As the cleanup of the contaminated sites proceeds and the sites themselves return to their natural condition, public confidence in the drinking water is expected to increase. As a result, tests of the water supply will not need to be as frequent, thereby lowering the overall costs of water management.

4. Costs to Tourism and the Economy

Another important aspect of the contamination and cleanup process identified by members of the Larkspur community is the losses to the tourist economy brought on by the presence of radiation contamination. As noted above, tourism, mainly associated with the Jefferson State Park, plays a large role in the economy of Larkspur. Since the contamination at the three sites in your community has become common knowledge in the state, fewer tourists have been taking part in summer and winter activities (e.g., skiing, hiking, camping, fishing, etc.) in the park resulting in a cost to local businesses who support these activities (e.g., shops, restaurants, hotels, etc.). In total, contamination at the nuclear weapons factory contributes to a 6.3% decline to the tourism economy in Larkspur. The irrigation tunneling project contributes to a 46.4% decline in tourism-related revenue for the town. In contrast, because of its size and distance from the park, contamination associated with the former fertilizer depot does not result in any losses to the tourism economy of Larkspur.

5. Unsightliness of the Sites

One of the other considerations highlighted by members of the community was the “eyesore” factor – or unsightliness – associated with the sites as they are being cleaned up. The objective of the cleanup is to return the location of the nuclear weapons factory to its original condition – a wilderness area – prior to when the factory was built. The soil repository will be removed at the irrigation tunneling site and the surrounding areas will be restored to open rangeland. The storage warehouse is the least unsightly of the three sites but a new façade for the building will be constructed once the Superfund cleanup is completed.

There are a number of other factors that may be of interest to you as you think about how the cleanup effort in Year 5 should proceed. These factors are referred to as “Site Quality Characteristics” and include such factors as:

- **The Level of Contamination** – For the three contaminated sites near Larkspur, contamination is expressed as the level above what is considered “normal” for this area.
- **Cleanup Resources Remaining** – When making choices about the cleanup of contaminated sites, it may be important to consider the percentage of the site that has been cleaned up to date, the total cost to complete the cleanup, and the time before the cleanup will be finished at the current rate of work. Spending more on the cleanup of one site will result in a faster rate of work and therefore, the cleanup of the site over a shorter time period. Conversely, spending less on a particular site will decrease the rate of work, thereby making the cleanup take longer.

Table 2 presents more detailed information on a number of key impacts that have been noted to be of concern with respect to the cleanup of the contaminated sites in your community. Different levels of impact are shown for each of the three different sites, depending on the level of effort and associated expenditures. Please read this information very carefully.

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Table 2. Summary of information about three contaminated sites near Larkspur.

		Abandoned Nuclear Weapons Factory	Irrigation Tunnel Project	Former Fertilizer Depot
Values Information	Overall environmental risks within 1 square mile of site: (0=no risk; 5=moderate risk; 10=extreme risk)	7	4	1
	Percent of alder affected within 1 square mile of site	20%	7%	2%
	Percent of deer affected within 1 square mile of site	30%	17%	2%
	Percent of brook trout affected within 1 square mile of site	5%	2%	0%
	Risk of radiation-related illnesses to humans: (0=no risk; 5=moderate risk; 10=extreme risk)	4	2	10
	Percent of workers and/or visitors falling ill	3.2%	1.7%	7.0%
	Risk of radiation-related deaths to humans: (0=no risk; 5=moderate risk; 10=extreme risk)	3	1	0
	Percent of workers and/or visitors dying	0.04%	0.01%	0.0%
	Annual costs of managing the Larkspur drinking water supply	\$1,000,000	\$2,000,000	\$250,000
	Annual costs to the Larkspur economy from reduced tourism due to contamination:			
	Summer Tourism (camping, fishing, etc.)	\$750,000	\$5,500,000	\$0
	Percent Decline	3%	22%	0%
	Winter Tourism (skiing, snowshoeing, etc.)	\$1,500,000	\$15,000,000	\$0
	Percent Decline	4%	36%	0%
Site Quality Characteristics	Judged unsightliness ("ugliness") of site: (0=not at all unsightly; 5=moderately unsightly; 10=extremely unsightly)	8	6	2
	Level of soil contamination within 100 m of site (x normal level): *average annual human exposure = 360 millirem/year	10.0 x	5.0 x	2.0 x
	Level of water contamination within 100 m of site (x normal level): *normal "background" level = 28 millirem	10.0 x	5.0 x	2.0 x
	Percent of site remaining to be cleaned after Year 5:	50%	70%	65%
	Projected time to finish cleanup at current rate of work (in years):	7	4	2
	Total cost to complete cleanup:	\$80,000,000	\$45,000,000	\$35,000,000

WHAT'S IMPORTANT TO YOU?

The previous discussion has identified six principal types of adverse effects and stakeholder concerns associated with the radiation risks at the contaminated sites in your community. These items are shown in the table below. Other information relating to the cleanup of the sites may also affect your decisions about how the cleanup funds for Year 5 should best be spent. A first task, however, is to think about the six types of adverse effects and to decide which of these concerns is relatively more or less important to you.

In thinking about your priorities, it is important to keep in mind what is actually possible at the three sites. For example, even if the entire \$30 Million budget is spent at one site, some adverse effects still would remain. This is shown in the “Best Possible Level” column where, except for row 3 (fatalities), some risks will remain. One way to think about cleanup priorities is to improve upon a cleanup strategy that does a poor job of addressing each of the six adverse effects (shown in the “Worst Level” column in the table). Rows 1-4 show concerns based on a general risk factor (on a 10-point scale). Rows 5 and 6 are shown as costs.

Look over the table and decide which one of these six adverse effects you would most want to improve to the best possible level that could be attained after Year 5. Rank that concern as your top priority and put a “1” in the “Rank” column. Follow this same procedure for the remaining five concerns, ranking them from 2 to 6. Ties are allowed, but please think carefully about your choices.

Concern	Location at end of year 4 of cleanup	Worst Level	Best Possible Level	Rank
1) Risks to the environment (plants, wildlife, and fish)	Nuclear Weapons Factory	7	4	
2) Human health risks contributing to illnesses	Former Fertilizer Depot	10	1	
3) Human health risks contributing to fatalities	Nuclear Weapons Factory	3	0	
4) The unsightliness of the ongoing site cleanup	Nuclear Weapons Factory	8	5	
5) Costs of managing the Larkspur drinking water supply	Irrigation Tunnel Project	\$2,000,000	\$666,667	
6) Costs to tourism and the economy	Irrigation Tunnel Project	\$15,000,000	\$5,000,000	

Take as much time as is necessary to ensure that your ranking accurately reflects your priorities about how the cleanup money should be spent in Year 5.

STOP AND CHECK WITH THE FACILITATOR BEFORE PROCEEDING.

TIME TO CHOOSE – TASK 1

In a moment, you will be shown 5 different alternatives for approaching the fifth year of the first phase of the cleanup. Each alternative involves an allocation of a fixed amount of funds to continue the cleanup at each of the three contaminates sites near Larkspur. Recall, the budget for the final year is \$30 Million.

The size of the allocation of funds for a given site affects the adverse effects associated with the contamination. For example, allocating \$20 Million for the cleanup of the abandoned nuclear weapons factory will reduce the environmental risks from a 7 on a 10-point risk scale to a 5. Similarly, allocating \$10 Million to the irrigation tunneling site will decrease the amount of money spent on testing the drinking water supply by almost \$500,000.

On the basis of what you now know about the three sites, the types of risks that are involved, and the adverse effects associated with them, we would now like you to select your preferred alternative for the allocation of funds across all three sites in Year 5 of the cleanup. Read over the alternatives carefully and select the alternative that you like the best by writing the number that corresponds with your choice in the space below. Then, answer the question that follows this task.

WHEN ANSWERING THIS QUESTION, PLEASE REFER BACK TO YOUR RANKING OF CLEANUP PRIORITIES ON PAGE 15.

My choice is Alternative _____

How comfortable would you be with this choice if the money really were to be spent according to your choice of alternatives?

1	2	3	4	5	6	7
Not at all			Moderately			Very
comfortable			comfortable			comfortable

HOW DO YOU FEEL ABOUT YOUR CHOICE?

Please answer the following questions that relate to the choice you made on the previous page. We know that you answered some of these same questions before. Still, we'd like you to answer them again. Some of your answers may have changed compared to your earlier responses and some may have stayed the same. Either is fine – we want to know *your* views as of this point in time. Use the seven-point scale that is shown just under each question and circle the response number that best represents your views. Again, there are no right or wrong answers; we want to know *your* views. Please don't look back at your previous responses.

1. How would you now characterize your level of knowledge about radiation risks?

1	2	3	4	5	6	7
Very little knowledge			Moderate amount of knowledge			A lot of knowledge

2. To what extent do you feel that you've identified the issues that matter most to you when thinking about radiation risks?

1	2	3	4	5	6	7
Not at all well			Moderately well			Very well

3. Was the information presented to you about radiation risks and cleanup issues sufficient for you to be able to achieve a comprehensive understanding of the problem and what to do about it?

1	2	3	4	5	6	7
Not at all sufficient			Moderately sufficient			Very sufficient

4. How well does your choice on the previous page match with what you believe would be the ideal allocation of funds for the cleanup of the contaminated sites in year five?

1	2	3	4	5	6	7
Not at all well			Moderately well			Very well

IT'S A COMPLEX PROBLEM – TASK 2

One of the troubling and more complex aspects of cleaning up contaminated sites is the uncertainty that typically accompanies the cleanup effort. This uncertainty can take many forms including:

- uncertainty about the magnitude of current risks
- effectiveness of the cleanup effort
- uncertainty about the timing of the cleanup

The presence of uncertainty means that scientists may disagree about the magnitude of risks or about the effectiveness of cleanup actions. In fact, some scientists believe that in the early stages of the cleanup, some aspects of the contaminated sites will actually become worse before they get better (for example, the amount dust associated with the early stages of the cleanup process may result in a higher number of illnesses among workers). This uncertainty can be expressed as a range of possible outcomes associated with each concern. For example, allocating \$10 Million for year 5 of the cleanup of the irrigation tunneling project means that the cleanup of the entire site could be finished sooner than expected (in two years) or later than expected (in four years) – depending on which scientist you asked.

Here are the same 5 alternatives for cleanup that you saw before. The difference is that they now include uncertainty depicted by the ranges of values present for each concern. As before, the budget for the final year is \$30 Million (this money already has been allocated, so it is not subject to uncertainty!). Read over the alternatives carefully. Then, select the alternative that you like the best. You may select a different alternative or stick with your prior choice: it's up to you. As before, please answer the question that follows this task.

WHEN ANSWERING THIS QUESTION, PLEASE REFER BACK TO YOUR RANKING OF CLEANUP PRIORITIES ON PAGE 15.

My choice is Alternative _____

How comfortable would you be with this choice if the money really were to be spent according to your choice of alternatives?

1	2	3	4	5	6	7
Not at all			Moderately			Very
Comfortable			comfortable			comfortable

HOW DO YOU FEEL ABOUT YOUR CHOICE?

Please answer the following questions that relate to the choice you made on the previous page. We know that you answered some of these same questions before but we'd like you to answer them again because some of your answers may have changed while some may have stayed the same. Either is fine – we want to know *your* views as of this point in time. Use the seven-point scale that is shown just under each question and circle the response number that best represents your views. Again, there are no right or wrong answers; we want to know *your* views. Please don't look back at your previous responses.

1. Given the uncertainty associated with the contaminated sites and their cleanup, do you think differently about the problem?

1	2	3	4	5	6	7
Not at all differently			Somewhat differently			Very differently

2. Given the uncertainty associated with the contaminated sites and their cleanup, to what extent do you trust risk managers working for the government to do a good job on the cleanup of contaminated soils?

1	2	3	4	5	6	7
I don't trust them at all		Moderate amount of trust				I trust them very much

3. Given the uncertainty associated with the contaminated sites and their cleanup, to what extent do you trust risk managers working for private companies to do a good job on the cleanup of contaminated soils?

1	2	3	4	5	6	7
I don't trust them at all		Moderate amount of trust				I trust them very much

- 7) Given the uncertainty associated with the contaminated sites and their cleanup, do you believe that the goal of the EPA Superfund program in Larkspur, which is to clean up the three contaminated sites to a designated safe level, will be achieved successfully?

1	2	3	4	5	6	7
No			Maybe			Yes

A DIRECT ALLOCATION OF FUNDS – TASK 3 (ON COMPUTER)

We'd now like to give you the opportunity to directly allocate the \$30 Million worth of funds for year five of the cleanup to the three contaminated sites.

Keeping the scientific information in mind, use the computer to allocate the amount funding of your choice to each of the three contaminated sites. As you do this, notice that the magnitude of risks or estimates about the effectiveness of cleanup actions varies depending on the amount of money that you choose to spend each site.

After you have finished, please write the amount of your desired allocation of funds for each of the three contaminated sites in the spaces provided below.

**IF YOU DO CHOOSE TO ANSWER THIS QUESTION, PLEASE REFER BACK
TO YOUR RANKING OF CLEANUP PRIORITIES ON PAGE 15.**

Site	Nuclear Weapons Factory	Irrigation Tunneling Project	Former Fertilizer Depot
Allocation	\$ _____	\$ _____	\$ _____

SOME FINAL QUESTIONS...

1. Suppose that we were to come back to you again in two or three weeks and ask you to complete these same three tasks. Do you think your answers would be the same?

_____ Yes _____ No
(please check one)

2. How well do you feel that the choices you made today about funding allocations reflect what you really care about when it comes to the cleanup of contaminated sites?

1	2	3	4	5	6	7
Not at all well			Moderately well			Very well

3. How useful did you find the information that was presented to you today to be for making your choices about the Superfund cleanup of the contaminated sites?

1	2	3	4	5	6	7
Not at all useful			Moderately useful			Very useful

4. In your view, how would you judge the quality of the technical/scientific information that was presented to you today?

1	2	3	4	5	6	7
Low quality			Medium quality			High quality

5. To what extent do you feel that the information presented to you today was distorted to suit the needs of the government managers in charge of cleaning up the contaminated sites in your community?

1	2	3	4	5	6	7
Not at all distorted			Moderately distorted			Very distorted

6. How would you now characterize your level of knowledge about radiation risks?

1	2	3	4	5	6	7
Very little knowledge			Moderate amount of knowledge			A lot of knowledge

7. How frustrating did you find it to complete the 3 allocation tasks in this workbook?

1	2	3	4	5	6	7
Not at all frustrating			Moderately frustrating			Very frustrating

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8. Do you think policy decisions about the cleanup of contaminated soils as part of the Superfund program should be based just on public input or should they be made just by technical experts?

1	2	3	4	5	6	7
Just public input			Public and expert input			Just expert input

9. Compared to other human or environmental risk management issues such as global warming or a loss of biodiversity, how important to you are issues related to radiation exposure through soil contamination?

1	2	3	4	5	6	7
Not at all important			Moderately important			Very important

10. How comfortable are you with the prospect that the choices you made today could have an influence on federal cleanup policies for contaminated sites?

1	2	3	4	5	6	7
Not at all comfortable			Moderately comfortable			Very comfortable

11. To what extent do you trust risk managers working for the government to do a good job on the cleanup of contaminated soils?

1	2	3	4	5	6	7
I don't trust them at all			Moderate amount of trust			I trust them very much

12. To what extent do you trust risk managers working for private companies to do a good job on the cleanup of contaminated soils?

1	2	3	4	5	6	7
I don't trust Them at all			Moderate amount of trust			I trust them very much

13. Do you believe that the goal of the EPA Superfund program in Larkspur, which is to clean up the three contaminated sites to a designated safe level, will be achieved successfully?

1	2	3	4	5	6	7
No			Maybe			Yes

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Did your choice of alternative in Task 2 differ from your choice in Task 1 (after you received information about the problem that was more “uncertain”)? Please explain why or why not.

This image shows a blank sheet of white paper with horizontal ruling lines. The lines are evenly spaced and extend across the width of the page. There are no margins, text, or other markings on the paper.

If applicable, please tell us, in as much detail as possible, about your thought processes when you completed Task 3 (on the computer) and directly allocated funds for year 5 of the Superfund cleanup.

This image shows a blank sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

Low Dose, Risk, Decisions, & Risk Communication

A Decision-Focused Approach

Appendix C

Color-Coded Charts

Task 1

		Current Status		
		Abandoned Nuclear Weapons Factory	Irrigation Tunnel Project	Former Fertilizer Depot
Values Information	Overall environmental risks within 1 square mile of site: (0=no risk; 5=moderate risk; 10=extreme risk)	7	4	1
	Percent of alder affected within 1 square mile of site	20%	7%	2%
	Percent of deer affected within 1 square mile of site	30%	17%	2%
	Percent of brook trout affected within 1 square mile of	5%	2%	0%
	Risk of radiation-related illnesses to humans: (0=no risk; 5=moderate risk; 10=extreme risk)	4	2	10
	Percent of workers and/or visitors falling ill	3.2%	1.7%	7.0%
	Risk of radiation-related deaths to humans: (0=no risk; 5=moderate risk; 10=extreme risk)	3	1	0
	Percent of workers and/or visitors dying	0.04%	0.01%	0.00%
	Annual costs of managing the Larkspur drinking water supply	\$1,000,000	\$2,000,000	\$250,000
	Annual costs to the Larkspur economy from reduced tourism due to contamination:			
Site Quality Characteristics	Summer Tourism (camping, fishing, etc.)	\$750,000	\$5,500,000	\$0
	Percent Decline	3%	22%	0%
	Winter Tourism (skiing, snowshoeing, etc.)	\$1,500,000	\$15,000,000	\$0
	Percent Decline	4%	36%	0%
	Judged unsightliness ("ugliness") of site: (0=not at all unsightly; 5=moderately unsightly; 10=extremely unsightly)	8	6	2
	Level of soil contamination within 100 m of site (x normal level): *average annual human exposure = 360 millirem/year	10.0 x	5.0 x	2.0 x
	Level of water contamination within 100 m of site (x normal level): *normal "background" level = 28 millirem	10.0 x	5.0 x	2.0 x
	Percent of site remaining to be cleaned after Year 5:	50%	70%	65%
	Projected time to finish cleanup at current rate of work (in years):	7	4	2
	Total cost to complete cleanup:	\$80,000,000	\$45,000,000	\$35,000,000

Task 1, continued

		Alternative 1		
		Abandoned Nuclear Weapons Factory	Irrigation Tunnel Project	Former Fertilizer Depot
Funding Allocation:		\$15,000,000	\$10,000,000	\$5,000,000
Values Information	Overall environmental risks within 1 square mile of site: (0=no risk; 5=moderate risk; 10=extreme risk)	6	3	1
	Percent of alder affected within 1 square mile of site	16%	5%	2%
	Percent of deer affected within 1 square mile of site	24%	13%	2%
	Percent of brook trout affected within 1 square mile of site	4%	2%	0%
	Risk of radiation-related illnesses to humans: (0=no risk; 5=moderate risk; 10=extreme risk)	3	2	9
	Percent of workers and/or visitors falling ill	2.6%	1.3%	6.0%
	Risk of radiation-related deaths to humans: (0=no risk; 5=moderate risk; 10=extreme risk)	2	1	0
	Percent of workers and/or visitors dying	0.03%	0.01%	0.0%
	Annual costs of managing the Larkspur drinking water supply	\$812,500	\$1,555,556	\$214,286
	Annual costs to the Larkspur economy from reduced tourism due to contamination:			
Site Quality Characteristics	Summer Tourism (camping, fishing, etc.)	\$609,375	\$4,277,778	\$0
	Percent Decline	2.4%	17.1%	0.0%
	Winter Tourism (skiing, snowshoeing, etc.)	\$1,218,750	\$11,666,667	\$0
	Percent Decline	3.3%	28.0%	0.0%
	Judged unsightliness ("ugliness") of site: (0=not at all unsightly; 5=moderately unsightly; 10=extremely unsightly)	7	5	2
	Level of soil contamination within 100 m of site (x normal level): *average annual human exposure = 360 millirem/year	8.1 x	3.9 x	1.7 x
	Level of water contamination within 100 m of site (x normal level): *normal "background" level = 28 millirem	8.1 x	3.9 x	1.7 x
	Percent of site remaining to be cleaned after Year 5:	41%	54%	56%
	Projected time to finish cleanup at current rate of work (in years):	6	3	2
	Total cost to complete cleanup:	\$80,000,000	\$45,000,000	\$35,000,000
	Remaining cleanup costs:	\$65,000,000	\$35,000,000	\$30,000,000

Task 1, continued

Alternative 2

		Abandoned Nuclear Weapons Factory	Irrigation Tunnel Project	Former Fertilizer Depot
Funding Allocation:		\$15,000,000	\$5,000,000	\$10,000,000
Values Information	Overall environmental risks within 1 square mile of site: (0=no risk; 5=moderate risk; 10=extreme risk)	6	4	1
	alder affected within 1 square mile of site	16%	6%	1%
	deer affected within 1 square mile of site	24%	15%	1%
	brook trout affected within 1 square mile of site	4%	2%	0%
	Risk of radiation-related illnesses to humans: (0=no risk; 5=moderate risk; 10=extreme risk)	3	2	7
	Percent of workers and/or visitors falling ill	2.6%	1.5%	5.0%
	Risk of radiation-related deaths to humans: (0=no risk; 5=moderate risk; 10=extreme risk)	2	1	0
	Percent of workers and/or visitors dying	0.03%	0.01%	0.0%
	Annual costs of managing the Larkspur drinking water supply	\$812,500	\$1,777,778	\$178,571
	Annual costs to the Larkspur economy from reduced tourism due to contamination:			
Site Quality Characteristics	Summer Tourism (camping, fishing, etc.)	\$609,375	\$4,888,889	\$0
	Percent Decline	2.4%	19.6%	0.0%
	Winter Tourism (skiing, snowshoeing, etc.)	\$1,218,750	\$13,333,333	\$0
	Percent Decline	3.3%	32.0%	0.0%
	Judged unsightliness ("ugliness") of site: (0=not at all unsightly; 5=moderately unsightly; 10=extremely unsightly)	7	5	1
	Level of soil contamination within 100 m of site (x normal level): *average annual human exposure = 360 millirem/year	8.1 x	4.4 x	1.4 x
	Level of water contamination within 100 m of site (x normal level): *normal "background" level = 28 millirem	8.1 x	4.4 x	1.4 x
	Percent of site remaining to be cleaned after Year 5:	41%	62%	46%
	Projected time to finish cleanup at current rate of work (in years):	6	4	1
	Total cost to complete cleanup:	\$80,000,000	\$45,000,000	\$35,000,000
	Remaining cleanup costs:	\$65,000,000	\$40,000,000	\$25,000,000

Task 1, continued

Alternative 3

		Abandoned Nuclear Weapons Factory	Irrigation Tunnel Project	Former Fertilizer Depot
Funding Allocation:		\$10,000,000	\$15,000,000	\$5,000,000
Values Information	Overall environmental risks within 1 square mile of site: (0=no risk; 5=moderate risk; 10=extreme risk)	6	3	1
	alder affected within 1 square mile of site	18%	5%	2%
	deer affected within 1 square mile of site	26%	11%	2%
	brook trout affected within 1 square mile of site	4%	1%	0%
	Risk of radiation-related illnesses to humans: (0=no risk; 5=moderate risk; 10=extreme risk)	4	1	9
	Percent of workers and/or visitors falling ill	2.8%	1.1%	6.0%
	Risk of radiation-related deaths to humans: (0=no risk; 5=moderate risk; 10=extreme risk)	3	1	0
	Percent of workers and/or visitors dying	0.04%	0.01%	0.0%
	Annual costs of managing the Larkspur drinking water supply	\$875,000	\$1,333,333	\$214,286
	Annual costs to the Larkspur economy from reduced tourism due to contamination:			
Site Quality Characteristics	Summer Tourism (camping, fishing, etc.)	\$656,250	\$3,666,667	\$0
	Percent Decline	2.6%	14.7%	0.0%
	Winter Tourism (skiing, snowshoeing, etc.)	\$1,312,500	\$10,000,000	\$0
	Percent Decline	3.5%	24.0%	0.0%
	Judged unsightliness ("ugliness") of site: (0=not at all unsightly; 5=moderately unsightly; 10=extremely unsightly)	7	4	2
	Level of soil contamination within 100 m of site (x normal level): *average annual human exposure = 360 millirem/year	8.8 x	3.3 x	1.7 x
	Level of water contamination within 100 m of site (x normal level): *normal "background" level = 28 millirem	8.8 x	3.3 x	1.7 x
	Percent of site remaining to be cleaned after Year 5:	44%	47%	56%
	Projected time to finish cleanup at current rate of work (in years):	6	3	2
	Total cost to complete cleanup:	\$80,000,000	\$45,000,000	\$35,000,000
	Remaining cleanup costs:	\$70,000,000	\$30,000,000	\$30,000,000

Task 1, continued

Alternative 4

		Abandoned Nuclear Weapons Factory	Irrigation Tunnel Project	Former Fertilizer Depot
Funding Allocation:		\$10,000,000	\$5,000,000	\$15,000,000
Values Information	Overall environmental risks within 1 square mile of site: (0=no risk; 5=moderate risk; 10=extreme risk)	6	4	1
	alder affected within 1 square mile of site	18%	6%	1%
	deer affected within 1 square mile of site	26%	15%	1%
	brook trout affected within 1 square mile of site	4%	2%	0%
	Risk of radiation-related illnesses to humans: (0=no risk; 5=moderate risk; 10=extreme risk)	4	2	6
	Percent of workers and/or visitors falling ill	2.8%	1.5%	4.0%
	Risk of radiation-related deaths to humans: (0=no risk; 5=moderate risk; 10=extreme risk)	3	1	0
	Percent of workers and/or visitors dying	0.04%	0.01%	0.0%
	Annual costs of managing the Larkspur drinking water supply	\$875,000	\$1,777,778	\$142,857
	Annual costs to the Larkspur economy from reduced tourism due to contamination:			
Site Quality Characteristics	Summer Tourism (camping, fishing, etc.)	\$656,250	\$4,888,889	\$0
	Percent Decline	2.6%	19.6%	0.0%
	Winter Tourism (skiing, snowshoeing, etc.)	\$1,312,500	\$13,333,333	\$0
	Percent Decline	3.5%	32.0%	0.0%
	Judged unsightliness ("ugliness") of site: (0=not at all unsightly; 5=moderately unsightly; 10=extremely unsightly)	7	5	1
	Level of soil contamination within 100 m of site (x normal level): *average annual human exposure = 360 millirem/year	8.8 x	4.4 x	1.1 x
	Level of water contamination within 100 m of site (x normal level): *normal "background" level = 28 millirem	8.8 x	4.4 x	1.1 x
	Percent of site remaining to be cleaned after Year 5:	44%	62%	37%
	Projected time to finish cleanup at current rate of work (in years):	6	4	1
	Total cost to complete cleanup:	\$80,000,000	\$45,000,000	\$35,000,000
	Remaining cleanup costs:	\$70,000,000	\$40,000,000	\$20,000,000

Task 1, continued

Alternative 5

		Abandoned Nuclear Weapons Factory	Irrigation Tunnel Project	Former Fertilizer Depot
Funding Allocation:		\$10,000,000	\$10,000,000	\$10,000,000
Values Information	Overall environmental risks within 1 square mile of site: (0=no risk; 5=moderate risk; 10=extreme risk)	6	3	1
	alder affected within 1 square mile of site	18%	5%	1%
	deer affected within 1 square mile of site	26%	13%	1%
	brook trout affected within 1 square mile of	4%	2%	0%
	Risk of radiation-related illnesses to humans: (0=no risk; 5=moderate risk; 10=extreme risk)	4	2	7
	Percent of workers and/or visitors falling ill	2.8%	1.3%	5.0%
	Risk of radiation-related deaths to humans: (0=no risk; 5=moderate risk; 10=extreme risk)	3	1	0
	Percent of workers and/or visitors dying	0.04%	0.01%	0.0%
	Annual costs of managing the Larkspur drinking water supply	\$875,000	\$1,555,556	\$178,571
	Annual costs to the Larkspur economy from reduced tourism due to contamination:			
Site Quality Characteristics	Summer Tourism (camping, fishing, etc.)	\$656,250	\$4,277,778	\$0
	Percent Decline	2.6%	17.1%	0.0%
	Winter Tourism (skiing, snowshoeing, etc.)	\$1,312,500	\$11,666,667	\$0
	Percent Decline	3.5%	28.0%	0.0%
	Judged unsightliness ("ugliness") of site: (0=not at all unsightly; 5=moderately unsightly; 10=extremely unsightly)	7	5	1
	Level of soil contamination within 100 m of site (x normal level): *average annual human exposure = 360 millirem/year	8.8 x	3.9 x	1.4 x
	Level of water contamination within 100 m of site (x normal level): *normal "background" level = 28 millirem	8.8 x	3.9 x	1.4 x
	Percent of site remaining to be cleaned after Year 5:	44%	54%	46%
	Projected time to finish cleanup at current rate of work (in years):	6	3	1
	Total cost to complete cleanup:	\$80,000,000	\$45,000,000	\$35,000,000
	Remaining cleanup costs:	\$70,000,000	\$35,000,000	\$25,000,000

Task 2

Current Status

		Abandoned Nuclear Weapons Factory	Irrigation Tunnel Project	Former Fertilizer Depot
Values Information	Overall environmental risks within 1 square mile of site: (0=no risk; 5=moderate risk; 10=extreme risk)	7	4	1
	Percent of alder affected within 1 square mile of site	20%	7%	2%
	Percent of deer affected within 1 square mile of site	30%	17%	2%
	Percent of brook trout affected within 1 square mile of site	5%	2%	0%
	Risk of radiation-related illnesses to humans: (0=no risk; 5=moderate risk; 10=extreme risk)	4	2	10
	Percent of workers and/or visitors falling ill	3.2%	1.7%	7.0%
	Risk of radiation-related deaths to humans: (0=no risk; 5=moderate risk; 10=extreme risk)	3	1	0
	Percent of workers and/or visitors dying	0.04%	0.01%	0.00%
	Annual costs of managing the Larkspur drinking water supply	\$1,000,000	\$2,000,000	\$250,000
	Annual costs to the Larkspur economy from reduced tourism due to contamination:			
Site Quality Characteristics	Summer Tourism (camping, fishing, etc.)	\$750,000	\$5,500,000	\$0
	Percent Decline	3%	22%	0%
	Winter Tourism (skiing, snowshoeing, etc.)	\$1,500,000	\$15,000,000	\$0
	Percent Decline	4%	36%	0%
	Judged unsightliness ("ugliness") of site: (0=not at all unsightly; 5=moderately unsightly; 10=extremely unsightly)	8	6	2
	Level of soil contamination within 100 m of site (x normal level): *average annual human exposure = 360 millirem/year	10.0 x	5.0 x	2.0 x
	Level of water contamination within 100 m of site (x normal level): *normal "background" level = 28 millirem	10.0 x	5.0 x	2.0 x
	Percent of site remaining to be cleaned after Year 5:	50%	70%	65%
	Projected time to finish cleanup at current rate of work (in years):	7	4	2
	Total cost to complete cleanup:	\$80,000,000	\$45,000,000	\$35,000,000

A Decision-Focused Approach Appendix C: Color-Coded Charts

Task 2, continued		Alternative 1					
		Abandoned Nuclear Weapons Factory		Irrigation Tunnel Project		Former Fertilizer Depot	
		\$15,000,000		\$10,000,000		\$5,000,000	
		Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Values Information	Overall environmental risks within 1 square mile of site: (0=no risk; 5=moderate risk; 10=extreme risk)	4	- 8	2	- 4	1	- 1
	Percent of alder affected within 1 square mile of site	11%	- 22%	4%	- 7%	1%	- 2%
	Percent of deer affected within 1 square mile of site	16%	- 33%	9%	- 18%	1%	- 2%
	Percent of brook trout affected within 1 square mile of site	3%	- 5%	1%	- 2%	0%	- 0%
	Risk of radiation-related illnesses to humans: (0=no risk; 5=moderate risk; 10=extreme risk)	2	- 4	1	- 2	6	- 12
	Percent of workers and/or visitors falling ill	1.7%	- 3.5%	0.9%	- 1.8%	3.9%	- 8.1%
	Risk of radiation-related deaths to humans: (0=no risk; 5=moderate risk; 10=extreme risk)	2	- 3	1	- 1	0	- 0
	Percent of workers and/or visitors dying	0.021%	- 0.044%	0.005%	- 0.011%	0.000%	- 0.000%
	Annual costs of managing the Larkspur drinking water supply	\$528,125 - \$1,096,875		\$1,011,111 - \$2,100,000		\$139,286 - \$289,286	
	Annual costs to the Larkspur economy from reduced tourism due to contamination:						
Site Quality Characteristics	Summer Tourism (camping, fishing, etc.)	\$396,094 - \$822,656		\$2,780,556 - \$5,775,000		\$0 - \$0	
	Percent Decline	1.6% - 3.3%		11.1% - 23.1%		0.0% - 0.0%	
	Winter Tourism (skiing, snowshoeing, etc.)	\$792,188 - \$1,645,313		\$7,583,333 - \$15,750,000		\$0 - \$0	
	Percent Decline	2.1% - 4.4%		18.2% - 37.8%		0.0% - 0.0%	
	Judged unsightliness ("ugliness") of site: (0=not at all unsightly; 5=moderately unsightly; 10=extremely unsightly)	4	- 9	3	- 6	1	- 2
	Level of soil contamination within 100 m of site (x normal level): *average annual human exposure = 360 millirem/year	5.3 x	- 11.0 x	2.5 x	- 5.3 x	1.1 x	- 2.3 x
	Level of water contamination within 100 m of site (x normal level): *normal "background" level = 28 millirem	5.3 x	- 11.0 x	2.5 x	- 5.3 x	1.1 x	- 2.3 x
	Percent of site remaining to be cleaned after Year 5:	26%	- 55%	35%	- 74%	36%	- 75%
	Projected time to finish cleanup at current rate of work (in years):	4	- 8	2	- 4	1	- 2
	Total cost to complete cleanup:	\$80,000,000		\$45,000,000		\$35,000,000	
	Remaining cleanup costs:	\$65,000,000		\$35,000,000		\$30,000,000	

A Decision-Focused Approach Appendix C: Color-Coded Charts

Task 2, continued		Alternative 2					
		Abandoned Nuclear Weapons Factory		Irrigation Tunnel Project		Former Fertilizer Depot	
		\$15,000,000		\$5,000,000		\$10,000,000	
		Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Values Information	Overall environmental risks within 1 square mile of site: (0=no risk; 5=moderate risk; 10=extreme risk)	4	- 8	2	- 5	0	- 1
	Percent of alder affected within 1 square mile of site	11%	- 22%	4%	- 8%	1%	- 2%
	Percent of deer affected within 1 square mile of site	16%	- 33%	10%	- 20%	1%	- 2%
	Percent of brook trout affected within 1 square mile of site	3%	- 5%	1%	- 2%	0%	- 0%
	Risk of radiation-related illnesses to humans: (0=no risk; 5=moderate risk; 10=extreme risk)	2	- 4	1	- 2	5	- 10
	Percent of workers and/or visitors falling ill	1.7%	- 3.5%	1.0%	- 2.0%	3.3%	- 6.8%
	Risk of radiation-related deaths to humans: (0=no risk; 5=moderate risk; 10=extreme risk)	2	- 3	1	- 1	0	- 0
	Percent of workers and/or visitors dying	0.021%	- 0.044%	0.006%	- 0.012%	0.000%	- 0.000%
	Annual costs of managing the Larkspur drinking water supply	\$528,125 - \$1,096,875		\$1,155,556 - \$2,400,000		\$116,071 - \$241,071	
	Annual costs to the Larkspur economy from reduced tourism due to contamination:						
Site Quality Characteristics	Summer Tourism (camping, fishing, etc.)	\$396,094 - \$822,656		\$3,177,778 - \$6,600,000		\$0 - \$0	
	Percent Decline	1.6% - 3.3%		12.7% - 26.4%		0.0% - 0.0%	
	Winter Tourism (skiing, snowshoeing, etc.)	\$792,188 - \$1,645,313		\$8,666,667 - \$18,000,000		\$0 - \$0	
	Percent Decline	2.1% - 4.4%		20.8% - 43.2%		0.0% - 0.0%	
	Judged unsightliness ("ugliness") of site: (0=not at all unsightly; 5=moderately unsightly; 10=extremely unsightly)	4	- 9	3	- 7	1	- 2
	Level of soil contamination within 100 m of site (x normal level): *average annual human exposure = 360 millirem/year	5.3 x	- 11.0 x	2.9 x	- 6.0 x	0.9 x	- 1.9 x
	Level of water contamination within 100 m of site (x normal level): *normal "background" level = 28 millirem	5.3 x	- 11.0 x	2.9 x	- 6.0 x	0.9 x	- 1.9 x
	Percent of site remaining to be cleaned after Year 5:	26%	- 55%	40%	- 84%	30%	- 63%
	Projected time to finish cleanup at current rate of work (in years):	4	- 8	2	- 5	1	- 2
	Total cost to complete cleanup:	\$80,000,000		\$45,000,000		\$35,000,000	
	Remaining cleanup costs:	\$65,000,000		\$40,000,000		\$25,000,000	

A Decision-Focused Approach Appendix C: Color-Coded Charts

Task 2, continued		Alternative 3					
		Abandoned Nuclear Weapons Factory		Irrigation Tunnel Project		Former Fertilizer Depot	
		\$10,000,000		\$15,000,000		\$5,000,000	
		Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Values Information	Overall environmental risks within 1 square mile of site: (0=no risk; 5=moderate risk; 10=extreme risk)	4	- 8	2	- 4	1	- 1
	Percent of alder affected within 1 square mile of site	11%	- 24%	3%	- 6%	1%	- 2%
	Percent of deer affected within 1 square mile of site	17%	- 35%	7%	- 15%	1%	- 2%
	Percent of brook trout affected within 1 square mile of site	3%	- 6%	1%	- 2%	0%	- 0%
	Risk of radiation-related illnesses to humans: (0=no risk; 5=moderate risk; 10=extreme risk)	2	- 5	1	- 2	6	- 12
	Percent of workers and/or visitors falling ill	1.8%	- 3.8%	0.7%	- 1.5%	3.9%	- 8.1%
	Risk of radiation-related deaths to humans: (0=no risk; 5=moderate risk; 10=extreme risk)	2	- 4	0	- 1	0	- 0
	Percent of workers and/or visitors dying	0.023%	- 0.047%	0.004%	- 0.009%	0.000%	- 0.000%
	Annual costs of managing the Larkspur drinking water supply	\$568,750 - \$1,181,250		\$866,667 - \$1,800,000		\$139,286 - \$289,286	
	Annual costs to the Larkspur economy from reduced tourism due to contamination:						
Site Quality Characteristics	Summer Tourism (camping, fishing, etc.)	\$426,563 - \$885,938		\$2,383,333 - \$4,950,000		\$0 - \$0	
	Percent Decline	1.7% - 3.5%		9.5% - 19.8%		0.0% - 0.0%	
	Winter Tourism (skiing, snowshoeing, etc.)	\$853,125 - \$1,771,875		\$6,500,000 - \$13,500,000		\$0 - \$0	
	Percent Decline	2.3% - 4.7%		15.6% - 32.4%		0.0% - 0.0%	
	Judged unsightliness ("ugliness") of site: (0=not at all unsightly; 5=moderately unsightly; 10=extremely unsightly)	5	- 9	3	- 5	1	- 2
	Level of soil contamination within 100 m of site (x normal level): *average annual human exposure = 360 millirem/year	5.7 x	- 11.8 x	2.2 x	- 4.5 x	1.1 x	- 2.3 x
	Level of water contamination within 100 m of site (x normal level): *normal "background" level = 28 millirem	5.7 x	- 11.8 x	2.2 x	- 4.5 x	1.1 x	- 2.3 x
	Percent of site remaining to be cleaned after Year 5:	28%	- 59%	30%	- 63%	36%	- 75%
	Projected time to finish cleanup at current rate of work (in years):	4	- 8	2	- 4	1	- 2
	Total cost to complete cleanup:	\$80,000,000		\$45,000,000		\$35,000,000	
	Remaining cleanup costs:	\$70,000,000		\$30,000,000		\$30,000,000	

A Decision-Focused Approach Appendix C: Color-Coded Charts

Task 2, continued		Alternative 4					
		Abandoned Nuclear Weapons Factory		Irrigation Tunnel Project		Former Fertilizer Depot	
		\$10,000,000		\$5,000,000		\$15,000,000	
		Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Values Information	Overall environmental risks within 1 square mile of site: (0=no risk; 5=moderate risk; 10=extreme risk)	4	- 8	2	- 5	0	- 1
	Percent of alder affected within 1 square mile of site	11%	- 24%	4%	- 8%	1%	- 2%
	Percent of deer affected within 1 square mile of site	17%	- 35%	10%	- 20%	1%	- 2%
	Percent of brook trout affected within 1 square mile of site	3%	- 6%	1%	- 2%	0%	- 0%
	Risk of radiation-related illnesses to humans: (0=no risk; 5=moderate risk; 10=extreme risk)	2	- 5	1	- 2	4	- 8
	Percent of workers and/or visitors falling ill	1.8%	- 3.8%	1.0%	- 2.0%	2.6%	- 5.4%
	Risk of radiation-related deaths to humans: (0=no risk; 5=moderate risk; 10=extreme risk)	2	- 4	1	- 1	0	- 0
	Percent of workers and/or visitors dying	0.023%	- 0.047%	0.006%	- 0.012%	0.000%	- 0.000%
	Annual costs of managing the Larkspur drinking water supply	\$568,750 - \$1,181,250		\$1,155,556 - \$2,400,000		\$92,857 - \$192,857	
	Annual costs to the Larkspur economy from reduced tourism due to contamination:						
Site Quality Characteristics	Summer Tourism (camping, fishing, etc.)	\$426,563 - \$885,938		\$3,177,778 - \$6,600,000		\$0 - \$0	
	Percent Decline	1.7% - 3.5%		12.7% - 26.4%		0.0% - 0.0%	
	Winter Tourism (skiing, snowshoeing, etc.)	\$853,125 - \$1,771,875		\$8,666,667 - \$18,000,000		\$0 - \$0	
	Percent Decline	2.3% - 4.7%		20.8% - 43.2%		0.0% - 0.0%	
	Judged unsightliness ("ugliness") of site: (0=not at all unsightly; 5=moderately unsightly; 10=extremely unsightly)	5	- 9	3	- 7	1	- 2
	Level of soil contamination within 100 m of site (x normal level): *average annual human exposure = 360 millirem/year	5.7 x	- 11.8 x	2.9 x	- 6.0 x	0.7 x	- 1.5 x
	Level of water contamination within 100 m of site (x normal level): *normal "background" level = 28 millirem	5.7 x	- 11.8 x	2.9 x	- 6.0 x	0.7 x	- 1.5 x
	Percent of site remaining to be cleaned after Year 5:	28%	- 59%	40%	- 84%	24%	- 50%
	Projected time to finish cleanup at current rate of work (in years):	4	- 8	2	- 5	1	- 2
	Total cost to complete cleanup:	\$80,000,000		\$45,000,000		\$35,000,000	
	Remaining cleanup costs:	\$70,000,000		\$40,000,000		\$20,000,000	

A Decision-Focused Approach Appendix C: Color-Coded Charts

Task 2, continued		Alternative 5					
		Abandoned Nuclear Weapons Factory		Irrigation Tunnel Project		Former Fertilizer Depot	
		\$10,000,000		\$10,000,000		\$10,000,000	
		Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Values Information	Overall environmental risks within 1 square mile of site: (0=no risk; 5=moderate risk; 10=extreme risk)	4	- 8	2	- 4	0	- 1
	Percent of alder affected within 1 square mile of site	11%	- 24%	4%	- 7%	1%	- 2%
	Percent of deer affected within 1 square mile of site	17%	- 35%	9%	- 18%	1%	- 2%
	Percent of brook trout affected within 1 square mile of site	3%	- 6%	1%	- 2%	0%	- 0%
	Risk of radiation-related illnesses to humans: (0=no risk; 5=moderate risk; 10=extreme risk)	2	- 5	1	- 2	5	- 10
	Percent of workers and/or visitors falling ill	1.8%	- 3.8%	0.9%	- 1.8%	3.3%	- 6.8%
	Risk of radiation-related deaths to humans: (0=no risk; 5=moderate risk; 10=extreme risk)	2	- 4	1	- 1	0	- 0
	Percent of workers and/or visitors dying	0.023%	- 0.047%	0.005%	- 0.011%	0.000%	- 0.000%
	Annual costs of managing the Larkspur drinking water supply	\$568,750 - \$1,181,250		\$1,011,111 - \$2,100,000		\$116,071 - \$241,071	
	Annual costs to the Larkspur economy from reduced tourism due to contamination:						
Site Quality Characteristics	Summer Tourism (camping, fishing, etc.)	\$426,563 - \$885,938		\$2,780,556 - \$5,775,000		\$0 - \$0	
	Percent Decline	1.7% - 3.5%		11.1% - 23.1%		0.0% - 0.0%	
	Winter Tourism (skiing, snowshoeing, etc.)	\$853,125 - \$1,771,875		\$7,583,333 - \$15,750,000		\$0 - \$0	
	Percent Decline	2.3% - 4.7%		18.2% - 37.8%		0.0% - 0.0%	
	Judged unsightliness ("ugliness") of site: (0=not at all unsightly; 5=moderately unsightly; 10=extremely unsightly)	5	- 9	3	- 6	1	- 2
	Level of soil contamination within 100 m of site (x normal level): *average annual human exposure = 360 millirem/year	5.7 x	- 11.8 x	2.5 x	- 5.3 x	0.9 x	- 1.9 x
	Level of water contamination within 100 m of site (x normal level): *normal "background" level = 28 millirem	5.7 x	- 11.8 x	2.5 x	- 5.3 x	0.9 x	- 1.9 x
	Percent of site remaining to be cleaned after Year 5:	28%	- 59%	35%	- 74%	30%	- 63%
	Projected time to finish cleanup at current rate of work (in years):	4	- 8	2	- 4	1	- 2
	Total cost to complete cleanup:	\$80,000,000		\$45,000,000		\$35,000,000	
	Remaining cleanup costs:	\$70,000,000		\$35,000,000		\$25,000,000	

Task 3

Current Status

	Abandoned Nuclear Weapons Factory	Irrigation Tunnel Project	Former Fertilizer Depot
Level of soil contamination within 100 m of site (millirem): *average annual human exposure = 360 millirem/year	3600	1800	720
Level of contamination (millirem) from:			
Alpha particles	450	575	25
Beta particles	1750	1150	450
Gamma rays	1050	75	245
X-rays	350	0	0
Level of water contamination within 100 m of site (millirem): *normal "background" level = 28 millirem	240	120	48
Level of contamination (millirem) from:			
Alpha particles	5	10	10
Beta particles	135	92	33
Gamma rays	70	18	5
X-rays	30	0	0
Environmental Health Impacts (measured as the number of animals/plants with radiation-related abnormalities per 100 sampled) within 1 square mile of site on:			
Plants	20	7	2
Terrestrial Organisms	30	17	2
Aquatic Organisms	5	2	0
Health Effects (measured as the mean number of radiation-related illnesses/deaths per 1000 workers and visitors to the site over the total 8 year cleanup time):			
Respiratory Infections	10	6	45
Non-Fatal Cancers	10	5	15
Radiation Sickness	2	0	0
Non-Fatal Bone Disease	5	4	5
Genetic Effects	5	2	5
Radiation-Related Deaths	4	1	0
Percent of site remaining to be cleaned after Year 5:	50%	70%	65%
Projected time to finish cleanup at current rate of work (in years):	7	4	2
Total cost to complete cleanup:	\$100,000,000	\$50,000,000	\$35,000,000

Task 3, continued

Alternative 1

	Abandoned Nuclear Weapons Factory	Irrigation Tunnel Project	Former Fertilizer Depot
Funding Allocation:	\$15,000,000	\$10,000,000	\$5,000,000
Level of soil contamination within 100 m of site (millirem): *average annual human exposure = 360 millirem/year Level of contamination (millirem) from: Alpha particles Beta particles Gamma rays X-rays	2925 366 1422 853 284	1400 447 894 58 0	617 21 386 210 0
Level of water contamination within 100 m of site (millirem): *normal "background" level = 28 millirem Level of contamination (millirem) from: Alpha particles Beta particles Gamma rays X-rays	195 4 110 57 24	93 8 72 14 0	41 9 28 4 0
Environmental Health Impacts (measured as the number of animals/plants with radiation-related abnormalities per 100 sampled) within 1 square mile of site on: Plants Terrestrial Organisms Aquatic Organisms	16 24 4	5 13 2	2 2 0
Health Effects (measured as the mean number of radiation-related illnesses/deaths per 1000 workers and visitors to the site over the total 8 year cleanup time): Respiratory Infections Non-Fatal Cancers Radiation Sickness Non-Fatal Bone Disease Genetic Effects Radiation-Related Deaths	8 8 2 4 4 3	5 4 0 3 2 1	39 13 0 4 4 0
Percent of site remaining to be cleaned after Year 5:	41%	54%	56%
Projected time to finish cleanup at current rate of work (in years):	6	3	2
Total cost to complete cleanup:	\$80,000,000	\$45,000,000	\$35,000,000
Remaining cleanup costs:	\$65,000,000	\$35,000,000	\$30,000,000

Task 3, continued

Alternative 2

	Abandoned Nuclear Weapons Factory	Irrigation Tunnel Project	Former Fertilizer Depot
Funding Allocation:	\$15,000,000	\$5,000,000	\$10,000,000
Level of soil contamination within 100 m of site (millirem): *average annual human exposure = 360 millirem/year	2925	1600	514
Level of contamination (millirem) from:			
Alpha particles	366	511	18
Beta particles	1422	1022	321
Gamma rays	853	67	175
X-rays	284	0	0
Level of water contamination within 100 m of site (millirem): *normal "background" level = 28 millirem	195	107	34
Level of contamination (millirem) from:			
Alpha particles	4	9	7
Beta particles	110	82	24
Gamma rays	57	16	4
X-rays	24	0	0
Environmental Health Impacts (measured as the number of animals/plants with radiation-related abnormalities per 100 sampled) within 1 square mile of site on:			
Plants	16	6	1
Terrestrial Organisms	24	15	1
Aquatic Organisms	4	2	0
Health Effects (measured as the mean number of radiation-related illnesses/deaths per 1000 workers and visitors to the site over the total 8 year cleanup time):			
Respiratory Infections	8	5	32
Non-Fatal Cancers	8	4	11
Radiation Sickness	2	0	0
Non-Fatal Bone Disease	4	4	4
Genetic Effects	4	2	4
Radiation-Related Deaths	3	1	0
Percent of site remaining to be cleaned after Year 5:	41%	62%	46%
Projected time to finish cleanup at current rate of work (in years):	6	4	1
Total cost to complete cleanup:	\$80,000,000	\$45,000,000	\$35,000,000
Remaining cleanup costs:	\$65,000,000	\$40,000,000	\$25,000,000

Task 3, continued

Alternative 3

	Abandoned Nuclear Weapons Factory	Irrigation Tunnel Project	Former Fertilizer Depot
Funding Allocation:	\$10,000,000	\$15,000,000	\$5,000,000
Level of soil contamination within 100 m of site (millirem): *average annual human exposure = 360 millirem/year	3150	1200	617
Level of contamination (millirem) from:			
Alpha particles	394	383	21
Beta particles	1531	767	386
Gamma rays	919	50	210
X-rays	306	0	0
Level of water contamination within 100 m of site (millirem): *normal "background" level = 28 millirem	210	80	41
Level of contamination (millirem) from:			
Alpha particles	4	7	9
Beta particles	118	61	28
Gamma rays	61	12	4
X-rays	26	0	0
Environmental Health Impacts (measured as the number of animals/plants with radiation-related abnormalities per 100 sampled) within 1 square mile of site on:			
Plants	18	5	2
Terrestrial Organisms	26	11	2
Aquatic Organisms	4	1	0
Health Effects (measured as the mean number of radiation-related illnesses/deaths per 1000 workers and visitors to the site over the total 8 year cleanup time):			
Respiratory Infections	9	4	39
Non-Fatal Cancers	9	3	13
Radiation Sickness	2	0	0
Non-Fatal Bone Disease	4	3	4
Genetic Effects	4	1	4
Radiation-Related Deaths	4	1	0
Percent of site remaining to be cleaned after Year 5:	44%	47%	56%
Projected time to finish cleanup at current rate of work (in years):	6	3	2
Total cost to complete cleanup:	\$80,000,000	\$45,000,000	\$35,000,000
Remaining cleanup costs:	\$70,000,000	\$30,000,000	\$30,000,000

Task 3, continued

Alternative 4

	Abandoned Nuclear Weapons Factory	Irrigation Tunnel Project	Former Fertilizer Depot
Funding Allocation:	\$10,000,000	\$5,000,000	\$15,000,000
Level of soil contamination within 100 m of site (millirem): *average annual human exposure = 360 millirem/year	3150	1600	411
Level of contamination (millirem) from:			
Alpha particles	394	511	14
Beta particles	1531	1022	257
Gamma rays	919	67	140
X-rays	306	0	0
Level of water contamination within 100 m of site (millirem): *normal "background" level = 28 millirem	210	107	27
Level of contamination (millirem) from:			
Alpha particles	4	9	6
Beta particles	118	82	19
Gamma rays	61	16	3
X-rays	26	0	0
Environmental Health Impacts (measured as the number of animals/plants with radiation-related abnormalities per 100 sampled) within 1 square mile of site on:			
Plants	18	6	1
Terrestrial Organisms	26	15	1
Aquatic Organisms	4	2	0
Health Effects (measured as the mean number of radiation-related illnesses/deaths per 1000 workers and visitors to the site over the total 8 year cleanup time):			
Respiratory Infections	9	5	26
Non-Fatal Cancers	9	4	9
Radiation Sickness	2	0	0
Non-Fatal Bone Disease	4	4	3
Genetic Effects	4	2	3
Radiation-Related Deaths	4	1	0
Percent of site remaining to be cleaned after Year 5:	44%	62%	37%
Projected time to finish cleanup at current rate of work (in years):	6	4	1
Total cost to complete cleanup:	\$80,000,000	\$45,000,000	\$35,000,000
Remaining cleanup costs:	\$70,000,000	\$40,000,000	\$20,000,000

Task 3, continued

Alternative 5

	Abandoned Nuclear Weapons Factory	Irrigation Tunnel Project	Former Fertilizer Depot
Funding Allocation:	\$10,000,000	\$10,000,000	\$10,000,000
Level of soil contamination within 100 m of site (millirem): *average annual human exposure = 360 millirem/year Level of contamination (millirem) from: Alpha particles Beta particles Gamma rays X-rays	3150 394 1531 919 306	1400 447 894 58 0	514 18 321 175 0
Level of water contamination within 100 m of site (millirem): *normal "background" level = 28 millirem Level of contamination (millirem) from: Alpha particles Beta particles Gamma rays X-rays	210 4 118 61 26	93 8 72 14 0	34 7 24 4 0
Environmental Health Impacts (measured as the number of animals/plants with radiation-related abnormalities per 100 sampled) within 1 square mile of site on: Plants Terrestrial Organisms Aquatic Organisms	18 26 4	5 13 2	1 1 0
Health Effects (measured as the mean number of radiation-related illnesses/deaths per 1000 workers and visitors to the site over the total 8 year cleanup time): Respiratory Infections Non-Fatal Cancers Radiation Sickness Non-Fatal Bone Disease Genetic Effects Radiation-Related Deaths	9 9 2 4 4 4	5 4 0 3 2 1	32 11 0 4 4 0
Percent of site remaining to be cleaned after Year 5:	44%	54%	46%
Projected time to finish cleanup at current rate of work (in years):	6	3	1
Total cost to complete cleanup:	\$80,000,000	\$45,000,000	\$35,000,000
Remaining cleanup costs:	\$70,000,000	\$35,000,000	\$25,000,000

Task 4

Current Status

	Abandoned Nuclear Weapons Factory	Irrigation Tunnel Project	Former Fertilizer Depot
Level of soil contamination within 100 m of site (millirem): *average annual human exposure = 360 millirem/year	3600	1800	720
Level of contamination (millirem) from:			
Alpha particles	450	575	25
Beta particles	1750	1150	450
Gamma rays	1050	75	245
X-rays	350	0	0
Level of water contamination within 100 m of site (millirem): *normal "background" level = 28 millirem	240	120	48
Level of contamination (millirem) from:			
Alpha particles	5	10	10
Beta particles	135	92	33
Gamma rays	70	18	5
X-rays	30	0	0
Environmental Health Impacts (measured as the number of animals/plants with radiation-related abnormalities per 100 sampled) within 1 square mile of site on:			
Plants	20	7	2
Terrestrial Organisms	30	17	2
Aquatic Organisms	5	2	0
Health Effects (measured as the mean number of radiation-related illnesses/deaths per 1000 workers and visitors to the site over the total 8 year cleanup time):			
Respiratory Infections	10	6	45
Non-Fatal Cancers	10	5	15
Radiation Sickness	2	0	0
Non-Fatal Bone Disease	5	4	5
Genetic Effects	5	2	5
Radiation-Related Deaths	4	1	0
Percent of site remaining to be cleaned after Year 5:	50%	70%	65%
Projected time to finish cleanup at current rate of work (in years):	7	4	2
Total cost to complete cleanup:	\$100,000,000	\$50,000,000	\$35,000,000
Remaining cleanup costs:			

Task 4, continued

Funding Allocation:				Alternative 1					
				Abandoned Nuclear Weapons Factory		Irrigation Tunnel Project		Former Fertilizer Depot	
				\$15,000,000		\$10,000,000		\$5,000,000	
				Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Level of soil contamination within 100 m of site (millirem): *average annual human exposure = 360 millirem/year				1901	- 3949	910	- 1890	401	- 833
Level of contamination (millirem) from:									
Alpha particles				238	- 494	291	- 604	14	- 29
Beta particles				924	- 1920	581	- 1208	251	- 521
Gamma rays				555	- 1152	38	- 79	137	- 284
X-rays				185	- 384	0	- 0	0	- 0
Level of water contamination within 100 m of site (millirem): *normal "background" level = 28 millirem				127	- 263	61	- 126	27	- 56
Level of contamination (millirem) from:									
Alpha particles				3	- 5	5	- 11	6	- 12
Beta particles				71	- 148	47	- 97	18	- 38
Gamma rays				37	- 77	9	- 19	3	- 6
X-rays				16	- 33	0	- 0	0	- 0
Environmental Health Impacts (measured as the number of animals/plants with radiation-related abnormalities per 100 sampled) within 1 square mile of site on:									
Plants				11	- 22	4	- 7	1	- 2
Terrestrial Organisms				16	- 33	9	- 18	1	- 2
Aquatic Organisms				3	- 5	1	- 2	0	- 0
Health Effects (measured as the mean number of radiation-related illnesses/deaths per 1000 workers and visitors to the site over the total 8 year cleanup time):									
Respiratory Infections				5	- 11	3	- 6	25	- 52
Non-Fatal Cancers				5	- 11	3	- 5	8	- 17
Radiation Sickness				1	- 2	0	- 0	0	- 0
Non-Fatal Bone Disease				3	- 5	2	- 4	3	- 6
Genetic Effects				3	- 5	1	- 2	3	- 6
Radiation-Related Deaths				2	- 4	1	- 1	0	- 0
Percent of site remaining to be cleaned after Year 5:				26%	- 55%	35%	- 74%	36%	- 75%
Projected time to finish cleanup at current rate of work (in years):				4	- 8	2	- 4	1	- 2
Total cost to complete cleanup:				\$80,000,000		\$45,000,000		\$35,000,000	
				\$65,000,000		\$35,000,000		\$30,000,000	

Task 4, continued

Funding Allocation:			Alternative 2								
			Abandoned Nuclear Weapons Factory			Irrigation Tunnel Project			Former Fertilizer Depot		
			\$15,000,000			\$5,000,000			\$10,000,000		
			Lower Limit		Upper Limit	Lower Limit		Upper Limit	Lower Limit		Upper Limit
Level of soil contamination within 100 m of site (millirem): *average annual human exposure = 360 millirem/year			1901	-	3949	1040	-	2160	334	-	694
Level of contamination (millirem) from:											
Alpha particles			238	-	494	332	-	690	12	-	24
Beta particles			924	-	1920	664	-	1380	209	-	434
Gamma rays			555	-	1152	43	-	90	114	-	236
X-rays			185	-	384	0	-	0	0	-	0
Level of water contamination within 100 m of site (millirem): *normal "background" level = 28 millirem			127	-	263	69	-	144	22	-	46
Level of contamination (millirem) from:											
Alpha particles			3	-	5	6	-	12	5	-	10
Beta particles			71	-	148	53	-	110	15	-	32
Gamma rays			37	-	77	10	-	22	2	-	5
X-rays			16	-	33	0	-	0	0	-	0
Environmental Health Impacts (measured as the number of animals/plants with radiation-related abnormalities per 100 sampled) within 1 square mile of site on:											
Plants			11	-	22	4	-	8	1	-	2
Terrestrial Organisms			16	-	33	10	-	20	1	-	2
Aquatic Organisms			3	-	5	1	-	2	0	-	0
Health Effects (measured as the mean number of radiation-related illnesses/deaths per 1000 workers and visitors to the site over the total 8 year cleanup time):											
Respiratory Infections			5	-	11	3	-	7	21	-	43
Non-Fatal Cancers			5	-	11	3	-	6	7	-	14
Radiation Sickness			1	-	2	0	-	0	0	-	0
Non-Fatal Bone Disease			3	-	5	2	-	5	2	-	5
Genetic Effects			3	-	5	1	-	2	2	-	5
Radiation-Related Deaths			2	-	4	1	-	1	0	-	0
Percent of site remaining to be cleaned after Year 5:			26%	-	55%	40%	-	84%	30%	-	63%
Projected time to finish cleanup at current rate of work (in years):			4	-	8	2	-	5	1	-	2
Total cost to complete cleanup:			\$80,000,000			\$45,000,000			\$35,000,000		
			\$65,000,000			\$40,000,000			\$25,000,000		

Task 4, continued

Funding Allocation:			Alternative 3								
			Abandoned Nuclear Weapons Factory			Irrigation Tunnel Project			Former Fertilizer Depot		
			\$10,000,000			\$15,000,000			\$5,000,000		
			Lower Limit		Upper Limit	Lower Limit		Upper Limit	Lower Limit		Upper Limit
Level of soil contamination within 100 m of site (millirem): *average annual human exposure = 360 millirem/year			2048	-	4253	780	-	1620	401	-	833
Level of contamination (millirem) from:											
Alpha particles			256	-	532	249	-	518	14	-	29
Beta particles			995	-	2067	498	-	1035	251	-	521
Gamma rays			597	-	1240	33	-	68	137	-	284
X-rays			199	-	413	0	-	0	0	-	0
Level of water contamination within 100 m of site (millirem): *normal "background" level = 28 millirem			137	-	284	52	-	108	27	-	56
Level of contamination (millirem) from:											
Alpha particles			3	-	6	4	-	9	6	-	12
Beta particles			77	-	159	40	-	83	18	-	38
Gamma rays			40	-	83	8	-	16	3	-	6
X-rays			17	-	35	0	-	0	0	-	0
Environmental Health Impacts (measured as the number of animals/plants with radiation-related abnormalities per 100 sampled) within 1 square mile of site on:											
Plants			11	-	24	3	-	6	1	-	2
Terrestrial Organisms			17	-	35	7	-	15	1	-	2
Aquatic Organisms			3	-	6	1	-	2	0	-	0
Health Effects (measured as the mean number of radiation-related illnesses/deaths per 1000 workers and visitors to the site over the total 8 year cleanup time):											
Respiratory Infections			6	-	12	3	-	5	25	-	52
Non-Fatal Cancers			6	-	12	2	-	5	8	-	17
Radiation Sickness			1	-	2	0	-	0	0	-	0
Non-Fatal Bone Disease			3	-	6	2	-	4	3	-	6
Genetic Effects			3	-	6	1	-	2	3	-	6
Radiation-Related Deaths			2	-	5	0	-	1	0	-	0
Percent of site remaining to be cleaned after Year 5:			28%	-	59%	30%	-	63%	36%	-	75%
Projected time to finish cleanup at current rate of work (in years):			4	-	8	2	-	4	1	-	2
Total cost to complete cleanup:			\$80,000,000			\$45,000,000			\$35,000,000		
			\$70,000,000			\$30,000,000			\$30,000,000		

Task 4, continued

Funding Allocation:			Alternative 4								
			Abandoned Nuclear Weapons Factory			Irrigation Tunnel Project			Former Fertilizer Depot		
			\$10,000,000			\$5,000,000			\$15,000,000		
			Lower Limit		Upper Limit	Lower Limit		Upper Limit	Lower Limit		Upper Limit
Level of soil contamination within 100 m of site (millirem): *average annual human exposure = 360 millirem/year			2048	-	4253	1040	-	2160	267	-	555
Level of contamination (millirem) from:											
Alpha particles			256	-	532	332	-	690	9	-	19
Beta particles			995	-	2067	664	-	1380	167	-	347
Gamma rays			597	-	1240	43	-	90	91	-	189
X-rays			199	-	413	0	-	0	0	-	0
Level of water contamination within 100 m of site (millirem): *normal "background" level = 28 millirem			137	-	284	69	-	144	18	-	37
Level of contamination (millirem) from:											
Alpha particles			3	-	6	6	-	12	4	-	8
Beta particles			77	-	159	53	-	110	12	-	25
Gamma rays			40	-	83	10	-	22	2	-	4
X-rays			17	-	35	0	-	0	0	-	0
Environmental Health Impacts (measured as the number of animals/plants with radiation-related abnormalities per 100 sampled) within 1 square mile of site on:											
Plants			11	-	24	4	-	8	1	-	2
Terrestrial Organisms			17	-	35	10	-	20	1	-	2
Aquatic Organisms			3	-	6	1	-	2	0	-	0
Health Effects (measured as the mean number of radiation-related illnesses/deaths per 1000 workers and visitors to the site over the total 8 year cleanup time):											
Respiratory Infections			6	-	12	3	-	7	17	-	35
Non-Fatal Cancers			6	-	12	3	-	6	6	-	12
Radiation Sickness			1	-	2	0	-	0	0	-	0
Non-Fatal Bone Disease			3	-	6	2	-	5	2	-	4
Genetic Effects			3	-	6	1	-	2	2	-	4
Radiation-Related Deaths			2	-	5	1	-	1	0	-	0
Percent of site remaining to be cleaned after Year 5:			28%	-	59%	40%	-	84%	24%	-	50%
Projected time to finish cleanup at current rate of work (in years):			4	-	8	2	-	5	1	-	2
Total cost to complete cleanup:			\$80,000,000			\$45,000,000			\$35,000,000		
			\$70,000,000			\$40,000,000			\$20,000,000		

Task 4, continued

Funding Allocation:			Alternative 5								
			Abandoned Nuclear Weapons Factory			Irrigation Tunnel Project			Former Fertilizer Depot		
			\$10,000,000			\$10,000,000			\$10,000,000		
			Lower Limit		Upper Limit	Lower Limit		Upper Limit	Lower Limit		Upper Limit
Level of soil contamination within 100 m of site (millirem): *average annual human exposure = 360 millirem/year			2048	-	4253	910	-	1890	334	-	694
Level of contamination (millirem) from:											
Alpha particles			256	-	532	291	-	604	12	-	24
Beta particles			995	-	2067	581	-	1208	209	-	434
Gamma rays			597	-	1240	38	-	79	114	-	236
X-rays			199	-	413	0	-	0	0	-	0
Level of water contamination within 100 m of site (millirem): *normal "background" level = 28 millirem			137	-	284	61	-	126	22	-	46
Level of contamination (millirem) from:											
Alpha particles			3	-	6	5	-	11	5	-	10
Beta particles			77	-	159	47	-	97	15	-	32
Gamma rays			40	-	83	9	-	19	2	-	5
X-rays			17	-	35	0	-	0	0	-	0
Environmental Health Impacts (measured as the number of animals/plants with radiation-related abnormalities per 100 sampled) within 1 square mile of site on:											
Plants			11	-	24	4	-	7	1	-	2
Terrestrial Organisms			17	-	35	9	-	18	1	-	2
Aquatic Organisms			3	-	6	1	-	2	0	-	0
Health Effects (measured as the mean number of radiation-related illnesses/deaths per 1000 workers and visitors to the site over the total 8 year cleanup time):											
Respiratory Infections			6	-	12	3	-	6	21	-	43
Non-Fatal Cancers			6	-	12	3	-	5	7	-	14
Radiation Sickness			1	-	2	0	-	0	0	-	0
Non-Fatal Bone Disease			3	-	6	2	-	4	2	-	5
Genetic Effects			3	-	6	1	-	2	2	-	5
Radiation-Related Deaths			2	-	5	1	-	1	0	-	0
Percent of site remaining to be cleaned after Year 5:			28%	-	59%	35%	-	74%	30%	-	63%
Projected time to finish cleanup at current rate of work (in years):			4	-	8	2	-	4	1	-	2
Total cost to complete cleanup:			\$80,000,000			\$45,000,000			\$35,000,000		
			\$70,000,000			\$35,000,000			\$25,000,000		

Low Dose, Risk, Decisions, & Risk Communication

A Decision-Focused Approach

Appendix D

A Decision Focused Approach for Identifying Cleanup Priorities At Contaminated Sites

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★Under review★

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Abstract

This exploratory study compares two approaches for involving non-expert stakeholders in difficult policy choices. Both approaches have as their goal informing members of the public about key elements of decisions relating to the cleanup of contaminated sites. The first approach focuses on technical information and seeks to improve the available knowledge base so that participants can make choices informed by the best available scientific data. This approach is similar in intent to many of the science-based initiatives in public involvement now being undertaken by EPA, DOE and other federal or state agencies. The second approach, in contrast, focuses on values-based information and seeks to improve stakeholders' ability to make difficult choices in the light of required tradeoffs across a variety of technical and non-technical concerns. The results demonstrate that although both approaches help to increase participants' level of knowledge, a values-based approach is more successful in terms of meaningfully involving non-expert participants in decisions about what have historically been viewed as primarily technical problems.

Risk Communication, Fugitive Values, and the Problem of Tradeoffs at Rocky Flats

A REPORT

prepared by

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Abstract

This report examines the processes of risk communication and public involvement in decisions about contamination and cleanup at Rocky Flats Environment Technology Site. It finds that risk- and science-communication efforts at Rocky Flats have been successful to the extent that much of the ‘involved’ public has achieved an impressive level of technical sophistication. However, this demonstrated scientific literacy did not lead to diminished conflict about the risks posed by residual contaminants at the site. Instead, improved public understanding of the risk estimates and the attributes of radiation hazards appeared coterminous with increased conflict and a crisis in confidence in public process. Our analysis finds that the periods of concentrated conflict, stress, and intermittent paralysis of public process at Rocky Flats were produced by the difficulty regulatory agents, the contractor, and the involved public all have managing the tradeoffs intrinsic to the cleanup. Public values, ethical concerns and objectives were not well organized or articulated in reference to key technical decisions. Consequently, the values central to the tradeoff dilemma had to masquerade as points about the scientific defensibility of different cleanup options. This in turn produced two central outcomes: First, the sublimated values (herein referred to as “fugitive” values) fostered a competitive (and sometimes detrimental) exploitation by all parties of technical expertise; second, the opportunity for democratic public involvement was eroded by, ironically, the success of risk-communication efforts as this lead to the reconstitution of public groups as each new group tried anew to realize agreement about cleanup decisions. We suspect that this pattern is not unique to Rocky Flats and thus propose a model for testing at other sites. The model explains the dynamics of risk communication and public-involvement processes as they pertain to low-dose radiation and possibly other hazards.

1. Introduction

The goal of this report is to examine the processes of risk communication and public involvement in decisions about contamination and cleanup at Rocky Flats Environment Technology Site. It begins with a brief history of the site, including significant production and post-production events, a discussion of methods, and a brief sketch of the public groups closely involved with cleanup of the site. Thereafter it examines the influence of the science of radiation hazards as well as budget and timeline constraints on public perceptions of risk and public involvement in cleanup. We focus on the way in which those involved in decisions at Rocky Flats both reflected and contradicted what is known about public perceptions of risk. We consider how knowledge about radiation risks played out in public-participation fora aimed at making decisions about the management of present and future risks at Rocky Flats. Finally, particular attention is paid to the problem of making difficult tradeoffs about the cleanup of Rocky Flats and the consequences of that difficulty for public participation itself.

The central thesis is that while ‘risk-communication’ efforts at Rocky Flats have been successful to the extent that much of the ‘involved’ public has achieved an impressive level of technical sophistication, this demonstrated scientific literacy did not lead to diminished conflict about the risks posed by residual contaminants at the site. Instead, improved public understanding of the risk estimates and radiation hazards appeared coterminous with increased conflict and a crisis in confidence in public process. Our analysis finds that the periods of concentrated conflict, stress, and intermittent paralysis of public process at Rocky Flats were produced by the difficulty regulatory agents, the contractor, and the involved public all have in thinking about the tradeoffs intrinsic to the cleanup. Tradeoffs are difficult because they are linked to value positions and because most cleanup efforts are constrained by time and cost. Consequently, achieving one objective or valued goal comes at the cost of giving up something else of importance (e.g., deciding whether to base soil cleanup levels on protecting the health of the most vulnerable citizens at additional costs versus protecting the health of the expected average citizen so as to realize cleanup gains elsewhere). Yet rather than developing the tradeoffs so as to render explicit the values or objectives of different participants, public discussion

fell into the default position of trying to increase scientific literacy to produce a more rational debate unencumbered by value disagreement. As a result, discussion became paralyzed by the sublimated value issues because the very values central to the tradeoff dilemma had to masquerade as scientific points about different cleanup options. This in turn produced two central outcomes: First, the sublimated values (herein referred to as “fugitive” values) fostered a competitive (and sometimes detrimental) exploitation by all parties of technical expertise; second, the opportunity for democratic public involvement was eroded by, ironically, the success of scientific risk-communication efforts as this led to the reconstitution of public groups each increasingly specialized and aimed anew at realizing agreement about cleanup decisions. We suspect that this pattern is not unique to Rocky Flats and thus propose a model for testing at other sites. The model explains the dynamics of risk communication and public-involvement processes as they pertain to low-dose radiation and possibly other hazards.

1.1 Methods

The central aim of this report is to better understand emerging processes of risk communication about low-dose radiation exposure at Rocky Flats. Rocky Flats is one of many facilities within the U. S. Department of Energy’s complex of nuclear arsenal production sites. The site is now permanently closed and is currently being remediated in order to return it to publicly useable space. Risk-communication practices at the site are currently concerned with low-level radiation in that the bulk of highly contaminated materials (e.g., concentrated volumes of plutonium) have or are being removed. Most attention is thus focused on the potential extent of residual low-level contamination in the site’s soil and water once cleanup is complete.

Rocky Flats is an ideal site for case study purposes for those interested in the intersection of risk communication and concentrated public involvement in risk remediation programs. An extensive group of individuals and stakeholders makes up what is referred to locally as “the involved public.” [More colloquially, the term is “Rocky Flats junkies.”] These are the staff, individual citizens, and activists affiliated with the Citizen’s Advisory Board; representatives (elected and not) of surrounding municipal governments (organized as RFCLOG or the Rocky Flats Council of Local

Governments); as well as a number of communication and coordinator specialists operating on behalf of the cleanup contractor (Kaiser-Hill), the U. S. Department of Energy (DOE), the Environmental Protection Agency (EPA), and the Colorado Department of Public Health and Education (CDPHE). Each of these groups plays an integral role in ongoing local deliberations about cleanup at the site, although the nature of that role and the importance of different groups has varied (a phenomena we explain herein). Other, less formally constituted groups were also significant actors in the public-participation/risk-communication network such as the Rocky Flat Cleanup Agreement Focus Group (or RFCA Focus Group), the RSAL Working Group, including the Decontamination and Decommissioning Working Group (D & D), the Stewardship Working Group, and the Rocky Flats History Project. Each of these groups is comprised of differing combinations of private citizens, members of the CAB, RFCLOG, and staff scientists along with representatives from DOE and EPA. (A list of abbreviations is included as Appendix A.)

1.2 Data Collection

Data collection involved two primary methods: field observations and interviews with members of the “involved public.” The specific interviewees and their group affiliations are listed below. Field observations involved attendance at ongoing group meetings and a tour of Rocky Flats. Between February and August 2001 one and occasionally both of the report’s authors attended a total of approximately 15 stakeholder meetings. In any one week, there were and are still several possible meetings to attend. Only the Citizen Advisory Board meetings were routinely held in the evening and scheduled monthly; other groups often met weekly or bi-weekly. These primary sources of information were augmented by reviews of the Annual Reports and monthly bulletins published by the CAB, report documents produced by the different technical working groups, and media coverage of specific events. We are indebted to Len Ackland (1999) *Making a Real Killing* for considerable historical and background information.

RFCLOG: Rocky
Flats Council of
Governments

CAB: Citizen
Advisory Board

**REGULATORS
AND
CONTRACTORS**
(*n* = 6)

ACTIVE PUBLIC
(non-CAB; *n* = 4)

Local journalists
(*n* = 3)

RELATED DISCUSSION GROUPS:

Specialist:

[comprised mainly of staff scientists]

- Decommissioning and decontamination working group
- RSAL working group (attended by mostly scientifically literate CAB members)

Multi-stakeholder groups:

[comprised mainly of members of the CAB, RFCLOG, and Kaiser-Hill representatives]

- RFCA focus group
 - Stewardship working group
 - RF history project
-

***N* = 35**

Interview Sample. A total of 35 ethnographic interviews were conducted by occasionally one and mostly both of the report's authors. These were conducted over a period of 9 months, from November 2000 through July 2001; the majority were conducted between April and July 2002 during one-week episodes of concentrated interviewing in each of the four successive months. The names of interviewees are not revealed for the sake of anonymity. The specific number and the group affiliation of interviewees is detailed in Figure 1 as are the names of linked hybrid 'spin-off' groups. You will note that we sought representation from all groups, but focused much of our attention on members of the CAB and RFCLOG (many of whom were also active participants in the Rocky Flats Focus Group). Reporters from local newspapers were interviewed to gain a sense of the patterns of coverage and public interest over time and to collect information about key events at the site in the recent period.

Interview Schedule. All interviews were open-ended. In each case our primary interest in risk communication and public involvement in decision making at Rocky Flats was stated at the outset. Each interview followed its own internal topical arc but in each case we were nonetheless careful to cover the following areas of interest, sometimes directly, sometimes less so:

- perceptions of low-dose radiation risks and health consequences
- discussion of radiation safety standards and their application at Rocky Flats
- observations about the constitution and role of public groups over time
- discussion of participants primary sources of information about low-dose radiation and discussion of the trajectory of their knowledge acquisition
- discussion of the primary channels of communication across groups and individual parties
- discussion of any trenchant problems facing public-participation efforts
- observations about the noninvolved public's perceptions of radiation risks
- discussion about the role of science and scientists in public participation at Rocky Flats

- expectations about future uses of the site
- impressionistic questions about how interviewees thought the site was currently viewed by the ‘non-involved’ and how it might be viewed in the future

Data Analysis. Virtually all interviews were taped, transcribed and coded. Coding roughly followed the above interview schedule. However, the volume of interview data focusing on some topics and not others suggested to us the importance of the content herein, namely, tradeoff difficulties, the disruptive play of fugitive values, and the changing constituency of public discussion groups. Moreover, the dynamic nature of the meeting venues and the often tense atmosphere that prevailed during meetings held throughout this research period directed our attention to understanding why the constitution of groups had changed over time, what differences in risk perception and values underlay the endless discussion of technical aspects of cleanup options, and how it was that a cohesive and knowledgeable group — this “involved” public — managed (or failed to manage) their differences of opinion as concerned cleanup.

2. Plant History

2.1 The Production Era

The Rocky Flats Environmental Technology Site (hereafter Rocky Flats) sits on a mesa sixteen miles north and west of Denver. Approximately 2 million people live in the greater Denver metropolitan area. Due to its proximity to Denver, in 1995 the DOE named Rocky Flats the most dangerous facility in the nation's cold war complex of production sites. Operating from 1952 through 1989, the plant manufactured the detonating devices at the core of hydrogen bombs. These cores are known as "pits," "primaries," or "triggers." The core's center is comprised of a "hollow plutonium shell about the size of a grapefruit but weighing seven to nine pounds A typical one explodes with the force of around 20,000 tons of TNT" (Ackland, 1999, p. 3).

The 1957 and 1969 Fires. Over the plants' multi-decade history, much of its operation went unrecognized by the local population. Several events contributed to a reversal of this general pattern. In 1957 a fire and a series of explosions broke out in building 771 where most of the molding of plutonium into pits occurred.¹ The ventilation systems in building 771, a vast structure in its own right, was designed to keep plutonium from escaping into other workspaces and outdoors. The glove-boxes in which the pits were molded, via rubber gloves, were connected by a conveyor belt system for the transportation of materials. Both infrastructural properties contributed to the fire's spread. The fire was officially put out in 24 hours. Employees and firefighters were checked for acute contamination; plutonium appeared in the fecal, blood, and urine samples of several workers in the subsequent few days. Dow Chemical's medical director nonetheless concluded that: "for all practical purposes, the plutonium contamination resulting from the fire [was] negligible" (Ackland, p. 120).

¹ Plutonium is combustible in response to both air and water and thus small fires were somewhat common though usually quickly contained. The explosions were likely caused by the combustion of volatile gasses and dust that had accumulated in the ventilation filters (Ackland, 1999, p. 119).

Table 1. Rocky Flats Timeline

Nuclear weapons development

- Manhattan Project develops atomic bomb
- 1950 Significant expansion of nuclear weapons program
- 1951 Atomic Energy Commission selects Rocky Flats site for production

2.1.1 Production Era 1952-1992

Dow Chemicals 1952-1975

- 1952 Rocky Flats began production of “pits”
- 1957 Plutonium fire in Building 771
- Plant production and support facilities expanded several times
- 1969 Plutonium fire in Building 776
- 1973 Tritium incident

2 2.2 Rockwell International 1975-1989

- 2 — 1975 Terminal ponds constructed on N. & S. Walnut Creek
- 1989 FBI raid (June 1989)

-
- EG&G brought in to safely resume production
 - 1991 Water replacement project funded

2.2.2 Post-Production Cleanup & Closure Era 1992–200?

2.2.2.1 EG&G 1990-1995

- 1992 Nuclear production mission ended
- 1994 Last defense-related shipment left Rocky Flats
- Planning estimate for closure — 65 years (2060) \$36 billion

2 2.2.2.3 Kaiser-Hill 1995-200?

- 2 — 1996 Tri-party Rocky Flats cleanup agreement signed
- 1997 Water replacement completed
- Kaiser Hill planning estimate for closure — 2010, \$7.3 billion
- 1996-98 Building d&d begins
- 2000-02 RSAL debate
- 2000 Closure contract & 2006 closure agreed upon
- Ongoing building d&d — over 700 structures
- Ongoing environmental restoration
- 2006 Closure target

2.2.3 Long-Term Stewardship

2.2.3.1 Questions to be resolved

- Ownership — Liability — Water monitoring and safety
- Land use — Maintenance

2.2.3.2

Calculating exposure for areas residents was a more difficult task, particularly as the smokestack monitors on building 771 had ceased to operate during the fire. Just over 18 pounds of plutonium was unaccounted for after the fire; later dose-reconstruction studies estimated that the fire likely released through the smokestack somewhere between 50 to 500 grams of plutonium. Microscopic quantities are dangerous if inhaled. The upper limit for exposure for a worker at the time was 1 gram of plutonium.

Successive expansions of the plant facilities, buffer area, and workforce occurred throughout the 1950s and 1960s as the U. S. nuclear arsenal increased its Cold War holdings. In 1969 a second plutonium fire broke out in Building 776. The near burning of the roof — which if it had disintegrated would have enabled a catastrophic release of plutonium into the greater Denver area in the form of a powdery ash — was of great concern. This was luckily avoided, although fifteen employees required decontamination showers having received significant doses. Local news media covered the story. Ackland (1999, p. 156) cites a *Denver Post* headline as reading: “Radioactivity: AEC Weapons Building Burns.” The story’s text declared the building “too radioactively hot” to enter. Were it not for the classified secrecy of post-fire reports, the possible Chernobyl-like outcome of the fire might well have outraged local residents. Nonetheless, many regard the event as an awareness-turning-point, the juncture at which the plant’s threat to the community was more fully realized.

A 1973 release of tritium (a radioactive form of hydrogen) into the local water supply also received considerable media attention and launched an effort by local governments to alter the source of residential water supply; a replacement water system was completed in 1997.

The FBI Raid. The actions of whistleblowers within responsible federal agencies and escalating activism at the site in the 1970s and 1980s culminated in a 1989 raid of the site. FBI agents and EPA investigators arrived onsite with no prior warning, and seized records and photographs from 31 buildings as well as samples from outdoor waste disposal sites. The FBI’s 116-page affidavit and application for a search warrant defended the stated “probable cause” that crimes [of unacknowledged exposure, disposal,

etc.] had been committed. The report was made public 3 days after the raid (Ackland, 1999, 216). Among its dramatic accusations was that waste was routinely and illegally burned in building 771. Ultimately only lesser charges were supported but widespread publicity ensured that Rocky Flat's status as a model site and employer was severely damaged.

Following the raid, charges of safety violations continued. The plant's production activities were temporarily suspended in November 1989. In the same year, the post-Dow Chemical contractor, Rockwell International, sued DOE as it found itself unable to reconcile the conflicting demands of the agency for production alongside the EPA's demands for safer environmental standards. The DOE responded by contracting with EG&G, operators of the DOE's INEL laboratory in Idaho, to prepare for resumption of production. Following a period of contentious public debate and activism, it was announced in January of 1992 that production at Rocky Flats would permanently cease.

2.3 The Post Production Era

As recently as 1993, the plant housed over 14 tons of plutonium (some in metal, the rest in compounds and mixtures) and more than 7 tons of highly enriched uranium. Moreover, thousands of barrels of contaminated waste were stacked in the hallways, rooms and parking lots on the site. Meanwhile, President Clinton's new energy secretary, Hazel O'Leary, ushered in an era of decreased secrecy on the part of DOE and high expectations for developing both a more informed public and a public actively involved in site decision making. DOE staff thus funded the 23 stakeholder Rocky Flats' Citizen's Advisory Board. "Members included plant workers, activists, academics, neighbors, and local elected officials" (p. 237).

The last defense-related shipments left Rocky Flats in 1994. That same year, the DOE in conjunction with EG&G estimated that cleanup would cost \$36 billion dollars and projected an astonishing 50 years for closure. In 1997 Energy Secretary Pna (a former Denver mayor), announced that Kaiser-Hill would be responsible for a \$7.3 billion dollar closure, scheduled for 2006. Then as now, members of the CAB have questioned the DOE's budgeting and decision-making process (Ackland, 1999, p. 240), a point that will be elaborated shortly.

3. Public Science, Risk Communication, and Risk Perception at Rocky Flats

3.1 Radiation Knowledge and Standards

Radioactivity refers to the “curie” or degree of energy — in the form of x-rays, beta or alpha particles, or gamma rays — emitted by the nuclei of a radioactive element as it spontaneously decays or disintegrates over either very brief or very long periods of time. The harmful effects of ionizing radiation were first recognized in 1925 (Martland, Conlon, & Knaf, 1925). The behavioral properties of radioactive materials vary as do their respective abilities to penetrate tissue and deposit energy in the human body through ionization.² Alpha particles, for instance, are relatively large and carry a double positive charge. They are not very penetrating and can be stopped by a piece of paper. They travel extremely short distances in human tissue but deposit all their energies along their short paths, with the potential of doing a relatively large amount of damage along these paths. Beta particles (electrons) are extremely small compared to alpha particles and carry a single negative charge. They are more penetrating than alpha particles, but can be stopped by thin aluminum metal. They travel much longer distances in human tissue and deposit much less energy along their paths. Gamma rays and X-rays, having no mass or electrical charge (electromagnetic radiation), can travel extremely long distances in human tissue compared to particle radiation (alpha and beta). They deposit much less energy along their paths, but can damage internal organs (MacGregor, 2002).

From the 1940s forward, the question of whether or not there exists “a threshold for somatic radiation injury” has persisted despite repeated efforts by scientists to discern a ‘safe’ dose (Walker, 2002, p. 20). The question endures in part because the evidence for low-dose radiation effects are derived not from direct empirical evidence but from linear extrapolations based on effects of high-dose exposure such as that suffered by victims of the 1945 bombings of Hiroshima and Nagasaki. This process of estimating the impacts of low doses on the basis of higher doses is sometimes referred to as the “linear hypothesis.” It seeks designation of comparatively safe doses based on these extrapolations yet also implies that all levels are to varying degrees detrimental to human health.

² Ionizing radiation can cause physical changes in human tissue because it can knock electrons from the atoms and molecules in its path.

By the 1960s new research suggested that low doses over an extended period of time were less harmful than equivalent doses delivered in a short time (p. 40), but not definitively so. Among Atomic Energy Scientists (AEC) there were strong disagreements on this point. Yet, by 1980 several prominent regulatory scientists argued that the linear model was “not appropriate . . . [because] adverse health effects increased very gradually at low doses and followed a linear model only at much higher levels” (p. 101). These disagreements about the legitimacy of a linear relationship between high dose and low dose initiated multiple debates among scientists about safe levels of exposure. In the recent period, the National Academy of Sciences’ BEIR V report (National Academy of Sciences, 1990) argued that the linear hypothesis was appropriate for estimating some but not all tumor risks; hence it was suggested that the linear hypothesis was appropriate at some but not all levels.³ Yet, by the mid-90s dramatically different opinions existed on the question of low-dose effects. Some “held that even the energy in very low doses of radiation could damage DNA strands in cells [and that] mutations that occurred in this way could lead to cancer” (p.143). Whereas others held that “cells had amazingly sophisticated repair mechanisms” and that “small doses of radiation [might even be] beneficial” (p. 144).⁴

Regulatory law, as set out by the Environmental Protection Agency, currently requires that the risks to which the public are exposed fall within a 10^{-4} to 10^{-6} risk range; that is, a 1 in 10,000 to 1 in 1,000,000 mortality risk.

3.2 Public Science at Rocky Flats

In the last two decades, a wide body of research has emerged on the role of science in society and on lay/expert debates about science. To this end, science is understood as both a set of theories and practices used in the pursuit of knowledge, a technical language employed in debates about policy, and even a “culture” with its own characteristic (and collectively held) body of beliefs. Among the many findings that have emerged from this

³ In competition during the writing of the report were the linear model and the quadratic model; the latter posited that adverse health effects increased very gradually at low doses and followed a linear model only at much higher levels. . . . In an effort to resolve differences on this point, “most members of the committee endorsed a “linear-quadratic” model that split the difference between the two approaches” (Walker, 2002, p. 101).

⁴ Hormesis is the theory that low doses of radiation are in fact health-beneficial.

new field is the paradoxical social fact that most public groups are strongly supportive of science at the same time that there are many heated public debates about the validity of science as it applies in particular policy and decision-making contexts. This latter point is particularly salient in the case of nuclear technologies where strong ‘scientists versus the public’ differences of opinion occur about the safety of nuclear technologies (Krimsky & Golding, 1992). Briefly stated, it has been found that much of the public disagrees with the expert community about the safety of radioactive isotopes if the source or location of those materials is also associated with weapons development, nuclear power, and nuclear waste. Moreover, it is well-established that government agencies assigned with the management of these technologies are distrusted by much of the general public (Slovic, 2000). Scientists and regulators have often viewed this distrust and difference of opinion as either (1) a problem of scientific and technical illiteracy on the public’s part (a failure to understand the science and hence a fearful or resistant attitude) , and/or (2) a problem of poor quality education and communication on the part of experts. Risk communication and public education is often regarded as the universal remedy for this problem and many approaches have thus developed to improve risk-communication practices (National Research Council, 1996).

Risk communication at Rocky Flats consists of an ongoing dialogue between the DOE, EPA, a citizen advisory board (CAB), one of the few fully independent citizen boards in the DOE complex, and a coalition of local municipal and county governments (RFCLOG).

3.3 Scientific Enculturation

The Rocky Flats risk-communication program has been remarkably successful in that many citizens have achieved an impressive level of technical sophistication about cleanup operations and probabilistic risk estimates. As such, conversations about the effects of varied decommissioning strategies, the implications of wind patterns on contamination dispersal in future open space, or the long term health effects of low-dose exposure from different levels of plutonium concentration in the soil are publicly debated.

This technical expertise was not easily achieved nor acquired by all participants. Rather, a core group of particularly knowledgeable participants became the predominant and most vocal public stakeholders at Rocky Flats. For those participants without significant training in the natural sciences or engineering, there existed tremendous normative pressure to “come up to speed” on the technical dimensions of cleanup before one could rightfully participate. Public participants readily admitted that the burden of becoming technically literate was enormous and that considerable effort had to be invested in order to participate meaningfully. Many, though not all, took this as a challenge worthy of pursuit.

When I decided to interview for the CAB, I knew right away that it was going to be a very steep learning curve, because it was about a whole lot of policy issues I hadn’t encountered before and also a whole lot of scientific arguments that I was only minimally aware of . . . and so god bless the activists who have thrown away all hopes for an otherwise bourgeois life to read the library.

In the words of another participant:

To have a meaningful public process, you have to have an informed public. To be informed takes a lot of work. And most people don’t even read a newspaper, let alone a [soil action level] report which is that thick. I spent last Tuesday doing that. I sat down and read it from cover to cover. It takes a lot of effort if you want to get informed.

For those who had only recently joined the CAB, the prospect of earning credibility as a public participant through intensive study and training was particularly daunting:

Just learning all about the different terminology. That has been an education in itself. It just blows me away sometimes. It’s like, OK, what did they mean by that, you know? And I have my little list of acronyms that I can relate back to . . . [I’m just going to] make sure that I’m up on everything, read all the material, which is mountains, mountains of material. It’s a monumental task.

Moreover, new CAB members regarded scientifically trained and more literate, long-term colleagues with what can only be described as awe: “These people have been doing this

for all this time and it's just, I find, remarkable. I really do and I really respect them for their dedication to it. It's been . . . an eye-opener."

3.4 Perceived Risk at Rocky Flats

Given the evolution of technical literacy at Rocky Flats among a core group of participants, it is appropriate to ask: (1) how knowledgeable this subset of participants is about the radiation risks and standards and (2) how fully their perceptions of risk conform to existing studies on the subject.

Nearly three decades of studies of the public perception of radiation risks has revealed that risks affiliated with nuclear power, weapons and waste are particularly salient in the public mind. They are regarded by the public as highly risky technologies as compared to most other sources of radiation exposure such as x-rays, cosmic radiation, sun, nuclear medicine, and radon (Slovic, Fischhoff, & Lichtenstein, 1979). More specifically, the characteristics of a hazard — whether it is seen as dreaded, involuntarily imposed on those exposed, thought to be beyond one's control, or regarded as unfamiliar — powerfully effect the perception of risk (Erikson, 1994; Slovic, 1987, 1992). It is argued that people fail to understand the relative or comparative importance of different risks — of low-dose radiation stemming from a nuclear power station as compared to, for instance, the risks of handguns or smoking. Equally, the public generally fails to understand the probabilistic reasoning and risk ranges that underpin expert risk estimates (Morgan, Fischhoff, Bostrom, & Atman, 2002). Studies of people's intuitive thinking about risk also reveals that most people evaluate radiation hazards on the basis of the source of exposure (i.e., the dose delivered by a medical x-ray is not thought to be as bad as an equivalent dose delivered by contaminants remaining from bomb production). Finally, in repeated surveys, Europeans and North Americans reveal themselves to be dose insensitive. That is, lay persons (as compared to experts in the toxicology and risk assessment field) are far more likely to believe that "there is no safe level to a cancer causing agent" and that even a small dose of a carcinogenic material will cause cancer or serious bodily harm (Kraus, Malmfors, & Slovic, 1992).

At Rocky Flats, however, the long-standing risk-communication program initiated by state and federal agencies as early as 1993 and the high epistemological standards that

came to characterize public discussions at the site resulted in a somewhat different pattern of knowledge and perceived risk. Fifteen of those interviewed from the core group of involved stakeholders were sufficiently comfortable technically to offer their own models and understandings of radiation risks and standards. Six of the fifteen can be characterized as regarding low-dose radiation as comparatively safe, two as cautious but undecided, and seven as leaning toward a characterization of low dose as unsafe. Only one of the fifteen offered “inaccurate” information about the behavioral attributes of radiation, or the meaning of the linear hypothesis, background radiation, exposure pathways, comparative risk ratings, and/or the probabilistic ranges of risks that mattered for regulatory purposes.

In sum, these core participants were extremely knowledgeable about the characteristics of ionizing radiation. They understood the difference between alpha particles and gamma rays and the kinds of mitigating protection each required.

I have a fact sheet on beta, gamma, and alpha radiation, and what penetrates and where it penetrates. Alpha can be stopped by a piece of cloth. . . . The only radiation that people understand is high-dose radiation. It makes you vomit, it makes you sick and then you die. They’ve got a clue about that.

Several core participants also understood the concept “below regulatory concern” and were cognizant of debates about the linear no-threshold (LNT) versus threshold models of dose and biological damage to human tissues.

[Low dose is] a non-acute dose . . . no [detrimental] observable response in the body . . . But, you know, I really think that we just don’t know. It may be far more dangerous than we think. They [theories of low-dose radiation] go from linear no-threshold to hormesis.⁵ But, right now, things are based on the linear no-threshold theory and there are enough people pointing to evidence that this [theory] is correct.

Many could also readily offer tutorials on the linear no-threshold hypothesis and were aware of both its meaning and its link to evidence historically derived from high-dose

⁵ This speaker was at all times careful to identify his own view in reference to others, and to characterize the perspectives of others carefully and respectfully.

exposure. When asked the meaning of low dose, one participant offered a graphical explanation and in so doing drew a invisible x-y axis in the air:

Well if you have a chart of exposure and time [and] it's getting down near the zero point, and I haven't spent a lot of time studying this, [but I know that] we don't have much data in this area. You know a lot of the studies or extrapolations of potential harm from radiation are based on high intensity, concentrated high dose.

Importantly, it was also the case that most participants were dose *sensitive* in that they understood fully the relationship between dose and hazard. Some could recite the comparative risks of different naturally and non-naturally occurring forms of radiation exposure as an expression of either millirem dose annually or as an expression of cumulative lifetime dose. Discussions of dose tended, instead, toward the more arcane and context specific influences of exposure such as the duration and intensity of exposure (chronic versus acute), pathways of inhalation or ingestion, physical attributes of the contaminant (gamma ray or alpha particle) and/or the age or vulnerability of the dose recipient.

The most notable difference between the knowledge articulated by those who were risk-averse as compared to those who were risk-tolerant were the technical points on which emphasis was placed. Those who represented themselves as less apprehensive about the health consequences of low-dose radiation, were more apt to highlight, during interviews, the high levels of local background radiation extant in the Colorado and greater Denver area,⁶ the mortality risks of other commonly encountered risks, the failure for some of the more dire predictions of radiation hazards to materialize, and to regard the by-products of nuclear weapons as an understandable risk in face of necessary Cold War benefits. An illustrative excerpt from a 'risk-tolerant' CAB member is as follows:

Many houses have very high radon here. . . . We're also at a higher elevation. Why, if it's ten times what it is, say, on the eastern seaboard, why don't we see some observable differences. Now I agree, it's very difficult because we're looking for a signal in a sea of noise and it's a fairly affluent society we have here. But . . . I would

⁶ Discussants were also aware of the vagaries of determining background radiation such as soil type or geological features, altitude, radon levels in individual households, etcetera.

expect to start seeing something at least. And even more so among airline pilots who are absorbing over a rad a year . . . and flight attendants too

One of my pet peeves is that I have a very difficult time between risk perception and reality, real risk. I don't see why they're not the same. And I know that's totally — but people get in their cars every day and accept at 10^{-4} risk of dying in their car from auto accidents. Now, ones that drive aggressively probably have a 10^{-3} [risk]. People that drive drunk probably have a 10^{-2} . So, we accept all these risks, but somehow radiation is in a different category. . . .

And then there's another way to look at risk, risk-benefit. This is where people philosophically on radiation part company very quickly. Were nuclear weapons a benefit or were they a hazard, solely a hazard with no benefit? I personally would ascribe a large benefit to nuclear weapons, and I think we would have been in a war with Russia within two years after World War II if we had. Now, that's my own belief. There's a lot of people that take the opposite side.

A similar pattern of thought is provided by another CAB member. This speaker did not explicitly state an opinion regarding the Cold War, but something of an opinion can be gleaned from references he made to those in the group regarded as motivated by anti-war activism.

There are those that come with their political agenda, anti-nuclear, anti-war agenda, that aren't going to be happy no matter what happens...

Living in the front range you get 250-300 millirems per year from background. You take a couple flights on a jet plane and you'll get 25 additional millirems. It's a perception about the danger. I think there are those that are extremely fearful of radiation. And there are those that accept radiation as just part of life. I mean we live in a radiation environment, there's nests of radiation all around us.... By choosing to live in Denver, you live in a higher radiation area for two reasons: Number one is altitude, number two is because of the high uranium concentration back in the mountains.

[Yet], apparently, we're not a bad species. We've got two hands, two legs, two eyes. It hasn't had terribly severe effects on us. You go get dental x-rays, you get a pretty healthy dose. You get a chest x-ray, you get a pretty healthy dose.

Those who represented themselves in interviews as risk-averse were more likely to emphasize the possible detrimental effects of single inhaled particles when articulating their understandings of radiation risks. They were also somewhat likely to emphasize the uncertainty inherent in scholarly understandings of radiation science and/or to exercise a precautionary approach by drawing the "acceptable" line at the conservative end of the risk range set out by federal policy, that is, a 10^{-6} risk.⁷

By way of example, one participant offered the following thoughts when questioned about the meaning of low-dose radiation. In so doing, he pointed to a photograph of a plutonium particle, magnified 500x, in the lung of a human being. The photograph portrayed a star pattern of tracks emanating from the lodged particle.

This set of alpha tracks occurred over a 48-hour period. This is one particle of plutonium. In the lifetime of a person with a particle like that, it's going to affect a lot of cells and it may damage some. It may kill some. If it kills them, that's helpful, but if it damages them, that's not very helpful. I know this is very controversial. Not everybody will [contract cancer.] It's a gamble, a person may contract cancer or genetic defects or some other health effect from that particle of plutonium.

A second participant also explained low dose as an emanating single particle. Earlier in the interview, we had discussed her knowledge of state and federal surface water standards for plutonium, exposure transmission routes for heavy versus fine particles of target materials, and the possible error rates of monitoring systems that sample local water reservoirs at 30 versus 7 day intervals.

Well [in reference to low dose], you have to talk about low energy, high energy, etc. At Rocky Flats we have high energy, plutonium. Plutonium is considered a high-energy source, an alpha particle.

⁷ We do not mean to suggest that the 'risk-tolerant' participants never mentioned the effects at the cellular level of a single exposure, they did. Our point is that the knowledge content most emphasized followed the patterns noted above.

She then switches to the behavioral attributes of beryllium to illustrate her thinking about the meaning of low dose. Beryllium exposure was newsworthy during this period, as reports of a compensation settlement for exposed workers had recently appeared in local headlines.

Last year, a local doctor from DOE was out here talking about beryllium. A city councilman asked him about how much exposure a person [can] have before they [should be] concerned. And he said, “one.” One exposure. Just one. He said that it only takes one particle in your lung. It keeps giving off energy. It’s the gift that keeps on giving. That’s what the workers call it. The gift that keeps on giving. One hot little particle sits there and does its damage. And for the worker, that really is the primary exposure.

Scholarly uncertainty across efforts to determine safe doses and personal control over the risks to one’s health were also cited as reasons to endorse a conservative cleanup. In one illustrative example, an active public participant noted that it takes a very long time to demonstrate the health effects of different exposures. Citing the relatively simple case of smoking and lung cancer, the speaker characterized efforts to understand low level radiation as a parallel albeit more complicated case. “Low level radiation is the same sort of thing, it’s a long range low level effect, very difficult to prove.” Because it is difficult to prove, and, he noted, won’t be understood with any certainty in the near future, the salient point for this participant was the difference between the risks that one has no control over (such as a natural disaster) versus those risks that are imposed on citizens.

An acceptable risk is one that there is a zero possibility of controlling, a lightening strike. Random acts of god. An unacceptable risk is something that man has designed and has some control over. I like the 10^{-6} number, one in a million. I like my chances better.

The above informed characterizations of low-dose radiation do not defeat earlier work on perceived risks. It is still the case that control over risks figures prominently in the acceptability of risks, as does thinking about dose sensitivity, albeit to a far more nuanced degree. Those who are risk-averse and understand the complexity of dose

estimates might still focus on the ‘chance’ that some people will suffer severe damage following an inhaled single particle or minimal physical insults. Those who are risk-tolerant continue to hold the point that the source of the risk does not matter — that citizens should think in terms of comparative risks and thereby tolerate risk exposure from Rocky Flats in the same manner that they tolerate exposure to the effects of living at high altitude or flying in a passenger jet. Thus, while risk communication at Rocky Flats reflects improved local knowledge of radiation risks, a clear distinction in patterns of thought between those who are risk-tolerant and those who are risk-averse remains evident.

3.5 Science as a Rationalizing and Tension-Reducing Force

It is difficult to determine precisely when and how a high intellectual standard and accompanying technical discourse was established at Rocky Flats. Two general points are relevant. First, a more technically trained and focused CAB appears to have replaced the activist climate that characterized the period between 1990 and 1996. Several long-time CAB members identified a gradual decrease in community and anti-nuclear activism among CAB participants and attendees at open meetings.

There were a lot of people who had been historically involved from an activist perspective. And that wasn’t all that was on the CAB, but that certainly influenced the sort of flavor of it. And we have a lot more now who have no historical connection to the work at the site, or the issue in any way. And some who I would characterize as being probably more conservative, including _____ [who is] still doing contract work [as a radiation scientist] at Los Alamos.

Second, as the site began to approach a 2006 or thereafter cessation of cleanup, the pressure to resolve some of the more trenchant debates escalated — debates about how safe is safe enough and how best to proceed with the decommissioning of buildings, the decontamination of soil, or the viability of institutional controls for monitoring residual risks. The increasingly technical discourse is linked to that pressure to the extent that the rationalizing forces of science were expected to resolve these debates.

Advocating the “best available science” as a rationalizing and hence guiding principle for cleanup decisions is a laudable goal and cleanup — most would agree — should be guided by a high standard of technical rigor. But such efforts do not necessarily forge a more effective public process. Indeed such assumptions contradict 20 years of work on effective risk communication (Fischhoff, 1995; National Research Council, 1996; Powell & Leiss, 1997).

4. Tradeoff Avoidance

It is our contention that it was not a failure of scientific literacy at Rocky Flats (e.g., a failure for the involved public to ‘understand what is meant by the numbers’) that exacerbated conflicts about cleanup, but, rather, a failure to take up and resolve the tradeoffs that were to determine what to do when and to what level. That is, one single variable appears to drive most of the conflict, stress, and at times the breakdowns of public processes at Rocky Flats. This is the pronounced difficulty regulatory agents (primarily from DOE and the Environmental Protection Agency), the contractor (Kaiser-Hill) and the involved public (the Citizen Advisory Board, the Rocky Flats Coalition of Governments as well as a handful of individual participants) all have both facing and addressing the tradeoffs intrinsic to the cleanup process.

If scarcity of resources (in this case money for cleanup) were not an issue, the tradeoff dilemma would be nonexistent. But there are in fact very few arenas in which citizens can expect unlimited resources.⁸ Put simply: If the federal government and the contractor were both willing and able to deliver on the idealized requests of the involved public, the grounds for conflict and controversy would be greatly reduced. Instead, a sometimes-agonizing struggle (locally referred to as “brain damage” or the hard work of public discussion) had evolved from efforts to resist, avoid, or circumvent any real and perceived limitations on cleanup of the site and hence to resist the necessity of making difficult tradeoffs involving particular gains or sacrifices.

The tradeoff impasse is a familiar one: Vocal critics of Rocky Flats cleanup activities reject fiscal and temporal limitations and maintain that the agencies and contractor must

⁸ We assume, of course, that concerned citizens will act in accordance with the conviction that it is their job to realize as much return as possible through political pressure, scrutiny of decision process, and the electoral and interest group venues.

spend whatever it takes to clean up the site. In contrast, the agencies and contractor have consistently worked from the assumption that they would pursue the best possible cleanup within the limitations of available time (i.e., a cleanup deadline of 2006) and funding. Clear statements regarding the divergent views of the DOE, the EPA and members of the involved public were apparent, both in the public meetings, and in our interviews with participants. For example, one member of the citizen's advisory board stated:

You know, this whole issue about what the cleanup level's gonna be. I don't get that. I'm like, are you gonna clean it up or are you not gonna clean it up. Why are we negotiating what the cleanup level's gonna be? I don't get that. If I can go out there with a Geiger Counter when you're gone, am I gonna get a click? What, what are we, what are we negotiating?

The above example represents some but not all of the perspectives of involved citizens. The following comments were, for example, typical of contractor and agency perspectives, but were also similar to the opinion of several CAB members.

It's all about this tradeoff. [But certain groups] reject the time line and reject the budget. The fact is that the fiscal constraints to this contract are so blatantly real that we just have to emphasize [the fact that]: Four billion⁹ dollars is what [Rocky Flats is] getting, it's irresponsible to ask for more. And that message has been conveyed by the congressional office,[and] on a one-on-one basis to some key people. But, you know, the way I look at it is: the government has basically said that they're willing to give Rocky Flats four billion dollars to clean this place up. And, that's a whole lot of money. And, we can get a great cleanup for that. And, there's a lot of possible outcomes on what the end-state looks like.

Over the multi-year period of public process at Rocky Flats the necessity of making time and cost limitations clear has repeatedly come up against the perceived negative consequences of this assumption. To some extent, the contractor and the two agencies

⁹ The overall budget for clean-up was earlier stated as 7.3 billion dollars; the amount cited here only included estimation of cost and does not include Kaiser-Hill's fee for the project. That fee will go up or down depending on unanticipated costs as well as cost to the company for fines levied due to time overruns and related unmet contractual obligations.

(DOE and EPA) found themselves in a classic decision maker's quandary by virtue of the expectation that they could minimize public conflict and simultaneously cope with a wide range of technical and financial uncertainties. In regard to the first expectation — minimizing public conflict — we were explicitly informed by agency personnel that the DOE and Congress had produced an agreement that guaranteed yearly appropriation of funds for the Rocky Flats cleanup as long as three conditions were met: 1) the cleanup be completed by 2006; 2) the cost and scope of the cleanup be contained (i.e., remain as negotiated); 3) conflict in the community be curtailed (given the history of public protest at Rocky Flats). This agreement, made in trust, was (and continues to be) validated through ongoing annual appropriations to Rocky Flats. Rocky Flats was in an advantageous position in that very few of the other sites in the DOE complex had been guaranteed (albeit conditionally so) annual appropriations. But as those funds were “conditional”, the contractor and the agencies were placed in the position of having to ‘minimize conflict’ while meeting bottom-line budget limitations regardless of any certainty that cleanup could actually be achieved with the available resources and within the agreed upon time line.

Those who study the difficulty people have making tradeoffs recognize that they become vastly more complicated when the degree of uncertainty about whether the actions taken will deliver the desired consequences is high (Gregory, in press). Uncertainty can be magnified both by “epistemic uncertainty” or lack of knowledge (i.e., the situation poses questions that science cannot yet answer) and by the behavioral complexity of the system being studied (i.e., uncertainty about future wind patterns, soil migration, flooding, and other such events at Rocky Flats) now and long into the future.

4.1 The RSAL Debate

The complexity of tradeoff considerations and their intersection with an heightened scientific discourse was nowhere more evident than in the multi-year discussion among stakeholders about Radionuclide Soil Action Levels or RSALs. This level refers to the maximum volume of radioactive materials found in the soil above which cleanup or removal of that soil is required. The implications for where the RSAL is set at Rocky Flats are enormous as soil cleanup represents the single largest remediation action at the

site. The decision dramatically influences the availability of resources for other decontamination measures. Moreover, there existed considerable external pressure in the form of the possibility that the RSALs set at Rocky Flats would establish a profoundly burdensome precedent at DOE. A low RSAL at Rocky Flats could mean exorbitant cleanup costs throughout the complex if DOE was held to the Rocky Flats standard at all sites. This is particularly the case given that some other sites are considerably more contaminated than Rocky Flats.

Setting an RSAL is a complex and uncertain science as it concerns the ability to accurately predict low-dose radiation for future users of the site from residual contaminants in the soil. Anticipated average annual doses can only at best be reasonably calculated based on a wide set of variables and assumptions including but not limited to:

1. Characterizations of the site including such variables as wind patterns, hydrology, soil morphology, slope, and so on, each of which contribute to a particular pattern of soil migration and contaminant concentration within and beyond the site.
2. Expectations about the future users of the site (suburban resident, subsistence farmer, recreational user of open space, wildlife worker, etc.) and the calculation of exposure for a 'typical' user.
3. Expectations about what activities characterize the likely movements of a future site user which in turn helps determine their rate of inhalation — or ingestion-derived exposure.
4. Expectations as to what a safe maximum annual dose is — given the uncertainties of hypothetical dose constructions and the heterogeneity of contaminant concentration.
5. Expectations regarding the likelihood of adequate institutional controls in the immediate future (50-100 year period and beyond).¹⁰

The DOE had initially proposed a maximum allowable plutonium RSAL of 651 picocuries per gram of soil whereas others had identified an RSAL of 35 pCi g⁻¹. Those rallying for a conservative RSAL (and hence a more thorough cleanup of soil) hoped that

¹⁰ How does one manage for the future when the capacity to engineer controls or monitor the dispersal of residual contaminants when dealing with material (e.g., plutonium 239) with a half-life of 24,065 years?

the “subsistence farmer” (aka “resident rancher”) affiliated with the 35 pCi/g would become the prototypical future user. [A resident rancher was defined as a person who lived full-time on the land and would grow and consume products from that land.] Others promoted somewhat less conservative scenarios including RSALs for a wildlife worker and a recreationalist. [A wildlife worker would manage the open space refuge that Rocky Flats would become, spending approximately 40 hours a week on the land. A recreationalist might only occasionally hike, jog or mountain bike on the same land.]

Under these circumstances it was essential that the responsible contractor and agency parties be utterly and consistently clear about the contextual factors (e.g., the budget assigned by the federal government) within which cleanup must take place. Without early and constant clarity, a “risk information vacuum” invariably surfaces to undermine future communication and possibly amplify the public perception of the risks involved (Powell & Leiss, 1997, p. 214).

Yet, however closely regulators were working with the involved public, our data suggests that the contractor and especially the DOE were ambivalent about making the cost/time/RSAL tradeoff explicit. Agency parties (DOE and EPA) and contractors (K-H) represented themselves as intent upon communicating the concrete reality of these constraints (and as having made these constraints clear all along). But this is contradicted by evidence from stakeholder meetings and several members of the public who regarded the agencies as having actively concealed the “true” nature of these fundamentally limiting ‘time and cost’ variables. As a result, there existed widespread suspicion about the possibility of “behind closed door” negotiations. The assumption was that federal parties had acted unethically and against the well being of the local community and that as such public participation was nothing more than a vacuous procedural gesture.

In June 2001, a particularly illuminating encounter was observed at a meeting of the RFCA focus group, a meeting regarded by many as the central point at which fiscal limitations (and hence the need for difficult tradeoffs) were first brought out into the open. Heretofore the tradeoff discussions had been masquerading as a technical discussion wherein the defensibility of the studies used to set RSALs were called into question.

The meeting was significant enough for the DOE representative to describe the exchange as a, “momentous discussion” and to characterize it as “throwing a dead rat on the table” — the “dead rat” being the fundamental limitations posed by a cost ceiling and hence need for tradeoffs. [Note, he is ostensibly admitting that only here was the tradeoff made explicit despite claims made in interviews with DOE personnel that tradeoff necessities had always been openly declared.] The exchange recorded below occurred midway through the meeting; it begins with a private citizen and long-time participant in the public process initiating a discussion about the future user of the site:

Citizen: This is presumably a dead horse but I hope it is not . . . The RAC study¹¹ used a Resident Rancher because it is most conservative. Is that [possibility] really dead? We can’t possibly say what will happen in 500 years . . .

EPA Staff: We base our assessment on reasonable maximum risk, but I don’t think a [resident] rancher is that— I won’t tell my boss that. Plus, a refuge worker is still conservative and reasonable.

Citizen: Would Christopher Columbus have been able to tell us how we are going to use the U. S. in 500 years? . . . that is totally unreasonable for you to say that it is reasonable . . .

DOE Staff: The agencies are constrained by laws, regulations, and policy. Furthermore we have to strike a balance here between what can be done in this place, at this time, and with this money . . . To put it bluntly, the RAC study was “unconstrained.” We don’t have that freedom . . . we have to depend upon institutional controls. In the interest of intellectual honesty, we have to work within these limitations.

The DOE representative’s emphasis on “intellectually honesty” brought the fiscal constraints around cleanup out from the shadows of “technical” and “scientific” discussions of RSAL and future use determinations. Through this candor, he attempted to include the public in the burden of these constraints so that more detailed decisions concerning tradeoffs within the established limitations could begin to be addressed.

¹¹ RAC stands for the Risk Assessment Corporation, the consulting group responsible for the CAB-initiated study of RSALs noted above.

Two outcomes followed in this and a subsequent meeting: (a) the critical public resisted the idea that the tradeoff had ever been made explicit and (b) treated the very idea of a tradeoff necessity as the product of corruption and deceit on the part of the DOE and the contractor, a deceit that is conceivable given the initial ambivalence of agency parties about revealing the necessary tradeoff in the first place.

The following exchanges demonstrate this clearly. In the first meeting, a citizen refers to the DOE agent's honesty and "thanks" him for being forthcoming: "Thank you for saying this, for this is the first time I've heard this said by any one of the agencies."

At a subsequent meeting, the issue of tradeoff deception is again central. Evident, on this occasion, is the fact that lack of transparency about tradeoffs has lead participants to doubt the legitimacy of their participation in the first place. His comments reflect the dissonance between the public's expectation that their comments are influential, and a growing awareness that the limits of the cleanup were predetermined by political and economic decisions that are beyond their sphere of influence. This is forcefully expressed in veiled accusations of foul play and open statements of dissatisfaction that lead, eventually, to the request that citizens be permitted an opportunity to address the "real" principles/decision makers.

The decision-making process is a lot more complicated, and there is a lot of subtlety, and there are a lot of pressures that are hidden to the people that come to these meetings. One of the reasons that I am interested in having an earlier meeting with the principles is because I think that they're entitled to hear from people that are unhappy with some of the decisions we've already been told have been made. They're entitled to hear from us, not just from the coordinators [on-site agency personnel]. The coordinators are clearly not the only decision makers about the soil action levels — despite the kind of neat logic of your presentations. And I realize they play a very crucial role. Take one item — which is the decision I've heard criticized a great deal, and that's the decision about the [future user] scenario that will be employed for calculating the soil action levels. We've been told that decision has been made. There's a good bit of unhappiness in this room about that decision and in the people that come to these meetings. And I suspect that there will be, beyond this, when the

news is available to people about the decision that has supposedly been made. But how — I'm really, I'm really, really interested, how that decision was made. Who made it? . . . If we can understand who is weighing in, then we know that we need to approach those people. Cause' those people are participating in the decision. I really, I really want to know. I think we're entitled to know.

Agency personnel then respond to the accusation that RSAL decisions were predetermined. In so doing, they articulate the regulatory rationale for their decision and argue that although the decision may not be consistent with the priorities of their critics, the public voice has nevertheless been included in the decision-making process. It is instructive, equally, to note that the effort to discuss tradeoffs has been dropped; discussion has returned to or been sublimated into a debate about the technical defensibility of different future user scenarios. In other words, a discourse of policy and scientific standards is used to neutralize the underlying tradeoff conflict.

EPA Rep: Well, from EPA, the status as I see it has been, was put forth in the latest revision to the Task I report, and it does have the wildlife refuge worker being the anticipated future user. And I — unless something comes up to change my mind, that's the recommendation I'm going to make to my [superior]. And I know of no other entity outside of — well I know of no other entity whose weighed in on this.

Citizen: Has that recommendation been made to your principle?

EPA: I told him that's the way I'm leaning.

Citizen: But it's your personal decision? .

EPA: It's supported completely by all the EPA policy I can find, and I vetted it with my attorney.

Citizen: So it's a recommendation to the principle at this point-

EPA: That's correct.

At this point, a DOE representative steps in to validate public process and the collective effort extended to generate and evaluate the 'risk numbers.'

DOE: I think the retort is a bit disingenuous. There's been a lot of process to decide what assumptions we should use to develop the numbers. We agreed that we needed to make assumptions about land use to develop the numbers. We ultimately, as a result of this process, are developing like five or six sets of numbers. And that's great. But the principle recommendations on things like land use, or the risk or dose basis for the number, are coming from the principles. We're not all sitting around in our showers and just deciding what sounds good. There's been a lot of process here. There's been the working group. There's meetings — technical meetings everyday. And so ultimately it comes to convergence at some point. When this came up [previously], I didn't want to mislead you; say, "no, it's wide open. We got the whole table and anything goes." Could a [RSAL] number anywhere on that table come out? Yes. Do we think that the number is going to probably coincide with the row that says "wildlife refuge worker?" That's probably going to be our recommendation unless some new information comes to bear that just throws that out the window. So, semantically, has a decision been made? No. Does it look like the Rocky Flats Cleanup Agreement principles are going to recommend that scenario as the basis for the RSAL. Yes.

Citizen: You're going round in circles. Someone wrote down in the write-up, whatever you call it — that was a decision. Now we are trying to find out who made that decision?

DOE: No, you're hearing what you want to hear. There's been a lot of process to develop information to determine what the most likely future land use would be. It doesn't mean that the outcome was always the one you wanted, but you absolutely influenced how these decisions were made.

To summarize these points, a central part of the trust compact made with Rocky Flats parties and Congress was that budgetary and time limitations would be met at the same time that public dissatisfaction would be contained. Given this informal mandate, these limitations eventually had to be broached by agency personnel. And yet, participants reacted so strongly and suspiciously to the suggestions of a cost tradeoff that all explicit mention of tradeoff limitations were thereafter avoided. It is not surprising that discussion

of tradeoffs was so quickly and easily converted to accusations of deal brokering between Congress and the agencies. In order to both avoid public controversy and cope with numerous technical unknowns, the central issue of economic and temporal limitations was not, and perhaps could not, be addressed directly. Instead, it was couched within the language of the RSAL and future user decisions. This sublimation of the basic conflict provided a mechanism through which discussion and negotiation could proceed and anticipated public resistance could be postponed and contained. However, the endurance and intensity of the subsequent debate over standards such as RSAL and the future user added to the public impression that their hard work and sustained input would be directly reflected in the cleanup decisions made at Rocky Flats. Public participants believed that they were influencing decisions that addressed their core concerns over cleanup. Moreover, the sustained discussion about RSALs (several years in entirety) reinforced the expectation that cleanup standards would be based upon a combination of public interest and scientific analysis, rather than fiscal/temporal limitations per se.

4.2 Taboo Tradeoffs and the Tradeoffs-Values Link

Tradeoffs are difficult because they are linked to value positions. We care, often deeply, about achieving outcome A over outcome B because the former is seen as fulfilling a desired value or goal more fully than the latter. Achieving one objective or valued goal comes at the cost of giving up something else of importance (e.g., deciding whether to base RSALs on protecting the health of the most vulnerable citizen at additional costs versus protecting the health of the average citizen so as to realize cleanup gains elsewhere). Yet rather than developing the tradeoffs so as to render explicit the values or objectives of different participants, public discussion fell into the default position of trying to increase scientific literacy to produce a more rational debate unencumbered by value disagreement. As a result, the RSAL discussions became paralyzed by the sublimated value issues because the very values central to the tradeoff dilemma had to masquerade as points about the scientific defensibility of RSAL modeling parameters.

Critical members of the involved public responded negatively and with suspicion to the DOE's suggestion that cleanup was constrained by cost precisely because they were

being asked to engage in what, borrowing Fiske and Tetlock's (Fiske & Tetlock, 1997) term, is known as a "taboo" or nonnegotiable tradeoff in which affiliated value positions are treated as "protected" and thus exempt from negotiation (Baron & Spranca, 1997; Baron & Leshner, 2000).

Taboo tradeoffs arise when people are asked to pit an important value intrinsic to a tradeoff against a qualitatively different category of value. Such tradeoffs lead respondents to believe that they must sacrifice a deeply held principle in order to participate in any negotiation, tradeoff, or decision process. This is particularly the case when strongly held normative positions from one sphere of life (e.g., beliefs about justice, fairness, democracy) come up against utilitarian values such as cost or time concerns. People generally regard such tradeoffs as undermining the integrity of the first set of values (e.g., justice, fairness, etc.). For example, to compare or evaluate the importance of one's children in juxtaposition to the cost of raising them is morally offensive to most people. Such acts reflect back to those making the tradeoff something "ugly" about themselves or their personal integrity precisely because they are asked to behave as though willing to transgresses important norms including the idea that "parenthood/childhood is priceless." Consciously or not, in the Rocky Flats case, public participants act on the premise that they are being asked to "sacrifice" human health for "dollars."

Moreover, when faced with tradeoffs that are actually or ostensibly taboo, a common set of "hallmark" reactions often occur. Among the hallmarks identified by Baron and Spranca (1997) and evident at Rocky Flats are:

Absolutism or Quantitative Insensitivity. This is the "all or nothing" quality of responses to taboo tradeoffs. People tend to believe that a small scale expression of an act is just as bad as a large scale one. The woman quoted above who negated negotiations with a concise: "are you going to clean it up or not" is a case in point. Under these circumstances, it becomes very difficult to discuss the 'wisdom' of variations in scale. In the RSAL case, the DOE began with a comparatively high number (651 pCg). What followed, save for a brief "dead rat/tradeoff" discussion, was several years of public effort to criticize the technical viability of that number and is so doing "use science" to

drive the number as low as possible. This is a perfectly understandable strategic reaction. But is it wise for those involved? If DOE had discussed, early and clearly, the cost limitations within which they were working, a different conversation might have occurred. Driving the RSAL as low as strategically possible might have been replaced by a better quality conversation on cost and scale. For instance, if a soil cleanup based on a 35pCg RSAL were to cost x dollars, while a 40pCg RSAL would cost 30% less yet represent only an infinitesimal change in health risk, it might be wise to spend the 30% saved elsewhere. (There are often diminishing returns for dollars spent, that is, the first $\frac{1}{2}$ of dollars spent realizes huge gains whereas the 2nd half of gain-per-dollar outcome is much poorer.) That 30% expenditure might have gone to realize a better health-protecting gain (the value behind the tradeoff) elsewhere.

Denial and Resistance. People often refuse to believe that they must face a taboo tradeoff in the first place and thus suspend the tradeoff/decision-making process until a more palatable option can be found. There were many expressions of this at Rocky Flats. Most obviously, the wish to talk to the principles/decision makers is driven in part by tradeoff resistance. In the words of one CAB member protesting against cost and regulatory limitations: “This can be influenced by the community, and you could make these kinds of recommendations to your bosses (i.e., reject the limitations on our behalf). That is not how this decision has to be made.”

The Slippery Slope Dilemma. This is the belief (and sometimes very real possibility) that any move in a particular direction will lead to or is symbolic of devastating future outcomes. The slippery slope problem is akin to legal decisions established on the basis of a minor infractions but ultimately contentious because they hint at the undermining of such inalienable rights as free speech. It’s expression is well represented in the above noted concern that a high-RSAL precedent at Rocky Flats will lead to poor quality outcomes at other sites in the DOE complex.

Given the thorny nature of taboo tradeoffs, those whose regulatory mandate it is to ensure that the tradeoffs are made must develop tactics to cope with the “perilous social

predicament of attempting a taboo tradeoff.”¹² Equally, they must address “the righteous indignation of observers who learn that sacrosanct normative boundaries have been transgressed” (Fiske & Tetlock, 1997, p. 285). This quandary often means that agency representatives (the tradeoff brokers) must adapt several tactics so as to deflect blame and ensure peace. These include the need to compartmentalize categories of discussion by explicitly invoking distinctions between spheres of consideration and negating the possibility of discussing two linked points simultaneously (e.g., to say “that’s a justice concern, we’re only talking here about technical issues”). Other tactics involve obfuscating the tradeoff and procrastination (p. 257).

4.3 Tradeoff Avoidance and Fugitive Values

Thus far, we have outlined a particular pattern of behavior at Rocky Flats. We have noted that a state of proficient and/or increased scientific literacy among public participants is widely evident. While positive in many respects, this state can also be attributed to the heightened attention granted technical discussion of cleanup options due to the belief that a more rational hence scientific discussion of posed options would serve to diffuse the escalating emotional climate engendered by difficult choice processes and the related problem of tradeoff avoidance.

It must be said that this is a problem common to virtually all public discussion fora. But ultimately, the most important aspect of this problem is the perennial “bogged down” state it produces. This state is best understood not only as a normal bi-product of group behavior in civic life, which it certainly is, but more importantly for public involvement, as an outcome of naïve efforts to eliminate all conflict by resorting to excessively technical discussions, and, importantly, by placing value discussions off limits. Wishing that public risk-communication venues be cleansed of value discussions does not make it so. Many risk scholars have clearly and repeatedly demonstrated that all risk debates are at their core value debates and that as such it is virtually impossible to suspend or eliminate this aspect of the debate (Kunreuther & Slovic, 1996). If this is what one tries

¹² We do not mean to suggest that these are consciously manipulative responses, but rather a normal human response to an uneasy situation. However, we do assert that (a) those facilitating public processes can become more aware of these tactics, and (b) employ decision-making strategies to help address resisted tradeoffs (discussed later in the report).

to accomplish, what invariably surfaces instead — the bogged down state — is in fact a state of “fugitive values.” The deeply embedded value positions that make the decision and tradeoff processes difficult in the first place go underground but do not go away. Instead, they entangle even paralyze public discussion precisely because they infuse every point of discussion about ostensibly technical problems. These values in operation are fugitive in the sense that they move from place to place and appear in a fleeting form without ever being brought into the open where they can often be put to constructive (and ultimately more democratic) use.

5. Value Sublimation

It is telling that at the very first public meeting that Satterfield attended at Rocky Flats (in February 2001), the facilitator announced unambiguously that all discussions in the meeting were to remain focused on technical points. Value-driven discussions were isolated and excluded as “explicitly off limits.”

Indeed, most participants recognized that over time, a silencing of value positions had taken place. Agreement, however, among public parties on whether this was a pejorative or successful outcome was mixed. Some CAB members regretted though tacitly accepted the fact that over time value or ethical debates had been eliminated as viable points of discussion.

Well, in the past there’s been a lot of ethical, moral, philosophical discussion. If you look back at statements by the advisory board [we made] sure that we put that up front. [But] I think DOE actually did try pretty hard to move the public away from that. A lot of what you get [now] is: ‘Well we’ve had all of that, we’ve had the moral and philosophical, but now it’s a science decision. And that’s really dominated the past two years.

In another case, the necessity of eliminating justice or related ethical concerns from discussion was described, quite literally, as a painful state:

I think it’s especially painful for the activists who are concerned not only about technical stuff, but also about peace and justice stuff. They’ve got to speak in one

dialect [a scientific one] but not the other dialect in which they are fluent [a value-based one].

Others openly complained that the silencing of value positions was insufficiently complete to the extent that they viewed stakeholder meetings as having descended into a chaos of competitive agenda-setting. “There’s a place for that [values], but when it starts to hinder the CAB process, then I think it’s not right, I think it’s counter-productive.”

5.1 Fugitive Values and Their Consequences

Regardless of whether public participants believe value sublimation tactics are a “good” or “bad” outcome, it remains the case that rendering value positions fugitive exhausts both human and fiscal resources. It can also produce unexpected consequences. First, it is exhausting for those who willingly volunteer their time as public participants only to find that the group is ‘getting nowhere’ and/or ‘spinning its wheels.’ Public discussion is often reduced to tedious and non-productive ‘talk,’ a point not missed by those involved. In the words of a CAB member:

They think it’s a good process because there’s lot of, uh, there’s lots of, lots and lots and lots of words and lots of lots and lots of time and that’s called public participation and it is public participation and it’s just, it’s just like a sponge, it’s absorbing huge amounts of human energy

Second, under these fugitive value/tradeoff avoidant conditions, wherein distinction between ‘facts’ and ‘values’ are not made and the objectives of stakeholders are redirected into debates about the technical merits of alternative cleanup actions, public participants must and do resort to the only available option: they become entangled in a troublesome good-science/bad-science debate. And they likely attack the scientific studies that are the basis for different cleanup options and seek to hire independently conducted studies of their own. This is not to suggest that conducting independent studies or reviews are wrong. Historically, there is an undeniable legacy of deception on the part of DOE regarding the impact of their operations on public health. But if such studies are based solely on distrust they may end up re-doing already adequate studies for

reassurance when greater attention to the objectives of different groups might reveal the necessity of other equally important studies.

At those points, at Rocky Flats, where irreconcilability of scientific interpretations threatened to paralyze cleanup, new studies were conducted and new data were collected based on the premise that new and better science would resolve lingering concerns because science is naively regarded as immune from political manipulation and value-free. In actuality, advocates for ever safer and more thorough cleanup standards are pitted against those who defend a lesser standard as scientifically robust and legally defensible, to wit, both sides claim to possess the scientific upper-hand. Many recognize and even enjoy the fallacy of this argument. During an interview, one CAB member noted that everyone appears to believe that:

the problem [of growing conflict] has a technical solution. The goal [they believe] is to use the best technical and scientific procedures and evidence possible to generate the best possible technical solution. So, it's sort of like a good science/bad science dilemma. I think there have been real powerful moments where DOE has found itself funding, to its credit, things whose outcomes it could not have predicted . . . So, one of the things I've tried to learn is the different ways the DOE is conflicted about its own imperatives and responsibilities. . . . Science is something that has previously been used in ways that, [to me] are criminal [e.g., weapons production]. Literally [now], I've seen it get used jujitsu, aikido-like, against them.

Again, the RSAL debate provides the best case in point. Recall that initially DOE posed and defended an RSAL for plutonium of 651 picocuries per gram. The question any level tries to address is that, given particular land use scenarios, what risk exposure is safe enough? The volume of plutonium remaining in the soil is converted, depending on said use conditions, to a probabilistic risk range that meets the EPA's health-safety standards. The minimum standard is a 10^{-4} risk level (a one in ten thousand chance of developing cancer), whereas the upper level of the range sits at 10^{-6} (a one in one million chance of developing cancer). The CAB could not agree on a unified position to present to DOE. They were deeply divided and had no means for reconciling their own profound ideological and ethical differences. There were those who thought the original RSAL

numbers were, quoting a CAB staff member, “based on enough scientific process that . . . they must be safe” and those who thought “they were the worst numbers ever.”

Those who argued for the higher number believed that regulatory agencies could, by and large, be trusted and that the posed standard was safe enough. Setting an unnecessary stringent standard at Rocky Flats, they argued, wasted public funds. Critical members of the public stated that a 651 level would not ensure the safety of more vulnerable populations, namely, young people whose biological systems are still developing, people with compromised immune systems, or future generations whose potential behavior on the land cannot be predicted and thus the only defensible plan was a conservative one. But as the concerns on both parts were essentially value-based or ethical in nature — they pertained to ideas about one’s social responsibility to the public, future generations, or the “rightness” of protecting some people less well than others — they were off limits. Instead, attention focused on the technical viability of DOE’s initial results and the need to re-calculate RSAL and risk estimates.

After considerable expense (\$400,000) and time, the new study recalculated RSAL numbers reflecting the complete range of end users each of which corresponded in fact to the range of CAB objectives. At the low end of the possible range, the (new) numbers were well under 40pCi-g-1 depending on the specifics of calculation inputs and the identity of the end user. The lowest number in the range (10 pCi g-1) was produced for the identity or end user known as “child of a resident rancher.” (Such a child might play in and eat soil and would also be fed food grown in the soil during his or her key developmental years.) But even the probable wild-life worker corresponded to a much lower number. Ultimately, at Rocky Flats, the critical public appeared to recognize that the realization of their competing value positions (however well disguised) hinged on their ability to present compelling and/or competing scientific evidence to support their positions (Nelkin, 1995).

Although the DOE consented to financing the second study, they were in the words of one CAB member, deeply “fearful [because of the cost implications] that the number would go down too far” and “horrificed” when they did. In the extreme tension that followed, involved stakeholders could not manage the diversity of opinion on RSALs

within their ranks and the DOE called for a ‘technical’ review of the 2nd study. Thus, a new group was convened to limit the complicating role of the CAB’s ethical-cum-technical division, and to, hopefully on DOE’s part, challenge the plummeting and hence costly RSAL numbers with further calculations and technical review.

5.2 Group Constitution and the Anti-Democratic Consequences for Public Participation

This brings us to our final point about the consequences of tradeoff avoidance, the heightened technical discourse it inspires, and the disruptive play of fugitive values. As tradeoff avoidance and decision paralysis persisted, the role and even presence of different public discussion groups was compromised. A successive chain of ‘spin-off’ groups emerged. Each tended to be smaller and more focused so as to have a greater chance at reaching agreement and confining discussion to increasingly esoteric technical content. These groups would often be comprised of both DOE and Kaiser-Hill staff and only those members of the CAB or RFCLOG technically literate enough to engage in the increasingly arcane details in the first place. For instance, as noted directly above, the DOE convened the RSAL working group to review and recalculate the outputs of the second RSAL study. Secondly, and more importantly, for public participation, the CAB’s role was de facto diminished. Instead, the locus of public discussion shifted to the newly convened Rocky Flats Cleanup Agreement Focus Group [or RFCA focus group]. The new group was justified as necessary because too many CAB members had neither the time nor the skill to “properly” understand the nuances of the science and the policy limitations set out in the Cleanup Agreement. Speaking specifically about the new RFCA focus group, an involved CAB member and trained Ph.D. scientist identified the group as a much anticipated opportunity to “really discuss the technical issues.”

We do not mean to represent this shift as an agency slight-of-hand. Public participants appeared fully aware that a pattern of open public involvement representing the diversity of opinion (and skill) embodied in the CAB was replaced by a smaller more literate group.

The Citizen’s Advisory Board is not nearly as knowledgeable. People like myself [i.e., one of a more knowledgeable subset or core group of CAB members] are paying

a whole less attention to the process of the advisory board than to the process of the focus group, because I think that's where the real discussion is happening We became very very involved with the soil-action level because we were knowledgeable about this particular highly technical stuff.

Further, the focus group's aim is to resolve any differences through extensive technical debate and thereafter abide by an "announce and defend" or "teach the public the numbers" format for public discussion. To wit, focus group members will communicate their findings to the "less educated" members of the public.

We've got a special work session planned to talk [to the CAB] about the calculations. We've done the work and we're going to bring the results of the working group back to the CAB. But what we're going to do with the CAB, is try to educate the members as to how the numbers were calculated. And then see if we can put together a recommendation [on RSALs for DOE] and hopefully we can get a recommendation fast.

The RFCA focus group was not the panacea that many hoped — a forum for rational scientifically astute discussion. Many complained that it, too, was "bogged down" and "totally dysfunctional" due to [he perceived] "people's political agenda."

Regardless of outcome, what occurred at Rocky Flats was a long and drawn-out pattern of group mutations where an ever more versed segment of the involved public along with the agency's science and policy staff, came to embody public discussion and involvement. In so doing, an important democratic principle — the need for a diverse CAB to deliberate and debate the means for achieving the best outcome for the public — was pitted against the ideal and elusive pursuit of scientific literacy and hence (it was argued) reasoned debate. Invariably, at Rocky Flats, much of the legitimacy and integrity of the former democratic principle was sacrificed.

5.3 Disenchantment with Public Process

Some long-time CAB members were deeply critical of the trajectory of public involvement and were indeed aware of their diminished access to direct participation and the related lost opportunity to become more knowledgeable.

They have all these committees that break out and then the committees give their reports. I think part of what I'd do to help with involvement and, and an understanding of the science, I would start holding committee meetings housed within our meetings on the important stuff, um, like the RSAL stuff. I would have that group [RFCA focus group] integrated into the monthly [CAB] meeting. I would stop all of this nonsense reporting [back to the group] crap that wastes our time.

The whole organizational structure of the CAB, I think, is ineffective. You don't involve the citizens within the structure that they have now. There's no process for making a Board member feel welcome. There's no process of helping a Board member through the intimidation of the science. I have no idea what these committees do because I can't read the reports. The reports are all like this heavy-duty science stuff. And, I'm not going to read 20 pages of science that I don't understand and get to the end of it and go 'I have no idea what I just read.'

As of the end of the research period, it was unclear as to just where those citizens who did not or could not articulate their concerns in a fully scientific and technical idiom fit. Many simply remained silent observers until such time as they felt confident enough to speak. They noted that a "freeze settled over the group" when the implications of certain technical discussions were neither "fully understood" nor "fully explored." It would then take "someone with considerable guts" to say: "What exactly do you mean by that? At which point the other person acts offended or kind of patronizing or something."

Others still observed that tension during meetings if and when ideas were voiced by those less technically literate were common:

You should see some of the body language that goes on around the CAB when a citizen is talking about something that we know is not right, but they don't. Instead of saying to this guy: your points have [merit]. No one responds. They just say [referring to meeting chair] 'oh, thank you very much.' That's not citizen participation, that's BS. You just bullshitted this guy. You gave him his time in the sun, you have him the microphone, he expressed a concern. You, all your body language just made fun of this guy. That is the CAB's definition of citizen participation, but it's not my definition.

Ultimately, the problem of creating a viable democratic public forum for citizens who were not able to discuss technical questions concerning cleanup was shouldered by the CAB staff. They were responsible for realizing a mandate that required that all citizens be able and welcome participants. At the same time, CAB staff were cognizant of the fact that the locus of opportunity for public participation had shifted from the CAB to RFCLOG, and in particular, the RFCA Focus Group.

I have problems with the fact that your average citizen is not sitting at that table, it's all professional people that work for either [one of the] agencies, the city or local government ... there's only two people that I could name that participate are actually members of the general public.

5.4 Discussion — The Dynamics of Risk and Science Controversies

Previous studies of risk have shed light on how risks are perceived and how risks become amplified. A very small set of studies evaluating (critically and not) different public-participation experiments are available (Arvai, Gregory, & McDaniels, 2001; Renn, Webler, & Wiedemann, 1995; Webler, 1997). Ample anecdotal evidence and some published evidence also exists for the fact that stakeholder groups addressing radiation risks often fail to reach consensus or super-majority support (Easterling & Kunreuther, 1995). Finally, there are a number of studies that highlight the differing values held by disputing parties in risk debates (Jasanoff, 1999; Nelkin, 1992). Nelkin (1995), in particular, has found that while disputes about science as it is applied to regulatory policy are often motivated by political or moral values, the debates themselves remain preoccupied with technical questions. The value complexity of debates is matched by their strategic complexity as “moral arguments are combined with extensive use of technical expertise . . . and technical expertise becomes a resource exploited by all parties to justify competing moral and political claims” (p. 452-3).

But, as yet, there exists little systematic effort to document ethnographically the specific processes (including the complex interplay of values and knowledge) that lead to discussion paralysis across stakeholders and the resultant influence of those processes on public involvement — its shape, its characteristics, and its perceived legitimacy. In the substantive portions of this report, we have drawn on field interviews and observations at

Rocky Flats to provide a descriptive portrait of the dynamics of risk and science controversies in public-participation contexts. What follows here is a summary of this description in the form of processual model. The aim is to develop a model that can accommodate the complex details of cases like Rocky Flats for the purposes of cross-case comparisons and the development of theory.

5.5 A Structural Description of the Dynamics of Risk and Science Controversies in Public-participation Contexts

Figure 2 posits that in the Rocky Flats case two types of pressure [box 1 and 2, horizontally displayed on the left-hand side of the diagram] were exerted which produced, in turn, four primary consequences or outcomes (boxes 3 through 6, vertically displayed on the right side of the diagram).

Box 1 — Decision Parameters. The first two boxes, “pressures,” denotes that decision parameters are necessarily imposed on stakeholders but that the actions under discussion involve a high degree of uncertainty. Federally, there exist numerous epistemological uncertainties about the health effects of and hence necessary standards for radiation exposure. At Rocky Flats, Kaiser-Hill is among the first engineering contractor to take on the task of cleaning up one of the many nuclear arsenal production sites within the DOE complex. They invested considerable time and resources preparing and negotiating a contract with the federal government and likely budgeted for numerous contingency or worst case scenarios. It is telling that the first cost estimate for cleanup, put forth by EG&G in 1990, was 36 billion dollars; the estimated cleanup deadline was 70 years or a 2060 closure date. This earlier estimate is nearly five times Kaiser-Hill’s 7.3 billion dollar budget and schedule. The gross discrepancy in estimates likely indicates that it is difficult at best to know with even a modicum of precision what cleanup will involve, what technologies will be used or developed to conduct the necessary decontamination and decommissioning of the site, how long it will take, and how much it will cost. (During the period of study, stakeholders widely acknowledge that Kaiser-Hill was over-budget and behind schedule as did the federal government, (U. S. General Accounting Office, 2001) These uncertainties placed the contractor and the client (DOE) in a position of heightened and chronic vigilance with regard to costs and schedule. This

Figure 2. The dynamics of risk and science controversies in public participation contexts.

vigilance came into direct conflict with efforts to set RSALs because the final RSAL would determine how to spend a significant portion of the overall budget (and because there was concern that a low RSAL at Rocky Flats would set a dangerous cost-precedent at future sites in the complex).

Box 2 — *Tradeoff Avoidance.* Cost limitations and temporal deadlines are a given in any project of this kind. Moreover, those most responsible for site decisions know only too well that tradeoffs must be made in order to achieve the end goal of cleanup. But it is invariably difficult for regulators to voice clearly and consistently the necessity of tradeoffs and to address them head-on with full recognition of what making such tradeoffs involves. This is due in part to agency fears that they will come across as assigning a monetary value to human life. More broadly, there are many psychologically compelling reasons why such tradeoffs are regarded as ‘taboo.’ These problems are augmented by the fact that regulators fail to recognize that it is virtually impossible to make tradeoffs without clearly addressing the objectives or values that underpin why one option is selected over and above other competing options.

These two phenomena — Box 1 and 2: decision parameters under uncertainty and tradeoff avoidance — converge to exert extraordinary pressure on the capacity for a diverse body such as Rocky Flat’s CAB, RFCLOG, and the many linked stakeholders to operate. Several outcomes can thus emerge.

Box 3 — *Increased Demand for Scientific Literacy.* The increased pressure and tension exerted by a climate of tradeoff avoidance and decision making under uncertainty was met by elevating expectations for scientific literacy under the guise that the more problematic value considerations could be cleansed from the discussion and a more rational debate across stakeholders would thus prevail.

Box 4 — *Fugitive Values.* When value considerations are increasingly sublimated, value differences across stakeholders do not go away, rather they become “fugitive” forces in the discussion. Points about value are forced to masquerade as technical points encouraging more than is necessary the competitive exploitation by all parties of technical expertise. At Rocky Flats this was most clearly demonstrated during the protracted debate about RSALs.

Boxes 5 and 6 — Group Mutation and Disenchantment with Public Process. As the interplay of tradeoff avoidance, fugitive values, and a “science only” discussion persists, the role of public discussion groups is compromised. New groups emerge, each more highly specialized and more highly focused on technical points of discussion. The assumption is that these new modified specialist groups will resolve their differences and having done so, will ‘educate’ or convince the larger involved group accordingly. In so doing, the very principle of a diverse citizen board and democratic public involvement is undermined and widespread disenchantment ensues.

6. Conclusion

Understanding the nature of risk communication and public-participation programs is a difficult task. However, little is known (beyond the anecdotal or the abstract) about just how and why efforts to involve an interested public in specific discussions about risk management and remediation programs suffer periods of protracted paralysis, even fail, or why they are forced to deviate from their initial democratic, multi-stakeholder (and intrinsically democratic) good intentions.

Risk scholars have argued vehemently that risk debates are value debates and that as such involving the public in risk-management decision processes is essential (National Research Council, 1996). Small group discussions (Gregory, 2000), citizen advisory boards (Vari, 1995), citizen juries (Crosby, 1995), and public opinion surveys have flourished of late in an effort to fulfill this widespread call for public involvement. Less academically, there are now any number of practitioners who consider themselves experts at facilitating public involvement. While this general trend toward public involvement should be applauded for its fundamentally democratic spirit, it is not the case that *any* public involvement is *good* involvement. Increasingly, federal agencies are embracing stakeholder groups with little or no knowledge of how to structure that involvement so it is productive and not destructive. Indeed, among those who follow public-involvement efforts, there is increasing talk of a “backlash” against public involvement because so many efforts exhaust all social and fiscal resources and yet fail to produce a decision outcome that is supported by the vast majority or ideally all of the those involved stakeholders.

Without better diagnostic evidence, there is little basis for improving the operation of citizen advisory boards, and their many variations, or for instructing federal agencies on the importance of good quality, well-structured public involvement. More importantly, the Rocky Flats case demonstrates clearly that any public participation effort that (a) fails to properly and systematically address the fundamental importance of making tradeoffs and decision parameters clear *and* (b) openly debate and analyze the value positions with which those tradeoffs are associated, will likely lead to a breakdown in public involvement. Further, an insistence on greater technical literacy has some benefits but if that 'literacy' is the product of naïve efforts to minimize conflict, then it will only serve to obfuscate the more fundamental ethical conflict at play and eventually erode the possibility of meaningful involvement across a demographically and educationally diverse public.

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Low Dose, Risk, Decisions, & Risk Communication

Risk Communication, Fugitive Values, and the Problem of Tradeoffs at Rocky Flats

Appendix A List of Abbreviations

CAB – Citizen’s Advisory Board

CDPHE—Colorado Department of Public Health and Education

D&D Working Group – Decontamination and Decommissioning Working Group

DOE – Department of Energy

EPA – US Environmental Protection Agency

EG&G – Edgerton, Germeshausen & Grier, Inc.

INEL – Idaho National Engineering and Environmental Laboratory

RFCA – Rocky Flats Clean-Up Agreement

RFCA Focus Group – ditto + focus group

RFCLOG – Rocky Flats Coalition of Local Governments

RSAL – Radionuclide Soil Action Level

Low Dose, Risk, Decisions, & Risk Communication

Radiation Risk Perception and Communication: A Case Study of the Fernald Environmental Management Project

A REPORT

prepared by

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Abstract

The aim of this exploratory study was to learn about the manner in which perceptions of low dose radiation risks develop in a social setting. The Fernald Environmental Management Project (FEMP) provides a case study about two risk issues: 1) public health risks from historical releases during site operation and 2) residual contamination from onsite disposal of wastes and the future use of the site. Both are associated with low level exposures to radiation in the community. The research reported here inquires into the ways that risk perceptions develop through social interaction. Specifically, I investigate: 1) the ways that social networks shaped the flow of risk information and 2) the ways that interaction within and among networks shaped individuals' risk perceptions of the public health risks from historical contamination and future use of the site. The report finds that networks can have three functions in risk communication: a) facilitate learning about risks, b) mediate the flow of information from one group to another, and c) generate their own information about risks that they communicate to others. Second, networks establish and modify relationships that can influence how risks are perceived. Third, new networks can emerge through the actions of agencies by being a point of convergence for individuals from other social networks. These findings suggest that theories of risk perception and risk communication need to account for social interactions to capture the relevance that existing or newly established groups play in the social understanding of risks.

1. Introduction

1.1 Overview

The Fernald Environmental Management Project (FEMP) is a former nuclear production facility located in a rural, residential area 18 miles northwest of Cincinnati, Ohio. The Fernald site is located in two Townships: Ross and Crosby. A third township, Morgan Township, has also been involved in clean-up related decision-making. The site operated from 1951 to until production was suspended in 1988. The main activity of the facility was to produce highly purified uranium metal products (“feed materials”) for US defense programs. In December 1989 the site was added to the U.S. EPA National Priorities List. In 1991 DOE officially ended production and the site was renamed the Fernald Environmental Management Project, or FEMP. It is now one of many sites that is being “cleaned” as part of the DOE’s Environmental Management Program.

Soils, debris, ground water, and surface water in the Fernald vicinity are contaminated with uranium, radon and other radioactive materials. In 1984 the site contractor announced that an accident released uranium dust.¹ At first they denied that any contamination occurred off-site. Subsequent investigations showed that was untrue. This was the first time that the community received such news and the response was anger, disbelief, and a sense of betrayal. Trust and credibility of DOE, Ohio state agencies, and site management was severely eroded. These feelings were exacerbated when news was released that the wells of several abutters were contaminated — and that the site had been testing the wells secretly for several years prior to the residents’ being informed. The response was a lawsuit brought by local residents against Fernald and the DOE (settled in 1989).

Extensive risk communication has taken place about public and worker health risks from production operations and clean-up activities. Risk communication experiences about two types of risks will be discussed in this report: a) the assessment of historical releases of radiological contaminants and b) the disposal of wastes on-site. In the case of

¹ There have been three site contractors: National Lead of Ohio (1951-1986), Westinghouse (1986 - 1992), and Fluor Daniels (1992–present).

risk communication about historical releases we focus on the public health risks. In the case of the on-site disposal cells and future use of the site the risk communication efforts centered on future risks to the community from residual contamination. They provide a rich source of data about how the risk communication efforts were experienced and how social networks played key roles in the formation of opinions about the risks.

Our approach to understanding the dynamics of risk communications about these risk sources is to enquire into how social networks generated, mediated the communication, and facilitated learning of risk-related information. Two pairs of social networks are discussed. The first pair were existing social networks within the community that concerned themselves with risks arising from Fernald: local government officials in the three townships affected by Fernald and the citizens watchdog group Fernald Residents for Environment, Safety, and Health (FRESH). The second type of networks were two advisory boards established by federal agencies, the Fernald Health Effects Subcommittee and the Fernald Citizens Advisory Board (formerly the Fernald Citizens Task Force). These boards were points of convergence for members of other social networks. Yet, through sustained periods of meetings and deliberations they emerged as new, formal social networks in their own right.

The DOE established the FCAB to obtain advice about clean-up and environmental restoration activities. The DOE Environmental Management Program points to the Fernald SSAB as one of its key successes in its set of site-specific advisory boards. Community members have praised the contractor's efforts to be more open and inclusive in its planning. The Fernald Citizens Advisory Board has played a key role in defining the strategies for disposing of radiological and mixed wastes. One key recommendation made in 1994 concerned the long-term disposal of certain wastes on-site rather than requiring the removal of all contamination off-site and disposal in other locations. More recently the board has taken a lead role in obtaining input from the community and developing recommendations about the future use of the site with the understanding that some contaminated materials will remain on-site in disposal cells.

The Centers for Disease Control and Prevention (CDC), National Institute for Occupational Safety and health (NIOSH), and Agency for Toxic Substances and Disease

Registry (ATSDR) have also played important roles in risk communication activities in the Fernald community. They established a Fernald Health Effects Subcommittee to obtain advice about health studies and risk communication. Several studies were subsequently completed that have characterized public health risks from off-site contamination. The results of a dose reconstruction study and two risk assessments were used to evaluate the feasibility of conducting an analytic epidemiological study in the community. Because it was unlikely that outcomes could be detected with epidemiological methods, the FHES and the CDC decided not to conduct such a study.

The remainder of this report provides a description of our methodology and conceptual framework for understanding the roles of social networks in the formation of risk perceptions and the flows of risk communication messages. Section 3 provides an overview of the site, including its history and the risk controversies associated with historical off-site releases of contamination and construction of the onsite waste disposal cells and decision-making about the future use of the site. The characteristics of the community and important groups are also described. Section 4 provides a detailed discussion of findings about flows of risk related information and the ways that meanings are attributed to different events. Specifically, we delve into the ways that the four social networks facilitated the generation of risk information, mediated the flow of risk information, and facilitated learning of risk information among its members. Section 5 is a brief summary discussion and Section 6 includes suggestions for future research.

2. Methodology

The intention of this research was to develop a better understanding of how social interactions influenced people's perceptions about low dose radiation risks. The study focused on individuals who were highly engaged in deliberations about risks in the Fernald community. Specifically, we sought to understand how individuals' social settings — and the ways that meanings were attributed to events and risk estimates within those settings — played a role in the way they developed their personal perceptions of low dose radiation risks.

2.1 Rationale for Selection of Case

Fernald was chosen as a case study based on several criteria. Each of them helps to make this case both interesting for the exploration of how social networks affect the formation of risk perceptions and the flows of risk information and accessible for qualitative social science research.

First, the community and a variety of risks have been studied. There is a very good historical record of risks, how they were assessed, and risk management implementation. These are accessible through Fernald staff and the DOE public information center. Interactions between key players (e.g., DOE, CDC, Fernald contractors, community members, local officials) are well documented.

Second, there have been extensive and multiple efforts of risk communication and public participation on radiation related risks from Fernald. The processes have evolved, and there are diverse opinions about their quality. In addition, risk messages have been multiple, spanning a range of years, and at times inconsistent. For example, health studies have reached inconsistent findings, and the community has received information about the inconsistencies and controversies. These efforts have occurred within the recent past making access to individuals who were involved more readily accessible. The fact that copious quantities of documents, risk communication handouts, meeting agendas, and other written materials exist in their original form allowed us direct access to the types of communications that ensued. There are also extensive audio and videotape collections that capture some of the risk communication efforts.

Third, there are a variety of players around Fernald. They range from strongly engaged (members of the advisory committees, FRESH, federal and state agencies) to less engaged and more peripheral. Those that are engaged from the community have dealt with complicated, and uncertain, risk-related decision making. For example, they have debated and reached consensus on whether to conduct an epidemiology study for lung cancer and what levels to set soil contamination clean-up standards. They engaged in extensive deliberations about the advantages and disadvantages of disposing of wastes on-site versus shipping them all to a disposal facility off-site (in Nevada).

Table 1. Site Visits to Fernald^a

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1. December 11 - 12, 2001: Seth Tuler and Jennifer Wilhoit
 2. March 12-14, 2002: Jennifer Wilhoit
 3. April, 2002: Jennifer Wilhoit
 4. June 20-23, 2002: Seth Tuler and Jasmine Tanguay
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^aJasmine Tanguay and Jennifer Wilhoit were graduate student research assistants who assisted with some parts of the field work.

2.2 Data Collection

We collected data for this study include through on-site visits, formal and informal interviews, document retrieval, and other published sources of information including websites. The on-site visits were useful for collecting written materials from Fernald as well as becoming familiar with the surrounding environs. We took a tour of the site. In addition, we familiarized ourselves with the neighboring community. A logbook of notes was kept from each visit. An important secondary source of data was transcripts from interviews conducted by the *Fernald Living History Project*.

Specifically, our information for the case study came from:

- informal interviews for background information;
- formal interviews with key informants;
- review of interviews conducted as part of the “Living History Project” at Fernald; and
- review of technical reports, meeting minutes, newsletters, video tapes, and audio tapes from Fernald, federal agencies (e.g., DOE, CDC, ATSDR), and advisory boards (Fernald Task Force/Citizens Advisory Board, Fernald Health Effects Subcommittee, and Fernald Community Reuse Organization).

Several site visits were made for data collection; they are shown in Table 1.

We sought to interview people who participated in important ways in the deliberations about low dose radiation risks at Fernald. Our goal was to interview a diverse mix of people from the contractor, DOE, regulators, citizen groups, local officials, and research scientists.

Table 2. Interview Subjects, Listed by Primary Affiliation

FRESH members

1. Marvin Clawson, member of FCAB, former member of FRESH
2. Lisa Crawford, core member of FRESH President, member of FCAB
3. Vicki Dashlung, core member of FRESH, Vice President
4. Pam Dunn, FRESH member, core member of FCAB, CRO member^a
5. Edwa Yocum, core member of FRESH and FHES

Local officials

6. Karl Dilhoff, Morgan Township Trustee
7. Jane Harper, Crosby Township Trustee, FCAB member
8. Daryl Huff, former Ross Township Trustee, prior member of the FCAB, CRO member (see ^a)
9. Gary Storer, former Crosby Township Trustee, member of CRO (see ^a) and FHES
10. Warren Strunk, Jr., Crosby Township Trustee
11. Don Theim, former Ross Township trustee, CRO member (see ^a)
12. Tom Willsey, Ross Township Trustee
13. David Young, Ross Township Trustee

Federal agency staff and advisory board staff

14. Owen Devine, Radiation Studies Branch, NCEH, CDC
15. Ken Morgan, DOE Ohio Field Office (formerly Public Affairs Office, FEMP)
16. Judy Qualters, Radiation Studies Branch, NCEH, CDC
17. Doug Sarno, Facilitator and Technical Advisor, FCAB

State regulatory staff

18. Tom Ontko, Ohio EPA

Site management/employees

19. Gary Stegner, Public Affairs Office, FEMP
20. Robert Tabor Sr., FEMP union representative and worker, member of FCAB, CRO (see ^a), and FRESH.

Others

21. Nancy Abbott, local resident
22. Jim Bierer, member of FCAB, Chair, Ross High School and Middle School teacher
23. Dr. Stephen Depoe, Professor of Communications, UC, member of FCAB, FRESH member, Director of Living History Project
24. Greg Young, Principal of Ross High School
25. Dr. Chandra Gravely, member of FHES, and resident in nearby community
26. Anita Holmes, resident of Ross, lives nearby FEMP site
27. Dr. Susan Pinney, Department of Epidemiology, University of Cincinnati, part of the Fernald Medical Monitoring Program, member of FHES
28. Susan Verkamp, member of FHES, 2nd chair, local resident
29. Randy Welker, Chair of Community Reuse Organization, Greater Cincinnati Chamber of Commerce

Note. Individuals can be associated with more than one of the groups in Table 2. Secondary affiliations are listed. Membership in the FCAB and FHES are also identified.

^aThe *Fernald Community Reuse Organization (CRO)* was another board created by the Department of Energy under the Office of Worker and Community Transition in 1996. The CRO's purpose was to develop recommendations for offsetting economic and social consequences from the downsizing and closure of the Fernald site.

A pre-defined interview guide was created to structure the interview conversations around the social aspects of risk communication (Appendix A). An interview guide is intended to provide general sets of queries that are asked with approximate wording. It is intended to facilitate a conversation, rather than dictate the precise wording of the questions. There were ten sets of nested questions that were asked in a semi-structured order. Interviews lasted from one hour to two hours in duration. Almost all of the interviews were conducted with one respondent at a time and with only one researcher present.

Informal interviews were not taped but extensive handwritten notes were made. We conducted approximately 10 informal interviews, sometimes with multiple conversations per person. The formal interviews numbered about 25 and were all tape recorded, except for 4 that were conducted over the telephone. Some of those informally interviewed were later formally interviewed. The list of people we interviewed is shown in Table 2. Any phone conversations or email exchanges with potential or actual respondents were also mined for relevant data. Data also were derived from informal conversation that occurred prior to and following the formal interviews.

Interviewees were asked to sign a consent form, which explained the project, guaranteed that their input would be anonymous, and explained their rights as human subjects involved in a research project. In this report, all references to statements made by participating individuals during the interviews to the researchers are considered confidential.²

2.3 Data Analysis

The author of this report was responsible for all the analysis of this case study. He reviewed all of the field notes, transcripts (and some tapes) of interviews, and the gathered archival literature. The first goal was to reconstruct the history and dynamics of the Fernald public health studies and clean-up activities. The next task was to identify the networks in the community and to identify interviewees. Interviews were then conducted

² Some quotations are taken from interviews conducted as part of the Fernald Living History Project. Citations for these quotations are given in the text, as they are part of public documents.

to characterize their views about the low dose radiation risks and how they formed their beliefs.

Following the data collection tasks, the author mined all of the gathered data. He focused on the salient themes of this study: risk perceptions, how information flowed and was generated, importance of stigma, importance and dynamics of trust, life histories of nodal networks. These subjects were examined one at a time, for each network. The interactions among networks were also examined. The report represents a depiction of the case as understood through the eyes of the interviewees we met with as well as through news clippings, meeting minutes, technical reports, workshop summaries, and Living History Project interviews.

2.4 Conceptual Framework

There are many groups that have played important roles in risk controversies and risk communication about the public health risk legacy and the clean-up and longterm stewardship of the site. These groups form a network within the socio-political system at local, regional, and national levels. We call these groups nodal networks to distinguish them from the larger web of interacting stakeholder groups and organizations. Nodal networks are not defined, necessarily, by ideologies, membership or employment, or even shared risk perceptions. Rather, we define such networks according to flows of information. Thus, nodal networks are groups of individuals connected by channels of information flow about a central identifying theme or purpose that is shared. The links between members can arise from direct personal interactions, sharing of written materials, and other forms of communication. Of course, each of these groups is by itself a network of individuals. In our study, the data do not allow us to evaluate the formation of risk perceptions and the flows of information at such small sociological scales. Finally, we recognize that individuals can be part of more than one network.

Our approach to deciphering the complexity of the social environment, the sharing of information, and the attribution of meanings to information was to identify the primary active nodal networks within the defined socio-political system network of the community that experienced a controversy about a low dose radiation risk. In this case study that is the community around the FEMP site. Each network had the opportunity to

influence the risk perceptions of their members and of people outside of the network, through their interpretation and reinterpretation of information, as well as their “gatekeeper” roles in the flow of information. Specifically, each network had the potential to be:

- A generator of risk information. Social networks can analyze existing data in a new way or conduct their own research to gather new data. In either case, the network provides new information to people that can inform risk perceptions. Usually the information is generated and shared in a social context.
- A mediator in the transfer of existing risk information. Social networks can act as channels for conveying existing information from one group to another. Information can be transferred among members within a network and from one network to another. The transfer of risk information does not imply that no reinterpretation or reframing occurs. Rather, it is to be expected that meanings are *not* preserved completely as information is provided to others.
- A facilitator of learning of risk information. Social networks can support the learning of risk related information by its members and by people outside of the network. Learning often occurs within a social setting, and can have a major influence on the ways that risks are perceived.

Each of these functions will be discussed in more detail in Section 4. Next, however, we turn to an overview of the history of the site and characterization of the community.

Table 3. Dose Reconstruction Estimates of Uranium and Radon Releases from FEMP, 1951-1988

Source term	Median	5 th percentile	95 th percentile
Uranium to atmosphere	310,000 kg	270,000 kg	360,000 kg
Uranium to surface water	99,000 kg	85,000 kg	120,000 kg
Radon to atmosphere	17,000 Ci	110,000 Ci	230,000 Ci
Radon-222 daughters	130,000 Ci	87,000 Ci	190,000 Ci

From Till, J. 1996, The Fernald Dosimetry Reconstruction Project: Overview and update. Radiological Assessment Corporation. Presented to the Fernald Health Effects Subcommittee June 12, 1996

3. Context and History

3.1 Overview of the Site and Contaminants

The Fernald facility, formerly known as the Feed Materials Production Center (FMPC), is located on 1050 acres northwest of Cincinnati, Ohio (Figure 1). During operations the site received shipments of uranium ore or recycled materials to process into highly refined uranium metal products for the US nuclear weapons program. Some thorium metal products were also produced. These metals were extracted through a series of chemical processes. Waste materials were stored on-site, including some wastes from the Manhattan Project era that were shipped from elsewhere. During its peak production years over 3000 employees worked at the facility; by the 1970's the number of employees was less than 1000 (OHEPA 2000).

Operations at the Fernald facility resulted in on-site and off-site contamination. An independent dose reconstruction study estimated uranium and radon released during production at the FEMP, as shown in Table 3 (RAC 1998). Uncertainties in estimates of releases occur because accurate logs and measurements were not kept. Waste materials that were stored on-site have been an important source for the releases. For example, four concrete silos were constructed to store radioactive materials in 1952. Two of them, referred to as the K-65 silos, contain high radium-bearing residues. The dose reconstruction study estimated that 170,000 curies of radon were released from the K-65 silos (RAC 1998).³ In addition, waste pits were used during past operations. They contain approximately 475,000 tons of waste, including uranium, thorium and other radioactive and chemical contaminants.

In addition, the waste pits are contributing to contamination of ground water. The Fernald site is located over the Great Miami Aquifer, which is designated a sole source aquifer and considered a valued natural resource. The Southwest Ohio Water Company operates a production wellfield approximately one mile east of the FEMP former

³ To reinforce the K-65 silos, a soil berm was added in the 1960s and enlarged in the early 1980s. In 1991, bentonite clay was injected into the tops of the two K-65 silos to cap the high radium residues and reduce radon and radon progeny emissions from the silos. A third silo contains lower-level dried uranium residues. The fourth silo has never been used.

production area. Ground water is contaminated with above background concentrations of uranium approximately one mile south of the site in the “south plume.” DOE provided bottled water for residents in the south plume area until 1996 when a public drinking water system became operational. Private wells had maximum readings of 170, 410, and 578 ppb of uranium in the 1980s (ATSDR 2000). DOE contributed approximately \$5.4 million toward this project. Residents living within a certain area were eligible to have the initial installation of the water service paid by DOE.

To address on-going environmental health risks from these and other contaminants, remediation work has been conducted and planned. They include the Waste Pits Remedial Action Project, capping and placing berms around the silos to reduce radon releases, and facility closure and building demolition. High level wastes are being shipped off-site. On-site engineered disposal cells are being filled with wastes that meet specific acceptance criteria. Mainly, they will contain contaminated soil and debris. No off-site waste will be allowed in the disposal cells.

3.2 The Community Context

The Fernald site is located in three Townships: Ross, Crosby, and Morgan. Local government in Ohio is rooted in the Townships; the governing bodies are the Ross Township Trustees, Crosby Township Trustees, and Morgan Township Trustees. These Townships are located in Hamilton and Butler Counties. Within the Townships are local towns or villages. The primary towns around FMPC are Harrison and Ross. Some, but not all, workers live in these communities. While they have a history of stability, they are becoming more like bedroom communities for Cincinnati. Longterm residents often express that their motives for moving to the area were connected to the quiet, rural character of the community.

The properties abutting the Fernald site are mainly farmlands. People residing on these farms, as well as many in Ross and Harrison, have long roots in the community, with the most disruption arising when the federal government took lands under eminent domain for the site itself. Many of the farms have been in the same families for generations. The 1990 census reported that 922 people in 333 housing units resided within 1 mile of the site boundary (ATSDR 2000).

The controversies that have grown out of the FMPC — whether releases actually occurred, whether the releases posed risks to offsite communities, whether production operations should cease and the site closed, and how it should be managed into the future — have torn at the social fabric of the nearby community. From a community standpoint, relationships have been strained or ruined.

For example, in 1980's, when Fernald was still in production, there was lots of anger toward those who were opposing the site and worried about health risks. Members of the local watchdog group, Fernald Residents for Environment, Safety, and Health (FRESH), were seen by many as agitators and activists, not as “community members,” even though virtually all of the core members lived very close to the site. Others have talked about how family disagreements arose because of Fernald.

There are many groups that have played important roles in risk controversies about the public health risk legacy, risk communication, and the clean-up and longterm stewardship of the site. These groups are themselves networks of individuals and subgroups. We call these nodal networks, to distinguish them from the larger web of interacting stakeholder groups and organizations.

The most active nodal networks involved with risk-related communications about the FMPC can be divided into:

- FMPC contractors. There have been three site contractors: National Lead of Ohio (1951–1986), Westinghouse (1986–1992), and Flour Daniels (1992–present);
- Federal government agencies and regulators. They include the Department of Energy (DOE), Environmental Protection Agency (EPA), Centers for Disease Control and Prevention (CDC), and Agency for Toxic Substances and Disease Registry (ATSDR). The Fernald Citizens Advisory Board (FCAB; formerly known as the Fernald Citizens Task Force) was sponsored by the DOE. The Fernald Health Effects Subcommittee was set-up by the CDC⁴;

⁴ The *Fernald Community Reuse Organization (CRO)* was another board created by the Department of Energy under the Office of Worker and Community Transition in 1996. The CRO's purpose was to develop recommendations for offsetting economic and social consequences from the downsizing and closure of the Fernald site.

- State government agencies and regulators. The Ohio EPA works closely with U.S. EPA under judicial consent decrees and enforceable inter-agency agreements to oversee the cleanup effort at Fernald. A 1991 Consent Agreement was signed by DOE and U.S. EPA which sets schedules for CERCLA documentation and implementation, and clarifies methods for assessing risk. Using state and federal legislation along with negotiated agreements, both EPAs are to ensure an effective cleanup at Fernald. In 1994, Ohio EPA created the Office of Federal Facilities Oversight (OFFO) to coordinate and manage regulatory activities at several federal facilities. OFFO was created to provide a consistent and comprehensive approach to oversight activities. Ohio EPA's activities at Fernald are funded a DOE Cost Recovery Grant. The Ohio Department of Health has played a minor role in activities associated with public health risks;
- Local governments. Three Townships have played roles in Fernald-related risk communication: Ross Township, Crosby Township, and Morgan Township; and
- The citizen, watchdog group Fernald Residents for Environment, Safety, and Health (FRESH).

Two additional networks at this site are:

- The Fernald Living History Project is a collaborative effort between Fernald, volunteers from the local community, the University of Cincinnati's Center for Environmental Communication, and Miami University's Institute of Environmental Sciences. The project involves community members conducting video-taped interviews with members of the Fernald community about their experiences. Its goal is to preserve a record of the environmental and social impacts of nuclear weapons production and clean-up and remediation activities at the Fernald site and in the surrounding communities. The Project was begun by Fernald, but is now being conducted by the independent group of collaborators. Over 120 interviews have been video-taped. Those interviewed include local community residents, local government officials, DOE staff, and Fernald workers

and management. Transcripts of each interview are available. We have used some of these interviews in our analysis.

- The Fernald Medical Monitoring Program, medical surveillance program of the population residing or working within a 5 mile radius of FMPC. Participation is voluntary and eligibility was mandated by a lawsuit settlement. The program began in 1990 and is administered by the Fernald Settlement Trust Fund and implemented by the College of Medicine at the University of Cincinnati and Mercy Health Partners (Fairfield, OH). Participants receive regular physical exams. Data from the program are now being used for health studies of the population nearby Fernald. Information and researchers from the FMMP played key roles in discussions about health studies in the Fernald community.

3.3 The Risk Management and Risk Communication Context

The perceptions of government agencies and institutions within the Fernald context are complex, and characterized by evolving feelings of trust, betrayal, and distrust. Individuals' feelings about the trustworthiness, honesty, and accountability of the federal government, Department of Energy, and Fernald contractors have evolved over time. Feelings toward other regulators, such as the Ohio Environmental Protection Agency have also evolved.

Risk communication activities varied significantly during the history of the site, including post-production. Prior to the 1980s very little information was provided to the communities around the facility about what type of work was being done on-site and risks. Workers and the community were told that they were safe.

In addition, there was a high degree of secrecy. Workers at the facility were required to have relatively high security clearances (Q clearance). As part of their conditions of work, they were told they could not talk about what they did with family or friends. In fact, security went much further than these conditions, as people recount in Living History interviews that they were watched in bars to ensure that they did not reveal any classified information. As a result of this secrecy, some nearby residents claim to have

not known what was done on the site. As one resident stated in her Living History interview:

It was understood to be that they made paint. It was called National Lead of Ohio and I automatically was thinking lead paint. And someone had told me that it was paint. (Yocum, pg. 1)

This view was repeated by one of those we interviewed:

The water towers were red and white checkerboard, had a lot of cows out in the fields in the front. The name of the site was Feed Materials Production Center, which would have led you to believe that maybe it is Purina Dog Chow.

At the same time, many that we interviewed claimed they new it was the “atomic plant,” even if they were not quite sure what that meant:

You really didn’t know much about this place. All you knew is somebody worked at the atomic plant.

We always called it the bomb factory as kids. We knew from the beginning that it wasn’t a feed plant. When people said a feed plant we knew that it meant it was a processing plant...we always referred to it as the bomb plant. (Harper, pg. 3)

During much of this time, Fernald was generally felt to be a good neighbor (aside from the lingering feelings among some residents about the federal government’s taking of land via eminent domain). It was a good employer of people from the community. The site supported and coordinated with local emergency response services. The federal government was viewed as caring about the welfare of the nearby community, the health of its neighbors and workers, and the local environment. It appears that many of these feelings were based on *not* knowing what was really happening at the site or about the potential risks of site activities and releases. As one local resident stated in an interview:

Nobody really had any sense there was any danger other than the danger in the manufacturing process itself. There wasn’t any sense that the community would be at risk...like radiation.

In the mid-1980s more information began to filter out. The first key risk communication event occurred in 1984 about air emissions of uranium from an accident involving a dust collector. A second major event occurred with the release of information about water contamination of abutters' wells. During this period risk communication was provided mainly through public meetings with regulators and the contractor (National Lead of Ohio). Many of the initial public meetings were very hostile. At times, people felt that they were not being told the full truth and that the site contractors and DOE were trying to hide.

In part, the hostility can be attributed to feelings within the community that the site contractors and DOE lied to the community. During the early years of information about the extent of contamination, many people felt a strong sense of betrayal. They were patriots, they were supporting the protection of the US against the Soviet Union, and they trusted the government. Later, they felt as if they were unwilling guinea pigs. Such feelings were expressed by many during our interviews. For example, one person said that"

[National Lead of Ohio] would tell us half truths and lies and if we didn't ask the right question they wouldn't give us the right answer. They wouldn't give you any information. So all that made me furious when I would go to those meetings and I would ask questions, and you would just look at them and say Bloodsuckers! Liars! And then you would find out later you were right! And you would find out the real information.

Such feelings were also expressed in Living History interviews:

I guess you don't think your government's going to work against you. It is just something you feel, like, well that's our government, they're our leaders, they'll do everything to protect us. And it was really a sense of, as I said before, betrayal. That the company, the people you place the most trust in were undermining the health of the area. (Harper, pg. 17)

By the early 1990's the contractor, Ohio EPA, and federal agencies began to establish more open, interactive ways of communicating with the public about risks. They sought

to reduce the anger and sense of betrayal. Flour Daniels became the contractor in 1992 and made a strong effort to learn from prior mistakes of National Lead of Ohio and Westinghouse. For example, the *Fernald Envoy Program* was established in 1994 by Flour-Daniel. Its purpose is to promote “one-on-one communication between team members and representatives of the local community” and facilitate two-way communication. In addition, Flour-Daniel has a very active Public Relations Office.

It is in the context of such risk communication activities that we discuss how social interaction helped to shape people’s beliefs about the low dose radiation risks from FEMP. A history that created feelings of betrayal followed by more meaningful efforts to provide information within a small, rural community contribute in critical ways to the processing of risk information within social networks.

4. Findings: Perceptions and Beliefs in the Community

In this section, we will present findings about perceptions of members of nodal networks in the Fernald community and the ways that judgments about risks were formed. We focus on two risk issues involving low level radiation exposures:

1. public health risks from historical releases during site operation and
2. residual contamination from on-site disposal of wastes and the future use of the site.

Four nodal networks, and their interactions, are discussed:

1. Township Trustees in Ross, Crosby, and Morgan;
2. core and peripheral members of Fernald Residents for Environment, Safety, and Health (FRESH),
3. Fernald Health Effects Subcommittee (FHES), and
4. Fernald Citizens Advisory Board (FCAB).

As part of our discussion of each of these networks we focus on the ways that they played a role in the formation of people’s risk perceptions. Each network, as discussed above (Section 2), had the potential to be a generator of risk information, a mediator in the transfer of risk information, and a facilitator of learning of risk information. Within each nodal network we focused on the following:

- the way that information flowed inside the nodal network and between networks,

- the kind of interactions that happened among individuals within the nodal networks that helped people shape their risk perceptions,
- the ways that nodal networks generated their own information and then shared it with others,
- the ways that networks were formed and emerged, and
- socio-psychological dimensions of risk that were important to the formation of beliefs about the risk, such as trust and stigma.

In the following sections, each of the four networks is discussed. Findings from interviews (and other data as described in Section 2) are used to illustrate the risk perceptions held by members of the network. The key factors influencing members' risk perceptions are discussed in relation to the roles played by the network in the flow and interpretation of risk communications. Finally, at the end of each section, the way each network interacted with the others is described.

4.1 Township Trustees

Local government in Ohio is centered in the Township. Elected officials are Trustees, and they have responsibilities for myriad issues and functions, including emergency response and zoning. Three townships played prominent roles in the risk communication activities related to the public health risks of radiological releases from FEMP and risks from residual contamination resulting from the onsite disposal facility and future use of the site. The three townships that played a part were: Ross Township, Crosby Township, and Morgan Township.

While there might not be complete agreement on issues and priorities among Trustees within a township or among those from different townships, the Trustees form a nodal network because of their common concerns about the areas and people they represent. These concerns are illustrated by the following two quotations:

My involvement of course concerned the residents of my community and I wanted to make sure this was cleaned up in a timely manner.

I think my main responsibilities are to the citizens to make sure that the cleanup continues and that the government is responsible for continued perpetual care of the site. I think we have to kind of serve as a watchdog to see that its never allowed to go into an abandoned condition. We need to be alert and keep in communication with them because we certainly don't want them to abandon the site completely. We want them to accept responsibility for it forever. (Harper, pg. 19).

4.1.1 Risk Perceptions

A variety of factors helped to shape the risk perceptions of the Trustees that we interviewed for this project. They included the level of technical understandings of radiation (or the lack thereof), familiarity with radiation, evaluations of the scientific understanding of risks, the availability and use of technical reports and presentations, quality of experiences with FEMP and DOE management, concerns about stigma (e.g., economic impacts), and personal experiences and observations.

The following quotes illustrate how Trustees expressed their views about the risks.

Some made comparisons to other risks, such as the “background” rates in Ohio:

There's never really been any determination exactly what the health risks are. I think there is a lot of speculation about that . . . Although there are health problems in the community, I am not sure they are from Fernald . . . This part of Ohio already has a high incidence of cancer and a lot of it is just living in this industrial valley.

Others on the basis of their limited knowledge about radiation:

It would appear to me that if you are around radiation, and radiation is not good for the human body, that yeah, the health risks in this area would be greater than they would be in Maine, or wherever. You know, it's like, my chances of getting shark-bit are much greater if I'm in the ocean than if I'm sitting here talking to you... We're living next to this thing, we don't understand it, we're not sure it is killing us, but we know it's not good for us.

In addition, perceptions grew out of factors that were not associated with the potential health effects from radiological contamination, such as stigma associated with the site:

I quite frankly don't have a problem with the low-level radiation. I have a problem with the 90 acre cell that we are going to have to look at for the rest of our lives.

The risk perceptions of the Trustees evolved over time — they were not static. New information and a renewed faith and trust in FEMP management and regulators played roles in the evolution of risk perceptions. For example, this quote illustrates evidence for learning by trustees:

Trustee: I don't feel that the contamination threat to the community was as bad as at one time I felt it was.

Interviewer: What changed your opinion?

Trustee: A lot of the studies they did, a lot of the information they've given us. They had their [water] monitoring devices all over the community. . .and I tend to believe that it's not as bad as I thought it possibly could have been...I thought that there was a possibility that it could [have been] a lot worse.

You can really see the progress. Form the first tour we took...I was kind of horrified at all the things sitting around. [Now] you can really see cleanup being done....Everything is much, much cleaner. Looking good, I'm impressed. (Harper, pg. 18)

4.1.2 Risk Communication

In the context risk of communication about our two issues of concern, the network of local government officials played two roles. It

1. facilitated learning of risk-related information among LGOs that played a role in formation of their risk perception and
2. mediated the transfer of risk-related information between others groups and LGOs, that helped in the formation of perceptions of trustees and others.

The network of Township Trustees did not play a role in generating new risk-related information.

4.1.3 Trustees as Learners of Risk Information

Trustees received risk-related information from a variety of sources. They actively sought out information. The information they sought consisted of more than just factual information about risk magnitude; they were also interested in the quality of risk management, economic impacts, trust in the DOE, and other qualitative factors that have been found to be important in risk perceptions.

In the 1980's Trustees knew very little about the site. They were often — especially at the beginning — in the same situation as the general community. They did not know what was being done at the site, they did not know what was being released at the site, and they did not know what the risks were from the site. In the course of our interviews, local Trustees recounted for us how little they knew about the site:

Well, unfortunately the Trustees did not know a whole lot about what was going on. A lot in the community thought we did, but I mean, we were in the dark just like they were.

I mean people didn't know and they weren't willing to tell us what was going on out there, at first. It took a long time before we actually started getting the facts. We got a lot of suppositions, no facts.

In December of the year of the dust collector leak I was interviewed, a television crew came out here and I've only been in office maybe eleven months and of course never been interviewed or had a TV camera or anything like that stacked on my face, and all that occurred in December of that first year I was in office . . . [They asked] how I felt about the situation and at the time the operators of the plant, I felt strongly that they were truthful and telling the community the truth . . . I made a commitment on the air that I was with [National Lead of Ohio] and that I believed what they were telling us and so forth, and I am sure the situation isn't bad, and kind of stuck up for them . . . I was being interviewed as a trustee so I stood behind the company and of course that was aired all over and I always felt embarrassed about that because it was found out that they were lying, it was found out that there was contamination beyond the fence.

Much of their information came from the FEMP contractors and the DOE. Trustees attended meetings with DOE officials, Ohio EPA officials, and FEMP management at public meetings.

Yeah, I went to them all (DOE meetings). I was one of the few Trustees that did. A lot of the Trustees at the time just called the place a bomb plant and hated the plant and never attended anything like that, but I was attending them all . . .

Trustees did not always feel that public meetings were informative. For example, the formal presentations by regulators and the contractors were described in this way by a Trustee:

I tend to call it the dog and pony show, they would put on their dog and pony show for us, and they would, when they can't blind you with brilliance, they baffle you with bull. So they would go for the dog and pony show, and of course, the majority of the people didn't have a clue what they were talking about, including me. Well they would talk about they monitored this thing, they monitored that there's so many rems and so many whatever, all these measures, so that nobody understands except people that deal with it.

In more recent years, the Trustees relied heavily on Flour-Daniel' *Fernald Envoy Program*, established in 1994. Its purpose is to promote "one-on-one communication between team members and representatives of the local community" and facilitate two-way communication. In the Envoy Program, Fernald employees act as formal, designated liaisons with stakeholder groups, including Township Trustees. Trustees received information from the liaison and they were able to share opinions and information with the liaison to take back to the site contractor. A Trustee stated:

We have an envoy that comes from [FEMP]. We meet twice a month. And I know he comes once a month, and he's also on the school board, so it's difficult for him to come twice a month, so he's done a real good job supplying information. And ever since they started that program, I think we've gotten a lot more information, and I think he's taken a lot of our concerns back that weren't getting back to them before, so it's worked well, a lot better.

The Envoy Program was successful in part because it relied on trusted members of the community to act as sources of information about the site. Trust between the Envoy Program liaison and the Township Trustees played a key role in how risk information was understood — how well learning took place. For example, without trust, the Trustees were unwilling to believe what the site was saying about risks. By using a trusted person as a liaison, the site was able to break through the resistance to listening:

Trustee: Now, in the beginning it was a person from the plant, we could contact somebody from the plant, and then that person would ... come to the meeting and then tell the answer. But the trust level was so low that the community people out here didn't want to hear from anybody from the plant. So then we got a liaison, a community member, and that person would then contact the plant and the plant would give them the answer and the community person would come back and give the answer [to us].

Interviewer: The information was coming from the same place: Fernald, right? But they would trust it if it came from a community member?

Trustee: Yeah.

Distrust with the site contractor and with DOE created a barrier to learning among the Trustees. For example, some Trustees expressed the conditional nature of how they understand the risks and the quality of the site's risk management:

Hopefully they're being a lot more honest with us. Communication is much better. When there are problems they do call the Trustees...I think there's a lot more open communication that there was in '84. We *hope* its honest and above board. We *hope* nothings being concealed. They *seem* like they really are trying to work with us and avoid any more scandal and any more scenes with newspapers and reporters gathering around. It *seems* like they're much more cooperative. *Hopefully*, that's what's going on. (Harper, pg. 21; emphasis added).

I'll never be convinced, ever in my life, that the DOE is cleaning this up for my people. I think they're cleaning it up to take the heat off the DOE. It's got nothing to

do with whether they give a damn about anybody down here, because, in my opinion they don't.

Many Trustees learned that they could not all be fully engaged in Fernald-related issues. There were many other concerns that they had to address. Thus, in at least one Township the Trustees divided responsibilities. Only one Trustee attended FCAB meetings. Some Trustees described for us how they felt overwhelmed by the amount of information they were provided and needed to learn to be effective participants. Too much information was a barrier to learning within this network.

One Trustee claimed that the DOE intentionally created a situation where people felt overwhelmed by the amount they needed to learn:

You know, they have overwhelmed me with information, and I mean that in a snide way. They've given me more information than I could possibly ever consume. I have an office at home, and I have a file about that size, oh that's not counting the things I've thrown away. I just have so much information that I don't understand. I'm sure a lot of people feel that way, and I think that was by design too.

4.1.4 Trustees as Mediators of Risk Information

Trustees played important roles as sources of information to others in the community about Fernald related risks. They helped to form the risk judgments of others. Trustees devoted time to discussions about Fernald at Township meetings. They were approached on occasion by members of the community outside of official activities (e.g., in neighborhood stores). Most importantly, Trustees created the opportunities for FEMP staff and others to provide information about Fernald at Trustee meetings. They did this for two reasons.

First, they found, as discussed above, that they could not attend all the meetings and digest all the information they were provided in reports, etc. Consequently, in at least one Township they began to rely more heavily on other groups to be sources of information about Fernald at Township meetings. The Trustees, then, acted in a way to convey information from one group to another.

Fernald is not the big issue for the Trustees of towns anymore, people go to FRESH meeting for information. Right now the trustees are focused on keeping this highway out of the township, I mean, the focus of the trustees is constantly changing. Sure, during those hot years so to speak, I mean, that was our main focus but even at that time we had problems, emergency service problems. So we couldn't sit there all night and just talk about Fernald cleanup. It was a segment of our meeting and then we'd moved on. Now FRESH has a segment in our meeting. They have a representative there, and they'll tell when the FRESH meetings are, where the meeting is going to be, and if there is going to be a speaker and that type of thing . . . Or even a question that could be funneled to them too, like the . . . you know, one of the K65 silos is going to be emptied of the radon gas. Well, if that question came up in the Township meeting, we may address that to FRESH, and FRESH would say 'we'll get an answer for you on that' or we can contact [Envoy Program liaison] if we wanted to, he could come back and give us an answer or FRESH would come back and give us answer.

Secondly, the Trustees took their responsibility as elected officials and leaders in the community seriously. It was important for them to create opportunities for informing residents in the community about important issues.

we always tried to disseminate information at our Trustees meetings, to the audience of people in attendance. Rather than talk in general terms, if we would have a discussion on it, we would try to tell the people in the audience where we got our information, and why were talking, and what was going on.

Interestingly, we found that Trustees did not only rely on formal channels of communication as recipients of risk-related information. They also relied on informal relationships. For example, a Trustee felt he received more information from informal interactions in this small rural community than from other "official" sources like DOE or the site contractors:

I know that at one time there was a guy, I won't mention his name, he would call me at home, and tell me things that were going on, that weren't actually for public knowledge. And he was in a position that he would always call and he would always

say, that this is an anonymous phone call. And he knew that I knew who it was. He was a site guy, and he said now this anonymous phone caller wants you to know that this is happening, and you need to ask this question, and you need to find out about this.

I know a lot of people that work there now and worked there through the clean up process and I talked to them first hand so I had first hand conversations with people that work there currently so that has provided another source of information as well.

The information they learn from these informal contacts was part of the information the Trustees then shared with others both inside and outside of their nodal network.

4.1.5 Interactions with Other Nodal Networks

Trustees were mediators of risk information because they were members of multiple networks. They were also members of, for example, FRESH (although, not core members), the Fernald Citizens Advisory Board, and the Fernald Health Effects Subcommittee. These are discussed below in sections on the other nodal networks.

4.2 Fernald Residents for Environment, Safety, and Health (FRESH)

FRESH is a key community group stakeholder, described as “watchdogs” of FEMP. Established in the mid-1980s, FRESH has emerged as a powerful voice in all issues related to Fernald risks and environmental management, including public health risks from historical exposures from FMPC.

For the purposes of this study we distinguish between two types of members in the FRESH network. First, there is a small group of “core members.” The core members consist of longtime members who are highly engaged in public processes related to Fernald public health and clean-up issues. They are the core organizers, setting the agenda of FRESH meetings and the agenda of the group. Many of the core members trace their initial involvement to the dust collector uranium release and to the news that residents’ wells were contaminated. They attend public meetings regularly, and have been members of the advisory boards. Second, a large group of FRESH members we call “peripheral members.” Over a 100 individuals pay dues and receive the newsletter. They

may write letters and attend public meetings sponsored by the agencies or DOE. They attend FRESH meetings, regularly or intermittently. Peripheral FRESH members include residents of the nearby communities, university researchers, workers, and others.

The early history of FRESH is one of finding voice and learning about the issues facing the community. FRESH members we interviewed recalled the feeling of being shut-out as a group by DOE and Fernald management during the 1980s and early 90s. But they were persistent in seeking information and having a voice:

There was a point where FRESH was sitting in the front row, and we just could not take it any more, you could just see the lies coming out. And that's when FRESH actually did some demonstrating. We got up and we wouldn't sit down. Because they just kept ignoring our questions, we would raise our hand and ask questions, and they would go to the other community people, and so finally we just got upset that we just stood up, and started asking these questions, and they finally started answering.

In this context, people became very angry — and they began to organize:

[What I first heard was] that there had been a release at the Fernald plant. When they said that there was this release, that there was no real problem, I didn't believe it. So, I had heard that they were going to have this public meeting at Crosby Elementary. I went to that meeting to get some more information, and I wasn't real happy with what I heard because I went and specifically asked one of the scientists that were there . . . 'I grow a garden and I feed this produce to my children, can you tell me with certainty that there is no risk to my kids?' . . . and he kind of hemmed and hawed and he couldn't say if there was a hundred percent no risk. So that propelled me into getting more involved in finding out more about what they did at the site . . . If the scientists couldn't give me the hundred percent assurance then I knew I had to look into it to see what the risks were for my own family.

Initially, FRESH was seen by many within the DOE, Fernald management, and the community as a group of agitators or activists:

In the beginning we were ostracized in the community as radical nuts that were stirring up a pot of brew that should just be left lay. We had many people come up to

us and say, ‘why don’t you keep your mouth shut, you are destroying our property values.’ They didn’t say it in those exact words but you got the inclination and that is what they meant. So everywhere we went, we weren’t very popular. We were really on the bottom of the list. We lost some friends, actually the community at that time would rather just throw a blanket over it, put a fence around it, put a padlock on the gate and just let it lay. That is what they wanted. They didn’t want it brought up.

Much of the anger towards them came from workers who were afraid of losing their jobs and those who thought that the risks were being overblown and creating a stigma in the community. Two FRESH members described encounters in their Living History interviews. They were told:

Go home and put apron back on (Yocum, pg. 2)

You need to go home and be pregnant and barefoot and you need to keep your mouth shut (Crawford, pg. 7)

FRESH understood that their credibility within the community was part of a struggle over how they and the issues would be framed. Thus, they worked hard to frame the issue as one of community health, rather than opposition to nuclear weapons, the mission of Fernald within the nuclear weapons production system, or the workers. They made a clear choice to not be “anti-nuclear” but rather to focus on health of the community. This effort was described in Living History interviews of core FRESH members:

If I went in the door screaming and ranting and raving, ban the bomb, no more nukes, you know, that I wasn’t gonna get anywhere [with important political figures]. That they were gonna just kind of disregard me and not listen to what I had to say. So, [FRESH] made a conscious decision when we began to talk to the, to the kind of the public arena here, that we are going in as concerned mothers, people caring — that cared about our environment and care about our community and cared about our issue” (Crawford, pg. 11)

[people in the community] still have the impression that we as the FRESH group are activists where the CAB and the CRO are more community oriented....I don’t like the word activist. I am just a concerned citizen. I am concerned about my family’s health

and safety. And I wanted their health and safety to be secure. And then too if my community's health and safety isn't well, my family's health isn't well. (Yocum, pg. 6)

According to a core FRESH member we interviewed, DOE attempted to paint a different picture of FRESH, and influence the community's attitudes toward the group. DOE tried to characterize FRESH members as "activists," a rhetorical move resisted by FRESH because of the way that term was reacted to by residents in this rural community:

DOE kept referring to us as activists, demonstrators. They were giving us a negative, coming across that we were negative, and so people would not relate with us, or become members with the grassroots groups, thinking that we were nothing but trouble-makers. That was at the time, where you would see demonstrators at the Fernald site, that had nothing to do with the community. A lot of people was upset, because their farm roads were crowded with these people, and they didn't want this out there in their community, and so when FRESH was formed [they thought] that we were basically the same type of people. And to this day, the DOE refer to us as activists. And we are not activists. We are concerned citizens about our community.

Ultimately, FRESH's approach — and their support of workers concerned about losing their jobs when the site switched from production to clean-up focus — helped to build a more positive relationship with workers and the unions.

It wasn't easy here sometimes saying, 'Hey, there's a problem,' because some of the workers thought 'you are going to shut this place down and nobody's going to have any jobs.' They weren't happy with community people who they thought didn't know anything getting involved with it-- especially a bunch of housewifey women! It didn't go over real good with some of them. But over the years employment has gone up, not down. I think a great many of the workers understand, and we've had such staying power for so long and have worked with trying to find solutions rather than just ranting and raving. And we haven't picketed or anything like that, that they have begun to realize that these people are sincere about this and so a lot of people have

come around to understanding why we have worked so hard. And we really do care about our kids and the community!

4.2.1 Risk Perceptions

A variety of factors influenced the formation of risk perceptions among the members of this network. They included perceived competence of management and regulators, access to information and independent technical experts, understandings of scientific information, familiarity with radiation, information gleaned from presentations and reports, perceived quality of the decision making processes, trust in the DOE and FEMP contractors, and personal experiences and observations.

In the beginning shared perceptions of the risks were based on fear and lack of knowledge. As the FRESH members became more active and educated about the site and its contamination, their perceptions emerged from a sophisticated understanding of technical issues, wariness of uncertainties and lack of scientific knowledge, and distrust of the responsible federal agencies.

The first experiences of FRESH members with the site as a source of risk came as a surprise and set the stage for their early risk perceptions. The core members were mainly people living near the facility who were unaware of risks from offsite contamination. They were not a coherent nodal network at this time, but their early, common experiences helped to shape the way that the network judged and responded to risk. One of the most dramatic illustrations comes from FRESH president Lisa Crawford. Her story is representative of the experiences of core FRESH members that played a key role in the character of this nodal network. In the 1980's she, her husband, and child rented a home abutting the site. In 1985 they discovered that the DOE had been testing their well for contaminants — without their knowledge — for several years. In her Living History interview she describes how she discovered, upon returning home from work, in 1985,

a man climbing out of our well. A man in a white . . . jump suit . . . he wouldn't talk to me. He would not answer my questions. He would not look at me. He had water samples in his hand and I dogged him all the way to his little white van that said 'U. S. Department of Energy' on the side of it. And he would not talk to me at all. And I think that played a part in making me more angry. You know, I am this ranting,

raving, angry housewife now, who is furious. That no one will talk to me. No one will answer my questions. (Crawford, pg. 5)

Not only was it hard to get information. Early risk communications were inconsistent. For example, the Ohio EPA and Ohio Dept. of Health gave conflicting assessments about the risks from wellwater contamination measurements of 190 picocuries/liter. The US EPA advised Lisa Crawford and her family to not drink water from their well and to find an alternative source. On the other hand, the Ohio Department of Health told them that 190 picocuries/liter was within DOE limits and that they could drink the water, not to worry.

One of the important, early formative events that influenced risk perceptions among FRESH members we interviewed was the residents' class action lawsuit against DOE; many FRESH members were part of the class action lawsuit. They learned of how workers were exposed to radiological and chemical contaminants, often without their knowledge or after being told there was no risk. A DOE memo stating that there are no safe levels of radiation exposure was particularly memorable to one of the FRESH members we interviewed.⁵

Actually your eyes got opened up during the trial. We were part of the trial, we were there every day for 8 days. Huge volumes of information. I took notes. I got a big notebook to write that all down, and I spent a lot of time writing. And I always like facts and figures, that is just a part of me, so I would write that all down and it was alarming, really. That is where the alarm come in for me.

The specific health-related concerns of core FRESH members are for cancer and non-cancer health effects from radiological and chemical contamination. They believe that there are health risks, but that they are not always measurable to a high degree of accuracy. They feel that the risk assessments done by the CDC, as well as more recent

⁵ In the Fernald lawsuit settlement, the DOE "Admit that, for purposes of radiation protection, it is assumed that any amount of unnecessary radiation exposure, however small, carries with it some increased risk of adverse health effect. Admit that, for purposes of estimating health effects of ionizing radiation, scientific groups, such as the BEIR committees of the National Academy of Sciences, assume that any exposure above zero increases the risk of adverse health effects..." (Fernald Litigation Master File Number C-1-85-0149, Admission #89)

studies by ATSDR and the Fernald Medical Monitoring Program, show that there are real risks from historical exposures (CDC 1998, 2000, ATSDR 2000). For example, a peripheral FRESH member stated that:

I think that the difficulty that we have with the workers, as well as the residents, is that a lot of the exposure happened in the 1950s and '60s. There are a lot of confounding factors, smoking and other health behavior issues that make it tough to pinpoint exactly X amount of cancer was caused by this radiological [release]. One thing that I am growing increasingly concerned about is some research that is coming to light here with non-cancer or non-cancerous illness such as birth defects or liver, kidney problems, and urinary tract cancer, bladder cancer.

Such statements were also made by core FRESH members:

The medical monitoring program has done a study on urinary systems, and it's not cancers. And see that's the other thing too, we keep talking about cancers, and people keep thinking, keep relating, well I don't have cancer, but yet I have this other illness. So they don't realize that radiation doesn't only cause cancer, there are the non-cancerous illnesses too, and that's what we're finding, a lot in this area.

As far as the risks involved, most of the people that were exposed were exposed earlier on. And we can't change those exposures. Whether there is more or less risk than we perceive, it is hard to tell. Time kind of tells you a lot of those things. Hopefully it is not as bad as some people in the community think.

FRESH never concerned itself solely with risk communication about risk estimates. For this group, risk related concerns were much broader. They were very concerned about the processes by which risks were studied and bringing out the truth, such as the transparency of decision-making processes, accountability of agencies, and access to information. Other non-technical concerns, such as cost-effectiveness of studies and remediation activities, potential economic impacts to the community, and employment, played important roles in how the core group of FRESH formed opinions about the risks and the risk management agencies.

We tried to keep everything as public as possible.

We looked at [clean-up recommendations] in dollar signs, but we also had to look at it from the scientific side too.

4.2.2 Risk Communication

In the following sections we discuss how FRESH, influenced by these factors, has played all three risk communication roles. This nodal network:

1. facilitated learning, or receiving, information that played a role in formation of risk perceptions among FRESH core and peripheral members;
2. mediated the transfer of information among stakeholder groups and between FRESH core and peripheral members;
3. created or generated information that played a role in the formation of risk perceptions among FRESH core and peripheral members.

4.2.3 FRESH as Learners of Risk Information

Oftentimes, members of FRESH were receivers of risk communication messages. FRESH — both core and peripheral members — were not passive recipients of information. They were actively engaged in learning and interpreting risk communication messages.

FRESH members worked hard to become educated about the issues. They did this on their own, by reading for example. One FRESH member was supported by the CDC to take a distance learning course on epidemiology. The FRESH member with responsibility for taking the lead on health related activities participated in a national working group of a federal advisory committee to the CDC and NIOSH on radiation health research efforts at DOE sites.⁶ Another core member was appointed to the DOE Environmental Management Advisory Board (EMAB). FRESH invited people to give presentations. When they did not understand the technical issues, they would reach out to independent scientists and concerned citizens for assistance, both locally and nationally, as well as to staff from regulatory agencies (i.e., US EPA, Ohio EPA).

For example, according to those we interviewed:

⁶ The Advisory Committee on Energy Related Epidemiologic Research (ACERER).

EPA was a lot of help, because if we did not understand a situation, we would ask them to give us a workshop, and see what their viewpoint was . . .

We would come to the reading room oftentimes, and get the documents from that. The state of Ohio was involved early on, so the Ohio EPA became a source of information.

If I found out some of the diseases or cancers I was not familiar with, I would read up on them and see how they were related to radiation, and chemicals, because chemicals were also used at the site, and were also found in the water, and how they were transmitted. How did uranium get into the food, and how, by eating the food raised in our area, where it would go in the body and things like that.

An underlying rationale for a focus on learning within FRESH was that core members felt that they had to be well-informed in order to be credible participants in decision-making processes about site clean-up and health studies of risks from historical exposures. As one member described in her interview:

Experts were the best, as far as getting information that helped us. And reports. [FRESH members] could use that information to show them the other side, and when we could show another side of what they were talking about, then that's what made them start saying that these people are not as dumb as what we thought they were...and then we could ask more questions. That is why we would always ask to see the information. If there was a hearing or a meeting, we would be able to look over the information for a day or two, before we came to the meeting, so we would have the right questions to ask.

Social interaction in deliberative settings was a critical mode of learning and important in the formation of risk perceptions. Learning was not just based on individual efforts or information per se. Relationships were critical. According to a core member's Living History interview:

We read a lot of books and *we found friendly people . . . You find these people or they find you. And you forge relationships with them and they help to educate you. You*

learn quickly who you can trust and you can't trust. (Crawford, pg. 18; emphasis added)

Important relationships were also formed when FRESH reached out to other communities that were facing contamination from DOE nuclear weapons facilities. They became members of the Military Production Network (now called the Alliance for Nuclear Accountability), a national network of over 35 groups. By meeting people from other communities they became aware of the inter-connectedness of the Fernald clean-up with the operations and clean-up of other facilities:

In the early years, I think we were so naïve. We were saying let's just clean this shit up and get it out of [Fernald], quick. Then all of a sudden we began to go to MPN meetings, we began to meet people from around the country and we began to see that they have this really big problem with Hanford and Nevada . . . And then all of a sudden it became like, we are shipping all of this stuff to Nevada and should we, consciously, should we really be doing that? Aren't we hypocritical by saying get it the hell out of here and give it to someone else and have them worry about it? That was our learning piece that we had to go through.

Social interactions at national meetings of the MPN were critical to their arriving at this understanding. Through their interactions at the meetings FRESH members learned about the risks faced by other communities and the impacts that would result from transfer of wastes *with their new colleagues/friends*.

More evidence for the importance of relationships and social interaction in the learning of risk information is found outside of formal meetings. FRESH would discuss detailed aspects of risk studies in informal settings that they felt were more conducive to honest dialogue, as one interviewee described:

[The contractor for the dose reconstruction study] was looking at a span of years that we didn't agree with, they were not high release years...We brought [the contractor for the study] to one of those public meetings and bickered and argued it out and we ended up going out to the bar and drinking it and changing it.

Finally, an important factor in the confidence that FRESH had in the credibility of risk communication messages was the stability of the agency staff and FMCP management. Longterm relationships have been formed with key individuals, and it has increased trust, credibility, and access. On the other hand, there is a difference between trust felt toward individuals and trust felt toward institutions. This is particularly apparent in feelings that FRESH core members we interviewed have toward the DOE. For example, a FRESH member stated in her interview that:

the level of trust toward the agency as a whole hasn't probably changed—I still don't trust information [from DOE]. Unless I can verify it. But trust in certain individuals, like at the site, has increased. Because at the time it seemed like they were changing people constantly, and we pushed real hard to have them not do that, so we could develop some trust and some communication with people—and that helped a lot. When you get to know people and been in enough meetings and you started working on projects with them, hopefully you can tell whether they're telling you the truth.

Parallel with the experience of a Township Trustee we interviewed, communication of risk information also occurred through informal networks. FRESH would also learn information from anonymous sources at the site, as told to us in our interviews:

[DOE] wasn't wanting to reveal information, and because we kept digging and some of the people at the plant new of things and weren't happy necessarily with what was going on . . . so Lisa would get little calls—a heads up, 'you know you might wanna do this or do that.'

I come home from work and find little manila envelopes in my mailbox with very damaging information sometimes . . . I've got a bunch of faxes. I've got a lot of stuffed envelopes with no return addresses on them . . .

While the media is often viewed as a source of for risk-related information, FRESH members we interviewed did not view the media as reliable. For example:

Sometimes we get good information from the press, sometimes we don't. Since we are involved with it, a lot of the times you could be at a meeting where you heard exactly what was said, and then you read the article or the TV is on and you are going

‘Huh?’ They don’t get it because they don’t have consistent reporters oftentimes that have the time to really learn what was going on. I know one time the Hamilton Journal wrote of rather scathing editorial about our group, and how we weren’t doing our job. We had had heavy rains and some uranium was going out to the river in some overflow— and we were aware of that and it happens frequently, and it is diluted in the river and we don’t like to see it happen but it wasn’t like there was an immediate danger to somebody and so wasn’t like you know . . . they acted like we should have warned the community. Well this is the same stuff that had been going on for years and years and years and they had been trying to eliminate these situations, but nature has its own mind and there was this really nasty editorial on our group and we thought, ‘well, where did this come from?’ If they had looked at the monitoring reports they would know how much flowed out to the river and this was a normal thing. And anybody who had gone to the meetings would know that. But it hurt. . . . Then about a year later they had another editorial that was praising FRESH to the hilt for protecting the community.

Learning within FRESH was dynamic — their beliefs and positions evolved. For example,

- As FRESH was formed and public deliberations began about how to clean-up the site after closure, they had a very clear position: clean-up the site completely, remove all contamination. As they learned more about the technical feasibility of such a goal, the economic costs, ecological impacts, and consequences to other communities that would receive removed wastes, FRESH members began to consider the option of onsite disposal of some wastes. They grappled with the question: what was an acceptable future risk to the community from waste cells onsite? During FCAB discussions on this subject, FRESH core members changed their position, and supported the option of onsite disposal for wastes meeting certain criteria (see below in discussion of FCAB).
- FRESH was an early advocate of having CDC conduct an epidemiology study in the community. They felt, initially, that such a study would validate the patterns that were being observed. However, after learning about epidemiology methods

and limitations within the FHES and other venues, the positions of FRESH core members began to evolve. They began to understand that the utility of an epidemiology study in the community would be limited because of low power. Consequently, they supported CDC's decision to not do an epidemiology study. However, they opposed the CDC's decision to disband the FHES and not do any more health studies within the community. FRESH continues to be concerned with addressing the broad picture, uncovering the puzzle of all contaminant releases and health risks in the community. In fact, both core and peripheral FRESH members have been instrumental in forming a new, non-profit, organization that will support research and education on public health risks because "CDC did not finish the job."

The evolution of risk perceptions within FRESH was a difficult process. The issues — and preferences for options — were controversial within FRESH. They were arrived at through extensive deliberations among members of the group. This process was described in a Living History interview of a core member:

I mean meeting after meeting after meeting you know, learning and educating, and reading documents and commenting on documents, and you know, arguing amongst everybody about what's clean and what's not clean. And how much waste — and it gets a little contentious at times and not everybody agrees. (Crawford, pg. 18)

4.2.4 FRESH as Mediators of Risk Information

FRESH played a mediational role in the communication of information between its members, the federal health agencies, Fernald Medical Monitoring Program, and others within the local community and outside of the region (e.g., with national stakeholder groups). This role was important in the formation of risk judgments, particularly for peripheral members. FRESH meetings frequently include presentations by researchers, independent scientists, and regulatory agency staff. In addition, FRESH distributed information about the process of conducting health studies, assessment of clean-up technologies and alternatives, the activities of the Fernald Health Effects Subcommittee and FCAB, and findings from the health studies in its newsletter. Often, its newsletter

would provide information about how people could obtain copies of the studies themselves.

The mediational role of FRESH in the communication of risk-related information was often active. They were persistent in their search for information and monitoring the status of the site. Moreover, they tried to ensure that information provided by the agencies and scientists would be understandable to its members:

The health stuff is really hard because when they do the studies it is really complicated and your average folk, they get a little confused. When they come into these public meetings and they've got all these scientists and docs, they are talking a totally different language. [Contractor for study] did a really good job explaining the dose reconstruction study. We had to yank his chain a couple of times but once that was done it set the stage . . . The challenge we made to him from day one was: 'when you come and talk to us you have to talk to us as lay people.' You have to speak to us in terms that your average Joe out here understands. You can't come in here and use these big fancy words.'

In her Living History interview, a core member made a similar observation:

And the [FRESH] board on a lot of occasions had to read a lot of the stuff and then kind of water it down enough so the average person sitting in the audience at these [FRESH] meetings could get it. (Crawford, pg. 19)

FRESH was viewed as a credible source of information. Sometimes they were viewed as *the* source of information, because people would not hear it from other sources. As a Trustee and a non-FRESH resident of the community stated in their interviews:

In our community, the only place you would hear this information was from the FRESH organization.

I think originally [the CDC] just blew it off as there weren't any health risks. I think through the efforts of the FRESH organization, that they brought [knowledge of public health risks] to light.

Although they were viewed as credible, FRESH positions could be controversial and not be fully supported. For example, when FRESH began advocating for the OSDF, a core member remembered in her interview that:

We took a beating about the first year or so [after changing their position on the OSDF]. We took a royal beating.

Of course, people's interest in risk-related information was also a function of factors external to FRESH. They could depend on what issues were salient within the community. For example, a CDC staff person noted in her interview how initial meetings about the findings from the dose reconstruction study were well-attended, but after that interest (as measured by numbers of people attending public meetings) declined. One of our FRESH member interviewees stated that:

There were times when more people would get involved-- if there was talk of a new release, or something else that hit the news. The more things were in the news or on the TV then the more people would be at the meetings. And also since, I hate to say it, but since the lawsuit's been settled and the money... you know, for a while a lot of people were coming to [FRESH] meetings to find out how to get their share of the pot. And now that that's solved, a lot of people just have kind of faded off.

4.2.5 FRESH as Generators of Risk Information

One way that FRESH initiated learning about risks was to gather their own data. Newly generated information became an important factor in the formation of risk perceptions. In the late 1980's FRESH core members began to gather information from other community residents about the incidence of cancers and other diseases. They did this via informal discussions with neighbors, family members, and friends. What eventually became known as "the health map" grew out of the core group's question: what is our risk?

It was very crude. We'd have pins, it's a very crude 5 mile radius map that has red and black pins on it. And [a FRESH member in the community] began to write down people's names who had died of cancer, had cancer, and that is how it started. But, we

depended on the community folks because once we got it on paper and got it together we put the word out and depended on them to feed that information to us too.

FRESH felt that no one else had useful information about potential public health risks in the community that might be attributable to historical releases from FMPC. As one core member put it: “we felt that if we made a map someone might listen.” That is, federal public health agencies might conduct health studies in the community and the community might become more alarmed and supportive of health studies. In a Living History interview we learned that:

We were trying to reach out to the community . . . trying to show them that there is a problem. So we started talking about the health concerns [within FRESH], let's form something that can be an educational tool . . . we thought we could use this as an educational tool and that people could see that there are health concerns, and if DOE could see that there are health problems here, and also we were trying to get health studies and get CDC and our public health department involved . . . if people would start seeing [the map patterns] they would start asking for help from these agencies (Yocum, pg. 3)

This was also reflected in our interview with a peripheral FRESH member:

The more meetings you went to the more pins you saw. And there are still pins being added. And when you look at that you realize that there has got to be something wrong. There is no way there can be that many pins on that map that close together. There has got to be a problem...I think it does have an impact. I think that maybe it's like one of the greater impacts, because you see that, it's something tangible. It's visible, and you know that each one of those little pins, it is or was a real live person. That was somebody's loved one.

By creating the health map FRESH engaged in risk communication in a variety of ways:

- It generated information that played a role in the formation of opinions about public health risks in the community. In fact, it helped garner the support of Ohio

senate and congressional members for legislation asking that CDC consider conducting an epidemiology study in the Fernald community.

- The map was used extensively as a tool for communicating with the community about the potential health risks from Fernald. FRESH discussed the map in its newsletters and always displayed it at public meetings. It was also used as a tool for networking with individuals within the community — locating them and educating them, bringing them in as FRESH members.
- The creation of the map played a role in the forging of relationships within the community, including expanding FRESH membership.
- For some in the community, the map provided legitimacy and credibility to FRESH as a citizen watchdog: the distribution of pins showed a pattern that was later confirmed by the dose reconstruction study estimation of downwind releases. Another way that the health map may have helped to influence perceptions of FRESH as a credible and trustworthy watchdog group was that the core members were adamant about refusing to provide contact information to the CDC about who specific pins on the map represented. FRESH promised confidentiality to its informants and strictly maintained that confidentiality.

At the same time, its limitations were understood by FRESH. They did not push its use in deliberations within the Fernald Health Effects Subcommittee (see below). According to CDC staff, FRESH “had feelings of the map’s limitations in health studies.” When NCEH first started to meet with community members, FRESH presented its “health map” showing pins for each known cancer or death in the community. Staff had, according to those we interviewed, extensive discussions about how the map data could be used in their assessments. Ultimately, staff decided it could not be used — the methods of gathering the information and medical bases for diagnoses were unscientific (e.g., lacked validation). The uncertainties could not be quantified.

4.2.6 Interactions with Other Networks

FRESH is a key player in efforts to understand the public health legacy of historical exposures to radiation from Fernald and to clean-up activities onsite. They interacted

with Township Trustees in ways that influenced the communities' understandings and perceptions of risk. In the remainder of this section, we discuss their interactions with Township Trustees. As will be discussed in sections on the advisory boards (see below), they have participated as advocates outside of and within frameworks set-up by the agencies. In particular, FRESH core members have been active participants in two other nodal networks, the DOE Fernald Citizens Advisory Board (FCAB) and CDC's Fernald Health Effects Subcommittee (FHES).

In some cases, Trustees we interviewed spoke of tensions that emerged between nodal networks within the Fernald community, particularly FRESH. The tensions were related to who speaks for and represents "the" community. For example, two Trustees spoke of their discomfort with not being perceived as fully informed spokespeople and representatives of the community, even while they simultaneously respected and supported the critical communicative role played by FRESH:

I was always a little resentful [about the dust collector release event] because all the interviewers, the papers, the TVs and that type of thing did not really seek interviews with the township officials. They always sought interviews with FRESH. And my attitude was, well, if they can get at the truth better than us go ahead and let them. But I think sometimes people forget that the elected officials are the ones that represent the people, not FRESH. FRESH did an effective job in seeking the truth, putting pressure on people and forcing the truth out, which is fine, you got to have those kind of people but still, they are not elected. They don't represent the view of people like the public officials.

Well, of course a lot of our information was limited to what people on site wanted to give us, also the FRESH organization, they did a lot of information on their own, and quite frankly, they brought a lot of things to light that I don't know would have ever came out. They have done a tremendous, tremendous job, and I can't give 'em enough credit. But they were a watchdog group. They're a special interest group. Their interest is in the residents that live around the Fernald site. It is not the Township as a whole.

As the above quotes illustrate FRESH was also a respected actor within the socio-political system network involved with risks at Fernald. This is reflected further, in the understanding that FRESH played a key role as a watchdog group in bringing “truth” to light. They were persuasive in controversial situations, and influenced Trustee’s perceptions and opinions. Trustee’s concerns about who represented the community did not prevent them from learning from FRESH or adopting its views. FRESH was viewed as credible and it was respected within the community. For example, as quoted above, a Township Trustee stated in regard to the on-site waste disposal cells:

Well, actually I was hoping that all of it would have been shipped out, personally. And there were a lot of people who, not a lot, I guess there were some people that really were opposed to building that disposal cell. But FRESH, I think, felt that that was probably the best solution to the mixed waste . . . I kind of defer to FRESH, I mean, that they felt that that was a decent solution.

4.3 The Fernald Health Effects Subcommittee

4.3.1 The Public Health Risks from Historical Contamination

The Centers for Disease Control and Prevention’s National Center for Environmental Health was asked by Congress in 1988 to consider conducting an epidemiologic study of the community surrounding Fernald. The CDC felt that an epidemiologic study would not be possible without first developing information about radiation doses to residents in the surrounding area. In addition to the need for reliable estimates of off-site exposures, the CDC and community also considered whether there were adequate data about plausible health outcomes and availability of demographic and health outcome information.

Subsequently, the Fernald Dosimetry Reconstruction Project was begun in 1990 to estimate off-site radiation exposures during 1951–1988. The NCEH Radiation Studies Branch worked with its contractor, Radiological Assessments Corporation (RAC), to complete the project in 1996 (RAC 1998). Scientific and public reviews were conducted for another two years and the final report was released in Sept. 1998.

The study’s results indicated that most of the estimated dose to the public came from inhalation of radon and radon decay products. These exposures came mainly from the

wastes in the K-65 silos. The highest exposures occurred in the 1950–1970s. Structural modifications to the silos in 1979 substantially reduced releases of radon and its decay products from the K-65 silos. The primary risk from radon exposure is lung cancer. Other isotopes of uranium and thorium contributed to the exposure of other organs, such as the kidney, bone marrow, bone surfaces, and liver.

There were multiple opportunities for the public to learn about and participate in discussions about the potential of an epidemiologic study to find positive relationships between exposure and outcomes. For example, preliminary estimates were made available — and discussed in a public workshop — by 1993 (CDC 1993). Even before the study was completed the CDC engaged independent experts and members of the community in discussions about the most appropriate means for following-up public health concerns with further epidemiologic studies.

An important step of the Fernald Dosimetry Reconstruction Project was the communication of the findings to the community. Considerable effort went into developing a communications program. To make the results more meaningful to the lay public, the CDC and RAC used nine scenarios to describe the estimated doses to representative people with different lifestyles. These scenarios, in a brochure, were widely distributed to the community, along with materials explaining the meaning of the scenarios. The implications of uncertainties and placing risks into a wider perspective were a focus of the communications efforts. On the other hand, the CDC acknowledged that “the risks estimated for the nine exposure scenarios did not provide a comprehensive summary of the potential health effect of the FMPC on all residents in the surrounding community. Many individuals, who could not relate their own experiences to those defined in the nine exposure scenarios, were left with questions about their risk” (CDC 1998, pg. 15). The CDC did not rely on comparisons to radiation protection standards in its communications efforts.

At the same time the dose reconstruction study was being completed and reviewed, the CDC’s National Center for Environmental Health set-up the *The Fernald Health Effects Subcommittee (FHES)* in 1996. The FHES was established as a committee under the Federal Advisory Committee Act. It held 18 meetings between June 1996 and August

2001, when it was formally dissolved. It had work groups with special emphasis on three topics: medical/educational, position papers, and community outreach.

The FHES played a significant role in the continuing consideration of whether an epidemiological study would be conducted in the community. Soon after the FHES was established the CDC initiated the Fernald Risk Assessment Project, in part based on input from the subcommittee. The Risk Assessment Project was intended to provide further information to inform a decision about the feasibility of conducting an epidemiologic study of the community. It was also initiated to help respond to the concerns of residents about their potential health risks from radioactive releases from the FMPC.

The Risk Assessment Project was conducted in two phases. Phase 1 focused on lung cancer risks from radon and radon daughter exposures (CDC 1998). Phase 2 focused on risk estimates for kidney cancer, female breast cancer, bone cancer, and leukemia (CDC 2000). Risks were estimated for exposures during the operation of the facility to residents living within a 10 km (6.2 miles) radius from the facility during 1951-1988. Risks from exposures after site closure were not estimated in these studies; the Agency for Toxic Substances and Disease Registry conducted a study of “current” exposures finding that no significant risks to the off-site community are occurring at this time from remaining contamination (ATSDR 2000).

The Phase 1 report, *Estimation of the Impact of the Former Feed Material Production Center (FMPC) in Lung Cancer Mortality in the Surrounding the Community* (CDC 1998) estimated mortality risks for the community and for specific sub-groups (e.g., smokers vs. non-smokers, sex, age). Overall, a median estimate of 85 deaths was calculated, with a 90% confidence range of 25 to 309 lung cancer deaths. The percentage increase in the number of lung cancer deaths over background rates due to FMPC-related exposures were 1-12% with a median value of 3%. The size of the community residing in the study area around FMPC during 1951-1988 was 40,000 to 53,000 people.

The Phase 2 report *Screening Level Estimates of the Lifetime Risk of Developing Kidney Cancer, Female Breast Cancer, Bone Cancer, and Leukemia Resulting from the Maximum Estimated Exposure to Radioactive Materials Released from the Former Feed Materials Production Center (FMPC)* was completed in March, 2000 (CDC 2000). The

calculated risks are lifetime risks for hypothetical exposures during the years of FMPC operation. Many conservative assumptions were made to calculate maximum doses, including lifespans of 100 years, all local food products were contaminated (e.g., eggs, milk, vegetables), and all irrigation water and air was contaminated: “it is important to remember when evaluating these estimates that they are based on the unrealistic assumption that everyone who ever resided within an area of the assessment domain received the estimated maximum dose associated with that area” (CDC 2000, pg. 16).

The risk estimates were called “screening levels” because the estimated increase in life time cancer risks to the target organs were calculated to a) provide members of the community with a reference point for evaluating their own potential risks associated with FMPC radiation exposure and b) guide further discussions of public health activities, including epidemiological studies, for the community. Based on the results, the CDC — with FHES agreement — did not recommend a more detailed analysis of the cancers studied in the Phase 2 assessment.

In addition, based on the findings from the dose reconstruction study and the Phase 1 and Phase 2 risk assessments, the FHES recommended that the CDC *not* conduct an epidemiological study of lung cancer in the Fernald community. FHES members agreed with CDC staff that the power of the study would be too low to identify effects. According to a CDC staff person we interviewed, he “did not want to be a salesman.” He stated that his approach was to tell the FHES members what he knew and let them reach their own conclusions, even though he had a strong opinion that an epidemiology study should not be done due to low power. At the same time he was clear that if the FHES did recommend that CDC conduct such a study, he would have argued strongly against it within the agency’s own deliberations and decision-making structure. When the FHES finally did recommend that such a study not be done, it was a position that was very different than the one advocated by many members of the FHES in the beginning, including those who were core members of FRESH. Through their interactions at committee meetings members established a new nodal network, with its own identity, structure, and processes. Through the intentional efforts of bring together diverse individuals the agencies created a place of *convergence* that led to the *emergence* of a new network.

The Subcommittee included 14 members representing a variety of groups, including:

- residents of the nearby communities, including core and peripheral members of FRESH;
- current and former workers;
- scientists, including individuals playing key roles in the FMMP;
- Township Trustees;
- members of the medical community;
- four liaisons were from the Ohio EPA, Ohio Department of Health, and the county health district.
- Staff from the federal health agencies, including the CDC NCEH Radiation Studies Branch, ATSDR, and NIOSH. Several staff usually attended meetings to give presentations and respond to questions from subcommittee members. A Designated Federal Official was from CDC NCEH Radiation Studies Branch (12 meetings from June 1996 — March 1999 and then again after March 2000) and from the National Institute of Occupational Safety and Health (three meetings, March 1999–2000).

While the importance of the FHES was understood by many, its purposes were often a subject of dispute. The lack of clarity had implications for how well its risk communication activities were viewed and caused friction between members of the FHES and agency staff. Agency staff defined its primary purpose narrowly as providing “consensus advice to the agencies on research and public health activities at [Fernald]” (COSMOS 2001b, pg. 2-5). On the other hand, FHES members identified other

purposes.⁷ As part of an evaluation project conducted by a contractor (COSMOS 2001b, pg. 2-4)⁸, a variety of purposes were expressed by participants:

- identifying, learning, and characterizing about health concerns in the community,
- learning about health effects in the community,
- providing advice on research and public health activities,
- representing the public,
- providing outreach and education,
- increasing government credibility,
- advocating for dose reconstruction,
- improving community health,
- advocating for health monitoring,
- providing agencies with information about the concerns of the community,
- sharing information from the agencies with the workers and from the workers with the agencies, and
- serving as a watchdog for the community against the site and monitor what happens.

For example, two descriptions of the purpose of the FHES from our interviews were that:

⁷ In August 2001 the CDC formerly ended the activities of the advisory board, saying that its work was completed. This is a position that was contrary to the views of most community members and advisory board members and was a cause of ill-feelings within the community toward the NCEH. In part this was a result of the lack of clarity about the purposes of the committee.

⁸ In 2001 the Radiation Studies Branch of NCEH received a completed evaluation of Health Effects Subcommittees from a contractor (COSMOS 2001a, 2001b, 2001c). The evaluation of the FHES was based on seven interviews with Fernald community members, an unspecified number of interviews with NCEH, NIOSH, and ATSDR staff, and 10 completed surveys (COSMOS 2001b; the contractor reported 11 returned surveys, but one was returned uncompleted).

one was to air the community's concerns; the other was to try to help the people in the community with some of their medical problems, and to also get the government to acknowledge the things that happened and that indeed there were some medical things, some cancers or chronic health problems that occurred as a result of what happened at Fernald. I know there's that major lawsuit, and I think that they wanted to somehow get some compensation for that as well.

I think what people were looking from the Fernald Health Effects Subcommittee was, we've proven that this [site] has impacted our family, has caused this cancer, now what are you going to do about it? I think the public was looking for some leadership and to answer that question, what are you going to do about it now? The people didn't need a million-dollar committee to be set up to give them an answer, yeah, that's where you got your lung cancer, it was from Fernald. I hope that is not the purpose of the committee . . . I think people had a higher expectation for that committee rather than just putting money into a study . . . I think until we get treatment for these people or sounder systems, I think we fall short of our goal. That you got your cancer from Fernald is kind of like telling the person that their arm hurts because they have a cut on it, I mean, they already know that.

4.3.2 Risk Perceptions Within the FHES

A variety of factors influenced the formation of risk perceptions among the members of this network. They included perceived access to information and independent technical experts, understandings of scientific information, familiarity with radiation, information provided through presentations and reports, perceived quality of the decision making processes, trust in the DOE, CDC, ATSDR, and FEMP contractors, perceptions about the degree to which agency staff cared about the community and its needs, and personal experiences and observations.

In the beginning the level of knowledge about Fernald and its risks from historical exposures within the FHES varied greatly. Some members, such as core members of FRESH, were very familiar with the history of the site and had followed the dose reconstruction study closely but they did not have a strong background in health research methods. Other members were more technically adept. Still others were not very familiar

with Fernald or the kinds of risks posed by historical releases from the site when they became members, as these quotes from our interviews illustrate:

Someone called me and asked me if I might be interested in being on the subcommittee. I'd heard about Fernald, didn't really know anything about it—I'd just heard the name.

Three-fourths of the people in the health-effects subcommittee were people who really had not paid that much attention to Fernald, other than reading what was in the papers and really did not understand the health issues, or the health impacts . . . We met quarterly, and it would take us a year to really get going and to see what we were wanting from the health effects subcommittee.

There were people that were put on the board that never should have been put on that board. While I know that [CDC] looked at diversity and educational issues, these people had never even been to Fernald. I mean, why would they give a damn?

The education efforts and openness of the agencies about the risks had unexpected effects on risk perceptions among FHES members. According to a CDC staffperson, in the beginning most FHES members felt that if the CDC would do studies, then they would learn that “people died” from exposures caused by Fernald. By the time that the FHES was dissolved the members we interviewed felt that they understood the risks better. They perceive risks as low but not zero, as a result of the findings from the Phase 1 and Phase 2 risk assessments. According to one CDC staffperson, FHES members in general felt “vindicated” by the findings that “good science” found that a small risk existed: “There was a belief that there could be a smoking gun but we won't be able to find it even after spending \$10 million.”

On the other hand, there were negative consequences to the openness and findings. One FHES member expressed that:

Well, now that everything about it is in the open, there's a lot more mistrust than trust, because in the beginning you people would say, my government would not do anything to harm me, and the very same they were making bombs to protect us, they were also harming us.

The views of FHES members were also affected by their perceptions that the CDC was not willing to study the full range of potential health effects from Fernald and that the CDC was not able to address the community's "real" needs of, for example, improving community health and advocating for health monitoring (although as mentioned above, these aims were not within the mission of the agency). In addition, FHES members felt that more studies should have been conducted, even if an epidemiology study was not going to be done. While the CDC was, for the most part, perceived as a credible source of information about risks that were studied, they were not viewed as fully committed. This had an important effect on the risk perceptions of those we interviewed: even if the risks of the diseases that were studied were viewed as low, other, unassessed risks were viewed as potentially being significant and the "real" needs of the community remained unmet.

4.3.3 Risk Communication

The Fernald Health Effects Subcommittee played only two of the three risk communication roles. While the FHES did not generate risk related information, it:

1. mediated the transfer of information among stakeholder groups with FHES members and between others groups and the FHES and
2. facilitated learning, or receiving, of information that played a role in formation of risk perceptions among FHES members and between FHES members and other stakeholder groups.

4.3.4 FHES as Mediators of Risk Information

The FHES was a source of risk-related information for the community. The FHES helped to convey information to others in the community that was generated by the health agencies (and the Fernald Medical Monitoring Program). For example, some of those we interviewed believed that the community had greater access to information and is more aware of health issues related to Fernald as a result of the FHES activities. Health care providers have received information about the risks of contamination from FEMP, as part of FHES sponsored seminars for health care providers. The FHES attempted to provide outreach to the broader community through newsletters, media announcements, and open meetings.

However, members of the FHES were divided about the quality of the process for informing the public of the subcommittee's meetings. They were also dissatisfied with the level of public involvement in meetings, and the subcommittee had repeated discussions about the need for meetings that would be more accessible to the public. Thus, the success of these efforts are unclear, but there are indications that not all goals were achieved, as these two quotes illustrate

I know that on two separate occasions they had a conference over at the Mercy-Fairfield Healthplex. It was more to try to educate the medical community and I thought that was a very nice idea. Not well attended— especially by physicians— mostly by the ancillary staff, nurses and the like.

Because we had meetings in the evening, they had an opportunity to come and have their opinions voiced as well. Unfortunately a lot of times there were other meetings at that same time, so there wasn't a very good turnout.

4.3.5 FHES as Learners of Risk Information

The FHES was not a network that, by itself, created or generated information that played a role in the information of risk perceptions. Rather, the federal health agencies, such as CDC, generated new information through health studies and they reported the findings and their significance to the FHES. Thus, the FHES was intended to be a forum for learning and dialogue among its members and agency staff. On the basis of deliberations within the FHES input into the design of health studies was received by the agency (e.g., what health outcomes would be assessed in the Phase 2 risk assessment).

The FHES was not completely successful at facilitating learning among its members. While considerable information was provided to FHES members, there were many complaints that the process was not conducive to constructive dialogue. For example, according to an evaluation report provided to the CDC by a contractor, overall, most subcommittee members were satisfied or very satisfied with the quality of materials they received (COSMOS 2000b). However, they were less satisfied with the timeliness of receiving the materials and their ability to review them prior to meetings.

On the one hand, as a newly established convergence network, considerable effort within the FHES was given to education of members. Because of a lack of familiarity with the issues, understanding of the history, or understanding of the relevant technical or methodological topics, the Subcommittee had to go through a year plus process of self-education. As part of the education process, agency staff gave multiple presentations on relevant topics, including the requirements for epidemiological studies, statistical power, and health effects of radiation. FHES members also requested special presentations on topics of interest to them, such as endocrine disrupters. A few of the members were supported in a distance learning course on epidemiology, including one person who would eventually become chair and a core member of FRESH. Another was the community resident member who was one of the few that continued to believe that an epidemiological study should have been conducted.

Agency staff that we interviewed felt that the education effort was successful. For example, they told us that:

- they were very “upfront about the quality of data and uncertainties”;
- that members asked “strong questions” and “insightful questions” during discussions of epidemiology;
- most members had a good understanding of uncertainty and power by the end and members made recommendations about the usefulness of an epidemiology study based on their understanding of the concept of power — “that there can be an effect, but little chance of finding it exists”;
- members learned about the relative costs and benefits of doing an epidemiology study, including the amount of money that a study would cost;
- they had formed strong relationships with FHES members, with one stating that “I enjoyed working with them”; and
- a cohesiveness developed among the members.

On the other hand, members and other public participants did not give the same kinds of positive characterization of the committee. We learned from FHES members in our interviews that they felt that that

the Health Effect Subcommittee meetings I attended were not very well focused in terms of agenda, they were just a series of often unrelated informational presentations by various scientists. And there wasn't a lot of agenda setting done.

There was little discussion within the FHES about the feasibility of an epi study, about power. Most people in the FHES did not know enough to ask questions

They had one [presenter to the FHES] who got up there and went on and on and on for 45 minutes and none of us could have even told you what this woman said...when she got done, one of us got up and said 'what the hell did you just say?' Its like you are talking way over people's heads and this is not a good use of...time.

Now there are times when it seemed like they may have a concern that they want to address at the next subcommittee that wasn't addressed-- I mean you are talking about a three months' time lapse [between meetings], where things got missed--- and I think that was a concern sometimes.

There were a couple of people on the committee that just seemed to be disagreeable about everything so I didn't really care for that. No matter what was being presented, they questioned it and I don't know, ridicule and jump all over it.

Also, according to the evaluation report, many of those participating in the evaluation did not feel that the FHES had an atmosphere conducive to constructive deliberations.

The COSMOS evaluation reports:

Many agency staff, especially scientists, express reluctance to make presentations to the subcommittee because of the sometimes hostile reactions they get from members. An agency upper management staff person states that staff have been subjected to verbal attacks, and some scientists, especially, do not want to go to meetings because of these confrontations. Agency staff member reports that a member of the Fernald Health Effects Subcommittee made threats at a June 2000 public meeting on the findings of the Fernald public health assessment, resulting in security concerns for

staff at the next meeting. However, one scientist commented that of the four Health Effects Subcommittees [then in existence], he would be willing to make future presentation only before the Fernald Health Effects Subcommittee. This scientist believes members of the Fernald subcommittee are not as disrespectful as members of the other committees” (2000b, pg. 2-8).

The type of learning within the FHES may have been affected by its role as a point of convergence of multiple nodal networks. Members did not, initially, share a group identity. For example, members represented different constituencies, had different concerns, and different perceptions about risks and risk management. As work progressed in the FHES, however, the group perceived that its own identity formed. However, the tensions over the purpose of the committee discussed above reveal that the sense of group identity may have been shallow. According to one agency staff member, the Fernald Health Effects Subcommittee relied heavily on “informal communications” (pg. 2-16).

4.3.6 Interactions Between the FHES and Other Networks

The FHES had significant interactions with Township Trustees and FRESH because their members were members of the FHES. During the period our study focused on, the FCAB was not involved with health risk communication. (However, initial FCAB recommendations were influenced by concerns about human health risks — Task Force 1994, pg. 35).

4.3.6.1 FHES and Township Trustees

The Township Trustees had little direct interaction with the FHES in their capacities as local officials. Most of the concerns they expressed in their official capacities as Trustees were about clean-up and future use of the site. Some did attend the meetings, however, because of their broad concern about the health of their community and a few became members of the FHES. Trustees had experiences with the FHES that were similar to those of other participants. For example, A Trustee said that

The FHES meetings were always held two days and it was difficult for me to take two days off work so I either attended the first day or the second day.

4.3.6.2 FHES and FRESH

On the other hand, FRESH felt that the FHES was an important source of information for the community. A core FRESH member said that

Most of the health information [for the community] came from the agencies, the health effects subcommittee, and FRESH.

It was also a network in which core FRESH members could participate and learn. However, their relationship with the subcommittee was often ambivalent. As noted above, CDC staff discussed the role of the FRESH health map in furthering understanding of the health risks in the community and they sponsored one core member in a distance learning course about epidemiology. Core FRESH members felt that they gained important knowledge from their participation in the subcommittee.

On the other hand, they never felt that the CDC was fully committed to unearthing the full story about health effects from Fernald, and by extension the FHES did not fully address the concerns of the community or listen to FRESH members, as these quotes from FRESH members illustrate:

They never really did what we envisioned and thought that they would do. They just plodded along and there was a lot of resentment. There wasn't clear leadership and I think that the CDC was pushing their own agenda through this group of people.

What were perceived as really big issues for the community, weren't big issues for some of the folks on this board. And while I know we needed the docs and some of the expertise there, we didn't really feel like they were really looking out for our best interest.

[FRESH member] felt that she was always discounted and I think we were too. They saw us as those hysterical FERSH women, they come and they raise hell all the time and no matter what we do it doesn't make them happy. We didn't get the working relationship [we wanted] and the 'lets all work together and lets go down the road and make these parts fit together.' What we got was this other thing, that they are

hysterical folks and no matter what we do its not going to be good enough for them anyway.

All of a sudden the commitments seemed to disappear until after two or three years, I'm trying to think just how long, about three years, when they changed directors the commitment was not there to work with the people and learn to understand the people, and what those people were really wanting. And then too I believe the advisory board was wanting more from the CDC then they wanted to give.

The relationship between the FHES and FRESH was further strained because of the way that the FHES operated. FRESH did not have input into how the Subcommittee was formed and who would serve as members — unlike their experience with the FCAB (see below). They felt that some of the individuals appointed to the FHES had conflicts of interest and that too few members of the community were selected. They took this as a sign of disrespect from the health agencies.

The feeling that the FHES was not really “for the people” was exacerbated by the reluctance of agency staff, the chair, and some members to meet more frequently (e.g., once a month like the FCAB) and to hold meetings at times during which people would not have to miss work. In particular, a core FRESH member was appointed to the FHES but was never able to attend the meetings because they were held during working hours. The evening portions of the meetings were not felt to be enough or to focus on the important, relevant topics.

We would go in the evenings and they would always schedule the stupid shit in the evenings, like the internal stuff and you know really cool things that we wanted to hear were happening during the day. We would argue with them about their agenda and why can't you do this in the evening and why can't you meet on a Saturday? They would not listen.

Such feelings had the effect of raising questions about the credibility of findings and the significance of other potential risks that remained unstudied. Although they accept the findings from the completed studies that suggest low risk from cancers (e.g., Phase 1 and 2 risk assessments), FRESH members remain unconvinced that the set of studies

conducted were adequate to show that fears of significant health effects from the full range of historical releases were unfounded. More recent findings from ATSDR and studies using the Fernald Medical Monitoring Program data reinforce this belief (Pinney personal communication). In summary, FRESH never felt that the FHES — and by extension the federal health agencies — provided full information about the broad range of health risks in the community or created an inclusive, accountable process. These feelings affected how they responded to and interpreted findings from the health studies.

4.4 Fernald Citizens Advisory Board

The Department of Energy Environmental Management Program, US EPA, and Ohio EPA established the *Fernald Citizens Task Force* (FTF) in 1993. Regular monthly meetings have been held since August 1993, in addition to periodic special public meetings and workshops. The FTF was originally chartered, under FACA, to advise the DOE about four specific issues:

1. What should be the future use of the Fernald site?
2. What residual risk and remediation levels should remain following remediation?
3. Where should the waste be disposed? and
4. What should be the priorities among remedial actions?

As a FACA committee, members were selected to represent diverse stakeholder groups in the Fernald community, including Township Trustees, local residents, workers, scientific researchers, and business. Ex-Officio members were from the federal agencies DOE, ATSDR, and EPA. An ex-officio member also represented the Ohio EPA. Members were selected by a well-respected professor from University of Cincinnati, Eula Bingham. She talked with many of the key stakeholders in the community and with agency staff to determine a broadly representative and respected group of individuals to serve as members. She also tapped John Applegate to be the first chair of the committee. According to a staffperson for the Task Force, one of her goals was to establish a committee of “individuals participating as individuals, not just with institutional perspectives.”

To accomplish their initial goals, the Task Force set itself an ambitious schedule of meetings and decision points that were coupled with extensive discussion of values and education of members about technical issues. The chair recognized that the committee had to be very focused on specific upcoming actions of the DOE and Flour-Daniel if it was to have any effect. Many members initially felt overwhelmed by the need to provide recommendations within a relatively short period. The chair and consultant evaluated what intermediate decision points would be most crucial to the determination of final remediation and use of the site. The recommendations are described in detail in a report released July 1995, and all recommendations save for one represented full consensus of the board (Fernald Citizens Task Force 1995).

The recommendations of the Task Force were to:

- protect the Great Miami Aquifer and to provide consistent protection across all land uses and environmental media;
- ship highly contaminated wastes off-site;
- dispose of wastes meeting criteria of low level contamination in an on-site disposal facility;
- accelerate remediation in response to reduced annual budgets and priorities for rapid protection of health and the environment, and;
- define future use of the site at a later time, but that decisions should avoid agricultural and residential uses and that a buffer zone be established around the on-site disposal cells.

The only recommendation for which unanimity was not achieved concerned waste disposition; this is the recommendation that concerned the on-site disposal facility for wastes that were to meet specific acceptance criteria. A local resident from Morgan Township opposed the recommendation because he preferred that “all contaminated material be removed from Fernald and disposed off-site” (Fernald Citizens Task Force 1995, pg. 36). According to our interviews, Ross Township was unable to muster additional opposition to the decision, in part based on the lack of scientific controversy

about the recommendation and in part based on the broad based support the recommendation had from other representatives in the community.

In 1995 the group was renamed the *Fernald Citizens Advisory Board* and was given a new charter to advise the DOE EM program about clean-up implementation priorities; the Task Force had been established prior to the Site-Specific Advisory Board process of the EM Program. It continues to meet once a month. More recently its focus has been on developing recommendations on the future use of the site.

4.4.1 On-Site Disposal Facility Project

The on-site disposal facility (OSDF) is an engineered waste disposal facility located on the northeast section of the site that reflects “the ‘balanced approach’ to waste management at Fernald” (FEMP 2001). It is designed to hold up to 2.5 million cubic yards of waste in seven separate waste cells. 85% of the wastes are estimated to be contaminated soils and 15% from building and other infrastructure debris. Waste acceptance criteria were established with the US EPA in the Operable Unit 2, 3, and 5 Records of Decision, with a goal of protecting the Great Miami Aquifer that is located underneath the site. Numerous physical protection barriers have been designed, including a leachate collection and conveyance system, that transports leachate to an Advanced Wastewater Treatment Facility and a cap and liner, constructed of clay, gravel, and plastic.

Waste disposal operations began in the first cell in 1997, which was completely filled in 2000. Cell 2 was about 2/3rds filled and cell 3 was about 1/3rd filled by the end of 2001 (FEMP 2001). When all the cells are filled the OSDF will be approximately 800 feet wide, 3700 feet high, and 65 feet high.

4.4.2 Future Use

The FCAB was cognizant that the decision to dispose of wastes onsite would have implications for the future use of the site. With onsite disposal of radioactive wastes would come longterm, although low, exposure risks. This lead the FCAB to also consider recommendations to guide the future use of the site. The FCAB touched on these guidelines in its set of recommendations in 1995. Specifically,

The Fernald Task Force focused its future use recommendations on creating a broad understanding of how the Fernald site could best be used following remediation, rather than identifying specific land use plans for the property. The Task Force believes that specific uses of the land should be determined close to the time of reuse by the people most impacted by that use, within the general guidelines established by the Task Force. As part of these general guidelines, the Task Force recommended that residential and agricultural uses be avoided on the property. However, it was also important to the Task Force that the land be used productively. Accordingly, remediation levels recommended by the Task Force allow for all other use, including recreation and industry. The Task Force also recommended that a substantial buffer area separate the on-site disposal cell and any other uses of the property (Fernald Citizens Task Force 1995, pg. V).

It began to address this issue with more effort in 1999, as part of its Stewardship Subcommittee activities. Ultimately, the FCAB sponsored a series of workshops in the community, and made several recommendations, as shown in Table 4.

Table 4. Results of the Third Workshop – September 26, 2000

VISION STATEMENT

Fernald Stakeholders envision a Future for the Fernald property that creates a federally-owned regional destination for educating this and future generations about the rich and varied history of Fernald. We envision a community resource that serves the ongoing information needs of area residents, education needs of local academic institutions, and reinterment of Native American remains. We envision a safe, secure, and partially accessible site, integrated with the surrounding community that effectively protects human health and the environment from all residual contamination and fully maintains all aspects of the ecological restoration.

ACHIEVING THE VISION

We believe that this vision can only be achieved through cooperation among all stakeholders and by recognizing the need to identify the funding and incorporate planning and implementation of future uses with on-site remediation. To achieve this vision, we would like to see the following elements implemented on the Fernald Site:

- Adequate property to provide reinterment of Native American remains in a protected park-like setting that recognizes the spiritual nature of this activity.
- Regulated access to the ecologically restored areas of the site through a series of marked and annotated trails that can be used for hands-on learning and discovery of indigenous plants and animals.
- Development of an on-property educational center that provides for the following:
- A complete history of the Fernald area beginning with the first Native American residents continuing through the Cold War years when the Fernald site produced feed materials for America's nuclear weapons arsenal, and culminating with the current efforts of site remediation and ecological restoration.
- Museum-quality displays and related educational programming on the role of Fernald in the Cold War and the many impacts of the production of feed materials for nuclear weapons on the lives of area residents and Fernald site workers, as well as the broader social and cultural impacts on the surrounding community.
- Museum-quality displays and related educational programming on the history of Native Americans in the Fernald region.
- Permanent housing of the public reading room containing copies of the public record of Fernald production and remediation activities and Fernald Living History materials.
- Classrooms and auditorium space.
- Environmental research and groundwater education facilities.
- Expedient access to environmental monitoring results.
- Detailed descriptions and displays on the Fernald environmental remediation process and results.

[Source: FCAB Future of Fernald webpage,
<http://www.fernaldcab.org/FutureFernald/FOF3rdWorkshop.html>]

4.4.3 Risk Perceptions

Risk perceptions related to the OSDF varied among members of the FCAB. They also evolved during the FCABs deliberations. A variety of factors influenced the formation of perceptions among the members of this network about the risks from the contaminated materials themselves and about the longterm integrity of the waste disposal cells. They included perceived access to information and independent technical experts, understandings of scientific information, familiarity with radiation, information obtained through presentations and reports, summary materials prepared by the board's facilitator, participation in simulation games, buy-in to the board's process, perceived quality of the decision making processes, trust in the DOE and FEMP contractors, and personal experiences and observations.

The following quotes illustrate how FCAB members perceived the risks:

Well, there are risks and I think they are probably with low level of contamination in the disposal cell. I don't feel like the risks are high.

A lot of these plastics have not been tested over a long time period. Plastic, if you look back in the history books, hasn't really been around that long. That disposal cell is going to be there hundreds of years. The durability and longevity of plastic we don't know.

My concern there would be, well, the standards we have today for the lining of that disposal cell right now we feel that is adequate. Is it going to be adequate a hundred years from now? Is that line going to stand up, is it still going to be as good as we say it is now? Is it going to protect the ground water?

Risk perceptions also arise over the future use of the site. In our interviews, FCAB members explicitly expressed views about risks or they alluded to them through their preferences for future uses. For example, statements made within our interviews revealed concerns about the risks to human health and the environment as well as local economic growth from residual contamination.

[We] are highly opposed to having walking trails and bike trails. Who is going to ride their bike around the waste cell?! Once a year I do the tour, but I don't want to go

there anymore than that. There needs to be some signage saying this is what this used to be. There are risks. A real risk. Because we are not cleaning it up to background. There is not enough money. We're only taking it to a certain level. In my mind, there is a risk — it may not be a huge one, but there is a risk.

I guess I'm just hesitant enough about the cleanup, that they know what they're doing, that I'd like to see 25 to 50 years go by before they use it in case something else pops up that they didn't realize and they got back and make tests something can go 'Oh no! We've got to go back and clean something up.' The community wants to see it used, and the EPA really wants to see it used.

I think the controversy [about future use] is just a matter of opinion on what people want to see it become. . . . It's not about risk to me. I think the risk is at a minimum.

For many, underlying the FCAB's discussion of the site's future was a concern for remaining risks in the longterm:

We have a lot of details yet to work out. How do you maintain safety there? How do you make sure that there's security, that none of the areas are in any way compromised? How do you maintain this for the long haul? And for the long-haul we're talking ten-thousand years, maybe. Short-term, a hundred years, so you know we have something here that's going to last for a long time.

Finally, concerns about the future use of the site are not about risk levels per se. They are about making the area a positive element in the community.

Obviously, the disposal cells will stay there, and they will be monitored, supposedly, forever, the rest of it is woods and natural habitats, and there's a big push to leave it remain a park, and you know, use it for a nature preserve and whatever, which I don't have a problem with that. But I'd like to see them extend that and involve a bike trail in there that would tie into the one that is presently over in Crosby Township. That would be something that the residents could use on a daily basis, and it's something that we need in this area.

4.4.4 Risk Communication

In the context of public health the FCAB has played each of the three roles in risk communication. The FCAB:

1. facilitated learning, or receiving, of information that played a role in formation of risk perceptions among FCAB members and between the FCAB and others in the community.
2. mediated the transfer of information between FCAB members and others (e.g., within the community, federal agencies);
3. created or generated information that plays a role in the formation of risk perceptions among committee members and among others that are non-members;

4.4.5 FCAB as Learners of Risk Information

The chair and facilitator of the FCAB intentionally established a forum for learning within the FCAB. FCAB did not only learn about technical facts. The chair and consultant also developed procedures for helping FCAB members to learn about each other's values and to learn about making trade-offs among alternatives on multiple dimensions (e.g., costs, health risk, environmental damage). They felt that members had to overcome their narrow self-interests:

[Initially] there were people in the CAB who wanted to clean it up . . . Originally it started 'get rid of it all.' Well, there are other issues. But if you are one of these very narrow minded person that says: 'I don't give a rat's butt about somebody in Nevada, I don't care about Georgia, I don't care about South Carolina, I don't care about Cleveland, I only care about Ross, I only care about my backyard. I want it gone.' Well, it doesn't exactly work out that way.

Thus, during the first six months, meeting monthly, they created an "intensive learning period" because FCAB members needed to be very well versed in the characteristics of the site and the clean-up alternatives being considered. The chair and consultant felt that major challenges were to maintain members' interest during the education process and to avoid overwhelming the members with technical information

(as discussed above in the section on Township Trustees, they were not always successful in this regard).

The Board chair and staff used a variety of methods to provide useful information to the members and to help them think about different options. For example,

- they created a “tool box” consisting of factsheets, technical summaries, and other information. They updated the information periodically.
- The designed an exercise, “Cleanopply,” to help people understand the DOE budget process.
- They designed a game simulation “Futuresite” to help members (and non-members) learn complex information about environmental contamination, health hazards, and potential future uses and to promote dialogue about options and their trade-offs (see Applegate and Sarno 1997 for more detailed discussion of its use). As part of the simulation, participants were required to use chose between on-site and off-site uranium waste disposal options while considering residual risk, budget constraints, environmental damage from soil removal, and public opposition to on-site disposal.

Furthermore, according to the Task Force:

Early in the process there was a great deal of mistrust in information provided by the DOE. However, the role of the consultant and the openness of DOE, FERMCO, USEPA, and OEPA throughout the process alleviated this mistrust over time. The unprecedented access given to the Task Force sometimes resulted in newly generated information being made available to the Task Force. In a few cases, key pieces of information changed over the course of the Task Force deliberations. Rather than create further mistrust, however, they changes were promptly identified, the reasons for the changes explained, and the revised information incorporated into the decision process. As a result, the level of trust in this information remained high. (Fernald Citizens Task Force 1995, pg 22-23)

Many of our interviews, supported this view:

They need to get some technical understanding. Fortunately, that was understood by a lot of the leadership and a lot the people. And so, some of the process is first of all getting comfortable with each other; second of all is getting some education, some real education. You know, what is the risk? What is the science of risk? What is that all about? And that was a big thing with us. And I am saying ‘us,’ the CAB.

What really helped us I think is that we went very slowly and we walked through everything. We met every month. It was a process that worked for us. We had a [toolbox] notebook and we would add to it every month, which is really helpful because then you can go back and review.

The Futuresite simulation was of particular importance for FCAB members and non-members (e.g., DOE HQ, contractors, regulators). The simulation was “run” in multiple meetings, including one that combined stakeholders, DOE HQ, DOE site, regulators, and contractors in organization specific and mixed groups. According to the FCAB consultant, the exercise led to “epiphanies for some members. They realized that ideological viewpoints did not make sense.” People who had different opinions had to engage each other, and encounter different perspectives. For example, the FCAB consultant observed that “stakeholders cleaned the site from the outside in, and technical people cleaned the site from the inside out.” They also encountered the difficulties of making choices. This is how the game worked, according to one of our interviews:

People sat with each other who didn’t want to sit with each other because we have these cliquy little groups. And then you had to spend so much money and what would you do with it this way, would you ship it here...All of a sudden we didn’t have any money at our table, we were broke, but we had all this waste kind of sitting here. And other tables were in the same boat that we were. It became glaringly obvious to all of us that there is not enough money to [clean-up the site to background levels]. So we started to badger and say we’ll just go back to Congress and we want this much money, we were trying to borrow money from others’ tables. And someone said this is not how we do it and we are always trying to change the rules. But I think that was probably the time the light dawned. [Clean-up to background levels] is not going to work.

As representatives of the broader community, some FCAB members, as well as the chair and consultant, were sensitive to the way that the committee could become isolated from the community: “After learning a lot, they could have become removed from the community.” They might be viewed as being co-opted.

In an effort to minimize the perception — or reality — that FCAB members would become “co-opted,” a series of community workshops were held. A set of workshops were held during the 18 months leading up to the first set of Task Force recommendations in 1995. Later, whenever a “big” issue was before the committee, additional community meetings were held. One example of such meetings was the series of workshops on future use of the site, as described below (also see Table 4 above). All of these meetings provided opportunities for FCAB members to learn from people outside of the committee. In some cases, however, tensions were revealed between the perceptions of those who were members of the committee and those who were not. While FCAB members may not have been “co-opted,” they did begin to form collective views about risks and appropriate future uses. This is illustrated by one FCAB member who stated that the meetings:

Were very hard. People showed up that had never been to anything else, saying ‘Well, what about horse trails [as a future use]?’ and we were all in the room just cringing.

Interviewer: People in the CAB or just FRESH people?

FCAB member: Everybody who had been through this stuff. You’re sitting there bickering with all these people you had never seen before, and they’re going ‘what about a wading pool?’ And we are going ‘Oh my god!’ They don’t understand. They live in the Township, so they have a right to do this, people who really haven’t lived around here as long as we have. And I also think people came in with a lot of self-interest.

4.4.6 FCAB as Mediators of Risk Information

The community meetings/workshops also provided an opportunity for the FCAB to provide information about risks to the broader community. The FCAB played an

important role as a source of information for non-members. Aside from the periodic community workshops, the FCAB used a variety of other mechanisms to provide information to the general public:

- a webpage was created, providing minutes of meetings, etc.;
- a newsletter and press releases;
- non-members were invited to participate in some activities, such as the Futuresite simulation.
- FCAB meetings were open to the public.

Within the FCAB, information was transferred to members as well. To address the challenge of making recommendations rapidly on technically complex issues the board's chairperson and facilitator attempted to foster an atmosphere where individual members and the whole group could come to their own conclusions. The consultant was tasked with:

- summarizing and “translating” technical information for CAB members and
- validating all information presented to the CAB (e.g., by DOE and contractors).

Thus, for example as mentioned above, they created a “tool box” consisting of factsheets, technical summaries, and other information. They updated the information periodically.

4.4.7 FCAB as Generators of Risk Information

As suggested above in the description of community workshops, the FCAB generated information that played a role in how risk perceptions have been formed within the FCAB itself. The committee was sensitive to moving beyond the larger community by virtue of their learning and group identity. For example, during the last few years the FCAB has endeavored to develop recommendations about the future use of the site. As part of this process the FCAB held a series of public workshops. One FCAB member estimated that 75–100 people came to each workshop. According to the FCAB webpage

To ensure that the surrounding community plays a significant role in determining the future use of the Fernald site, the Fernald Citizens Advisory Board developed a process that allows the community to provide direct and detailed recommendations to the DOE regarding issues of future use...The Future of Fernald Workshops were designed to provide citizens a direct voice in determining what kind of public facilities should be developed, as well as the types of activities that will be permitted on the Fernald site following the remediation.

The idea for the workshops emerged because some people in the community asked DOE to consider how a “positive legacy” could be left in the community. FCAB members wanted to learn what was the diversity and depth of opinions within the community, and thus they embarked on a process to collect information:

In late 1998 there was an environmental assessment document that DOE had to prepare in terms of final land use, and they had a hearing and a comment period, and during that hearing, some people in the community stood up, including some people from the Crosby Township Historical Society — folks that hadn’t been that active in the site to that point. They said, we want to have a positive legacy out here, we want to use this in a positive way for the community down the road and why don’t we start thinking about a cultural/educational center. The DOE did note that the public was interested in finding public uses for the site. From there, the [FCAB] stewardship committee picked it up and said we need to see in more depth is this really a community consensus or is this just 50 people that wrote letters to DOE. Because you never know who is writing these comment cards, it could be 50 crackpots that want something.

Three workshops were held (April 20, 1999, May 24, 2000, September 26, 2000). During the first workshop participants discussed the potential future activities at Fernald, including:

1. Native American history and remains;
2. public use of the land;
3. environmental education; and
4. local and Cold War history

The second workshop (which was also broadcast on the internet to allow participation of people that could not physically attend) asked the 100+ participants to consider potential future uses in terms of:

- What are the things you would most like to see as possible community assets at the site?
- What are the things you would definitely not want to see at the site?
- How would you like to see these assets managed within the community? Where should long-term support come from and who should be involved?

The third workshop was held to give the community a chance to discuss and reach consensus on a vision statement that was developed by the FCAB Stewardship Committee. The vision statement is provided in Table 4, above. The FCAB continued to generate its own information for informing discussions of the future use of the site by a feasibility study of the design and construction of an education facility (sponsored by the FCAB under a grant from the DOE; it is open to Ohio colleges and universities).

The “results” of the workshops were important, according to FCAB members we interviewed, in the formation of their recommendations about future use and their need to work more closely with the community to ensure acceptance of specific uses. In particular, a number of residents were alarmed at the thought of public access to the site, particularly close to the on-site disposal facility. Although such access would have minimal risks, the FCAB realized that the community was not yet ready to envision the site as a safe, accessible property and that the FCAB would need to do more education and dialogue before such activities could be discussed.

4.4.8 Interactions with Other Networks

4.4.8.1 FCAB and Township Trustees

Trustees from different townships were members of the FCAB at various times, including the period when the recommendations were developed about retaining radioactive wastes onsite in the disposal cells and during public discussions of the future use of the site.

Three Trustees we interviewed thought that the decision for on-site disposal cells was actually made by DOE in advance of the FCAB deliberations — a belief that reflected a deep distrust of the process and DOE:

I don't know, a lot of it seems to me like they already had a plan and it didn't matter what I said or anybody else said. That's the impression I got. They already knew what they were going to do. So all of this stuff was just good PR brought on by them—that's my personal feeling, they already knew what they were doing.

Early on in the CAB's existence, when I was serving on the board . . . They showed us numerous slides of disposal cells around the world, and I thought: 'why are they showing this?' . . . And everybody was confused running around, why in the world are we going to do this type of thing. There were probably 10 or 15 sites, something like that, some were mounds, some were underground, some were, you know, different types. And to me, the decision had already been reached. They were just going to get people in place, committees in place to make it look like the committees came up with this idea. Well, this idea initially, and probably very few people even realized this, was presented to us that way. Sort of like the illegal thing they do with commercials where they take one frame and show a frame of popcorn and then later in the movie, it works on your self-conscious, and I wonder if, by seeing those disposal cells that that was supposed to lead us toward that as a final resolution to this whole problem...Pushed is probably too strong of a word. I felt like it was being suggested and guided toward that final outcome without our knowing it. Very subtly.

The following quote from a Trustee echoes the distrust of DOE, but it also suggests (at the end) that trust is being regained (*emphasis added*):

If you lie to me, from that point on, I will think that everything you tell me is a lie, because I have nothing else to gauge it by. So, in my opinion they lied to us from the beginning, and they being some of the people that were in management or mismanagement. At that point, I didn't know who to believe and who not to believe. When you have a guy look you right in the eye and tell you, we're doing core samples in this area to satisfy the people in Nevada where we're taking this stuff, to prove to

them that we can't keep it on-site, and then you have a guy come behind this, a construction guy, and say, they've had plans drawn up for two years on a disposal site, and you're on the site, one of em's lying. I tend to believe the guy that told me that they had the plans, because they came up with a disposal site. So I kinda think the lied to us, and *then it took a long time for me to start to believe them again.*

Distrust of the advisory board process was also reflected in the comments of a Trustee who was never a member:

I am sure people are well meaning people but I think it is probably just a waste of time. Citizen advisory boards generally are just political puppets. I have been on one myself and generally they are looking for some citizens to endorse what they want to do and make it sound good. That is my opinion of that.

During the development of the recommendation for the OSDF, and subsequent to its planning and construction, many Township Trustees' opposition mellowed. Those we interviewed have now turned their attention to the future use of the site and the longterm reliability of the cells. The Trustees concerns about the OSDF and future use of the site are primarily related to stigma associated with contaminants being left onsite. Concerns about stigma were often about the potential economic costs associated with the area being perceived in a negative light, as suggested by this Living History interviewee:

I think a lot of people seemed to feel like, I'm glad it isn't us living by it. And I actually felt like some of them thought, oh, they're all radioactive...I still find when I got to government conventions or something and mention that Crosby Township is the home of Fernald, they all kind of laugh and say well I'm glad it's you and not us. So it's got a stigma with it. (Harper, pg. 14)

The stigma associated with economic loss is not just an abstract possibility. Community members reported experiencing real economic impacts:

The farm was an inheritance, we were all proud of that because no matter what else we had, we had that farm. After it came push to shove, you found out that farm wasn't worth squat [because of contamination from Fernald].

It's kind of a black-eye for our community. I mean it's not a building block, it's not something that we want to go around and say, hey come to Ross Township, and you can live next to the Fernald nuclear plant. I mean it's not something that I feel has been beneficial to this community. But I think it has provided a lot of jobs over the years. It still provides a source of economic income, because of the jobs, and the impact on the rest of the businesses in the community. And when they finally walk away from it, it definitely will have some impact on our community, because there'll be a loss of the jobs and the income.

For another, one way to deal with the stigma is to help people forget. This desire ties in directly with preferences for the future use of the site:

Residential [use] would be nice, so people could get by the stigma of what's there.

I don't know why anybody would want to go out there and take any kind of a risk. I don't think I want to go there, I mean, I don't care what people would say. I just wouldn't want to take that kind of a chance, really. I think the best thing to do is just let it go. I know they are trying to be creative and thinking of uses for the site but, again, my high opinion is 'put a fence around it, let nature take over and forget.'

4.4.8.2 FCAB and FRESH

The Fernald Citizens Advisory Board provided a place for FRESH to learn, to gain a *fresh perspective*:

I think when you do this work for as long as we've done it, you begin to get some blinders on your eyes and you only see what you want to see. And I think when the idea of the FCAB got floated out there, we were very overwhelmed and thinking 'boy, you know we need some help here.' And you know, 'how clean is clean? And 'we only have so many resources to go to.' And they seated the CAB and it was a very good thing for us because it brought in some people who hadn't been involved. (Crawford, pg. 18)

Initially, FRESH was worried that the FCAB was "a way to get around the community." FRESH core members were "adamant that the CAB be balanced and that it

have people on it that we could trust.” They gained a high degree of trust in the CAB process when the convenor, Eula Bingham from the University of Cincinnati, consulted FRESH about possible members, and even allowed them to choose community representatives.

It’s good, its effective, they have got a good variety of people on it, which partly occurred because we helped to formulate the types of people that we wanted on it. When they formed that board, Lisa and several of us were interviewed by the lady who put the board together. She picked the actual people, but she talked with us so she knew the things that were important, so that she wouldn’t create a board that had some flaws in it so it would be doomed from the start. So, its working real well. Some of the things that it’s heading toward I don’t necessarily agree with, but it is a democracy.

They also gained trust in the process based on the actions of the first chair, John Applegate, who was perceived to be very fair.

It has been a long road trying to get them to sit down and listen to the stakeholders and view the stakeholders not as an enemy but as an ally. But when that switch in their thinking occurred, then we could get together and really look at the problems and to try to see the solutions, and make the compromises that might have to be made as far as clean up level. So, it helped when we were all on the same page. It almost has become the site people with the community against the federal government saying ‘we need the money, you owe us a cleanup’ — and so it is definitely a different situation.

The FCAB and FRESH have continued to work together on key topics, including the future use of the site. In particular, the FCAB invited FRESH, as an organization rather than through membership of specific individuals, to co-sponsor the Future of Fernald Workshops with the Stewardship Committee (FCAB also invited the CRO and the Living History Project to work with the FCAB Stewardship Committee).

Through their participation in the FCAB, FRESH members developed important relationships with others. For example, the FCAB was a point of convergence for multiple networks, including FRESH, workers, and Trustees.

And she's been a big salvation to the worker as far as safety and jobs, whether they know it or not. Well, you wouldn't have had that insight if you didn't have an opportunity to work with [FRESH members on the FCAB], and if you didn't have an opportunity to understand her personality. [We] are good friends . . . It takes you a while to develop that friendship . . . If I have to talk to her about something confidentially or if I say: 'listen I want you to be aware of these things, is there something we should do together here?' . . . It takes a while to develop this comradery.

FRESH members' points of view were significantly changed by their participation on the FCAB in some instances. In particular, FRESH moved from a position of advocating that the site be completely cleaned-up to background levels of contamination to accepting on-site disposal of wastes and residual risks to be managed through longterm stewardship activities. For core FRESH advocates the decision to accept and advocate for on-site disposal of waste was an "epiphany" based on learning and social interaction.

Furthermore, FRESH "took quite a bit of heat" from people in the community for their reconsideration of their opposition to leaving any contamination onsite. Their change of view was based on informed consideration of what they had learned from participation in the FCAB and from independent experts.

Interviewee: We came to the realization that there is not enough money in the entire federal treasury to pay for [clean-up to background levels]. We also looked at if you took it to background, we would have had to go way off site — we would have a moonscape, and gone through a whole bunch of people's property. The regulators have assured us that [the agreed upon levels of residual contamination] are safe.

Interviewer: 'This is safe' sounds like a scientific determination. It sounds from what you just said that it wasn't really that, it was economic.

Interviewee: We looked at it in dollar signs but we also had to look at it from the scientific side too. [Independent expert advising FRESH] had to assure us that this was an OK level. We found that across the country, these were OK levels. They're not perfect. Tolerable. We always know there is going to be a risk, it is small but there is a risk. This is our burden. People will hopefully learn from the mistakes that were made here. It's a legacy. A lot of people have died. There are heroes in a lot of different ways.

At the same time, FRESH core members we interviewed were very concerned about the quality of recommendations, clean-up activities, and health studies. As one interviewee who is a peripheral member of FRESH stated:

In time, as [the FCAB] starts talking about future use of the site, I do think you will have a bit larger group of people, and frankly, that is viewed as a mixed blessing by the core [FRESH] group. Because let's say for example, someone from Ross who is a realtor comes in and starts stirring up trouble — what is all this stuff about this on-site disposal facility, and they haven't been involved in the debates up to this point and they really could throw a monkey wrench at this. I don't know how I feel about that. You are sort of liberal democratic idealism would say, more participation is always better. But I don't know. In this case, with this sort of discussion, I don't know what that would lead to in terms of discussion about some of the more technical aspects of clean up. For example how much of a discussion could you have with folks that have not ever come to a Fernald meeting before about this re-base line [of the budget]?

Although this observation could have important implications for who is viewed as a legitimate participant in discussions of clean-up, we found no evidence that the FCAB or its members explicitly grappled with this problem.

5. Discussion of Findings

We have conducted an exploratory case study on the roles of social networks in risk communication about low dose radiation risks. Our case study focused on the Fernald Environmental Management Project (FEMP), a former nuclear production facility located in a rural, residential area 18 miles northwest of Cincinnati, Ohio. The site operated from

1951 until production was suspended in 1988. The main activity of the facility was to produce highly purified uranium metal products (“feed materials”) for US defense programs. We studied the risk communication experiences of people in the community about two types of risks: a) the assessment of historical releases of radiological contaminants and b) the disposal of wastes on-site. In the case of historical releases risk communication we focused on the public health risks. In the case of the on-site disposal cells the risk communication efforts centered on future risks to the community from residual contamination. These two issues, within a much larger set of issues dealt with in the community, provide a rich source of data about how the risk communication efforts were experienced and how social networks played key roles in shaping opinions about the risks.

Our approach to understanding the dynamics of risk communications about these risk sources was to enquire into how social networks generated, mediated the communication, and facilitated learning of risk-related information. Specifically, within each nodal network we focused on the following:

- the ways that networks were formed and emerged, and
- the way that information flowed inside the nodal network and between networks,
- the kind of interactions that happened among individuals within the nodal networks that helped people shape their risk perceptions,
- the ways that nodal networks generated their own information,
- the ways that nodal networks mediated the transfer of risk-related information among members and between networks,
- the ways that nodal networks facilitated or prevented learning among members about risks,
- non “risk” factors that were important to the formation of beliefs about the risk, such as trust and stigma.

Two pairs of social networks were discussed. The first pair were existing social networks within the community that concerned themselves with risks arising from

Fernald: local government officials in the three townships affected by Fernald and the citizens watchdog group Fernald Residents for Environment, Safety, and Health (FRESH). The second type of networks were two advisory boards established by acts of federal agencies, the Fernald Health Effects Subcommittee established by federal public health agencies and the Fernald Citizens Advisory Board (formerly the Fernald Citizens task Force) established by agencies focused on clean-up and future use of the site. These boards were points of convergence for members of other social networks. Yet, through sustained periods of meetings and deliberations they emerged as new, formal social networks in their own right.

We found that for each social network there were important factors that helped people shape their risk perceptions. They included technical understandings of radiation (or the lack thereof), familiarity with radiation, evaluations of the scientific understanding of risks, the availability and use of technical reports and presentations, quality of experiences with agency and contractor management, trust in the DOE, CDC, ATSDR, and FEMP contractors, perceptions about the degree to which agency staff cared about the community and its needs, concerns about stigma (e.g., economic impacts), perceived access to information and independent technical experts, perceived quality of the decision making processes, participation in group activities (e.g., FUTURESITE simulation), and personal experiences and observations. Many of the factors were similar for each network, although the ways that they affected members of each network or their relative importance varied.

In the following sections we discuss six key themes that arise from our analysis of how the networks generated, mediated the communication, and facilitated learning of risk-related information. These themes are the role of personal relationships, trust, technical competence, ebbs and flows of attention and resources, struggles over voice, and networks as generators of risk information.

5.1 Personal Relationships

Our definition of nodal networks is based on the flow of information. Nodal networks are groups of individuals connected by channels of information flow about a central identifying theme or purpose that is shared. The links between members can arise from

direct personal interactions, sharing of written materials, and other forms of communication. They are not defined, necessarily, by ideologies, membership or employment, or even shared risk perceptions.

We found in our analysis of this case study that the character of personal relationships was a critical underlying factor in the sharing of risk-related information and formation of risk perceptions. Personal relationships were formed — and broken — among individuals within networks (e.g., members of FRESH) and between networks (e.g., Township Trustees and FRESH members). They affected the flow of information and the shaping of risk perceptions in several ways.

First, personal relationships provided access to information about risk-related issues. The quality and substance of information have been important elements in the shaping of risk perceptions about low dose radiation risks from Fernald. For example, core FRESH members were able to pick up the telephone and call managers at any time — and get a response to their questions. The stability of staff at Flour-Daniel facilitated the development of such access by helping them develop personal relationships with people in the community. The Fernald Envoy Program is another example of how access to information from the site contractor was created. As described above (section on Township Trustees) personal relationships with liaisons from the site were important to the credibility attributed to information. Similarly, personal relationships of FRESH members with others in the community allowed them to gather sensitive and private information for the health map (see below).

But, not all information was accessed through formal channels. Several people we interviewed from FRESH and the group of Trustees discussed the importance of informal communications for risk-related information. They also relied on informal relationships. For example, a Trustee felt he received more information from informal interactions in this small rural community than from other “official” sources like DOE or the site contractors. The evaluation of the Fernald Health Effects Subcommittee also found that informal communications were important between CDC staff and members of the FHES. Finally, informal channels of communication were important to FRESH, whose members learned “insider” information about risk related issues from workers on the site.

Second, relationships were important to the perceived trust of others. Such beliefs had implications for the shaping of risk perceptions within the nodal networks. For example, trust was important to whether individuals in each of the nodal networks believed the information provided to them by the DOE or site contractor was credible and believed that DOE and the contractor were committed and honest risk managers. In the early years of this risk controversy, deep feelings of distrust emerged among Trustees and FRESH members toward the DOE and FEMP contractors. People felt lied to and betrayed. Later, FEMP Flour-Daniel had to work hard to regain trust by Trustees and FRESH so that risk studies and information they provided members of these networks was believed. We learned that one factor contributing to such feelings was that turnover of site management and staff before 1992 hampered the formation of trust because *personal* relationships were not well-formed, for example, with Township Trustees and members of FRESH. In this sense, access helped to foster trust.

At the same time, personal relationships were not always enough to overcome institutional distrust and barriers to the sharing of risk information. For example, FRESH members and Township Trustees could express trust in individual managers with the site contractor or staff with the DOE, but they held continued, deep distrust of DOE as an organization because of the legacy of lies that were revealed since the 1980's. A similar dynamic occurred in the relationships between FHES members and the CDC. FHES appear to trust the staff from CDC who managed the FHES.

Personal trust was also an important factor in the shaping of perceptions toward FRESH and, consequently, the shaping of risk perceptions among Township Trustees and members of the FHES and FCAB. They learned that sensitive discussions could take place with core FRESH members in confidence. In addition, while core FRESH members had strong opinions, others felt that they were not unreasonable or unwilling to shift views based on new information (e.g., change in support for epidemiology study and on-site disposal of wastes). In turn, they became more willing to listen to and consider risk-related information from FRESH, including information they brought to discussions from outside, independent experts. Again, a factor that played a role in the development of personal trust among these networks was longterm stability of key individuals. Core FRESH members were, often, longterm residents in the community. By repeated

interaction members of these networks were able to feel confident that FRESH members were informed and committed. In this sense, trust helped to foster access.

This dynamic highlights a third role for relationships in the sharing of risk-related information and the formation of risk perceptions. Social interaction in deliberative settings was a critical mode of learning and important in the formation of risk perceptions. Learning was not just based on individual efforts or information per se. Relationships were critical. Personal relationships affected learning within and between networks about both technical information and the values of others. In particular, the advisory boards, FHES and FCAB, created important venues for the development of new relationships and learning. Core FRESH members spoke of their support for the FCAB, in part, because it would provide a place for people with different opinions to engage each other in dialogue and encounter different perspectives. The FCAB was a point of convergence for multiple networks, including FRESH, workers, and Trustees. In addition, as core FRESH members developed personal relationships with independent experts they were able to learn important technical information about clean-up technologies and dose reconstruction.

We found additional examples of personal relationships supporting learning, and strong suggestion that they helped to form of risk perceptions. For example, personal relationships between an Envoy Program Liaison and the Township Trustees played a key role in how risk information was understood — how well learning took place. New information and a renewed faith and trust in FEMP management and regulators played roles in the evolution of Trustee's risk perceptions. As another example, FRESH members developed relationships with community activists concerned about other DOE nuclear weapons facilities (i.e., once called the Military Production Network, now the Alliance for Nuclear Accountability). In fact, these relationships were critical to FRESH's developing understanding that they should not demand that the Fernald site be cleaned-up to "background levels." From people from other DOE-affected communities they learned that wastes from Fernald would impose risks on others — and they would not do this.

Fifth, personal relationships facilitated dialogue and reaching agreements. The ability of core FRESH members to debate and reach agreement on controversial issues, such as onsite disposal of wastes, depended in large extent on the quality of their relationships. Similarly, the FCAB chair and facilitator worked hard to establish respectful relationships that supported listening and constructive dialogue among members of this network. The quality of these relationships, we learned, supported members' ability to discuss controversial subjects and to reach agreements (and make recommendations) about controversial issues.

Sixth, the ability of a network to generate information was based, in part, on personal relationships. The way that relationships can support the gathering of new data is exemplified by FRESH's efforts to create a "health map." FRESH core members were able to gather potentially sensitive private information from people in the community because of the personal relationships established within this stable, rural area. As discussed previously, the health map was important to the shaping of risk perceptions. In addition, people in the community learned they could trust core FRESH members, which enabled FRESH to continue to collect data for the health map. Core members were adamant about refusing to provide contact information to the CDC about who specific pins on the map represented. FRESH promised confidentiality to its informants and strictly maintained that confidentiality.

Finally, personal relationships allowed deference to other network's positions about risk. For example, a Township Trustee expressed to us in an interview that he accepted, grudgingly, longterm onsite disposal of wastes at Fernald because he deferred to FRESH's stance on this issue. Similarly, we observed that peripheral members of FRESH would defer to the stances of core members about risk management controversies. Unlike the findings from the sister case study on the tritium release controversy at Brookhaven National Laboratory (Webler 2002), we did not find evidence here that interpretations of risk-related information were settled by ideological forces or that members of a networks conformed to established beliefs about risk. Rather personal relationships supported such deference. It is unlikely that such deference would have been extended if close social ties did not exist.

5.2 Trust

Trust was a salient dimension of risk perceptions among members of the four nodal networks. In this section we describe how trust toward two risk management institutions, DOE and CDC, evolved and helped to shape perceptions about risks and those institutions. In addition, our case study suggests that “openness to sharing information” and “respect” are two underlying dimensions of trust, in addition to competence, predictability, caring, and commitment that have been proposed previously (Kasperson et al. 1992).

Early risk perceptions were formed in a context of strong distrust of the DOE and site contractors (National Lead of Ohio and Westinghouse). Members of the larger community, including Township Trustees and members of FRESH, felt lied to and betrayed. They received inconsistent risk messages. They felt they lacked critical information. Similarly, within the FCAB initially there was a great deal of mistrust in information provided by the DOE.

The DOE, as well as Flour-Daniel, USEPA, and Ohio EPA, worked hard to regain the trust of the Fernald community. In spite of the oft-stated belief that trust, once lost, is hard to regain, we found that DOE-Fernald and FEMP were able to regain trust with FRESH, Township Trustees, and the FCAB (as opposed to DOE Headquarters). The renewed trust, however, was conditional and not unanimously shared among members of these networks.

As described above, feelings of trust were related, in part, to the emergence and stability of personal relationships among members of the nodal networks and DOE staff onsite (as well as Flour-Daniel managers): “when you get to know people and been in enough meetings and you started working on projects with them, hopefully you can tell whether they’re telling you the truth.” We found that trust was also based on:

- perceived technical competence;
- willingness to share new information, even if it was “negative”;
- perceived willingness to listen and consider alternative points of view;

- consistency of information, including consistent statements that knowledge was uncertain;
- belief that input mattered to risk management decisions; and
- ability to verify, independently, claims about risk.

These factors are related to those that have been proposed as critical to perceptions of trust in risk controversies: competence, care, commitment, and predictability (Kasperson et al. 1992). However, they also reflect something more. The perceived openness of the risk management institutions was also important to the re-emergence of trust by FRESH and Township Trustees. We found that its re-emerge after a period of deep distrust and feelings of betrayal was associated with people's ability to verify information and the basis for decisions and explore hidden agendas, whether real or perceived.

Another issue associated with the re-emergence of trust was respect. For example, as an advisory board established by the DOE, the FCAB (then the task Force) was initially met with some distrust by members of FRESH. Initially, FRESH was worried that the FCAB was "a way to get around the community." However, they found that their opinions about the make-up of the committee was respected. Such feelings of respect helped to gain the trust of FRESH in the process, where they ultimately learned and shaped risk perceptions. Similarly, members of FCAB received clear feedback from the site and DOE that their input mattered; this was a sign of respect for their time, effort, and preferences.

In addition, we found that trust worked at different levels. As described above, members of the FCAB, FRESH and Township Trustees expressed feelings of trust toward individuals who worked for DOE and the site contractor Flour-Daniel. On the other hand, they did not express the same degree of trust toward the institutions themselves: "the level of trust toward the agency as a whole hasn't probably changed."

We also found that feelings of trust could vary among individuals within a nodal network, while the network as an entity as a whole could extend trust toward another (group or organization). For example, some Township Trustees expressed to us continued

distrust of DOE-Fernald. However, as a network we found that, overall, the DOE-Fernald was a trusted source of risk information and risk manager.

The history of relations among the nodal networks and the risk management institutions responsible for clean-up of the site suggest that trust can be regained. The experience of the CDC in this case provide another example of how easily trust can be lost. Unlike the DOE and Flour-Daniel, the CDC initially held the trust of the community when they arrived to work on public health impacts. When the CDC dissolved the FHES in 2001 they left under a cloud of distrust and resentment. Trust was lost when the CDC was perceived as uncaring, uncommitted, and disrespectful, even while it was simultaneously viewed as a competent and open source of risk-related information.

In particular, risk-related views of FHES members were affected by growing perceptions that the CDC was not willing to study the full range of potential health effects from Fernald and that the CDC was not able to address the community's "real" needs. Although CDC staff disagreed with this characterization of what happened, the point is that these were the salient beliefs of FHES members we interviewed. This had an important effect on the risk perceptions of those we interviewed: even if the risks of the diseases that were studied were viewed as low, other, unassessed risks were viewed as potentially being significant and the "real" needs of the community remained unmet. CDC as a risk management institution was viewed as wanting.

In addition, the relationship between the FHES and FRESH was strained because of the way that the FHES operated. FRESH did not have input into how the Subcommittee was formed and who would serve as members — unlike their experience with the FCAB. They felt that some of the individuals appointed to the FHES had conflicts of interest and that too few members of the community were selected. There was resistance within the FHES to accommodating the wishes of FRESH members to hold meetings at different times and more frequently. FRESH took these as signs of disrespect from the health agencies. A feeling of disrespect exacerbated the view that the CDC was not committed and did not care deeply about the risks faced in the community. It influenced the creation of distrust and the shaping (e.g., strength) of risk perceptions among the FRESH network and some non-FRESH members of the FHES.

5.3 Technical Competence

As described earlier one factor in the shaping of risk perceptions was the formation and quality of personal relationships. A second factor was technical competence. Like personal relationships, technical competence was mediated by social interaction within and among networks.

Gaining technical competence was a primary goal within the nodal networks studied. For example, FRESH members worked hard to become educated about the issues. Core members felt that they had to be well-informed in order to be credible participants in decision-making processes about site clean-up and health studies of risks from historical exposures. In the end, FRESH was viewed as a credible source of information; sometimes they were viewed as *the* source of information. Within other networks, some individual's perceptions of risks and risk management were influenced by the views of FRESH. Similarly, the FHES help meetings that allowed members to discuss the details of strengths and weaknesses of epidemiological studies for assessing the risks from FEMP historical exposures. These opportunities went beyond seeing network members as passive recipients of information. Rather, the networks established interactions that enabled the members to be actively engaged in learning and interpreting risk communication messages.

FRESH members gained competence about complex risk topics in a variety of ways. While, for example, they read on their own, social interaction was critical. FRESH members learned from regulators, independent experts, and contractors at workshops and meetings. Through their interactions with others from outside of community (MPN/ANA), FRESH members learned about the risks faced by other communities and the impacts that would result from transfer of wastes. Within the networks created by the advisory boards, FRESH members — as well as Township Trustees — learned about, for example, dose reconstruction and health risk assessment methods, the concept of statistical power, budgetary issues, and clean-up and waste isolation technologies. The FCAB used an innovative approach to learning with a simulation game to help its members understand tradeoffs related to resources (e.g., budgets) and clean-up levels. Its

members, too, understood the need to be well-informed if they were to play a useful role in decision-making about Fernald risks.

The technical competence gained was important to the formation of risk perceptions. As discussed, Township Trustees, FRESH, and FCAB members were for the most part in strong support of a complete clean-up of the site after closure. As they learned more — together — about the technical feasibility of such a goal, the economic costs, ecological impacts, and consequences to other communities that would receive removed wastes, these networks began to consider the option of onsite disposal of some wastes. They grappled with the question: what was an acceptable future risk to the community from waste cells onsite? And, most members of these networks agreed to their use. As we have observed in much of this case study, however, there was rarely complete agreement. For example, some members of the FCAB and Township Trustees felt that the onsite waste disposal cells were not a good solution to the management of contaminated wastes from the site.

A similar effect of learning was observed within the FHES. Like FRESH, FHES members for the most part were advocates of having CDC conduct an epidemiology study in the community. However, after learning about epidemiology methods and limitations within the FHES and other venues, this view changed. They began to understand that the utility of an epidemiology study in the community would be limited because of low power and they supported CDC's decision to not do an epidemiology study.

5.4 The Ebbs and Flows of Attention and Resources

The nodal networks concerned with risk issues around Fernald were not just involved or uninvolved. Their attention and participation in processes related to risk management ebbed and flowed. The degree to which networks involve themselves in particular risk-related processes, including formal deliberation and informal community organizing and risk communication, has implications for the ways they help to shape risk perceptions. Similarly, how they structure *who* pays attention and is involved can also have important implications for how risk perceptions are shaped within and among networks.

First, the involvement of networks can change. For example, during the development of the recommendation for the OSDF, and subsequent to its planning and construction, many Township Trustees were actively engaged in seeking risk-related information and discussing risk management options. Those we interviewed have now turned their attention to the future use of the site and the longterm reliability of the cells. The Trustees concerns about the OSDF and future use of the site are primarily related to stigma associated with contaminants being left onsite. Moreover, instead of actively seeking out information themselves, they more frequently turn to other networks for information, including FRESH. As discussed above, FRESH is viewed as a trusted and technically competent source of information. They also turn to the FCAB for guidance. Such dynamics suggest a topic for further research: how does the timing and degree of involvement of different networks in risk-related communications affect the formation of risk perceptions?

Second, members of the nodal networks often found themselves overwhelmed by information. Sometimes it was the complexity of information that was overwhelming. In other cases it was the sheer volume. The nodal networks adapted to this situation by distributing labor and resources within the network. The two advisory boards created subcommittees and working groups. The FCAB relied on a facilitator that received high marks for his abilities as a “science translator.” On the other hand, the Township Trustees and FRESH formally assigned specific individuals to focus on particular topics. Within a Township the Trustees selected one member to attend to Fernald clean-up and/or health effects. The distribution of attention was achieved in two ways within FRESH: a) assigning particular core members to focus on specific subjects (e.g., health, clean-up technologies, clean-up budget, political organizing and networking) and b) by people self-selecting as core or peripheral members. These kinds of structural arrangements suggest two topics for further research: a) how is critical information shared within a network? and b) how important are “key individuals” at defining the risk perceptions of others within a network?

5.5 Struggles Over Voice

The ability of social networks to influence risk perception within a larger community is related to the power of their voice. “Voice” is related to credibility and the social legitimacy of leadership and it can help to shape risk perceptions in two ways. First, as a group gains voice their views may be more widely shared and perceived as credible. Their views can gain persuasiveness. Second, as a group gains voice they can gain the power to speak *for* others. They can claim to represent the views of a larger community of people, including those that are not formally part of the nodal network (whether as core or peripheral members). The dynamics by which such effects on risk perception can occur is an important topic for further research.

Within this case study we found several examples of struggle over who best represented the risk perceptions and spoke for the views of “the community.” One example is the way FRESH struggled to gain a voice within the community, and to be perceived as credible stakeholders. This was in part a struggle over how they were characterized or framed. FRESH attempted to portray themselves not as activists or “hysterical” housewives. They made a clear choice to not be “anti-nuclear” but rather to focus on health of the community. According to a core FRESH member we interviewed, DOE, site contractors, and Trustees all attempted at one time to paint a different picture of FRESH, and influence the community’s attitudes toward the group. DOE, for example, tried to characterize FRESH members as “activists,” a rhetorical move resisted by FRESH because of the way that term was reacted to by residents in this rural community.

The interactions between the Township Trustees and FRESH is a second example of a struggle over voice. Some Trustees raised the question about who legitimately speaks for “the community.” Trustees spoke of their discomfort with not being perceived as fully informed spokespeople and representatives of the community — even while FRESH was viewed as *the* source of information, because it has access to information that was not available to others and even while simultaneously respected and supported the critical role played by FRESH in the ongoing controversy.

5.6 Networks as Generators of Risk Information

Nodal networks can analyze existing data in a new way or conduct their own research to gather new data. In either case, the network provides new information to people that can inform risk perceptions. Usually the information is generated and shared in a social context.

For example, FRESH core members began to gather information from other community residents about the incidence of cancers and other diseases. This resulted in the creation of a “health map,” that, in turn, played an important role in communicating about risks with non-FRESH members in the community as well as politicians (e.g., Senator Glenn’s staff, who later supported legislation calling for an epidemiological study in the Fernald community). It played a critical role in shaping risk perceptions among FRESH members who observed clear patterns among instances of diseases and fatalities in the community. In addition, the generation of risk-information through interactions with community members had secondary effects. In particular, the health map may have helped to influence perceptions of FRESH as a credible and trustworthy watchdog group (e.g., by Township Trustees, FHES). Core FRESH members were adamant about refusing to provide contact information to the CDC about who specific pins on the map represented. FRESH promised confidentiality to its informants and strictly maintained that confidentiality.

The FCAB also generated its own information. It gathered, through a series of public meetings it sponsored, data about the diversity and strength of views in the community for the future use of the Fernald site. This information helped to shape the perceptions of FCAB members. This does not mean that FCAB members necessarily agreed with what they heard. Rather, in some cases it reinforced their opinions that more education with the general public was needed as to why residual contamination should preclude certain uses (e.g., bike riding). As in the case of FRESH, the FCABs efforts to gather input from non-members may have played an important role in how it was perceived within the community.

The generation of risk-related information was not a role played by all of the nodal networks studied. FRESH and the FCAB generated their own information, while the

Township Trustees and the FHES did not. The reasons for this difference appear to be complex, but included considerations about:

- availability of resources. For example, Township Trustees did not have the resources to start their own data gathering efforts in the community;
- roles and responsibilities. For example, CDC viewed it as their responsibility to conduct (or have contractors conduct) the the studies;
- expertise. For example, CDC did not view the FHES members as having the appropriate expertise to design and conduct studies, even though they were viewed as important for providing recommendations about them. On the other hand, some Township Trustees held implicit assumptions that, as elected representatives, they knew the concerns of the community.

5.7 Summary

Underlying our analysis of the four nodal networks studied in this case study is the idea that discourse can generate new understandings about issues, perceptions about risks, and preferences for alternatives. Social interaction is used as a means to allow for the emergence of new meanings. This conceptual understanding is borrowed from a framework that describes how a communication functions to generate new meanings as listeners and speakers use utterances as “thinking devices” (Tuler 2000).

Risk communication research often rests, implicitly or explicitly, on a transmission model of communication (Renn 1992). We found that the four nodal networks acted as channels for conveying existing information from one group to another, as suggested by this model. Information is sent from a source, through a channel, to a receiver of that information. For example, the FCAB placed much emphasis on creating an atmosphere where individual members and the whole group could come to their own conclusions. Each member was provided with a “tool box” consisting of factsheets, technical summaries, and other information; this “tool box” of documents was updated periodically as new information, reports, etc. were made available. In this sense, the networks played the role of a channel of risk communication messages.

The sender-receiver model also characterizes “errors” of interpretation between senders and receivers of risk messages as arising because the “true” meanings are not correctly preserved by message recipients. However, semiotic theory can offer another possibility: that the message is used as a “thinking device” as part of a creative, dialogic function of communication. The recipients of risk messages may be playing a different “semiotic game” than the risk manager/communicator. Similarly, recent research has highlighted the ways that risk controversies are “amplified” or “attenuated,” in part as a result of the ways that “risk signals” are interpreted and the ways that symbols (semantic images) play a role in the generation of social meanings (Kasperson et al 1988, Kasperson 1992, Renn et al. 1992). In other words, generative meaning making activities are “rational” (Wertsch 1990). Our findings support the claim that the transfer of risk information does not imply that no reinterpretation or reframing occurs. Rather, it is to be expected that meanings are *not* preserved completely as information is provided to others. For example, FRESH publishes newsletters summarizing new reports from the DOE, but it also provides commentary about the strengths and weaknesses of that report. Similarly, The FCAB’s tool box was based on summarizing and “translating” technical information for CAB members.

This conceptualization of risk communication has important implications for how the activities and participation of agencies, researchers, local officials, and community members are understood and judged. In addition, it has implications for future research, as discussed in the following section.

6. Conclusion and Suggestions for Future Research

The Fernald Environmental Management Project’s efforts to understand and manage 1) public health risks from historical releases during site operation and 2) residual contamination from onsite disposal of wastes and the future use of the site provides a rich case study for those interested in the dynamics of risk communication. The exploratory research reported here illustrates the importance of social interaction in the formation of risk perceptions among members of groups and of the ways that risk information flows within and among social networks in a community facing a hazard. This is an underdeveloped area of social science research on risk issues. In the previous section

several key themes emerging from the analysis of the case study were discussed, and their implications for future research highlighted. In this section we suggest additional questions that were raised by this research and can usefully be explored. In conclusion, we offer suggestions for areas of further research (in no particular order of importance).

First, in prior research trust has been conceptualized as arising from four factors: predictability, consistency, competence, and care (Kasperson, Golding, and Tuler 1992). Our findings suggest that these were important factors in establishing and undermining trust among individuals, groups, and organizations in the Fernald community. However, another factor also played a role in feelings of trust toward the agencies in this case. It has to do with the ability to verify, independently, the claims of the agencies, the contractors, and experts conducting studies and analyses on behalf of the agencies and site contractor. The importance of “openness in the sharing of information” and the way it interacts with the other four factors is an interesting topic for further research. We also found evidence of a concern about respect in attributions of trust/distrust. While respect may be related to the dimension of caring, it may be an additional dimension in its own right.

Second, we found that technical competence was an important goal within the nodal networks. While there is much concern over the need for technical competence within risk communication literature (e.g., NRC 1996), there is a paucity of research about how social interaction facilitates or limits learning within risk controversies (Depoe 1997). With increased attention to the need for “analytic-deliberative” processes (NRC 1996) and forums for public involvement, greater attention to group learning processes would be helpful for scholars and practitioners.

Third, risk communication research often rests on an assumption that the sender-receiver model is valid. However, this research provides additional evidence that perceptions, interpretations, and attributions about risks are constructed dialogically, in social interaction. A useful avenue of future research would be to apply alternative theories of communication and semiotics to risk communication, to deepen our understandings of how information flows and is interpreted.

Fourth, we found that some social networks generated risk-related information, and that such information could be important in the formation of risk perceptions both within

and outside of the network. What are the important factors that support the generation of new knowledge by local organizations? What factors make such information play a role in the formation of risk perceptions? Why is the information trusted or not? These are some of the important on this topic that can be helpful for risk managers to understand as they interact with local groups in risk controversies.

Fifth, we discussed two networks in this report that emerged through the actions of the agencies. These advisory boards, the FHES and FCAB, were points of convergence for individuals in the community who were not initially part of the same social networks. As points of convergence they became emergent networks, and are one form of capacity building within a community. A reflection of how the FHES, as a point of convergence for multiple nodal networks led to the emergence of a new nodal network is found in the creation of a new non-profit group that will continue to promote health studies and risk communication in the community. The new group was established by former members of the FHES, as well as others in the community, including a member of the FCAB, former Township Trustee, and peripheral and core members of FRESH. Future research can elucidate the ways that networks can be created and sustained.

Finally, we found that many individuals were members of multiple networks or received risk-related information from more than one network. Yet, those we interviewed also clearly privileged some information sources over others. In our discussion of findings we identified some of the factors that make certain sources more salient, such as familiarity with and credibility of the source. Similarly, we found that individuals tended to privilege specific ways of characterizing risks from low dose radiation associated with Fernald, while they also appeared able to understand and utilize other ways of framing the risks. Such phenomena have been observed in prior studies (e.g., Wertsch 1987, Tuler 2000). It would be interesting to study in more depth the reasons that certain sources and frames are privileged, and the ways that the privileging arises through interactions among individuals and subgroups of networks.

6.1 Final Conclusions

The case study of the legacy of radiological releases from the Fernald nuclear weapons facility and efforts to clean-up and understand their effects explored the ways in

which people's participation within social networks helped shape their perceptions of low dose radiation risks. The findings from this case study strongly support the hypothesis that social networks affect the ways individuals form risk perceptions. Such networks provide means for information to be distributed and interpreted for the members of the network. They also provide opportunities for people to learn and play more informed roles in risk-related decision-making and management.

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Low Dose, Risk, Decisions, & Risk Communication

Radiation Risk Perception and Communication: A Case Study of the Fernald Environmental Management Project

Appendix A Interview Guide

In this interview, we will be asking you about a series of events or issues that occurred during the clean-up and public health assessments at Fernald.

Iterate through questions 1-3, asking about each issue.

NOTE to interviewer: be careful about whether to use present tense or past tense. This may depend on the issue (e.g., future use is a current issue, setting of soil clean-up standards is a past issue).

1. Tell us, briefly, **what happened** during
 - a) the planning and development of the onsite-waste-disposal facility?
 - b) setting of soil clean up standards?
 - c) CDC's efforts to characterize community health effects from Fernald?
 - d) efforts to define the future use of the site (e.g., Future of Fernald workshops)?

- Can you highlight some of what were for you the key points in the history of this issue (a-d)?

The purpose here is to bring the person's mindset back to the issue. We are not necessarily seeking information at this stage, but we won't ignore new information, obviously. Keep this discussion short!

2. As far as you are concerned, **what was this issue about (a-d)?**

Probes

- *Risk and danger?*
- *Trust and mistrust?*
- *Community and economic development?*
- *Accounting for past harms?*

3. Talk a little bit about **your take on this issue (a-d)**.

Probes

- *What do you think about the health risks? (their risk perceptions)*
- *What kind of images do you have of the facility?*
- *How do you view the officials at the Facility (past and present)?*
- *What is your solution to the problem?*
- *What outcomes would you like to see?*
- *What do you think of the process?*
- *Do you think there is anything the officials can do about anything at all or are their hands tied?*
- *What information and events were important in shaping your views?*

If they mention trust:

- *Is trust an issue because there is:*

no satisfactory way to discuss the risks?

Control or eliminate the risks during the near term?

4. What **other issues** do you care about? Where do these four fall in terms of its importance to you given all the things you care about?

For the following questions, focus on the most important issue(s) to the interviewee (a-d in Question 1)

5. What opportunities did you have to discuss these issues with other people? **Can you tell us about the kinds of places or venues where you had interaction with other people about this issue?**

The goal here is to get a list of the discourse spaces.

Probes:

- Were you a member of an advisory board (FCAB, CRO, FHES)? If not, did you attend any of the advisory board meetings?

FEMP Case Study Appendix A: Interview Guide

- Do you belong to any citizens groups (e.g., FRESH) where this was discussed? Did you attend any meetings of local citizens groups?
- Do you belong to any civic organizations where this was discussed?
- Did you talk about it with neighbors?
- Did you talk about it with close friends? If so, in what settings?
- Did you attend any meetings or presentations where Facility/state agency employees talked about the issue?
- Did you read about it in the newspaper? On television or radio?
- Were there key networks that you tapped into for information and/or support?
- What other places or venues did you go to that provided information?

Where any meetings or events particularly important to you (e.g., particular workshops, advisory board meetings)?

6. Now we would like to talk about **what the quality of the discussion was like in these different venues**. What were these different venues for discussion like?

Ask about each one individually

- Describe the kinds of people you might talk face-to-face with about these issues.
- How did conversation unfold in these settings?
- Did you have a chance to talk?
- Did you have the sense that people listened?
- How would you characterize the conversation (dialogue, interaction, discussion) there?
- Was your point of view respected?
- Were you able to get a sense of what other people in the community are feeling?
- How do you get a sense for how people at the Facility/state agency are feeling?
- Did you think that the discussions were well informed technically?
- Were people able to talk about non-technical issues and concerns?

7. Now we want to discuss **the way that information was brought into these settings**.

What are the different sources you draw upon to gain knowledge about the risk, safety, and health issues related to these issues?

- What sources did you rely on for factual information?
- Are there particularly important sources of information that you relied on (people, reports, etc.)? How would you rate these various sources? (good, bad?; some sources better for some issues and not so good on other issues?)
- What happens for you when there is an overt conflict in opinions between one source and another, or between one group and another (e.g., local environmentalists and the facility managers)?

8. Do you know of any **standards** that are relevant to the allowable levels of risk (contamination, exposure) for these issues?
 - Do you think that the standards are too high? Too low? For an adequate level of protection?
 - How well do the experts and scientists at the facility understand the risks to the community? How do you view science as a source for making management decisions about these issues?
 - How do other people in the community view science as a source for making management decisions about these issues?
 - If science is not enough, what other standards and values ought to apply?
9. Is there anything **unique about this region** that we need to know about in order to understand why these issues unfolded in the manner that they did?
 - History of previous controversies
 - Culture of behavior
 - Personal animosities among people
 - What has been the role of the facility in the community? (e.g., primary employer, “good neighbor”, a mystery)
 - Multiple townships, agencies, etc.
10. Now we’d like you to reflect on how your **opinions about these issues changed over time**.

This needs to link back to question 2 (what is this controversy about) and should iterate from one issue to the next (a-d)

 - What is your opinion right now about this issue?

Probes:
Do you feel it was a serious danger to human health?
Do you feel that the Facility was honest about the dangers associated with the issue?
Do you feel that people were concerned about health risks or something else?
 - What were some of the more important things that shaped the way you feel about this risk?
 - What are the key factors that have influenced your opinions about what is good and bad, acceptable and unacceptable with regard to the issue?
 - Can you point to any significant changes in your opinion?
 - How would you describe how other people in the community — not Facility employees — generally interpret this issue?
 - Does this differ from how Facility employees interpret the danger associated with this the issue?
 - How have views, opinions regarding the issue in the community changed over time?
 - Why do other people in the community care about this? Or not?

Low Dose, Risk, Decisions, & Risk Communication

Low Dose Risk Perception and Communication

A Case Study of the Tritium Controversy at Brookhaven National Laboratory

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A REPORT
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Abstract

This manuscript reports on how individuals in and around Brookhaven National Lab came to their perceptions of a low-dose radiation risk from tritiated water that contaminated the groundwater aquifer directly beneath the Lab. The focus is upon the role that risk communication messages played in forming individuals' perceptions. Based on the presumption that people interpret and deliver such messages via interactive processes with others, this research inquired into: (1) the ways that different social networks distributed and processed information about the risk, (2) the way that interaction in such networks shaped individuals' risk perceptions of the tritium, and (3) the role radiation stigma and regulatory standards played in influencing risk perceptions. The report identifies three key social networks and examines each independently, but also explores how the networks intermingled. The report finds that, in this case study, people who decided to become engaged in the tritium risk controversy relied on the resources of social networks to acquire and evaluate information. Social networks served to filter and channel technical information and expert interpretations of that information to members. Also, networks offered members opportunities to collect peer feedback on opinions about the risk and the controversy. These findings suggest that theories of risk perception, in addition to their present focus on the psychological level, need to develop a sociological dimension to capture the relevance social networks play. The findings also suggest that the practice of risk communication needs to recognize that risk messages are interpreted socially. Conceptualizing a risk discourse among all interested parties seems to be a promising way to think about risk communication.

1. Introduction and Background to the Case Study

1.1 Entrée to the Case

In December of 1996 radioactive tritium was detected in the groundwater beneath Brookhaven National Lab (BNL). The news could hardly have come at a worse time for the Lab. A year earlier, BNL had announced a plume of chemical contaminants had migrated off site to the populated area south of the Lab. Drinking water wells in private homes were contaminated with chemical solvents at unsafe levels. Initially BNL and the county health department suspected an industrial park sandwiched between the Lab and the residential area, but subsequent testing proved that most of the contamination came from the Lab.

BNL occupies a site that has been used for governmental purposes for the better part of the last century. Camp Upton was a training ground for soldiers in World War I and was reoccupied during World War II. The Lab suspected that the present chemical pollution originated in times when the base was run by the Army. Nevertheless, it acknowledged responsibility for the contamination and in January of 1996 the DOE offered to hook-up to public water approximately 800 homes in the affected area that were presently relying on private wells for drinking water.

During 1996, while the DOE was paying to hook-up houses to public water, public concerns about BNL's credibility mounted when a second groundwater plume, this one containing ethylene dibromide (EDB), an agricultural pesticide, was found to have migrated off site into a residential area east of the one being hooked-up to public water. These residents also demanded free hook-ups, which the DOE eventually consented to do (about 500 homes).

Although the contamination that led to DOE paying for water hook-ups was of composed of chemicals associated with past uses of the BNL site, people were concerned about radioactive contamination as well. BNL had already admitted to accidental releases of radiation to air and water. Residents were concerned that, if chemicals had migrated off-site, radiation might not be far behind. They were right.

The tritium detected in December 1996 and publicly reported in January 1997 severely aggravated an already-bad situation for the Lab. Tests in early 1997 revealed the tritium was migrating in the same direction as the first chemical plume — right toward the residential neighborhood immediately south of the Lab. Embarking on a massive well-drilling program, BNL followed the plume from its origin at the High Flux Beam Reactor spent fuel pool toward the community. Each week the Lab released results from the newest line of wells. The media dutifully reported each new result. The public saw the extent of the contamination grow week by week. The community waited in fear. After weeks of testing the Lab finally concluded that the tritium had *not* moved off-site and the public was safe. Many other people in the community had reached a different conclusion. BNL had violated the public trust and had been careless in its handling of radiation.

By some measures, BNL and DOE managed these controversies well. They disclosed information as soon as it became available, they invited the public to venues to learn about the contamination and to ask questions, and they took mitigative measures voluntarily, even before the community could demand it be hooked up to public water. Therefore, the degree of community outrage that resulted came as a surprise to many in the Lab and the DOE.

In the end, the controversy cost DOE and BNL dearly. Associated Universities Incorporated (AUI), who had run the Lab for the DOE since 1947 was fired. BNL went through four directors in the course of a little more than one year. Senator Alfonse D'Amato (R-NY) and Congressman Mike Forbes (R-NY) held hearings with DOE to examine their handling of the affairs on Long Island. There was talk in *The New York Times* of closing down BNL. BNL countered by investing heavily in public relations efforts. They admitted past errors and took responsibility for ameliorating them. They succeeded in finding ways to talk with their opponents. They moved forward with groundwater remediation. And, perhaps most important of all, no major new problems arose.

Today, BNL is able to look back on the experience with minimal discomfort and ask, "What can we learn from this experience?" At present, the Lab has a positive community image. Even many anti-radiation activists in the community concede this. The public may

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never trust BNL blindly, but the institutions that enable the public and the Lab to communicate are in place. The Lab is widely considered to be a “good neighbor.”

1.1.1 Origins of Brookhaven National Laboratory

Brookhaven National Laboratories is located on 5,300 acres in Suffolk County in the center of Long Island, some 75 miles east of Manhattan. The Lab sits atop the sole-source aquifer that serves as the primary water source for all Long Island residents in the region. The soils of Long Island are sandy, which makes aquifer protection an important public issue.

BNL was established by the Department of Energy in 1947 on the original site of Camp Upton, a former U.S. Army base. The facility serves as a major gathering point for scientists from around the world. Its multifarious research endeavors include basic and applied research in the fields of physics, chemistry, materials science, biology, and nuclear medicine. The Lab is proud to announce that no nuclear weapons work has ever occurred at the site, although it has supported other DOE Labs' work in this area.

Three nuclear reactors have existed at the BNL site. The Brookhaven Graphite Research Reactor (BGRR) was the first started in 1950 and it was shut down in 1968. During its operation, the BGRR emitted radiation to air, surface water, and groundwater, leaving a legacy of contamination. The BGRR is now in the final stages of decommissioning and clean-up. The High Flux Beam Reactor (HFBR) is the reactor whose spent fuel pool leaked the tritium. This reactor was shut down for routine maintenance in 1996 just before the tritium was discovered. It was never restarted. In November 1997 DOE Secretary Richardson ordered the reactor closed. There is also a small medical research reactor on the site. The Brookhaven Medical Research Reactor (BMRR) was started in 1959 and it continued to operate throughout the tritium crisis.

Map 1-1. Census map of central Long Island with BNL site identified in white in middle of map. Peconic River starts at BNL and flows easterly toward Riverhead. The Shoreham nuclear power station was located just northwest of Wading River.

For the first fifty years of its existence, Associated Universities, Inc. (AUI) managed the Lab.¹ AUI's contract was abruptly terminated by the DOE in 1997, just when AUI should have been celebrating its 50th anniversary. What should have been a party atmosphere at the Lab turned into a nightmare. Since 1998 the Lab operations have been contracted out to Brookhaven Science Associates (BSA), a not-for-profit partnership between the Research Foundation of the State University of New York at Stony Brook and Battelle.

To the east of the Lab is the town of Easthampton, where many of New York City's elite own summer cottages and mansions. A handful of prominent people from this community would be instrumental in organizing an activist group that would challenge BNL.

A few miles north of the Lab sits the notorious Shoreham nuclear power station, which was built, but never brought on-line. In what is undeniably the most notable public challenge to commercial nuclear power generation, activists around Shoreham managed to win popular support for dismantling the completed facility, at a terrible cost. The legacy of Shoreham has much to do with what happened in the tritium controversy in 1997.

Just a few miles northwest of the Lab lies the State University of New York at Stonybrook, a prestigious academic institution. Its president until 1994, John Marburger, played influential roles in mediating controversies in the region, and later took over the management at BNL, seeing the tritium controversy through its resolution. Marburger is widely recognized as the person responsible for seeing BNL safely through these challenging times. He has since moved on to Washington D.C. to serve as President Bush's top science advisor.

¹ For a history of the first 25 years of BNL, see Robert Crease (1999).

1.2 Precursors to the Tritium Controversy

1.2.1 Shoreham Nuclear Power Station

Shoreham has been called, “the greatest nonaccident nuclear fiasco of the commercial nuclear power program” (Aron 1997:5). In the late 1960’s the Long Island Lighting Company (LILCO) endeavored to build a nuclear power station on the north shore of Long Island in Brookhaven Township at the location known as Shoreham. Shoreham lies just a few miles from the entrance gate of BNL. The area selected for the plant lie on a beautiful beach in a region of the town where housing values were high. Still, LILCO had good reason to believe the plant would be realized. Support for nuclear power was strong in the country and on Long Island, state and local officials all supported the plant, and LILCO was widely respected by the Long Island public as a sound business and a responsible member of the community.

At the beginning of the licensing procedure in 1968, the only opponents of the station were a small band of activists and the immediate residents of the Shoreham community. As the process dragged on, year after year, hearing after hearing, the opponents saw every one of their challenges to the plant defeated. In 1989 the facility was completed and issued an operating license by the Nuclear Regulatory Commission. However, the license had come at a cost — the loss of public trust. Despite seemingly insurmountable odds, the anti-nuclear activists never ceased their opposition. They scrutinized everything that happened during the planning and construction of the plant. To widespread concern, the planning and construction was fraught with problems. The number and seriousness of the errors discovered was unbelievable. Many of the errors were discovered by the Nuclear Regulatory Commission during its own inspections. In many instances, whole portions of the plant had to be retrofitted or totally demolished and rebuilt. The cost of the plant soared and the timetable was pushed back. Over time, LILCO lost public support, which translated into loss of support from the NY state government. But what really sealed the fate of the facility was the inability of LILCO to produce an acceptable evacuation plan for the region. The challenges of evacuating a densely populated Island were overwhelming. In the end Governor Mario Cuomo decided to oppose the plant and recommended its dismantlement. Although the plant was finished, ready to operate, and

obtained an operating license, the NRC, at the request of LILCO, reacted to immense public outrage and political pressure and in 1991 allowed LILCO to begin dismantlement.

Explaining the Shoreham controversy adequately would require examining a myriad of factors, including Three Mile Island, the economics of energy supply and demand, New York State politics, and so on (for a thorough study see Aron 1997). The legacy of the Shoreham controversy with relevance for BNL's tritium controversy includes two major aspects. First, Shoreham produced a group of committed and able anti-nuclear activists. These were individuals from communities immediately surrounding BNL who learned to read technical reports, learned to negotiate public hearing and comment processes, learned how to use the media to get their message out, learned how to amass and mobilize resources (including connections with politicians), and who learned how to influence public opinion. All of these skills would be applied in the BNL case in 1997.

The second legacy of the Shoreham event for BNL came in the area of public relations. The Lab learned not to do what LILCO did. When faced with public outrage and opposition, LILCO responded by closing down the process and limiting, whenever possible, public involvement in the planning, building, overseeing, and licensing the plant. In doing this LILCO enjoyed the support and accommodation of the NRC. Indeed, the NRC's own evaluation of the Shoreham "debacle" (in their eyes) led to the conclusion that public input needed to be further limited (Aron 1997: 130–131).² The effect of such actions was, of course, merely to anger the public further. Although excluding public involvement did enable LILCO to get the plant finished and licensed, it also escalated the political opposition to the point where the Governor himself became involved in stopping the plant. During the Shoreham controversy, John Marburger was the President of the New York State University at Stonybrook, just miles west of Shoreham. He observed the managerial approach LILCO and the NRC took and he observed the effects on the Long Island public. Dr. Marburger, in his new role as Director of BNL, clearly applied the lessons from Shoreham to the controversy over tritium at BNL.

1.2.2 Historical Releases of Tritium to Groundwater

At the east end of the Lab property the Peconic River has its origins. For most of the year the riverbed is dry at its extreme westerly portion, being fed by high groundwater levels only in the springtime. For most of the year, water flow in the riverbed actually begins with the outfall pipe from the BNL sewage treatment plant. And many summers, even this water seeps back into the ground before leaving the site boundary.

Since the High Flux Beam Reactor (HFBR) began operating in 1965, there had been discharges of water contaminated with tritium to the Peconic River via the Lab's sewage treatment facility. Since water in the river mixed with groundwater, the groundwater in that area of the Lab was contaminated with tritium. The level of contamination, for the most part, remained well below the drinking water standard. This contamination was known in the late 1960s. Because effluent from the Lab ends up in the sewage treatment plant, the pollutants to the Peconic River include a wide array of contaminants, including PCBs, heavy metals, and many radionuclides. The river is now Superfund site and the riverbed is to be cleaned up.

Further downstream, where the Peconic River empties into the Greater Peconic Bay (inside the fork at the eastern end of Long Island), anglers pull fish from the river and sportsmen hunt waterfowl. The possibility that the river, and thereby the organisms in the river, were contaminated with radioactive isotopes was a matter of concern to these groups and individuals. One activist from this community, Bill Smith of Fish Unlimited, was a leading voice in controversy with BNL about the contamination of the Peconic River. Bill Smith became a public figure during the controversy over the dewatering of the sewage treatment plant (discussed below).

In 1984 a monitoring well along the Lab's eastern boundary began to show elevated amounts of tritium in groundwater near the Peconic River. Further investigations conducted in 1984 and 1985 found elevated levels of tritium in the effluent from the Lab's sewage treatment plant. Since this effluent is released into the River, groundwater became contaminated. Studies revealed the existence of a groundwater contaminant

² Joan Aron herself takes issue with this conclusion and instead concluded that excluding the public would further aggravate these conflicts. She instead argues for more public involvement.

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plume at the eastern border of the BNL site. At the most impacted off-site monitoring well, the tritium concentration had reached 25,000 Pico curies per liter (pCi/l) (the drinking water standard is 20,000 pCi/l). This became known as the eastern tritium plume. Effluent from the sewage treatment plant can reach groundwater through the sand filter beds or by directly recharging along the Peconic River. The source of the tritium was found to be distillate from the evaporation process at the waste concentration facility that was discharged to the sewage treatment plant. To communicate with the public about this contamination, Brookhaven sent William Casey (Manager of Environmental Health and Safety) and Mona Rowe (Media Relations Officer) door-to-door in communities near the river. Through informal discussions with local people, they informed people of the contamination.³

In addition, the Suffolk County Department of Health Services began sampling private supply wells in an area down-gradient of the contamination and east and southeast of BNL. Their goal was to determine if the contamination had reached private drinking water wells. Tritium was detected in some of the samples, but none of the concentrations in the wells approached the drinking water standard. The highest level found off BNL property was 822 pCi/l, or four percent of the drinking water standard.

Since 1984 the tritium concentration in the effluent from BNL has declined, however, the contamination continues to be an issue for local residents and activists along the river. Residents are also concerned about other contaminants in the river and the superfund clean-up process.

1.2.3 The Tiger Team Investigation

When Admiral James Watkins became Secretary of Energy early in 1989, one of his first acts was to emphasize compliance with OSHA regulations as one of his key agenda items. He inaugurated what are called environment, safety, and health “Tiger Teams” to visit all of DOE’s major facilities. The purpose of the Tiger Teams was to investigate environmental and safety problems at the sites and to ascertain the status of compliance with OSHA regulations. Then he invited OSHA to participate in workplace inspections,

³ Downloaded August 2001 from: Proposed Plan for Operable Unit V Peconic River/Sewage Treatment Plant (<http://www.bnl.gov/erd/peconic/ou5pptext.html>)

which they did at three key facilities. Results from the first three inspections confirmed that DOE's facilities were substantially out of compliance with OSHA's requirements.⁴

Brookhaven's visit from the tiger team came in 1989. This investigation was chiefly responsible for getting BNL placed on the National Priorities List (NPL) or "Superfund list." BNL became a Superfund site for many reasons, including contamination from the Brookhaven Graphite Research Reactor. At the time of the tiger team, no one knew about the tritiated water leaking from the HFBR spent fuel pool. However, the tiger team did suspect this could be a possibility. One of their recommendations was to have the groundwater near the HFBR tested for possible radioactive contamination. However, work orders to install the wells outside the HFBR were not signed until March 1996, six years after the tiger team's original recommendation, and the wells were not installed until September 1996.⁵

1.2.4 The Tristan Fire

In March of 1994 there was a fire in the HFBR. This became known as the TRISTAN fire after the acronym for the experiment with which the fire was associated. In the experiment, fissile material in a vacuum tube was subjected to neutrons from the reactor. Insulating material caught fire during the experiment and 18 millicuries of radioactive gases were released to the atmosphere. Seven personnel had their clothing and skin contaminated and required decontamination.⁶

1.2.5 Dewatering at the Sewage Treatment Plant

In 1995 the Lab began to pump down the groundwater level at the sewage treatment plant. To install a new facility, the Lab needed to dig foundations and to do this, they first needed to lower groundwater levels.

⁴ Downloaded August 2001 from: <http://tis.eh.doe.gov/docs/shc/sc92dec.0007.html>

⁵ Sources used to for this section were: Tiger Teams. *Science* 19 April 1991: 366-368. P.D. Goldis. 1989. Questions and answers about Tiger Teams. *EDPACS, the EDP Audit, Control and Security Newsletter*. Vol. 27, Nr. 4. pp.1-10. (October 1989).

⁶ Sources: The type B investigation of the March 31, 1994 fire and contamination at the TRISTAN experiment, high flux beam reactor. (Brookhaven National Laboratory: Upton NY). U.S. Department of Energy Office of Oversight Environment, Safety and Health. Integrated Safety Management Evaluation of the Brookhaven National Laboratory. April 1997. Downloaded from: <http://tis.eh.doe.gov/oversight/reports/evals/9704bnl/9704bnl.html>.

The problem was that the groundwater being pumped out of the ground was contaminated with tritium. Therefore the Lab was discharging water contaminated with radiation directly into the river. From the very start of operating reactors on the site, tritium had been released into the Peconic via the sewage treatment facility. BNL maintained that the levels of tritium in the effluent were low.

Bill Smith, an environmental activist interested in the river, noticed that, if BNL did follow through with the dewatering regimen, a large amount of tritium would be introduced to the Peconic. There was concern that this radiation might be taken up and bio-concentrated in fish and waterfowl, which local residents and sportsmen consumed. Smith was able to get his word out to the press. Public concerns about BNL's handling of radioactive waste were heightened. Yielding to public pressure, in the end the Lab agreed to stop pumping the groundwater. The sewage treatment plant was eventually completed without pumping down groundwater, but the construction costs were much higher.

1.3 Outline of this Report

This report discusses the tritium controversy that occurred from 1996–1998 in Suffolk County on Long Island, NY. It recounts the events as they happened and discusses BNL's approach to community relations during the event and the ways that certain people in BNL and the surrounding community formed perceptions of the risk posed by the tritium. The intention of this research was to create an understanding of how sociological considerations influenced individuals' perceptions about a low dose radiation risk. The study focused on individuals in a community that was actively engaged in a risk controversy. Specifically we sought to understand how individuals' social situatedness played a role in the way they developed their perceptions of low dose radiation risks.

The following section describes the methodology used for case study selection and also outlines the research protocols used in the field research and data analysis. Section three provides an in-depth examination of the tritium controversy, situating the event in a broader social and cultural climate. In section four three social networks are presented and each examined in sequence: the Friends of BNL Network, the Community Residents

Network, and the Long Island Activists Network. For each of these key networks we describe its identity, what perceptions of the risk dominated in the network, how information moved through the network and contributed to risk perceptions, the learning that happened within each network, and how each network interacted with the other two networks. Section five presents results on two thematic issues we pursued in the case study: the role of standards and stigma in shaping risk perceptions. Section six draws conclusions based on the results presented in sections four and five.

2. Research Design and Methodology Used in the Case Study

2.1 Research Design

Our approach to deciphering the complexity of the social environment was to discern distinct social networks within a defined community that experienced a controversy about a low dose radiation risk and then to identify relevant individuals in these different social networks. These individuals were interviewed. Within each network we focused on the following:

- the way information flowed inside this network and between networks,
- the kind of interaction that happened among individuals in the networks that helped people shape their risk perceptions,
- the importance that regulatory standards played in shaping individual risk perceptions, and
- the ability of the term “stigma” to help interpret the formation of individual risk perceptions.

2.1.1 Case Selection

To generate a pool of potential case studies, we scoured the literature for information about radiation controversies at nuclear power stations, nuclear waste management facilities, and Department of Energy laboratories across the United States. We made phone calls, searched the published literature, searched for archival data, and in some

cases made site visits to potential case study sites before selecting Brookhaven National Laboratory.⁷

Brookhaven was chosen as the site for this case study based on several key criteria. First, it has a history that includes an intense period of interaction with the surrounding community regarding low dose radiation risk. This period of time (spanning approximately one and a half years) was characterized by a controversy that erupted between this Department of Energy facility and the community surrounding the Lab. Second, this controversy occurred within the recent past making memories of the events readily accessible to individuals who were involved. Third, there were many Brookhaven officials who supported this study by referring us to key community members, allowing us open access to all published documents, and agreeing to allow us to conduct the study at their site. Non-lab employees active in the controversy also indicated a willingness to speak with us about the controversy. Fourth, the interactions that occurred between the Lab and the surrounding community on Long Island were very well documented. The fact that copious quantities of documents, risk communication handouts, meeting agendas, and other written materials exist in their original form allowed us direct access to the types of communications that ensued. There were also extensive audio and videotape collections which capture some of the risk communications as well as thousands of pages of newspaper clippings.

2.1.2 Desired Participants

We sought to interview approximately twenty people who participated in important ways in the controversy. Our goal was to interview people at the Lab, in the community, and in governmental agencies who played important roles in the controversy. National NGOs would only be included if they had a person assigned to work in the community, or they played a key role in local discussions/dynamics.

⁷ Two other sites are also being investigated by other researchers. Seth Tuler of SERI is studying the Health Effects Subcommittee's work at the Fernald facility in Ohio and Terre Satterfield of the University of British Columbia is studying the perception of low dose risk at the clean-up of the Rocky Flats site in Colorado. These reports should be available on the web site: Decisionresearch.org

2.1.3 Interview Guide

An interview guide was created to structure the interview conversations around the social aspects of risk communication (Appendix A). An interview guide is intended to provide general sets of queries that are asked with approximate wording. It is intended to facilitate a conversation, not necessarily to dictate the precise wording of the questions. There were ten sets of nested questions that were asked in a semi-structured order. Interviews lasted from one to one and three hours in duration. Almost all interviews were conducted with only one respondent and only one researcher present at a time. A few interviews had two respondents and/or two researchers present at a time.

2.1.4 Human Subjects Protection

Interviewees were asked to sign a consent form, which explained the project, guaranteed that their input would be confidential, and explained their rights as human subjects involved in a research project. In this report, all references to statements made by individuals participating in this study to the researchers are considered confidential.

2.2 Methodology

2.2.1 Definition of the Community

Once we settled upon Brookhaven as a case study site, we sought to delimit the extent of the case. One way we did this was to focus on one main controversy — the tritium that leaked into the groundwater from the spent fuel pool at the high flux beam reactor. We also sought to delimit the geographic and political boundaries of the case study.

Geographically, the BNL site occupies a large area in the central area of eastern Long Island. It is also situated more or less in the middle of Suffolk County and in the middle of Brookhaven Township. Because of its geographical extent and the size of its workforce, what happens at BNL has consequences for the Town of Brookhaven as well as for other neighboring towns. The Suffolk County health department and water authority were both deeply involved in the controversy, which made this a county-wide issue. Despite the broad public interest, most people involved in the controversy lived in towns closest to the Lab. Towns in the very western part of Suffolk County saw little involvement of their residents.

To the east lies the town of Easthampton, a community where many affluent people from Manhattan maintain summer “cottages.” Celebrities Alec Baldwin and Christie Brinkley from Easthampton became engaged in the tritium controversy at BNL. They and others pooled resources to establish an anti-nuclear activist group, which located itself in downtown Easthampton, about an hour’s drive from Brookhaven National Lab. Thus, although Easthampton lay quite a distance from the Lab, it was home to several people who played important roles in the controversy.

Box 2-1. Sources of Data

- Informal interviews for background information
- Formal interviews with key informants
- Videotapes of public meetings at BNL
- Archived technical reports, meeting minutes, meeting transcripts, newsletters, news clippings, news transcripts

Box 2-2. List of Site Visits to BNL⁸

• November 2000 (Webler and Wilhoit)	Preliminary investigations.
• January 2001 (Webler and Wilhoit)	Collect archived materials. Interviews.
• March 2001 (Wilhoit)	Collect archived materials.
• April 2001 (Wilhoit)	Collect archived materials. Interviews.
• May/June 2001 (Webler and Tuler)	Field interviews.
• June 2001 (Webler and Tanguay)	Field interviews

⁸ Jasmine Tanguay and Jennifer Wilhoit were graduate student research assistants who assisted with some parts of the field work. Seth Tuler is a researcher at SERI.

2.2.2 Data Collection and Analysis

Data were collected for this study from on-site visits, formal and informal interviews, document retrieval, and other published sources of information including websites (see Box 2-1). The on-site visits were useful for collecting written materials from Brookhaven as well as becoming familiar with the surrounding environs. Six visits to the case study area were made (see Box 2-2). Most site visits were made by a team of two researchers. While on the site we were given several tours of various parts of the Lab and spent days on site walking around the campus. In addition, we familiarized ourselves with the neighboring communities assessing local governmental structures, socioeconomic factors, services, and environment. A logbook of notes was kept from each visit.

2.2.3 Archival Data Gathered

BNL archived a library of paperwork concerning the tritium controversy. The material is well organized. The media and community-relations department at the Lab maintain notebooks containing:

- Television Transcripts from 1997 (approx 600pp)
- Newspaper clippings from local media in 1997 (700 pp)
- Newspaper clippings from national media in 1997 (1000pp)
- Press releases from BNL 1997 (600 pp)
- Other BNL publications in 1997 (150 pp)
- Information about tritium (700 pp)
- Three notebooks of the Suffolk County Task Force (2000 pp)

In addition, there is a videotape library. All presentations made at Brookhaven were videotaped. Many of these are instructional lectures on radiation, groundwater, etc. One videotape recorded the highly contentious public meeting from January 16, 1996. This was held just days after the DOE announced it would pay for public water hook-ups for people living in the area south of the Lab whose wells were being contaminated with chemicals (not tritium) that leached off-site

BNL Employees

1. William Casey (Former Head of Department of Environment and Safety, BNL) [†]
2. Robert Crease (Historian, BNL and Professor from SUNY — Stonybrook)
3. Kathy Geiger (Manager, Community Relations, BNL) [†]
4. William Gunther (Former Head of Department of Environmental Restoration, BNL) [†]
5. John Marburger (Director of BNL)
6. Mona Rowe (Media Relations, BNL)
7. Ken White (Community Relations, BNL)

Organized Interest Groups

8. **Dick Amper** (Long Island Pine Barrens Association)
9. **Scott Cullen** (STAR) [†]
10. **Adrienne Esposito** (CALA — Coalition for Lab Accountability)
11. Peter Maniscalco (Local environmental and peace activist)
12. **Jean Mannhaupt** (Neighbors Expecting Accountability and Remediation) [†]
13. Judy Pannullo (Long Island Progressive Coalition)
14. Randy Snell (Citizens for Clean Brookhaven)
15. Roger Snyder (Long Island Alliance for Peaceful Alternatives)

Civic Association Leaders

16. Lori Baldisari (President of ABCO — Association of Brookhaven Civic Organizations)
17. **Rita Biss**, (Lake Panamoka Civic Association)
18. **Ron Clipperton** (Former Lab employee and Ridge Civic Association)
19. William Doyle (Bay Area Civic Association)
20. **Don** and **Liz Garber** (Former BNL employees and Former members of ABCO)
21. **Mike Giacomaro** (East Yaphank Civic Association)
22. Jane Gibbons (Presiding Officer, Lake Panamoka Civic Association)
23. **Joe Gibbons** (Lake Panamoka Civic Association)
24. Helen Guthy (President of the Wading River Civic Association)
25. **Connie Kepert** (President of the Longwood Alliance, Former President of ABCO)

Unaffiliated Citizens from the Affected Area

26. Ron Crofts (Resident of North Shirley) [†]
27. Rick Stավdall (Resident of North Shirley)
28. Dawn Triche (Resident of North Shirley)

Names in **boldface** indicate the individual was a CAC member as of September 2001.

[†] indicates that individual was interviewed twice

2.2.4 Interviewees

We conducted both formal and informal interviews on and off site. Some interviewees were chosen based on their level of involvement in specific risk communication events. Others were selected based on their proximity to the Lab. Interviews were generally set up in advance, although a few spontaneous informal interviews were conducted. These spontaneous interviews were not taped but notes were handwritten both during and after the conversations.

We conducted 34 formal interviews, with six individuals interviewed twice. Most formal interviews were tape-recorded. Most of these tapes were transcribed. The tapes were then destroyed. In addition to the tapes, handwritten notes were taken prior to, during, and immediately following the interviews. This allowed us to capture un-taped portions of conversations as well as to reflect immediately upon the interview. Any phone conversations or email exchanges with potential or actual respondents were also mined for relevant data. The preceding page contains a list of individuals interviewed.

2.2.5 Data Analysis

The author of this report was responsible for all the analysis of this case study. He reviewed all the field notes, transcripts and tapes (when necessary), and archival literature and videos. The first goal was to reconstruct the emergence and transaction of the controversy.

The next task was to identify core distinguishable networks active during the controversy and to identify each interviewee with one or more networks. Once these were defined, the field data were used to characterize the way that each network influenced individuals' perceptions of the risk.

Following this, he mined all the gathered data to identify data relevant to the central themes: risk perception, role of information, importance of stigma, and water quality standards. These subjects were examined one at a time, for each network in turn. The report represents a depiction of the case and the social networks as understood through the eyes of these twenty-eight interviewees in thirty-four interviews as well as through hundreds of pages of written documents, news clippings, and videos.

Box 3-1. Timetable of Key Events Associated with Monitoring Well at the HFBR Building

• 1987	• County Board of Health tells Lab to double line pool and all pipes. Lab agrees to do it, but does not.
• 1989	• Tiger Team recommends lab install monitoring wells near reactor. Lab does not.
• 1993	• Citizens group asks that well be installed. Lab does not.
• September 1996	• Monitoring wells installed
• October 1996	• Initial test sample taken
• December 1996	• Initial results received
• December 1996	• Second sample taken
• January 1997	• Second results received
• January 1997	• Results announced to public

3. The Tritium Controversy

3.1 Unfolding of the Tritium Controversy

In December of 1996 test results from a groundwater monitoring well located just to the south of the building housing the spent fuel pool for the high flux beam reactor (HFBR) reported a high incidence of tritium. When the contamination was verified in January 1997, BNL quickly notified the public of the contamination. Two things about the event were significant. First, the timing could hardly have come at a worse time for the Lab. The Lab was in the midst of a public relations nightmare due to chemical contamination of private drinking water wells in a residential area just south of the Lab. Second, the monitoring well was itself highly controversial. Community residents and watchdog groups had asked that a monitoring well be sunk at that site as early as 1993. Indeed, the Department of Energy recommended a well there as early as 1989. The Lab had refused, citing other priorities and a certainty that no contamination would be found there.

A simple recap of the chronology of main events reveals the low importance the BNL assigned to investigating whether or not the spent fuel pool might be leaking tritium (see Box 3-1). Starting in 1987 the Suffolk County Board of Health suspected the pool could be leaking when it passed new regulations requiring certain water systems contain double walls, including the spent fuel pool at the HFBR. Brookhaven Lab signed an agreement with Suffolk County in 1987 that it would comply with the new code. However given that the existing tank was filled with spent fuel, it was not a simple matter to empty the tank and replace it. The next warning came in 1990 when the Tiger Team recommended that three to five monitoring wells next to the HFBR would be a good idea. BNL agreed to follow the recommendations, but these wells were assigned low priority and the work orders to install the wells were not signed until six years later in March 1996. It took until September 20th of 1996 for the wells to actually be installed. The first water samples were taken in October, but these were not analyzed until December 1996. The high levels discovered in this first test were suspect, so a second test was ordered. This sample was analyzed much more quickly, with results available in January 1997. Almost ten years

had passed since the County had suspected the spent fuel pool was a hazard. It was later estimated that the pool had been leaking for 15 years.

As BNL sought to ascertain the origin and extent of the tritium contamination, they drilled more monitoring wells and conducted more tests. They started at the origin of the plume and worked out from there, drilling more and more wells. In total over 700 monitoring wells were drilled on Lab property. Each time tests found tritium BNL reported the finding to the community. Over the first few months of 1997 to people reading the local papers it appeared that the extent of tritium contamination at BNL was growing daily. As the confirmation about the size of the tritium plume grew, so did public outrage. By mid-spring 1997 the Lab was in a full-blown risk controversy with the communities on Long Island, a conflict the Lab was ill equipped to manage.

3.2 Factors that Helped Propel the Tritium Controversy to Crisis Status

As with any public controversy, a number of factors came into confluence and complicated the affairs. It is not possible, even with hindsight, to say which factors were critical and which were ancillary. Instead, we take note of a number of things that came to play an important role in turning the tritium leak into a massive public relations problem for BNL.

3.2.1 *The Brilliant Scientists “Goofed Up”*

Perhaps the greatest contribution to the controversy was the realization that BNL should have known their spent fuel pool was leaking. “We goofed,” said one of the higher-up managers at the Lab. At our first visit to the Lab we asked how BNL could have been oblivious to the leaking of the spent fuel pool. “Didn’t you realize something was wrong when you had to keep adding water to the pool?” we asked. The answer surprised us, as it did many citizens and activists when they first heard this four years ago: “We never measured how much water we had to add.” They expected there would be a need to add water, since there is some evaporation from a large pool of water. So there was a mechanism to add water. But there was no way to check if the expected evaporation rate was matching the rate at which water needed to be added. As it turned out it wasn’t. Once the problem was recognized, the Lab used a laser measuring system

to detect small changes in the pool level. This is how they confirmed the pool was leaking.

But what is perhaps even more significant than the realization that BNL did not know the pool was leaking is the realization that some at BNL suspected it was probably leaking, however they did nothing about it. One interviewee recounted a story of a public meeting she attended where she recalled the Lab director at that time, Nick Samios having said, “Well, I’m not surprised that it’s leaking.” In our interview she continued to paraphrase from memory Samios’s statement, “Well, basically, it’s like a big bathtub. It’s a concrete hole with some ceramic tiles, and you know, the concrete got supersaturated and it leaked.” This interviewee was appalled and amazed that the Lab’s director could think such a thing and yet take no action to correct it.

When the word came out to the public that the pool was leaking, that BNL was not surprised about this fact *and yet it had done nothing to correct the problem, despite being urged by certain parties to take action*, the outrage ensued. The response of the woman at the public meeting where the Director at the time, Nick Samios, admitted his suspicion about the leaking pool was typical for many:

I’m thinking, You knew that? Why didn’t you check?!!

To which she added:

Here’s the most brilliant minds in the nation, in the *globe* — forgive me. How could you not notice that 15 gallons per day of highly radioactive water are missing, over 15 years?!! *It was just such a cavalier, lackadaisical attitude about it.* [emphasis in original]

The consequences of BNL’s apparent lack of interest in seeking out environmental contamination worried people and led to a crisis of credibility for BNL. The danger did not lay so much in the tritium itself, but in the uncertainty of what other contamination BNL knew about but wasn’t doing anything to manage. As events unfolded in 1997 and more and more plumes and types of contamination were revealed, this suspicion grew and BNL’s credibility faltered, as this environmental activist reported to us:

I think it led us to believe that it was worse than we thought. Because if they were so casual, and so cavalier about highly radioactive water in a fuel pool — that they should have known and should have been monitoring and apparently did know would probably become supersaturated and leak into the groundwater in a hydrologically sensitive area — then what else are they casual and cavalier about?

3.2.2 Changes in Leadership

One reason this tritium controversy became seminal for Brookhaven's history, was that it significantly altered the management of the Lab and the focus of research for the Lab. One of the consequences was the firing of Associated Universities Incorporated (AUI), the manager of BNL, just shortly before Brookhaven's 50th anniversary party. The reasons why DOE fired AUI when it did are unclear and were not investigated for this report.⁹ It remains a point of much tension between the Lab and the DOE, with people at the Lab feeling betrayed by DOE for this surprising trip-up. The point of the matter is that firing the Lab management certainly further damaged BNL's credibility with the community because it confirmed that the Lab had done something wrong.

When Federico Pena took over as Secretary of Energy in 1997, the BNL event was in full swing. DOE staff during this period also changed. At Brookhaven in mid 1997, calls to shut down permanently the HFBR were becoming more frequent. (The reactor had been shut down for routine maintenance, by coincidence, during the early days of the controversy and had not been restarted.) In the summer of 1997 local U.S. Congressperson Michael Forbes as well as New York U.S. Senator Alfonse D'Amato both opposed the restart of the reactor. Later in 1998, Pena was replaced by Richardson. It was Richardson who made the decision to shut down the HFBR.

3.2.3 A Culture Of "In-Your-Face" Controversy

Another factor many people mentioned as relevant to this study is the culture of direct confrontation that is endemic to Long Island. Many people mentioned that, for better or for worse, Long Islanders have a reputation for being direct (some would say to the point

⁹ For a report of the contractor dismissal see: US General Accounting Office. November 1997. Department of Energy. Information on the tritium leak and the contractor dismissal at the Brookhaven National Laboratory. GAO/RCED-98-26 Department of Energy.

of being rude). Long Islanders even pride themselves at their willingness to speak directly to the issue and to not beat around the bushes. This forthrightness made palatable material for television news and also prevented the controversy from being obscured from the public eye.

3.2.4 Other Contamination Events

A key factor that accelerated the tritium controversy to the crisis level was that there had been a number of other events that attracted public scrutiny (see below). The tritium became the straw that broke the camel's back in the sense that it was another in a series of events that finally mobilized the community around the Lab to ask questions and to hold the Lab accountable for the answers. The "TRISTAN" fire, the dewatering associated with the upgrade of the Lab's sewage treatment plant, and the chemical contamination (probably historical contamination from the time when the site was an Army base) all produced a heightened state of concern among some that the Lab was acting competently. This in turn led to a higher level of media scrutiny of the Lab.

3.2.4.1 Tritium Spike Near Medical Reactor January 1997

In January 1997 routine monitoring wells down gradient from BNL's second operating nuclear reactor, this a small 3 MW medical reactor, detected a sudden surge in the tritium concentration of the groundwater. In subsequent months a maximum reading of 10,000 pCi/L was detected. The presence of this small secondary tritium plume was not announced to the public until July 1997 leading some critics to protest BNL's secrecy. A newspaper account of the announcement at a public meeting reported:

Frank J. Crescenzo, deputy group manager for the lab for the U.S. Department of Energy, which owns the lab, said that "we fully intended to tell the public" about the tritium discovery, but "not right away" because it had not been considered "so significant" (Grossman 1997).

In terms of level of contamination, this secondary plume did not apparently add a significant amount of tritium to the groundwater. The real damage of this event came in terms of BNL's credibility. For a good eighteen months BNL had been in the hot seat,

learning about the need to communicate quickly and effectively with the public, yet the DOE and the Lab still hesitated in telling the public the bad news. It was just one in a long string of events that served to maintain public outrage about the way BNL managed its reactors.

3.2.4.2 Tritium Spike at Sewage Treatment Plant Outfall Pipe July 1997

On Friday, 27 July 1997 a routine sample taken from the sewage treatment plant outfall pipe was taken. When this sample was analyzed on Monday, it was found to contain tritium at a concentration of 90,000 pCi/L or about 4.5 times the level allowed in the Safe Drinking Water Act. Samples taken on Tuesday revealed levels were again normal. The Lab concluded that a “slug” release had taken place sometime during Thursday and Friday of the previous week. An investigation committee was formed to inquire of all possible sources of the slug.

3.2.5 Complications Due to BNL’s and DOE’s Responses to the Controversy

Several things that BNL and DOE did helped keep the fire going under the tritium controversy. DOE’s decision not to allow Brookhaven to restart the HFBR contributed to a public opinion that BNL was not capable of managing nuclear reactors safely, or that nuclear reactors were simply too dangerous to allow on crowded, traffic-jammed, Long Island.

Another was the way that BNL and DOE initially responded to public outrage and requests for information during the early stages of the controversy. Early attempts to suppress public scrutiny (by discouraging involvement of some activists) and to educate the public (instead of dealing with their concerns) fueled outrage among some interested and affected parties.

3.3 Key Participants and Parties to the Tritium Controversy

3.3.1 The Suffolk County Task Force (SCTF)

This group was broad in representation, having constituents from the Suffolk County Department of Public Health, Brookhaven personnel, community experts (such as doctors

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and legislators), as well as concerned community members. The local government had 18 legislators from Suffolk County in addition to the acting executive on this committee. The county is reputed to be responsive to local concerns and progressive. The Task Force did conduct a science study that looked at epidemiology, radiology, and non-radiation contamination issues. They also brought in Brookhaven and Department of Energy employees as well as other officials to testify. One concern some activists raised with the Task Force was that they did not conduct an epidemiological study specifically on Rhabdomyosarcoma, the rare form of cancer being detected in a disproportionate number of Long Island children. One person said, “it needs to be investigated, [it] raises cause for concern.”

3.3.2 Civic Organizations

Politically, Suffolk County is divided into townships. However, these towns are quite large. Brookhaven town, for example, has about 350,000 residents. Consequently, residents are somewhat remote from town government. Towns are further delineated into villages and hamlets. Some regions of the town fall outside these formal designations, but most of the population of a town lives in a village or a hamlet. These are geographically defined entities with no government themselves. Instead they are used to identify sub-sections of the town. Another political unit that is used is the school district. School districts do not coincide with town or hamlet boundaries, and there can be multiple school districts in one town.

Civic organizations exist in many hamlets of the towns. These are not formal units of governance, but are basically clubs for residents of a certain area. Some “civics,” as they are known, include several hamlets or villages. Any resident is free to join the civic organization. Some charge membership fees and use these to purchase or rent a small building for meeting and office space. The purpose of the civics is to channel public input to the appropriate levels of town or county government. Each civic organization elects a president. The presidents of all the civics in the town of Brookhaven meet together and make up a group known as Associated Brookhaven Civic Organizations (ABCO). ABCO plays an important political role in the town, and BNL stayed in close communication with ABCO throughout the controversy.

Although many of the presentations made by BNL at civic associations were confrontational and challenging for the BNL representatives, for the most part a strong alliance existed between the civics and the Lab. This was particularly true for the civic organizations located to the North and East of the Lab, areas not impacted by tritium or chemical plumes of contaminated groundwater. Moreover, several civic organizations included members or had presidents who were BNL employees or ex-employees. Most important of all, perhaps, was the fact that the leader of the umbrella association for all the civics, ABCO, was an ex-lab physicist named Don Garber. Dr. Garber was a strong advocate of the Lab and he spoke out in many venues including letters to the editor of local newspapers, but also in the bulletin of ABCO, and via press releases from ABCO.

Because the civic organizations were generally deemed to represent a community voice that is independent of the Lab, a certain tension persisted between the civics and the environmental activists. The two groups competed for recognition from the general public. One environmental activist explained how BNL would use the civics to combat the environmentalists.

So they would play the civic activists against the environmentalists. That's golden for them.

The civics made several claims against the environmentalists, claims that carried a great deal of force in the local media. First, they claimed to speak for the local population, and they accused the environmentalists of being outsiders or representing people from outside the area. This was particularly effective against environmental groups located outside of the region, such as STAR in Easthampton, but other national environmental groups as well. Second, they claimed concern for the economic viability of the region and painted environmentalists as people who didn't care if jobs were lost. Third, they argued that environmentalists, by stirring up the controversy, were devaluing the local housing market, implying that people wouldn't be able to sell their houses if they wanted to move.

3.3.3 Establishment of CALA (Community Activists for Lab Accountability)

CALA, the Community Alliance for Lab Accountability, is a Brookhaven Lab watchdog group comprised of 33 environmental, health and spiritual organizations in the

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eastern part of Long Island. It arose from a common concern regarding environmental contamination emanating from BNL and serves today as a focal point and primary organization for residents and community groups to get information, recommend policies, and register health, environmental and moral concerns about BNL's operations.

By unifying the positions of diverse groups, CALA has become an environmental, health and ethical organization that is recognized by BNL and the DOE. Its member groups represent more than 50,000 Long Island residents. CALA's mission is to act as an information clearinghouse for member organizations and the public, to initiate community education and outreach, and to establish a direct line of communication with BNL and DOE for the purpose of gaining information and demanding accountability. CALA has demanded environmental representation on BNL's new board of directors, and has established a means of consistent and direct communication between CALA and lab management through monthly meetings. The member organizations work together and separately to develop comments and recommendations on lab operations.

The group was birthed midway in the tritium controversy, in summer 1997. From early 1996 until mid 1997, environmental activists from the area had been attending the Community Working Group (CWG). When the grant destroyed the CWG, some of the activists proposed they meet together to discuss coordinating their actions with regard to the Lab. The early CALA meetings were attended by DOE and BNL officials. They hoped to continue communication with their critics. But the birth of CALA was not easy. Twenty-five activists with different interests and objectives were difficult to weld into one unit. During this process, DOE and BNL was asked to leave. In time, CALA did compose a mission statement, which specified the agenda they hoped to accomplish with regard to BNL.

3.3.4 *Birth of STAR*

STAR (Standing for Truth Against Radiation) is a Long Island activist group located in Easthampton (more than an hour East of BNL). They formed in 1997 just after the tritium leak was exposed. They were attracted to the issues at Brookhaven, which were, at that time, receiving a large amount of media attention. Although they are not neighbors to the site, their influence has been significant in part due to the wealth and fame of the

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Easthampton area. STAR's Board of Directors includes prominent celebrities such as Christie Brinkley and Alec Baldwin. Dr. Helen Caldicott and Dr. Jay Gould have also been instrumental in supporting STAR. Until CALA was formed, STAR was the activist group with the most involvement in Brookhaven issues. With the ebb of the Brookhaven controversies, STAR has taken on a national focus on radiation issues.

STAR has been involved with many activities involving the Brookhaven site. In addition to participating in BNL's meetings, STAR has endeavored to boost community knowledge about the Lab and radiation. Their most significant event on Long Island during this controversy was a workshop they hosted at the State University of NY at Stonybrook.

3.4 DOE's and Brookhaven's Risk Communication Efforts

Brookhaven's public relations difficulties were well developed in early 1996 on account of the sewage treatment plant dewatering controversy and the chemical-contaminated groundwater that led the DOE to offer free public water hook-ups south of the Lab. The January 16, 1996 public meeting where the hook-ups were announced was terrible for the Lab. The discovery of tritium in the groundwater twelve months later mushroomed public outrage at the Lab.

To their credit, despite a crisis of leadership both at DOE headquarters in Washington D.C. and at the Lab itself, the Lab moved forward with a variety of risk communication strategies all aimed at establishing communication channels with the local residents and the outspoken critics. It is not the aim of this report to evaluate those efforts. Many scholars of risk communication might applaud these actions. On the other hand, some activists charged the Lab with wanting to placate the public, to discourage inquiry, and to block considered investigation. Employees at the Lab, on the other hand, claim they sought an authentic dialogue with the public where facts and reason prevailed. For the purposes of this research, we only need to note the character of these risk communication efforts.

3.4.1 DOE Oversight of BNL Risk Communication

One of the key factors shaping the Lab's approach to risk communication was the role that DOE headquarters played. During 1996–1998, DOE underwent a change in leadership from O'Leary to Pena to Richardson. However, for a period of time there was no one at the head of the Department. Consequently, Assistant Secretaries took on responsibility for specific functions. Assistant Secretary Tara O'Toole took charge of the Brookhaven controversy.

O'Toole's approach was to exercise her authority as owner of the Lab and to require the operator (AUI at the time) to submit for her review and approval every public statement or action the Lab proposed to make. Thus, whenever new test results were available, staff at BNL's media relations office would draft a press release, fax this draft to Washington, wait for the Assistant Secretary to review it, edit it, and fax it back to BNL, before the information could be released. In our interviews with BNL employees we learned that it was not unusual for this process to take three or four days. Some interviewees suggested that the time lag made the Lab look bad, as if it were hiding something, because the Lab was never able to give a direct answer to a direct question. It had to wait for DOE Headquarters to approve every statement.

DOE made the judgment that BNL's public relations office did not have the ability to handle this controversy. In response, it flew in experts from other DOE sites where controversies had been handled. BNL employees recounted (with some chagrin) how these "experts" inevitably went running for the airport after one or two encounters with the Long Island public. The implication among the Lab employees was that DOE staff from other sites simply did not understand the local culture of Long Island and were shocked by the aggressive "in-your-face" attitude of the people.

Much more successful and valuable to BNL staff were the experts in public participation and risk communication brought in to train BNL's employees managing the controversy. Hans Bleiker, James Creighton, and Peter Sandman, three of the biggest names in the field of public controversy all made their appearance at BNL during the controversy. Their advice proved useful and BNL made efforts to act on it. Several approaches to establish communication with the public were taken.

3.4.2 Brookhaven Executive Roundtables (BER)

DOE and BNL established the Brookhaven Executive Roundtables to improve communication among the management dealing with the tritium and the other controversies. They were also meant to improve communication between BNL and the surrounding communities. The BER met about six times between August 1997 and December 1997 and has continued to meet bi-monthly since. The following depiction of the BER was taken from the minutes of the first meeting:

Mr. Helms stressed the importance of the formation of an Executive Committee for BNL. He stated that the principal purpose for the new committee would be to improve communications and to integrate the various activities, to better interact with the various stakeholders, to solicit their input to the greatest extent possible and to diligently seek mechanisms by which we can identify key issues.

The initial membership included DOE and BNL representation along with representatives from Brookhaven Town and Suffolk County governments. The USEPA was also represented, but New York State government was not represented. No activist groups or independent community members were members, although several were allowed to attend meetings as guests. The minutes of the first meeting documented how membership was established by the individuals invited to the first meeting:

attendees were requested to provide lists of the groups they feel should be represented at future meetings. Generally, all members felt the membership was complete.

In other words, the membership of the BER made up of DOE, BNL, and town and county government decided among themselves that no one else needed to be a member of the organization. This may have served as an important means for a risk communication discourse among government officials and the Lab, but it would not be the venue for a discourse with the publics.

The format for the BER was to be open communication in an informal manner. It was decided that the Committee would maintain a rotating chairperson and that neither DOE nor BNL would be eligible.

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[Mr. Helms] also stressed that DOE and BNL were members with equal standing as the others and would not impose structure or dictate procedure for the Committee. He further stated that it will be the Committee's duty to responsibly react to issues that are raised by any of the members or the community. Mr. Helms cited environmental safety and addressing citizens' concerns as DOE's priority items for consideration but that the agenda could be as broad as the committee desired. He also stressed that for the committee to be successful, each member would need to commit to be responsive to the concerns of the others.

Roundtables became the vehicle for communication because Brookhaven employees did not want to repeat the kind of adversarial communication with the community that characterized the January 16, 1996 public meeting. Brookhaven often solicited the assistance of outsiders (non Brookhaven employees) to present expert knowledge to the public.

At one of the first few meetings it was decided that future meetings would be open to the public, but only by invitation. People who wished to be invited could contact the Lab. Time would be allowed at the end of such meetings for a question and answer period.

**Box 3-2. Target Audience of HFBR
Roundtable Meetings (Listed in
Chronological Sequence)**

1. BNL senior management
2. Regulators and local officials
3. Librarians and public information sources
4. Environmental organizations
5. Civic groups
6. Business community
7. Activist groups

3.4.3 DOE's HFBR Roundtable Workshops

Over the course of September and December of 1997, the DOE held seven roundtable workshops. These were held at BNL and at locations out in the community with the purpose of both educating the public and listening to the publics' concerns. Each roundtable originally planned to focus on a different population (see Box 3-2). A list of questions to discuss in each roundtable was prepared by the BNL community relations office. Scheduled to last 3–4 hours, the roundtables were intended to combine different forms of communication. A facilitator or a team of facilitators ran the discussion. The typical schedule included a formal presentation by DOE or BNL followed by a facilitated discussion (anonymous 1997a).

These meetings were advertised by the DOE, not by BNL. They were billed as information sessions. A brochure advertised the meeting as follows: “Learn and Comment! The U.S. Department of Energy is holding an INFORMATION SESSION to discuss the HFBR one-on-one, and accept your input” (DOE 1997a).

To ensure that the targeted people knew about and attended the meetings, letters were sent to individual people. These letters billed the event as a “roundtable discussion” and as a “workshop designed to get input from the community” (D’Ascoli 1997). These letters were on BNL stationery labeled “Office of the Director” and were signed by the community relations coordinator at BNL. After the workshop, letters of thanks were sent to people who attended. These letters came from the Brookhaven Group of the DOE and were signed by the Director of the Nuclear Program Division. Appended to this letter of thanks was a list of comments collected from the attendees with a note that the comments were being sent to the Secretary of the DOE in Washington.

BNL prepared carefully for the roundtable meetings. At planning meetings the DOE and BNL participants reviewed who would speak about what and for how long. Presentations were rehearsed and critiqued. The documentation from these meetings emphasized how the meeting should come off to the participants. For instance, one note commented:

Box 3-3. Advice Provided BNL Employees at Poster Sessions

Demeanor:

- smile
- be welcoming
- face the audience when speaking about your poster
- if they have questions you can't answer write them down and we'll get back to them
- if people appear "lost" engage them in conversation
- no gum
- don't be defensive

We want this meeting to be as flexible as possible, want attendees to have control over how meeting is run — facilitator is there to help them run it “their way.” This requires facilitator to be able to suggest options for managing group discussion, and keeping them on track. Preference is to avoid breaking up into sub-groups (Anonymous 1997a).

One component of several of the roundtable meetings was poster sessions, which are discussed in the following section.

In January 1998, after the roundtables were completed, the Executive Manager of Brookhaven Office of the DOE made a report to Secretary Peña that included the following conclusions:

- There is little widespread opposition to continuing the operation of the HFBR provided it can be demonstrated that it can be operated safely.
- A relatively small number of stakeholders strongly oppose continued operation of the HFBR under any circumstance.
- A far larger number of stakeholders support the continued operation of the HFBR.
- Scientists from academic institutions and businesses worldwide strongly support the continued operation of the HFBR.
- Senator Alfonse D’Amato and Congressman Michael Forbes strongly oppose the operation of the HFBR.

3.4.4 Poster Sessions

Poster sessions were aimed at disseminating information and engendering communication with the public. These sessions were set up with tables designated to specific topics. At each table stood one or more Brookhaven employees. When people approached the table to read the information, Lab employees were available to converse with them and answer any questions. At some early poster sessions, Brookhaven also had tables available for local activists to set up displays with their information, brochures, meeting times, and local events.

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As BNL gained more experience and training with community relations, poster sessions became more refined and highly planned. Notes of an “employee session” included the advice listed in Box 3-3.

Another list titled “steps to follow with angry people” included these items:

- do not meet hostility with hostility
- show you are a caring person
- show you are open to hearing their concerns — listen
- project an empathetic nature

Some people were assigned to be greeters, others were to stand by their posters and engage visitors in conversation. Everyone had a name-tag. Media were funneled to the appropriate representative. Everything about this planning document suggests BNL was putting into practice the advice provided by its public relations consultants.

3.4.5 Meetings with Civic Organizations

One of the most significant things BNL did to communicate their risk messages to the public was to leave the Lab and speak to residents in their own communities. Civic organizations were the natural venue for this kind of outreach. “Civics” are neighborhood groups that meet to discuss problems of governance. Because the Town of Brookhaven is so large, individual neighborhoods find civic organizations a good way to channel their local concerns to town government.

During the period of 1996–1997, BNL employees made dozens of presentations at local civic organizations in Brookhaven and neighboring townships. Meetings were held in firehouses, libraries, schools, and civic group meeting halls. Sometimes the purpose of the meeting was to allow BNL to make a presentation. Other times the Brookhaven employee in attendance would merely field questions.

The dynamics at these meetings varied greatly. Some were highly vocal and contentious. Others were calm and quiet. The most contentious meetings were held in the communities thought to be most impacted by the contamination, those areas to the south of the Lab.

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According to people at Brookhaven, there were two reasons why BNL reached out in this way to the civic organizations. First and foremost, the goal was to rebuilt trust with the publics. They felt that the best way to do this was to first get the publics to trust individuals from BNL. As one presenter put it, the goal was to show, “you are a well-meaning person who wouldn’t do bad things intentionally.” Once the public came to see BNL scientists and management as reasonable and “good” people, they would eventually come to trust the Lab again. The second goal of these meetings was to provide the publics with “a point of contact.” The BNL employees who made presentations in these venues told people to call them if they had any questions. Again, the purpose of this was to humanize the relationship the publics had with the Lab.

3.4.6 Canvassing the Community

Another strategy used by BNL to reach out to local residents was to go door to door in the most affected neighborhoods. A pair of BNL employees, one public relations person and one scientist/manager knocked on doors of houses in the water hook-up areas. They handed out information and offered to answer any questions people might have.

3.4.7 The Rise of the Community Working Group (CWG)

In the early days of the chemical contamination controversy in the first part of 1996 (nearly a year before the tritium was discovered), BNL attempted to establish a Community Working Group (CWG). BNL’s goal was to engage the publics in a dialogue that would enable the Lab to accomplish a number of things. First, the Lab sought to get its message out to the local residents. The message explained the cause of the contamination, the extent and risk posed, the plan to mitigate the risk, and the changes BNL were making to prevent future contamination. Second, the Lab sought to reduce conflict and build trust with the local population. Several of the civic organizations joined activists in expressing anger, fear, and amazement that BNL could act so imprudently. BNL needed a venue where it could admit its former shortcomings and begin to build a positive relationship with local residents. Third, BNL saw the CWG as an opportunity to test risk communication messages. They would make available to CWG members summary reports and inquire into how the reports were received. Changes could then be made before the final report was issued publicly.

BNL assembled the CWG by telephoning and writing letters of invitation to individuals from the local community who were interested in the events. One member of the North Shirley neighborhood reported that he was invited to attend after making a few telephone calls to the public relations office requesting information. Although BNL invited specific individuals, the CWG membership was open. Anyone could attend. At the first meeting, which was held at BNL, those attending asked BNL employees to leave the room, in order to give the group the space it needed to discuss what it wanted to achieve from these meetings. When BNL was invited back in, the attendees presented a list of fourteen items that the CWG wanted to discuss. For about a year, the CWG seemed to operate fairly well. BNL let those attending direct the focus of the meetings and mainly played an educational role.

3.4.8 The Grant that Destroyed the CWG

The CWG operated reasonably well until early 1997. Around that time, BNL offered the CWG a grant and office space at the Lab in which to operate. Two main individuals in the CWG, proposed accepting the money and proposed themselves as co-directors of the group. They would receive a modest salary from the grant and take over more leadership responsibilities in the CWG. The money was funneled to these individuals through the Long Island Progressive Coalition, an established non-profit on Long Island that was active in shutting down the Shoreham power plant. A member of the Progressive Coalition had facilitated the early CWG meetings. Two of its lead figures had been active in the CWG from the beginning. The Progressive Coalition formally applied for and received the grant.

Of the people we interviewed who were on the CWG, it was widely acknowledged that the grant destroyed the CWG. People complained about the secretive nature of the grant. We had CWG members from very different perspectives claim that the grant was done “behind the back” of the CWG and pushed through at a meeting that was not widely attended. They claimed that the Lab would not release the grant proposal or the conditions under which the grant was given. This promoted the notion that the Lab had a secret arrangement with the two individuals who accepted the grant and it raised the

suspicion that they were now working for the Lab. One of the more outspoken critics said this of the grant:

When Associated Universities was running that laboratory, they gave a woman, by the name of [names person] a \$50,000 grant to do whatever she was going to do. [...] They give her a \$50,000 grant with no conditions. It's a bribe. It's not a grant, it's a bribe. [...] They wanted to buy a buffer and [names person] was willing to be the buffer. She was going to be the one to present the information to the community, she had environmental credentials, and so she sold out for that money and was going to be their intermediary, their buffer. She was going to answer all the questions that the community had as to what was going on at the laboratory. That what's they wanted, that's what they wanted to buy.

When some members of the CWG objected to what they perceived as Brookhaven taking over the CWG, the CWG splintered, some formed a new organization called the Environmental Advocates. Several members of the CWG joined this informal group, which continued to meet as an advisory body to BNL. But many other activists, especially those who were leading established organizations walked out of the CWG at this time and later formed CALA. At this time several local residents who had participated actively also walked out disgusted and never returned, complaining that everyone (BNL *and* the environmental activists *and* the civic leaders) had their own pet "agendas" and none of them was interested in a reasoned discussion about the facts.

3.5 Post-Tritium: The Community Advisory Council (CAC)

After the demise of the CWG, BNL began to study the possibility of setting up a Site Specific Advisory Committee, similar to those at other DOE lab sites. After much consideration of SSAB (Site Specific Advisory Boards) at other DOE sites, and because of the limitations of forming a formal advisory committee, the Lab decided to call the board a Community Advisory Council (CAC). Unlike with CWG, whose membership was open, membership on the CAC is determined by rules. CALA and STAR are represented, as are the civic organizations and a number of other advocacy groups, including groups supporting the Lab. Because the CAC was established after the tritium

controversy had largely been played out, it has not been an active participant in that event. The CAC continues to meet bimonthly and deal with ongoing issues between the Lab and the community.

In the years since the controversy, the Community Advisory Council has helped steer BNL toward doing more research in renewable energy. At the same time, the decision was made to also allow the medical research reactor to cease operation. Thus, the tritium controversy was significant in getting BNL to end its relationship with nuclear reactors and to shift at least a portion of its research efforts toward renewable energy sources.

4. Findings: The Role of Social Networks in Shaping Risk Perceptions

This section reports the results of interviews with Lab employees, community members, and activists. Because the main purpose of the study was to comprehend how people formulate risk perceptions in a social environment, the section is organized around key social environments, or social networks. Three distinctly different networks were found in the community studied. Although it may seem so at first glance, the networks are not defined by ideology or even risk perception. We have defined these networks according to channels of communication. Despite this, many (but not all) people in each network may have a similar worldview or even similar beliefs. The point is, simply, that not all members of each network share the same beliefs or perspectives. In describing each network, we consider each of the following: risk perception, conceptual frames, changes in risk perception, information flows, and the connections with the other networks.

A small set of independent community members tapped all three networks, but refused to express any preference for belonging to any one of the three defined networks. These people walked among all three of the networks, seeking information and explanation and intentionally sought to maintain their neutrality and independence. In fact, rather than expressing allegiance to one network over another, they were strongly critical of all three networks for being biased.

For the purposes of this study, we understand a social network to be a pattern of personal connections about a central identifying theme or purpose that a group of individuals shares. Furthermore, we presume that within each network are other networks. For example, within the BNL site, the National Weather Service staffs a small facility. This small group constitutes its own network, yet they were clearly also part of the BNL facility network. The level of analysis invoked in this study, however, makes it impossible to adequately characterize any of these smaller networks. Instead, the focus is reserved for the three broadest networks.

Finally, it is clear that some individuals are capable of spanning networks, becoming members of two or more networks. Three of the people we interviewed had strong associations with both the Friends of BNL network and the Community Residents network. We also interviewed two people who were associated both with the Community Residents network and the Long Island Activists network. We did not find any individuals who identified themselves as being both a member of the Long Island Activist network and the Friends of BNL network.

4.1 Friends of BNL Network

4.1.1 Characterization of the Network

The core membership of this network includes current and recently retired Lab employees (some of whom are unionized under the International Brotherhood of Electrical Workers Union Local 2230), DOE officials, scientists from other institutions who use the Lab for research (known as “facility-users”), as well as the formal organization called Friends of Brookhaven. Something like 3,200 employees work on the BNL site. Several members of this network were also members of the Community Residents Network discussed below. The Friends of BNL network is made up of individuals linked through a variety of communicative channels including many face-to-face encounters. Even retired employees often come to the Lab to attend professional presentations or other public events. In addition, a newsletter called *Brookhaven Bulletin* is published by the Public Affairs Office and keeps readers abreast of the Lab’s recent doings.

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People working at the Lab share many things in common, but workplace is recognized to be a key factor shaping an individual's sense of identity, especially in the United States. All people who worked at BNL shared this identity. They become, in a way, part of a family. One interviewee from the Lab felt uncomfortable with the word "family," but still captured this important idea. Speaking about what it was like in 1997 he said:

[. . .] that's the atmosphere that generally existed at the laboratory. Because we're all part of the same . . . not family . . . but same group that works on site. Very collegial atmosphere. Friendly atmosphere, amicable.

People working at the Lab also had other important commonalities. For one thing, many of them shared a belief in the importance of verifying knowledge through a scientific process and a belief in the positive nature of science to society. Not everyone in this network is a scientist, it includes employees and other on-site workers from public relations, accounting, construction, security, health care, etc. Still, to be affiliated with BNL is to be affiliated with a belief in science, both as a way of knowing and as a way of improving the quality of life. This case study suggests that a predominant aspect of the ideology of this network is a belief in the positive role that science plays in improving the quality of life. This was especially true for the scientists. One put it in these words:

As an employee at the reactor, we believed in what we were doing, believed in the science, we believed in our contributions.

Interestingly enough, as the controversy developed, BNL would come to be criticized for being too enthusiastic about the science. They were criticized for putting science first, and the environment second, when proper environmental practices should have preceded the science.¹⁰

This belief in the positive value of science is closely linked to a second belief harbored by members of the Friends of BNL network: that the science happening at BNL is of excellent quality. People routinely spoke of BNL as a "world-class laboratory," proudly noting that scientists come from all over the globe to work at the site. One

facility user, Jean Jorden-Sweet, linked both of these key concepts (science is good and BNL does good science) when she was quoted publicly as saying:

Our national labs are our nation's treasures! [. . .] [They] produce patents, contracts, tech-transfer, [and] medical advances, and build up the high-tech know-how of this country. We cannot do strong science without the necessary tools such as BNL's [HFBR]" (High Flux Beam Reactor) (*Brookhaven Bulletin*, Sept 26, 1997 p.2).

4.1.2 Perceptions of Risk: Human Health Risks from the Tritium in Groundwater

We take it for granted that within any network people will hold a wide variety of perceptions of the risk. We do not expect a consensus. However, we also recognize that some networks are defined around an ideology or around a certain experience, as the Friends of BNL network is defined around the experience of working at the Lab and a belief in science. This may be expected to produce a strong agreement on risk perception. Indeed, we found that the institution advanced a specific risk perception. The people from this network who we interviewed indicated that they agreed with this perspective, as we describe below. However, we would not say that everyone in the Friends of BNL network felt the same way about the risk from the tritium.¹¹

For many of our interviewees from the Friends of BNL network, the controversy over tritium in the groundwater under Brookhaven National Lab was strictly about human health risks. Tritium is a carcinogen if it is ingested or breathed in. Contaminated groundwater might be taken up by a private or public drinking water well and consumed by residents in the neighborhood or employees at the Lab.

When we asked interviewees to think back to the early days of the controversy and recount their risk perception, several mentioned concern or apprehension. They felt that this might be a serious health risk, but there was too much missing information to say for sure. They wanted more information. Specifically, they wanted to be sure of the source of the tritium, the amount that had leaked, its location in the groundwater, and they wanted

¹⁰ This point was first raised in the Tiger Team report a decade earlier (see above).

¹¹ The people we interviewed from the Lab were those most deeply involved in the tritium controversy. Employees in non-science departments (human relations, accounting, maintenance, etc.) might have very different risk perceptions.

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to know about the hydrological conditions of the contaminated aquifer. As these data became available, those interviewees who did acknowledge an initial concern or apprehension about health risks rapidly reached the conclusion that the risks were extremely low. Initial studies done by BNL showed that the contaminated groundwater was not near any drinking water sources, either inside the Lab or outside of it. *Still, this assessment of the risk hinged on the tritium staying where it was thought to be.*

Since groundwater moves, it was possible, reasoned these interviewees, that the tritium-contaminated groundwater could, in the future, pose a risk to human health if it contaminated a drinking water well. The Lab draws its drinking water from wells on site. Just outside the Lab boundary to the west are drinking water wells for the public water supply for local communities. To the south are private wells in the North Shirley residential area. Studies in 1997 showed none of these drinking water wells was in danger of tapping the tritiated water, at least not at that point in time. However, further investigations conducted showed that the tritium plume was moving in the same direction as the chemical plume that contaminated drinking water wells to the south of the Lab. Still, because of the chemical contamination in 1996, DOE had hooked up to public water nearly all the private residences in the danger area south of the Lab. As test wells were drilled and the groundwater model was finalized, the consensus within the Lab community was that the tritium would pose no danger to the Lab's drinking water or the public water supply wells. Yet there remained the possibility that it could impact the private wells sometime in the future.

Our interviewees from the Friends of BNL network pointed to three factors that led them to conclude that even this migrating tritium posed no danger to human health. First, tritium naturally decomposes, losing its radioactivity with a half-life of about 12.3 years. Studies showed that, given the slow rate at which the groundwater was moving and the dilution of the tritium in the groundwater, by the time the contaminated water reached the Lab boundary, the level of contamination would be below the standards set in the Safe Drinking Water Act. The conclusion that many people drew was that even if the Lab did nothing, the problem would "fix itself" with time.

Yeah, just leave it alone, and by the time it reaches the boundaries of the lab, the dilution would have taken care of any health issue.

Second, the groundwater models showed that, as the plume migrates southward, toward the ocean, it is also going deeper into the earth. Estimates were that the contaminated plume would be far deeper than any private well was likely to ever be. Therefore, even if the tritium concentration did not decline, and even if people did consume their well water, they would not ingest tritium, simply because the tritiated water was deeper than their wells.

The third reason why the risk to human health from the tritium was perceived by many to be low was the simple fact that the groundwater under the homes in North Shirley was already contaminated with toxic chemicals. The DOE had paid to hook-up to public water everyone with a private well in the danger area. In other words, people were not drinking the water anyway, thus there could be no exposure even if the hazard were present.¹²

4.1.3 Information Shaping Risk Perceptions Among the Friends of BNL Network

The Friends of BNL network relied on scientific reasoning to make its decisions. Scientific reasoning is a chain of logical associations based on evidence. Therefore, in order to draw conclusions about the risk, individuals in this network needed hard evidence, they needed facts. Two specific sources of information were cited as being key.

The first and most important data were the test results from the test wells that had been drilled across the BNL site. Over 700 test wells were drilled on the BNL site during the course of this controversy. Samples taken from these wells were routinely analyzed for tritium (and other contaminants as well). By monitoring the concentration of tritium in the groundwater at different depths, times, and locations, it was possible to assemble a picture of the danger. People in this network interpreted the data in different ways in order to derive meaning from the numbers. Some physicists we interviewed translated the

¹² As an aside, during our interviews we learned that while nearly all houses did hook-up to public water some kept their well functioning. It is known that at least one family used the well to fill their swimming pool. Thus, it should not be taken for granted that people are not using their wells, just because they got hooked-up to public water.

test results into numbers of atomic disintegrations per second. However, this metric was not widely used. For the most part, people in this network used two different milestones to interpret the significance or dangerousness of the contamination.

The key criterion people in this network used to evaluate the risk was the drinking water standard of 20,000 pCu/l. People routinely talked about concentrations as percentages of this standard (e.g. 25% of the standard, twice the standard, etc.). Although at some wells near the reactor, concentrations of more than fifty times the standard were found, the concentrations generally declined with distance from the reactor. When concentrations became many times the drinking water standard, it was less common to use this metric. Instead, notation apparently switched back to bald numbers of pCu/l (although this is an anecdotal observation and has not been systematically verified).

The second metric commonly used to interpret the dangerousness of the contamination was the amount of tritium in an “EXIT” sign. These signs, which are found in theaters and other buildings, contain tritium gas which emits radiation, striking a phosphorized tube that glows. The benefit of these signs is that they remain illuminated without the aid of electric power, making them useful in the event of emergencies. EXIT signs reportedly contain about 20–25 Curies of radioactive tritium, which can provide illumination for more than ten years. Since EXIT signs are ubiquitous in our society, the implication is that the risk posed by that level of tritium is acceptable. Our interviewees reported the common use of the EXIT sign risk comparison. The total amount of tritium leaked from the HFBR spent fuel pool was characterized by BNL as being less than the amount contained in one EXIT sign.

The EXIT sign also showed up in our interviews in a second way. During 1997, there were two different cases in neighboring New Jersey where teenagers broke EXIT signs and were exposed to tritium. In November a teenager destroyed a sign, exposing himself to the tritium gas. In May, three teenagers ingested some tritiated water from a broken sign while eating sunflower seeds in their home.¹³ The home was tested and urine from the boys and a firefighter was tested (the tests were done at BNL). While it was reported that one of the boy’s urine contained tritium at a concentration of 28,600,000 pCu/l (more

than 1000 times the level for drinking water acceptability), the doctors suggested only that the boy drink a lot of water to flush his system. People we interviewed made reference to this prescription. They reasoned, if a boy can be exposed to that much tritium and the doctors are not even worried, why are we fretting about much lower levels in drinking water?

The metrics for comprehending the seriousness of the risk that were privileged in this network clearly depended on the knowledge of the parties speaking to each other. Physicists speaking among themselves might choose to use “number of atomic disintegrations per second,” while engineers speaking to the accounting department might use the EXIT sign metaphor.

The second most important information source to Friends of BNL network was the hydrogeologic model of the contaminated plume. BNL brought in a top-notch team of scientists to characterize and model the plume. Using the best science available at the time and barring no expense, the team produced thick reports and detailed color maps, which characterized the plume in terms of concentration, position, and movement. The major findings of this model (that the plume was moving slowly toward the boundary and deeper into the earth) were substantially responsible for shaping the perceptions of people in this network. The model served to assuage concerns based in uncertainties about the location, velocity, direction, and contamination of the plume. Although the model itself was informed with empirical data (from the monitoring wells in part), such modeling also requires the making of certain assumptions. What assured people in the Friends of BNL Network that these assumptions, the interpretation of the empirical data, and the composition of the model were all made competently was the reputation of the members of the modeling team and the commitment of the Lab and DOE leadership to excellence in the modeling effort.

4.1.4 Risks to Human Health from the Remediation of the Tritium-Contaminated Groundwater

Despite a near consensus among the Friends of BNL network that the tritium in the groundwater posed no immediate or future threat to human health, BNL did agree to

¹³ Downloaded from: <http://www.lightpanel.com/tritiumpress.htm>

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remedy the contamination. Two specific actions were taken. First, the Lab pumped about 95,000 gallons of the most contaminated groundwater just adjacent to the spent fuel pool and shipped this water via truck to Oak Ridge National Laboratory in Tennessee for disposal. Many of the same people who told us the tritium posed no risk if it remains where it is also mentioned that there is probably some human health risk from the mitigation measures being taken.

[Removing the tritium] that's really removing no risk. Actually it's creating risk because now you pump it out, you put the employees pumping it out get some exposure, they're receiving some exposure, regardless of how small. And then you have to put it on the highway. You've got a truck trucking it down to Tennessee, so they have vehicular issues, transportation issues take place. And then you get to Tennessee and they evaporate it up into the air anyway.

The second mitigative action BNL took was to install a line of wells to intercept the plume as it moves south. Since 1997 it has been pumping this contaminated groundwater to a recharge basin, where the contaminated water re-enters the aquifer. There are some emissions of tritium to the air in this process at the recharge basin. The logic of this exercise is that, by keeping the tritium contained in this loop of groundwater flow, pumping, and recharge, one prevents contaminated water from migrating closer to the site boundary while the natural disintegration of the unstable tritium progresses. After a certain number of years, the process can be ended with assurance that the radioactivity in the groundwater is acceptable.

One group of special concern at the Lab was a unit of the National Weather Service (NWS) that is occupying a building on BNL land close to the recharge basin. The workers there were concerned about the risk associated with their exposure to tritium that is evaporating off the pond. This concerned them so much that the Environmental Health and Safety Office had to have multiple meetings with those employees to explain why their risk, while not zero, was very low.¹⁴ To address their persistent concerns, the Lab set up air monitoring stations and provided the current levels to the National Weather

¹⁴ While we tried many times, we were unsuccessful in getting an interview with anyone at the National Weather Service office near the evaporation pond.

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Service personnel every day they came on-shift to work. While we were unsuccessful at gaining any interviews with employees of the National Weather Service at BNL, other interviewees suggested that the NWS employees were not as ready as other BNL site-users or employees to accept the tritium risk. A reason why is that, although the exposure levels were probably quite low, the NWS building is adjacent to the recharge basis. In other words, they were more at risk than most other people at BNL to fugitive air emissions of tritium. A second factor is that the NWS personnel were not tightly integrated into the BNL community. They were new to BNL since 1995 and were not necessarily enthusiastic about making the move from their previous location elsewhere on Long Island. Moreover, their building is in a remote portion of the Lab, not a short walk to the cafeteria, which made it difficult for the NWS employees to develop connections with other people on the BNL site.

4.1.5 Learning About the Risks: Education Within the Friends of BNL Network

4.1.5.1 Learning by Lab Employees

During the height of the controversy the Lab began a program of outreach and education for its current employees. For about a month, a team made the rounds of employee departments to speak about the Lab's drinking water, the HFBR reactor and pool, and the groundwater mitigation project. The meetings lasted about one hour, took place at the worksite of the employees, during the employees' paid workday, and were oriented toward answering whatever questions or concerns people had. The people who orchestrated these meetings felt they were very successful.

When asked what made them successful, they reported that employees were given lots of opportunities to ask questions and get answers from the people directly responsible. They also reported that by holding these meetings on the Lab's time they conveyed the notion that the Lab really cared about how they felt. Both those things contributed toward making it a positive experience.

One of the key topics for employees was the drinking water at the Lab. Several employees had noted that people in the Administration Building were supplied with bottled water, while most other buildings had drinking fountains hooked up to Lab water.

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Some employees were concerned that possibly the Lab's water was contaminated and the administration knew about it. This came as a total surprise to management:

[T]hey [Lab employees] were really concerned about their own health and safety and that . . . And that really opened up our eyes, like wow, we really do need to communicate better with our own employees about some of these issues. Particularly the drinking water. "Why is there a bottled water in the Director's office and I'm drinking out of a fountain. You know, am I in danger? And why is the Director's office getting bottled water? Shouldn't I?" Just simple things like that. Those are great issues. [. . .] Almost people instigating that there was a class system. That the higher people were saved and the rest of us got the junk. So it really opened up a number of issues, kind of ancillary to groundwater contamination, the tritium plumes.

While some members in the Friends of BNL network, namely engineers and project managers, needed to base their risk perception on empirical data, we learned that at these employee meetings there was no demand to "see the data." We asked one interviewee who was central to these educational meetings about the role that information played in helping to shape the employees' risk perceptions. He answered that, at these meetings for Lab employees, no one ever asked to see the reports:

I can't even think of a case where somebody [a Lab employee] said, "You're full of baloney. I don't believe you." Or "Prove it." So, again, I think that was . . . we were all together. And I think that's the atmosphere that generally existed at the laboratory

We asked why he felt the employees did not ask to see the actual reports that characterized the risk. His answer was that there was a lot of trust among Lab employees:

I think that there was a certain level of trust and it wasn't just me . . . but, a fellow employee, speaking about the laboratory and what was going on.

In summary, within the Friends of BNL network there were people who perceived the tritium risk to be important enough that they raised objections and spoke out about the conditions at the Lab. However, according to those we interviewed, these perceptions were lessened when Lab management listened to employees' concerns, let them ask

questions, and conveyed a sense of collegiality and competence. This is clearly different from encounters that the Lab personnel who were responsible for the remediation had with the community residents (see next section).

These sessions with Lab employees certainly helped employees develop a perception that the risk from the tritium was slight, but they also served a second purpose. During the sessions it became clear that one of the issues facing employees was what to say to their neighbors outside the Lab. Employees indicated a desire to deliver information and messages to their neighbors:

A lot of people did say, “Yeah, oh, okay. You know okay, give me more information. I’d be happy to talk to my neighbors, be a pain in the ass. You know? I’m going to tell them the right things, you know?”

4.1.5.2 Learning About Public Participation and Public & Media Relations

When it became clear to Brookhaven that the crisis was largely about the public lacking trust in them, the Lab set about learning how to better involve the public. They sought out information from a number of sources.

One thing the Lab did was to tap the network of DOE facilities across the country. DOE headquarters helped to bring in experts from other sites which had had public controversies. Staff from these sites visited Brookhaven and made recommendations for how the Lab should cope with the problem.

A second thing that the Lab did was to bring in experts on public controversy. Hans and Annemarie Bleiker, two well-known consultants in the field of public participation in controversial decision making, came to provide BNL Public Relations staff with a mini-version of their week-long workshop. One of the Bleiker’s major pieces of advice is to resist the urge to block off participation, and instead to seek out the involvement of concerned people, especially the involvement of the most vocal critics.

Box 4-1. Factors Shaping Risk Perceptions for Friends of BNL Network

- Familiarity with radiation and knowledge about its health effects
- Familiarity with scientific terms associated with the contamination (e.g. pCu/liter)
- Confidence in the honesty, integrity, and competence of scientists & Lab management
- Belief that the Lab produces net positive social benefits
- Availability of technical information and groundwater models
- Opportunity to learn about the issue on “company time” with minimal effort
- Tolerance for contamination

Peter Sandman, an internationally known speaker in the area of risk controversies also visited the Lab to deliver a seminar. Sandman emphasizes the difference between cognitive and emotional responses on the part of the public and recommends strategies for dealing with each.

4.1.6 Factors Shaping Risk Perceptions for Friends of BNL Network

Based on these interviews we learned that seven main factors seem to be most responsible for explaining how individuals in the Friends of BNL network developed opinions about the risk from the tritium in the groundwater.

First, familiarity with radiation came up as a significant factor. Some of our interviewees from this network had worked with tritium and radiation for decades. For people with this level of experience and familiarity with radiation opinions about the risk of low doses of radiation were probably established years ago and are fairly stable. For example, this individual said,

I don't know. Maybe having been a former Lab employee, I was at the Lab for more than 30 years, maybe I don't worry so much about radiation.

Associated with this is the idea that knowledge of the risk may affect one's perception:

Probably I'm less worried about it because I know more about what radiation is and how it might affect somebody.

And this person attributed her low concern to her professional history:

So my perception of the risk as it existed didn't change a whole lot, partly because of my background: probably 20 years of a technical background.

Second, many, but not all of these individuals were competent in the scientific language used to characterize the risk. By far the most common term used to illustrate the difficulty associated with comprehending this risk was "picocuries per liter" (pCu/l). This is the unit measure used to characterize water polluted with radiation. The Safe Drinking Water Act includes standards for radiation in drinking water, stating that the levels must be below 20,000 pCu/l. Even scientists at the Lab who did not work with radiation, were

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familiar with prefixes like “pico,” “nano,” and so on. They would also have been familiar with seeing things characterized in terms of large numbers, as this interviewee stated:

If you work in a scientific field, everything is 10 to the minus something or 10 to the plus something. That is no foreign concept to my mind. But to a lot of people it is.

This was not necessarily true for all members of the Friends of BNL Network, but was more applicable to those with backgrounds in sciences.

Third, people tightly linked to the Friends of BNL network had confidence in the honesty, integrity, and competence of their colleagues at the Lab and in other scientific institutions. This made it much easier for those dealing with the controversy to speak with the other employees and users of the Lab. For instance, one person told us a story about communicating with the Lab personnel about the tritium contamination. He noted that, even when personnel were not familiar with radiation and its terminology, they were willing to listen and to believe, mainly because they trusted the integrity of their colleagues.

We started talking picocuries and what the regulatory standards were. Everybody was, “What?!” It was all new to a lot of people, certainly even to the management of the laboratory. So, I think we were all educating everyone at the same time, employees or non-employees. But again, maybe their [Lab personnel’s] openness and willing to listen and willingness to trust what we were saying was certainly different [from the publics’].

Fourth, people in the Friends of BNL network shared a fundamental belief that the Lab did *good things* for society. Thus, there was a sort of presumption of innocence — the Lab was a good neighbor, a good citizen, and any malicious or bad behavior would have to be proven. Even if they admitted that the Lab occasionally made mistakes, the underlying premise was that the net effect was positive for society. From this standpoint, people were disposed to believing what the Lab said. During the period of this controversy, people at BNL perceived the Lab as “under attack.” The sense of moral rightness combined with this perception of attack from enemies (the media and the

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environmentalist activists) led to a circling of the wagons mentality, and further strengthened the trust among Lab employees for the Lab and each other.

Fifth, two central pieces of evidence and technical information that the Lab used to characterize the risk were seminal in shaping the risk perceptions of many people in the Friends of BNL network. The first piece of information was the test results from the test wells. Hundreds of test wells were sunk all over the lab property and samples were routinely taken to measure tritium contamination. The second kind of information was the hydrogeologic model that characterized the tritium plume. The main lesson from this model was that, by the time the plume reached the Lab boundary and entered the area beneath private homes, the tritium contamination in the groundwater would be below the limits allowed in the Safe Drinking Water Act.

Sixth, people at the Lab enjoyed the luxury of learning about the controversy on company time. A team of people made visits to all the worksites at the Lab, giving an educational presentation and entertaining direct questions. Not only were employees paid, essentially, to learn about the contamination, they were also spoon-fed the information. They did not have to make the initiative to go out and get information, the information came directly to them. These meetings were instrumental in shaping the risk perceptions of many Friends of BNL network members. These meetings were one of the key locales where social interaction among the people in this network was focused explicitly on the low dose risk.

Seventh, people in this network, but particularly the scientists see as unavoidable that, in the practice of science, there will be waste products. These contaminants inevitably find their way into the environment, at least at some level. From this perspective, it is infeasible to expect that no waste will escape and it is economically and technically infeasible that waste can be cleaned up entirely. Thus these individuals are likely to entertain a certain tolerance of environmental contamination. The issue is not whether contamination is tolerable or not. Since some contamination is unavoidable, especially at a large lab like BNL, the issue is how much contamination is tolerable. The public, of course, sees this issue quite differently. They equate contamination with mistakes or failure.

The *key point* to take from this case study is that the Friends of BNL network, through its various channels of written and oral communication, served to nurture and reconfirm these risk perception factors among its members. For example, when the Lab newsletter would include a story about prestigious science happening at the Lab, all the members of that community would have reconfirmed their fundamental belief that the Lab was doing good things for society. And when management of the Lab would speak about radiation as a routine matter with which the competent and experienced employees at the Lab were accustomed to dealing, the employees would have reconfirmed their notion that radiation was a familiar entity that could be handled routinely in a safe manner. In numerous communicative channels throughout this network, all of these risk perception factors were confirmed and renewed.

4.2 Community Residents Network

4.2.1 Characterization of the Network

The core of the Community Residents Network is the membership of the civic organizations in Brookhaven Township. BNL is located pretty much in the middle of Brookhaven Township, a town with several hundred thousand residents. Because the community is quite large, town government is somewhat remote from its citizens. Many residents in the town live in small villages, known locally as hamlets. These hamlets can have their own post offices, their own schools, their own water suppliers, and so on, but they have no governing capacity because all the governing is done at the level of the township. Civic organizations were set up to provide hamlets a means for democratic expression. They offer local residents a place to turn when local problems arise. The civic organization then takes these concerns to town government.

About a score of civic organizations exist in Brookhaven Township. A typical “civic” will have a small building where meetings are held and a membership of 100 or more. Members pay dues and elect a president. In addition to local civics, there is a mother organization known as ABCO (Associated Brookhaven Civic Organizations) whose membership consists of the presidents of the local civics. ABCO also elects a president, a person who thus gains a great deal of prominence in township affairs. ABCO publishes a

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newsletter called the *Civic Sentinel*, which keeps the civics abreast of local political event. During the tritium controversy, the *Civic Sentinel* printed numerous articles with regard to the Lab and the controversy.

Although it would certainly be incorrect to depict people in civic organizations as uniform, it is reasonable to suspect that there will be similarities among them, as this interviewee claimed:

I think people feel comfortable with people that have the same beliefs as they do, and not just on that subject, . . . in general. To be a civic volunteer I guess, that draws a certain kind of person. It's a lot of work and you have to kind of have a passion for it. That's why our core group has developed that way, because we all have our own little passion.

The civic organizations have a strong interest in local business, but they are also interested in protecting the health of the local residents and the quality of the local environment. Because of this the civics often positioned themselves as being between the Lab and the activists. On the one hand the civics were interested in seeing the Lab stay in business. BNL employs something near 3,200 people, so the economic health of the region is tightly coupled to the Lab. On the other hand, if the Lab contaminated the community, housing values would decline, quality of life would suffer, and the community might even become stigmatized as a contaminated place. Thus, the civics had a strong interest in seeing the Lab survive, but also ensuring that the Lab operated responsibly.

Only a very small percentage of the town population belongs to a civic organization. The Community Residents network also includes people living near the Lab who did not attend meetings of local civic organizations. These people may be active in community affairs in other ways (e.g. school board, local library, clubs, etc.). People living in the North Shirley neighborhood directly south of the Lab and people in the Manorville area near the southeast corner of the Lab were commonly seen as the most directly impacted (they live in the zones where DOE agreed to pay to hook up their homes to public water).

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These residents were motivated to learn more about the tritium risk by a concern to protect their health and their property.

Just as there were many networks within the Friends of BNL network, there are many networks within the Community Residents network. ABCO would be one example of this. One interview who attended some ABCO meetings remarked about how people in ABCO have come to depend upon each other and still they tend to approach the issue from a similar perspective:

I guess we've created, with this affiliated civic organization a core group of people who have varying degrees of expertise in different things. I guess we depend on each other to say, "Hey! Did you read that?" And, "What did you think?" You definitely can't stay on top of every issue — it's impossible — and be really in tune with what's happening. There's so much conflicting information. But I think we've built this core group that's really, we rely on each other. It's helpful, because you don't have to be an expert on everything. And yet, you know that, that there's some, you can depend on these people, because they're looking at things from a point of view that's similar to yours.

4.2.2 Perceptions of Risk: Links to Organizational Practices

Community residents not affiliated with the lab who we interviewed reported that, at first they were concerned about the tritium contamination, however people had different reasons for being concerned. One person remarked that the novelty of tritium was frightening:

At the beginning it was very frightening. You don't know anything about tritium.

Another person remarked that he perceived the risk as high because the concentrations of tritium in some well samples were well above the drinking water standard:

Because some of the concentrations in the center [of the plume] were very high: 750,000 pico-Curies [per liter]. I mean they were *very* high.

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A couple of people both mentioned they were initially concerned that the tritium plume seemed to be moving toward drinking water wells, thus it seemed possible that the problem could get a lot worse.

Still, what is interesting is that the risk perceptions of people in this network included evaluations of the performance and credibility of the laboratory. When we asked people to tell us what their perception of the risk was at the present moment, they frequently responded by talking about the competence or credibility of the Lab. This respondent's answer to our query about her perception of the tritium risk is exemplary:

I guess . . . well . . . I have one question that I wrote down. Why didn't they discover the leak sooner than they did? Because you can't tell me that if you're losing water out of the storage tank, constantly, you could figure out what the radi..not the radia . . . uh, what the evaporation should be. And I think that it was well over the evaporation rate.

In hindsight, most people with whom we spoke in both the Friends of BNL network and the Community Residents network came to the conclusion that the tritium controversy was primarily a controversy about loss of trust and confidence in the Lab, not a crisis of public health. And it is with the community residents that the Lab lost trust. Certainly the Lab never enjoyed the trust of the Long Island activist community. Perhaps *trust* is not even the right word. And perhaps the local residents did not *not trust* the Lab so much as they were willing to ignore the Lab and leave it alone. Whether or not this should be interpreted as a vote of confidence that the Lab was acting responsibly is impossible to say based on the data gathered in this study.

One interviewee from this network posed an interesting hypothesis. She was commenting on how BNL had remained a secret, since opening in 1947. No one knew what was going on there. As long as nothing bad happened, people ignored the Lab. But when radiation leaked or media reported other controversial information about the lab, concerns would rise. She concluded that distrust emerges from fear, and that fear emerges from a lack of knowledge. In other words:

Lack of knowledge → fear → distrust

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By not engaging the local community, BNL produced the condition that the local population lacked knowledge about the Lab. Then, when the media or activist groups made assertions about dangerous conditions at the Lab, the public became fearful. When the Lab failed to address those fears in an expedient manner, or when the Lab failed to inform the local population about what was happening at the Lab, the public quickly became distrustful of the Lab. This distrust was certainly accentuated when DOE punished the Lab by firing AUI for incompetence.

What is known is that the members of the Community Residents network that we interviewed were angry about the Lab's poor performance. When we asked about their perception of risk from the tritium, people talked about the poor behavior of the Lab. This person uses the Lab's own boisterous claims that it is a "world-class facility" to express his utter disappointment with the Lab's environmental protection record:

I think what was disappointing was that such a prestigious, world-class research institute could allow such a thing to happen. That's where they lost public support. "World-class" nuclear research facility, measuring a tritium pool with stick rulers and floating things! I mean, that was where I think they really lost *a lot* of their credibility, was the fact that they did come out after so many years and they either didn't admit it, or they couldn't tell.

One person likened BNL's pollution of the aquifer to aiming a shotgun at the community, explaining that, like groundwater, shotgun pellets spread out, there is not a narrow line of fire. The tritium pollution was equivalent to an attack on the community, which displayed a lack of caring on the part of BNL:

And I kind of felt like this was a shotgun on us. The BNL was here and they could reach us. And there could be some potential problems. Or at least address it, you know? If you're gonna fire a shotgun, let me know about it. I'll stand back here until you get done. But this was just uncaring from my way of thinking about it.

This last quotation introduces the idea of maliciousness. It suggests that this respondent might be implying the Lab intentionally meant to create harm. This a sentiment was not unheard of in our interviews, but it was uncommon to hear it among

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people in this network. For the most part, community residents seem to have felt a combination of incredulousness / disappointment (I can't believe they let this happen!) and anger (don't they care enough about us to do things right up there?!).

It is interesting to examine these findings in the context of an article on trust in risk controversies (Kasperson, Golding, Tuler 1986). Kasperson et al. concluded that trust contains four components: caring, commitment, competence, and prediction. In other words, people are likely to trust organizations when they perceive the organization as exhibiting these four characteristics. These data echo two of these features. They show that people perceived the Lab as uncaring (aiming a shotgun at them) and as incompetent (failing to notice that gallons and gallons of radioactive water had been leaking for 15 years!).

In the end, many community residents who entered the controversy cautious of the risk ended up, years later, concluding the risk to human health was slight. The following exchange occurred with a community resident in the impacted area:

I am well-known as an environmentalist but I just didn't see this as a threat either to, quote "to the environment" or to health and safety, of the nearby residents.

Another exchange with a different person conveys the same message, but it also reflects a learning process the person went through:

Q. What's your opinion on how dangerous the tritium is now?

A. I don't think it's nearly as dangerous as the media hyped it to be. I think that if you believe what the Lab says, it's extremely low-dose. You know once again as I told you on the phone, I think that the other issue is much more toxic, that was the VOC issue, the solvents in the groundwater. Tritium. I just don't think that tritium is that bad, quite frankly.

Q. Did you think that at the beginning?

A. Yeah, I think they helped me make up an opinion on that, based on the fact that tritium is naturally available.

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It is interesting to note that the individual qualifies his remarks with “if you believe that the Lab says.” This points to the point raised above for this network. People were not willing to separate a discussion about the risks of the tritium from a discussion about the credibility and consideration of the Lab. Another community resident we spoke with said almost the exact same thing.

Q. What’s your opinion on how dangerous the tritium is now?

A. Well, if you believe the data, then the tritium is not a concern.

We asked if this person believed the data. The response was that he “tentatively” believed the data, but was ready to disregard this belief at any sign of data that suggested the opposite was true. Clearly, the issue of trust lies just below the surface.

We conclude that, presuming that the individuals we interviewed are typical of many other community residents, the residents are willing to trust the Lab and their characterization of the risk, but this trust is conditional on the Lab maintaining the openness, honesty, caring, and commitment from top leadership to sound environmental practices. At the first sign of another mistake or the first sign that the Lab is clamming up, lying, or misrepresenting something, the residents will withdraw their trust and their perceptions of the risks will increase in importance.

4.2.3 Learning About the Risks: Education Within the Community Residents Network

The people we interviewed from the Community Residents network explained that they put a lot of effort into learning about tritium and the contamination. All of them stated that they did this with out of a sense of need, rather than preference. All said they had other things they’d rather be doing, but they felt obliged to get involved in this issue.

This sense of obligation arose in two ways. For people living in the areas south of the Lab — the water hook-up zones — people felt obliged to get educated out of a need to protect their own interests. One person replied that he became involved after noticing a crew drilling a well out behind his house. He asked what they were doing and they told him, “drilling a test well,” but they would not tell him what they were testing for.

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They are drilling to find something. I wondered what they are looking for? That's what motivated me to investigate.

Up until this point residents had assumed the Lab was operating responsibly. But when it became obvious that the Lab had been remiss — at least in failing to notice tritiated water was leaking from a storage pool — they felt a need to step in and protect themselves.

Another person remarked that she decided to educate herself on the issue after she found it difficult to find a reliable source of information. She realized that she would need to rely upon herself:

Well, see I had great fears at first that, after I was lied to a couple of times, unless I taught myself how to understand this stuff, I would never really know the difference of whether or not I was being lied to.

It is interesting to note that they did not trust the overseer of the Lab (DOE) to step in and protect their interests, nor did they readily put their trust in EPA or NY State government, nor did they trust the Suffolk County government to protect them, nor the town government. This loss of trust in BNL was accentuated by a loss of trust for all other levels of government, at least in the immediate term. As time passed, community residents did come to trust the state and county government, although it was clear that neither of these had but very limited ability to influence what the Lab did. Instead, people relied on these other levels of government to provide water quality testing and epidemiological studies, information that would help the residents verify the Lab's data and information that would help the Lab make decisions about how to manage the contamination.

The second way that members of the Community Residents network developed a sense of obligation to become educated and involved in this controversy arose out of a personal sense of community responsibility. This held mainly for people active in civic organizations, especially those outside the hook-up area. The presidents of civic associations to the North and West of the Lab became involved because their members expected them to be knowledgeable about the issue. Clearly BNL was an important part

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of civic life for the whole region of Long Island and the civic associations wanted to be abreast of the happenings there.

People in the civic organizations were galvanized to interest in the BNL controversy by dramatic newspaper and media stories. However, few people said they turned to the media for information. In fact, one of the things that our interviewees reported changing over the course of this project was their view toward the media's portrayal of the controversy:

When you hear all that stuff, or reading the paper, and we tend not to believe the papers anymore. I used to, but I don't anymore.

People reported that the media exaggerated stories for sensationalist purposes, that the media were used by the different parties for political ends, and that they simply often "got it wrong." In other words, after a few months of educating themselves, these community residents were more knowledgeable than were the reporters about what was happening at the Lab. They no longer saw the media as an important information source.

To educate themselves, community residents turned to a variety of different sources. In contradistinction to the Long Island Activist network, community residents did not reject the Lab's information out of hand. The level of suspicion among community residents toward the Lab did vary a great deal, but all the people we interviewed from this network felt that the Lab had information that was essential. People who basically trusted the Lab, and this mainly included people living outside the hook-up area to the south and east, accepted the Lab's information at face value. Those more directly impacted sought to confirm the Lab's information with other sources.

Anything they [the Lab] said, I would ask for documentation, use the Freedom of Information Act and get my own research.

In 1997 the internet was not as pronounced as it is today. People relied on the library for information:

I think only once, we went to the library [to] research some of those things. . . . [W]ell we were going there actually to find out what picocuries meant and things like that,

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because nobody over there told us, you know, the millionths of a curie or anything like that. We had to figure that out ourselves.

Other key sources for information for community residents came from the Suffolk County Task Force (see above) and the Suffolk County Board of Health, which did water quality testing for the Lab. The NY State Department of Environmental Protection and the US EPA also performed water quality testing, and at the request of community residents, blind samples were taken to demonstrate that no one was intentionally manipulating the results.

Several people mentioned the importance of a DOE report — the Tiger Team report from the late 1980s. As mentioned in Section 3, the DOE dispatched assessment teams to each Lab. The BNL team produced a report that contained a recommendation to install monitoring wells near the HFBR. Community residents cited this as a very important piece of information. However significant this may have been, even more important was another vignette extracted from this report. Lab scientists who were interviewed by the Tiger Team were quoted in the report as saying that safety was a hindrance to science. To the community residents who told us about this, it indicated that Lab personnel cared less about the health and welfare of the surrounding community than they did for the science they were doing. This conclusion was further confirmed when the residents brought this report to light in a meeting with BNL. “They [BNL] hated us for finding that report,” said one community resident. When we asked how they knew, we were told it had to do with the surprised and angry response from BNL representatives at the meeting. Statements like, “Where did you get that?” and “How did you get that report” signaled to the residents that they were onto something the Lab did not want them to know.

While some community residents did spend evenings and weekends pouring over technical reports and data, people attributed a great deal of importance to attending meetings and presentations. While not everyone would agree with this person that reading was not important, they would probably agree with the sentiment expressed, that meeting and talking among themselves was *essential* to reaching informed judgments.

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When people read things, they ignore it. But when they hear people talk, then it affects them.

All the people from this network that we interviewed had attended presentations at the Lab. Sometimes the Lab came to the civics to make presentations. The county officials from SCTF and Department of Public Health made presentations. Presentations and workshops were also arranged by STAR. At these venues, residents often had one-on-one encounters with specific individuals. Some reported that these were much more important in shaping their perception of the risk than were formal presentations or thick technical reports. The civic organizations in Brookhaven, and especially the ABCO organization, relied heavily on an ex-Lab employee and physicist for knowledge and interpretation. This individual argued strongly in the Lab's favor and frequently made himself available for civic organization meetings. Not everyone in the community residents network was willing to accept this individual's point of view, however, some residents criticized the civics for listening too much to him.

One interviewee relied heavily on a personal relationship she had with a technical expert outside of the region. The connection was brought about by coincidence and, via mail and telephone calls, a relationship was built that ended up being very instrumental to this person's education.

But by far, the single most important venue for self-education was the interaction that happened at the Community Working Group. Because the CWG included involvement by people from the other two networks, it is discussed below. Still, the CWG was initially established by the Lab for the purpose of engaging the community in the issue.

Confidence in being able to learn about a technically complex issue is an important factor in explaining why some people went to these efforts while others did not. We only interviewed one resident of the hook-up area who did not participate in any way in the controversy, and she reported a lack of self-confidence in being able to learn about the topic. She had no formal training in sciences and felt intimidated by the complexity of the issue. Instead, she chose to ignore the whole thing, while expressing anger and distrust at the DOE and at BNL.

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We inquired of our interviewees whether they felt it is necessary to be a scientist or have a training in some science-related field to become involved in educating oneself about the controversy. Not only was the material technically challenging, but there was a need to understand the way that scientists think. Most agreed that having a science background — even if it is in an unrelated topic — certainly is an advantage, especially if you want to be able to ask tough questions:

You can't ask a tough question unless you know what's truly going on.

Those community residents who did get involved, often wished more of their neighbors were involved as well. Some people expressed frustration at their neighbors. One person recounted, sadly that the largest community meeting turnout was when a law firm held a community meeting to get people to sign onto a class action law suit against the Lab. He went on to say that community residents who did show up to meetings faded fast, because, in his analysis, they were only looking for someone to blame. "No, the Lab didn't cause your cancer, you only moved here two years ago!" he said to one person.

Box 4-2. Factors Shaping Risk Perceptions for Community Residents Network

- Familiarity with the Lab and personal relationships with individuals in Lab and DOE
- Sense of commitment by Lab leadership to be open and do the clean-up right.
- A jury mentality where they listen to information and arguments made by the two arch-enemies: the Activists and the Lab.
- Personal ability to understand technical information.
- Verifying the data given by the Lab.

4.2.4 Factors Shaping Risk Perceptions for Community Residents Network

Based on these interviews we learned that several factors seem to be most responsible for explaining how individuals in the Community Residents Network developed opinions about the risk from the tritium in the groundwater.

First, residents reported the importance of breaking down the barriers of secrecy surrounding the Lab. With those barriers in place, perceptions of the risk were high because fear was high. They recognized a need to arrive at a better understanding of the Lab. Toward this end, they emphasized developing personal relationships with leadership at the Lab and the DOE. As people came to trust these individuals, they came also the trust the institutions for which these individuals worked and the risk messages they were delivering.

I knew [names person] when he was in charge of a certain portion of the clean-up. So I got to know him. Now he's in charge of DOE over there. And you get to know people like [names another] and others. So, I trust them. I mean when we have discussions, they don't sound like they're trying to put anything over on anybody.

Second, residents scrutinized the Lab's leadership, looking for signs that the Lab was not only taking this situation seriously, but that they had a reasonable and competent approach to dealing with the contamination. When residents felt the Lab leadership was arrogant or careless, they reported higher concerns for the tritium risks. But as Marburger became settled in the position as Lab director, residents reported feeling much less concern about the risk. This was mainly because to the Community Residents Network Marburger seemed authentically interested in the Lab changing and in getting the Lab to fix the problem in a way that would regain public credibility. People remarked that Marburger treated everyone with respect, that he seemed interested in hearing what all people had to say.

Third, the community network saw itself more or less as a jury who listened to the Lab and the Activists make their respective cases. The open antagonism between the Lab and the Activists gave the Community Residents the space they needed to feel neutral. They could be comfortable in their neutrality, knowing there were gadfly activists

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overseeing the Lab and able Lab leadership making the case for the Lab. Members of the Community Residents Network did not just sit back and wait for the show to begin. They also initiated their own investigations and engaged in dialogue with each side before reaching a tentative position. The position is tentative, because it is subject to present understandings and present levels of trust in the Lab, which they now view as a fluid variable, not set in stone. These quotes from people in this network illustrate these points well:

You have to listen to both sides. I mean you can't just take one side or the other.

Well, I listened to both sides because I knew the people who wanted the lab shut down had reasons for it and I wanted to find out what their reasons were. Not just because it was a DOE laboratory sitting there, but because the lab might be harmful for the environment or the surrounding areas. That was one of the main reasons that I listened to both sides. I still listen to both sides.

Fourth, although most members of the Community Residents Network who participated in regular meetings with BNL were trained in engineering or the sciences, most community residents probably did not have the expertise needed to interpret and critique technical analyses. Even those who were trained in a scientific discipline often felt limited in their ability to comprehend the technical information, as this individual expressed in an interview:

Now, there are things you have to take for granted that . . . as just a citizen, I know nothing. I am not a scientist and I know nothing about that . . . I knew nothing when I first started, I didn't even know what tritium was when I went over there. . . . and for me to say that 20 different scientists are wrong [. . .] would be ludicrous. I'd be stupid to say that because I don't know. I have no idea.

This quote comes from a person who worked as an engineer (not at the Lab) and who mentioned that he was often called upon by his peers to interpret technical reports. Despite this limitation, the members of the Community Residents network that we interviewed emphasized the importance of seeing the technical information and reports. Unlike people in the Friends of BNL Network whose engineering and physics

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background predisposed them to accepting risks, there was less consistency among the people in the Community Residents Network. Some were more like BNL employees, comfortable with ideas of radiation and contamination management because they had professional experience in these areas (although not at the Lab). Others who had similar technical backgrounds took more critical stances toward the Lab and sought to validate the Lab's assertions through independent data.

Fifth, people in this network certainly did not trust BNL blindly. They came to trust the Lab with time, but at first they sought to verify information they received from the Lab. Because the residents did not have the technical expertise they needed to discuss technical issues with the Lab, they relied on verification of data by other governmental agencies. Unlike the Long Island Activist network, which produced its own understandings based on independent information, people in the Community Residents network primarily relied on information and interpretations of information from the Lab, but they had key portions of this information validated by outside parties.

4.2.5 Relationships with Other Networks

4.2.5.1 Relationship Between the Community Residents Network and Friends of BNL Network

At the start of the controversy, many members of the Community Residents network were disappointed, angry, and even suspicious of the Lab. Until the mid-1990s the Lab was probably seen as an asset to the community. People were proud of having a “world-class laboratory” in their community. This shifted as the community learned about one source of contamination, then another, then another, until finally the radioactive tritium plume was announced in 1997. Even pro-business civic association members began to ask themselves, “What the heck is going on up there [at the Lab]?” For a while it appeared as if the Lab could do nothing right.

As far back as 1993, community residents had asked BNL to sink monitoring wells just to the south of the High Flux Beam Reactor (HFBR) to test for possible radiation contamination of groundwater.

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We had requested (name removed) and a few of the others had requested that they install observation wells just south of that reactor. And they, I don't know whether they . . . I don't know whether they outrightly refused, or they said they were unnecessary at that time, and they didn't put them in. And that was in 1993.

And even earlier than that, in 1989 the Suffolk County Health Department had asked BNL to double-line the spend fuel pool, just to protect the aquifer in the case of a leak. The protective liner was never installed and the monitoring wells were not installed until October 1996. Monitoring wells were installed all over the Lab, but the Lab did not sink one near the reactor, where the citizens had specifically asked one be sunk. This led one civic leader to ponder the reasons why:

They put up 700 monitoring wells all over the place, but they didn't put one *there* [in front of the HFBR]? Am I *stupid*? Am I reading something into it and it's not there or is there really something there?

Whatever the reason, it was not going to look good for BNL, he concluded:

It was either stupidity or lack of caring that they didn't put the wells in.

The frustration civic leaders felt toward BNL for failing to detect the contamination — even after they told BNL where to look for it! — produced a great deal of frustration among civic leaders:

Well. At the beginning I was concerned about the tritium leak. I was concerned and I was a little bit angry because we had asked the lab to sink wells around the reactor. And I had actually thought that that had happened. But we [the civic organizations] found out that they decided to sink the wells only on certain occasions around the reactor, and not, you know, not everywhere. So they didn't find the tritium plume until very late. So there was a little bit of anger there and sort of disenfranchisement with the BNL itself, that they really didn't take the recommendations of both the community and the Suffolk county health department and do what they really should have around the tritium, around the nuclear reactor. So, certainly, we [the civic organizations] were angry at them.

This frustration and disappointment that community residents felt toward the Lab peaked in the first half of 1997. After that, BNL succeeded in regaining trust and confidence of the community residents. Every member of the Community Resident network that we interviewed remarked that, at present, they feel satisfied that the Lab is acting responsibly and they recognize the Lab as a credible source of information. The Lab succeeded in turning around public opinion, at least among the community residents network through extensive public outreach. The only caveat to add is that the Lab is basically on probation with the local residents. As long as it continues to be well-behaved, the residents will continue to rate it as a good neighbor. But at the first sign of any secrecy or untruthfulness, the residents will certainly withdraw trust again.

4.2.5.2 Relationship Between Community Residents Network and the Long Island Environmental Activists Network

As the relationship between the Community Residents network and the Friends of BNL network improved over the course of the controversy, the relationship with the Long Island Activists network remained strained.

Many interviewees from the Community Residents network denigrated the activists involved in the controversy. At the center was the criticism that the activists were never interested in having a reasoned, open discussion with the Lab. Instead, the activists were seen as having a pre-established agenda, which they sought to achieve in any way possible. The activists' goal was always to shut down the nuclear reactors at the BNL facility. Some of the groups also sought to shut down BNL. Activist groups were characterized by community residents as not being open-minded, and open-mindedness was seen as an important attribute for good discussion and learning. The following quotation again conveys the notion that community residents saw themselves as needing to listen to both sides :

Groups like STAR. The problem with some of those groups that we've found [. . .] is that, it seemed that they had their opinion made up before information was given to them. And we [the civics] tried very hard not to do that.

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Community Residents saw themselves as skeptical of BNL, concerned that there might be a serious problem, and willing to do what it took to get at the truth. This individual did a nice job of comparing himself (and other civic association members) with the activists. In this quote he mentions that he initially thought like the activists did, that BNL should be shut down, but as he learned more about the situation, he changed his mind. He also mentions his concern that BNL might have been lying to him and emphasizes that State and county agencies verified the data BNL was putting out.

There was one group that wanted that reactor shut down right away. They wanted the lab closed. They wanted everybody to pick up their stuff and get off Long Island, that they don't belong here because of our groundwater table — the sole source aquifer that we have in this area. And there still is a group that wants the lab out of there, I know that. We actually, at the beginning, we were thinking that way too. But after a while we figured out that it's not as bad as they're making out. Because they [the activists] used to put press releases out to *Newsday*. And we used to read them. And they were completely exaggerated what was happening over there. Because we knew what the concentrations were at that time. They were checked by the regulatory agencies — EPA, DEC [NY State Department of Environmental Conservation] in Albany, and Suffolk County Health Services department. They're checking all those readings and they all agreed with them. And they would come to the meetings and sit and tell us exactly how it was. So I felt nobody's trying to fool us here. That's what's going on. And it's the truth. And I didn't find any instances of where they lied. Yet, there were certain people from certain organizations that said they were lying all the time. And I couldn't see it.

Activists were also cited for grandstanding and theatrics, both of which prevented any reasoned discussion from taking place:

[A]t one of the meetings, one of the activists, a man that I'm sure you've heard and you may have probably have talked to, (name removed) stood up on the table and started bellowing [. . .] in order to attract the attention of the cameras, and he got his way. Because that was what they showed that night and the next morning, that they showed him standing on a table, expressing outrage.

Community residents spoke critically of anyone who had “an agenda.” By this they meant a political goal to accomplish, as opposed to the goal of reaching informed understanding. In critiquing those with “agendas,” these residents were expressing the ideal that the process ought to focus on getting the facts straight and making a reasoned decision. They reacted negatively to what they saw as the politicization of the controversy:

Not having an “agenda” is real important. People who have an agenda are not interested in really learning and getting the facts. They are interested in bending the facts and the meaning to suit their own agenda.

4.3 Long Island Activists Network

4.3.1 Characterization of the Network

For the community of environmental, health, and social justice activists in eastern Long Island, a seminal event was the controversy over the construction of the Shoreham Nuclear Power Station during the 1980s. Activists on Long Island fought Shoreham from the first hearing in the 1960s until July 1991, when, fully constructed, operational, and ready to go on-line, the facility was instead permitted by the NRC to be dismantled. In the struggle against Shoreham, activists from the region took on what seemed to be insurmountable odds and won. In so doing they learned how to collaborate with each other. They succeeded in self-organizing into a confederation of groups with a common goal. From the stories these activists tell today, the Shoreham experience was positive and empowering.

Activists in eastern Long Island also learned another lesson that would come into play again during the tritium controversy at BNL in 1997. They had seen how taking a hard-line stance based in principle and refusing to compromise had led to victory over forces that seemed unbeatable. That principle was that there should not be an atomic reactor on Long Island. Not only did this corps of activists stop the fully completed Shoreham facility, it also defeated plans for two additional commercial nuclear power stations on Long Island. In those controversies, activists succeeded in winning over public sentiment

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by conveying the notion that nuclear reactors were dangerous, too dangerous for the highly populated, difficult to evacuate, ecologically sensitive region of Long Island.

During the Shoreham controversy, the nuclear reactors just up the road at BNL remained uncontested. This was apparently because it was not widely known that there were reactors at BNL. Although some activists and community members clearly did know about the reactors at the Lab, it was not an item of widespread public scrutiny.

The string of controversies at BNL over the 1980s and 1990s that culminated with the tritium controversy of 1997 drew the attention of activists to the Lab. And while individual events such as wildlife contaminated with radioactivity, radiation releases to the Peconic River, and hazardous chemical emissions to the ground and air were important in motivating activists' opposition to the Lab, the controversy with BNL was fed and sustained largely by the same factor that sustained the Shoreham resistance — a vision of Long Island without any nuclear reactors.

The activist community of eastern Long Island includes environmental activists. One major environmentalist party is the Long Island Pine Barrens Association. The Pine Barrens of Long Island is a sensitive ecosystem presently being protected by land conservation and land management practices. Trout Unlimited is another major environmental group in the BNL controversies. They were especially concerned with tritium contamination in the Peconic River. Another important segment of this network are the public health organizations. One in Nine is a group that focuses on the issue of breast cancer. Because of the connection between radiation and breast cancer, this group was particularly interested in radiation controversies in the region. Another local group, Citizens for a Clean Brookhaven was also based around a concern that the Lab's emissions might be causing illness in the local communities. The third type of group involved in this network was the peace and social justice groups. Groups such as the Long Island Progressive Coalition and the Long Island Alliance for Peaceful Alternatives had been active on the Island for years. (These are just a sampling of some groups, many others exist and also comprise this network.)

Two other groups came to play significant roles in the tritium controversy of 1997. The first was STAR — Standing for Truth Against Radiation. STAR is a Long Island

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activist group located in the upper-class vacation community of Easthampton (more than an hour East of the Brookhaven Lab). STAR formed in 1997 just after the tritium leak was exposed. They were attracted to the issues at Brookhaven, which were, at that time, receiving a large amount of media attention. Although they are not neighbors to the site, their influence has been significant in part due to the wealth and fame of the Easthampton area. STAR has grown to become a nationwide organization since the dying down of Brookhaven controversies. STAR activists also still attend the Citizens Advisory Council, where they encourage the Lab to develop research programs into alternative and renewable energy sources.

CALA, the Community Alliance for Lab Accountability, was the second group that developed during 1997. When the grant that set up Environmental Advocates destroyed the CWG, some of the activists proposed they meet together to discuss coordinating their actions with regard to the Lab. CALA is a Brookhaven Lab watchdog group comprised of 33 environmental, health and spiritual organizations in the eastern part of Long Island. It arose from a common concern regarding environmental contamination emanating from BNL and serves as a focal point and primary organization for residents and community groups to get information, recommend policies, and register health, environmental and moral concerns about BNL's operations. STAR is a member of CALA.

The early CALA meetings were attended by DOE and BNL officials. They hoped to continue communication with their critics, as the public participation specialists Hans and Annemarie Bleiker strongly advised BNL to do. But the birth of CALA was not easy. Twenty-five activists with different interests and objectives were difficult to weld into one unit. During this process, DOE and BNL were asked to leave. In time, CALA did compose a mission statement, which specified the agenda they hoped to accomplish with regard to BNL.

By unifying the positions of diverse groups, CALA has become an environmental, health and ethical organization that is recognized by BNL and the DOE. Its member groups represent more than 50,000 Long Island residents. CALA's mission is to act as an information clearinghouse for member organizations and the public, to initiate community education and to reach out and establish a direct line of communication with

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BNL and DOE for the purpose of gaining information and demanding accountability. CALA has demanded environmental representation on BNL's new board of directors, and has established a means of consistent and direct communication between CALA and lab management through monthly meetings. The member organizations work together and separately to develop comments and recommendations on lab operations.

4.3.2 Perceptions of Risk: Deep Concerns for the Harmful Effects of Radiation

4.3.2.1 Deep Concerns for the Harmful Effects of Radiation

Based on the discussions we had with people in this network, it is reasonable to claim that a fundamental belief for people in this network is that radioactivity is a serious and dangerous matter. Interviewees regularly cited testimony from experts — in particular Helen Caldicott and Jay Gould, but others as well — who claim that even one atomic disintegration is capable of causing cancer, thus there is no “safe” level of radiation dose. Consequently, even low dose radiation risks could be significant threats to human health. When asked about the tritium releases, this activist replied:

Of course they are a concern. Look in any medical book, it tells there's no safe level of radiation. Of course they're a concern.

There is a corollary to this belief that is also central to people of this network. This is that radiation, even at low levels, when combined with other risk agents, can have effects on human health that are greater than the sum of each of the risks. For instance, it is known that cigarette smokers exposed to radon gas have a risk of developing lung cancer that is many times greater than the sum of the risk to smokers not exposed to radon plus the risk to non-smokers exposed to radon. This interviewee put it more clearly:

And they [the low level radiation risks] are also a concern in a way that they [the Lab] never address, they *never* address. They never address the synergistic effects of radiation with other toxic chemicals. And they . . . everybody knows that it enhances its toxicity.

4.3.2.2 Tritium Risk and Nuclear Weapons Research

Our results show that the activists in this network did not perceive of risk in the singular dimensional language of risk to human health. They interpreted the risk of the tritium in many dimensions.

Whereas people in the Friends of BNL network readily spoke about risk to human health from the tritium when we inquired, and people in the Community Residents network spoke about trust (or distrust) in BNL, people in this network were quick to point out that risk had to be interpreted in a larger context. For this individual the context included the mandate of the DOE to make nuclear weapons.

. . . what's important for me is to relate to you that I see this in a context. This is not the tritium, this is not this, it's not that. It's a package. And that package comes about by virtue of the fact that the DOE, its purpose is to make nuclear weapons. And to make nuclear weapons, you have in mind the mass murder of hundreds of millions of people.

In this perspective, the controversy about the tritium is not simply a controversy about the human health risk from this single hazard. It is one of the scores of unwanted side effects of a nuclear weapons culture. The tritium in the groundwater becomes symbolic of the insanity of creating weapons of mass annihilation. Thus, it becomes impossible (logically and morally) to disassociate any single contamination event from the entire weapons program.

4.3.2.3 Tritium Risk and BNL's Attitude Toward Radiation

Interviewees from this network routinely told us they believed that the Lab did not care about releasing some radiation into the local environment. As evidence, they cited Lab advocates who argued that small amounts of radiation were actually therapeutic (the hormesis effect). They also cited statements made by Lab personnel that indicated the belief that small amounts of radiation were not dangerous. In addition, they cited government personnel who argued that the important science that the Lab was doing justified any accidental releases.

So we met with this congressional investigator, named [name removed]. And we kept showing her more evidence of environmental abuse, what about this and this, and finally we could tell that she really didn't want to hear too much about it, she was just going through the motions. So after everyone else had left and I was left there with her alone, after peppering her with about 5 other things that I wanted to show her, she turned to me and said, "[first name], *did you ever think that you would have to live with additional risks because of the good that Brookhaven lab does for the entire country?*" So I looked at her and I said, "So what you're saying is, that it's okay to kill a few, for the good of the many?" [italics added]

It is not inaccurate to report that activists (as well as many in the Community Residents network, see above) concluded that the Lab just did not care about the environment or the local community.

4.3.2.4 Tritium Risk and BNL's Attitude Toward the Community

Uncaring, arrogant, and patronizing sum up how activists depicted BNL's attitude toward the neighboring communities, as these two quotations illustrate:

East Yaphank, Mastic Beach, Mastic, Shirley [the communities directly south of the Lab], those are working class people. You know, they're written off. Those are the people who sacrifice for them to get Nobel prizes over here. And they don't give a shit! They don't give a shit about those peoples' lives.

Their whole attitude is arrogant. They know what's best for you. You should just sit down and be a good sheep and we're the intelligent ones and we're going to tell you what's good for you and what's harmful for you and you have to believe us. You know the whole thing with the acceptable levels of radiation, to me, my opinion is an acceptable level is just an acceptable death rate. We expect so many to die when exposed to this amount of radiation, and that's okay for us. But if you're one of those people, it's not okay.

To these activists, BNL's attitudes toward the community are part of the reason that tritium leaked in the first place. If BNL had listened to the public and installed

monitoring wells outside the HFBR as requested in the early 1990s, much contamination could have been prevented. But the Lab did not assign high priority to what the community wanted. It did not put in the wells until much later.

On top of this, activists frequently mentioned to us the Tiger Team report from the 1989 assessment. In that report, according to our interviewees, was a paragraph that stated that the investigators revealed an attitude among BNL scientists and management that science comes before environmental protection. The idea that BNL would demote environmental protection to the preference of scientific advancement was atrocious for people in this Network. Several members of the Community Residents Network also cited this data source and expressed the same level of outrage at BNL.

Consequently, for people from the Long Island Activist network, the attitude of the Lab and of employees at the Lab toward the local community is an important dimension of the risk due to the tritium. This interviewee summarized it nicely:

Well, I think that the tritium is a microcosm of everything that Brookhaven lab has done. It's just one example of how they polluted the environment. They've ignored the community around them. You know things that they probably could have prevented and they didn't for a couple of reasons. You know, 1) they didn't think it was important, 2) they have a very understated opinion on how dangerous tritium and other types of particles are, and 3) it's just science first. You know, it's science first, and everything else should be secondary to that. And that's what I believe their opinion is.

4.3.2.5 Risks to Human Health from the Tritium

It was difficult to get our interviewees from this network to express a perception of the risks to human health posed by the tritium in the groundwater. One person simply stated it was "extremely important." The tritium plume contaminating the Peconic River was cited as an important source of health risks to people eating the fish. For the most part, however, people avoided answering the question directly, instead choosing to respond to other dimensions of the risk. For example, this exchange was typical:

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Q: What's your thought right now on the tritium in the groundwater? Is it dangerous? Is it bad?

A: Well you never want a radioactive element in your groundwater.

Others saw it as a matter of principle:

It [tritium] doesn't belong in the sole source aquifer. You don't contaminate drinking water.

Still, it is probably fair to say that most of the activist environmentalists who now communicate regularly with the Lab seem to feel that the tritium that leached from the spent fuel pool at the HFBR is not a major human health concern at the moment, nor is it likely to be in the future. That does not mean they are satisfied with the Lab, that they do not want to see the medical reactor (or the Lab) shut down, or that they do not feel revisions in the way BNL handles radioactive waste and emissions are necessary. Several other dimensions of risk associated with the tritium release remain salient for this network. However, the tritium that was released from the spent fuel pool at the HFBR, that is sitting in groundwater beneath the Lab, is mainly accepted as an unwanted, but non-dangerous consequence, mainly because, if the present understandings are correct, there is no pathway for human exposure to that tritium.

The person quoted above went on to explain that BNL violated the public trust and that the tritium should not be there and, therefore, it should be removed. Then he continued to say:

Well, you know, to us it's, you know, one more contaminant in the groundwater. And you know our groundwater in Long Island, we're sole source aquifer, we're filled with contamination. We have organic chemicals, we have pesticides, you know the whole gambit, you know, of things that we shouldn't be drinking in various levels. So, you know, it's not a good thing. *But you have to keep it in perspective with everything else* (emphasis added).

Another well-known activists very critical of the Lab put it this way:

But, I mean I guess, in the strictest sense if you had to ask me what the immediate health risk was of that tritium from the spent fuel pool, if it's all on site, even though it's in really high concentrations, nobody's drinking that at the moment. But I think that they still have a responsibility to clean it up to deal with it responsibly and there shouldn't be tritium at 32 times the drinking water standard in our aquifer. That's the bottom line, they put it there, they have to clean it up. But nobody is actually, you know, is anybody drinking that immediate water right there? No, but that doesn't give them the excuse to put it there or keep it there.

Clearly the activist community is especially concerned with the leakage of any radiation and they are particularly concerned that even very low doses of radiation can be harmful. However, the general assessment in this network seems to be that there is presently no way that people can be exposed to the tritium so long as it remains where it is reputed to be.

4.3.2.6 Risks Associated with Remediation

Of course, pumping out groundwater and reinserting it into the water table further upstream could potentially create some exposures. For instance, we mentioned the concern of the National Weather Service employees at a small facility at the Lab, near the recharge basin. We also mentioned earlier that some 95,000 gallons of tritiated water was trucked to Oak Ridge, where it was allegedly evaporated off. The environmental activists did express a concern for worker safety, but they still supported the removal and translocation of the tritiated water for two reasons.

First, they felt that BNL needed to correct its mistake. There are two motivations for this. For some people it was a punitive action made to teach the lab their lesson. For others it was a matter of social responsibility. Brookhaven acknowledged that they had made mistakes, those mistakes should be remedied. If the Lab got away with merely an apology, this line of reasoning went, then they might not be motivated to change their behavior. Several people in this and other networks pointed out that BNL initially assigned the contamination little importance. Getting BNL to recognize that they needed

to treat radioactive contamination much more seriously was key for the activist community.

Second, they wanted the tritium removed as a precautionary measure, to ensure that there would be no further exposures or damage caused. While, for the most part, the activists accepted that the groundwater modeling was correct, they did not harbor a high degree of certainty in the model. If the model were wrong, or if there was a portion of the plume that was incorrectly modeled, then the tritium could potentially contaminate more groundwater, which may lead to exposure. Since even very low levels of radiation are considered dangerous by people in this network, any exposure would be a cause for concern. For both of these reasons, activists supported remediation of the tritium.

4.3.3 Information Shaping Risk Perceptions Among Long Island Environmental Activists

As stated above, risk perceptions of this group of people are multi-dimensional, taking into account much more than data about the concentration of tritium in the groundwater. For this group, concentrations are not very meaningful for two reasons. First, any concentration can be dangerous because there is no safe level of radiation dose. Second, because of the likelihood of synergistic effects, even low levels of radiation can possibly have devastating effects on human or ecological health. Because of this, technical information about the tritium was of less importance than it was to the other two networks.

4.3.3.1 Information Shared Within the Network

For people in this network, one of the key sources of information was the other activists in the network. The activists we interviewed mentioned that they felt competent to do their own research, to learn about the issue that motivated them, and to reason out a solution. Thus, people who felt their health had been compromised by the Lab gathered together in groups such as Citizens for a Clean Brookhaven or One in Nine. In these settings they worked independently and came together to share what they had learned. Later on, CALA would become the hub of the activist network. Sharing information among other like-minded activists became a core function for CALA.

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If there was a great study, somebody would make the copies, disseminate it out. You know, a good research article on something. We always used it [CALA] as an information exchange. That was one of the great features of it.

We all had set up groups to try to research different aspects of what was going on and then report back. You know, we had initially wanted to set up a library of what we found out and things like that.

The library never did get off the ground. Instead, STAR came onto the scene, promising to be a clearinghouse for information about radiation. Once STAR was born, activists reported that they relied on it for information about the lab and about radiation in general.

When the STAR foundation came along, that was my source of information.

Mention was also made of controversies among the activist community during the emergence of STAR. We did not delve into this topic during our interviews, but it would be interesting to examine how STAR won over the trust of this community.

4.3.3.2 Information from Accepted Experts

Members of this network did rely on information from experts who lie outside the network focused on the local impacts of BNL on eastern Long Island. Two expert scientists were particularly prominent in this debate. These were Dr. Helen Caldicott, M.D. Dr. Jay Gould, Ph.D.. Both are nationally known figures active in the debate about nuclear radiation.

Dr. Caldicott was frequently cited for the assertion that even one single atomic disintegration (the smallest dose imaginable) is capable of initiating cancer.

. . . and I read Helen Caldicott's book, and did a lot of things like that. And it started to make me realize. I started to form my own opinions about it

One of the reasons Dr. Caldicott was involved so much in this case was because she lived nearby:

And I went to her house, which was cool because, I mean, in college, as an undergrad back in 1979, one of her books was required reading in one of the classes that I had, and that was pretty cool, right?

4.3.3.3 Information Received from the Lab

The activists we interviewed reported to us that, during the controversy, they did not receive useful information from the Lab. People were skeptical about what came out of the Lab. They saw it as PR material meant to change attitudes.

I would read their stuff but I never got anything of value from the lab; it was all sugar-coated and media promotion.

Other individuals were a bit more open to reading what the Lab put out, but they too were wary of the Lab's bias:

And we were getting a lot of information from the lab — they were loosening up a little bit, giving us information. But then you know you always have that question about: Well this isn't really independent information.

Two other problems with getting information from the Lab were cited from activists we interviewed. Either the Lab would respond with too much data, which activists interpreted as meaning to overwhelm and discourage the person who asked for the data. Or the Lab would respond with inaccurate data, which required lots of work to validate and correct.

See, part of what the lab does. They either took one of two tracks. If you asked them for something, they'd give you tons of information. You know, thinking, "Get through that." Or, they would give you some bogus sheet that we would find riddled with inaccuracies. Like a fact sheet, or you know. We thought that the information that they handed out was really inaccurate. So, and then we would get together and go through it and figure out why it was inaccurate and go back to them and they would agree and change it.

When the activists mentioned that they did not rely on information from the Lab, they were clearly speaking about a particular type of information — mainly documentation of

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the tritium contamination, the Lab's past practices, and evaluative information about the performance of the Lab or the acceptability of the risk posed by the tritium. Information of those types was not relied upon by activists. But even if they did not necessarily trust or believe the information coming from the Lab, activists did read the information and used it to inform their perceptions about the Lab. For instance, some people concluded that the Lab lied to the public, a conclusion that requires listening to what the Lab says to the public. In addition, activists relied on other types of information to form judgments about the risk. For example, a Lab official rolling his eyes at a citizen complaining that the Lab poisoned her children is information that informs a judgment about the consideration or caring the Lab exhibits for the local community. We conclude, therefore, that activists did use information from the Lab, but not necessarily all types of information and not necessarily in the manner the Lab might have hoped they would use it. These activists did not accept the Lab's judgments or conclusions. But they scrutinized the Lab's communiqués for consistency and validity. They scrutinized the behavior and demeanor of Lab representatives for authentic concern for the community and the environment. Because they concluded that the Lab was not being honest or forthright, the information about the tritium that the Lab supplied contained little credibility for the activists.

Over the several years that have past since the tritium was first revealed, the Long Island Environmental Activist community has come to a working relationship with BNL. Leaders from STAR and CALA now sit on the Lab's Citizen Advisory Committee and others work together with the Lab on other projects, such as the clean up of the Peconic River. To some extent this cooperation may be possible because, in essence, the activists succeeded in achieving one of their major goals — the decommissioning of the HFBR. But the cooperation is also possible because of the change in attitude within the management of the Lab. Several activists pointed out to us that Marburger was a "good man." He was truly interested in listening to what the activists had to say and in trying to find ways that the Lab could act on their concerns. The result has clearly been a better working relationship between the Lab and the activists. Consequentially, we now hear the activists talking about the Lab as a source of information. Certainly they do not accept everything the Lab says with blind faith, but when we asked people about their present

perceptions of the tritium risk, the activists indicated that they were using information from the lab to inform their opinions.

For example, it was stated above that the estimates about the risk are heavily dependent on an accurate understanding of the state of the contamination and the likely movement of the plume. The data about the location and movement of the plume come from BNL. Activists are now using these reports to form their own opinions, although they may retain some guarded suspicion of the Lab's data. "If the plume is where we think it is..." said one activist, before issuing his estimation of the present risk posed by the plume. Nearly all people we interviewed were willing to accept that the plume is fairly well understood and that the hydrogeologic model is probably correct. However, many of these same people held this belief tentatively, ready to reject the present understanding the moment that contrary data become available.

4.3.4 Learning About The Risks: Education Within the Long Island Activists Network

Activists were eager for information and knowledge on all issues associated with the Lab and the tritium contamination. They sought to educate themselves as quickly as possible. But, as mentioned above, they were loath to be educated by the Lab, for fear that the Lab's biases would distort the knowledge being disseminated.

A great deal of education was enabled via CALA. This organization tightened the activist network tremendously. Subcommittees were formed that specialized on certain topics. The people on these committees did research and reported back to the whole group, sharing what they learned with everyone. And since the people on these committees were also active in other organizations, and since some of these organizations were national in scope, people in CALA had access to a tremendous amount of information.

Many of the organizations in CALA had their own expertise. One group has a professional hydrologist on staff. Others hire ecologists or health experts. These experts became resources for the whole of CALA.

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What we would do is, [. . .] if it was some document that was 400 pages, he [person from another group] would have people that he knew read through it. [Our] hydrogeologist, um, she would read through some of the groundwater reports. And then we would compare notes and figure out what's important and go from there. Uh, with the health survey, for instance, we relied a lot on the breast cancer groups because they had done health surveys of their own. They had worked with experts who do health surveys and when we analyzed the Brookhaven lab so-called health survey, uh, the breast cancer groups were the ones to say, "This is absolutely ludicrous. This is bogus."

Some people on these subcommittees in CALA developed a very tight relationship. we'd each read it and then we used speak three times a day.

4.3.4.1 Learning About How Each Other Think About the Controversy

A major difference between people in the Community Residents network and those in the Long Island Environmental Activist network was that the former reported that they got a lot of information and knowledge from the Lab while the latter group minimized the value of information from the Lab. In fact, this individual reported feeling that the Lab came to the meeting more for the purpose to collect information than to deliver it.

Q: So what kind of information would BNL present at these kinds of meetings?

A: Nothing that we didn't know before. I mean, sometimes it felt like they were trying to find out how much we actually knew instead of the other way around.

Q: So they didn't provide any information to you?

A: They would try that. But it almost seemed like . . . they would try to find out where we were coming from. "Let me see what my opposition is thinking." You know, that's how I felt sometimes.

This theme of BNL seeking to learn what the activists know was not widely reported in our interviews with people from this network. It is difficult to interpret the importance of this observation. On the one hand, it may indicate that BNL was doing what its public participation advisors told it to do — to go out and "know your audience." The purpose for that might have been very innocent — so that they could better communicate with them. On the other hand, BNL may have sought to understand how the activists were thinking so that BNL could predict the rhetorical strategies of the activists in the battle to win over public opinion. In any event, it is probably fair to say that, whenever two groups are in conflict, they each seek to understand how the other is thinking.

As an aside to this, we note that a clearly stated (and never challenged) purpose of the community working group was for BNL to test its risk communication messages before sending information out to the general public. In other words, BNL also sought to understand how people on the CWG would respond to certain messages.

4.3.5 Factors Shaping Risk Perceptions of Long Island Activists

Based on these interviews we learned that six main factors seem to be most responsible for explaining how individuals in the Long Island Activist network developed opinions about the risk from the tritium in the groundwater.

First, members of the Long Island Activist network firmly believe that there is no level of dose from radioactivity that is 100% safe. This is the so-called “no threshold” model.” This statement was not necessarily disputed by the Lab. An interviewee from the Lab described the Lab’s position like this:

We did not take an opposite view that there was threshold or anything like that. Our statements are always, “There is some risk. This is the level of risk as we understand it. It’s a very small level of risk, we think, what do you think?” And we would try to compare it to other types of risk.

Still, the general feeling among our interviewees from the community was that the Lab *was* implying that the risk was acceptable. The activists took the opposite view, that the risk was unacceptable.

Second, the activists we interviewed ascribed to the precautionary principle in this instance. That is, they preferred to err on the side of safety instead of err on the side of the Lab. This principle presumes that safety and Lab goals are in competition. Obviously, safety is also one of the Lab’s goals, but the gist is that scientists or Lab management might be willing to risk a spill in the interest of fulfilling their mission, if they feel that the spill is likely to be largely harmless. Activists who believe in the precautionary principle instead would argue that safety should be demonstrated beyond a doubt before moving ahead with actions to complete the Lab’s mission.

Third, many activists believed in the fundamental immorality of nuclear weapons. And, although BNL did not construct nuclear weapons, it did contribute to their development in indirect ways. Furthermore, the Lab itself is owned by the DOE, whose mission includes the development of nuclear weapons.

Box 4-3. Factors Shaping Risk Perceptions for Long Island Activists Network

- Belief that there is no safe level of dose to radioactivity.
- Adherence to the precautionary principle
- Belief that the nuclear weapons are morally wrong
- Sense of responsibility to protect public welfare and environment.
- Lack of trust in Lab employees
- Technical information from independent sources

Fourth, the activists in the Long Island network feel a sense of responsibility to lobby for interests that are often disadvantaged in the policy sphere. This includes interests such as those disenfranchised by the political system (frequently minority groups), but also children, future generations, and the environment. This sense of responsibility is linked to the belief in the precautionary principle (above).

Fifth, at the time this controversy began, members of this network did not trust the Lab. In fact, one could even go so far as to say they actively distrusted the Lab. The origins of this distrust are many, but it characterizes the initial condition for this network. This is a difference from the Community Residents network who did not actively trust or distrust the Lab at the onset of this event.

Sixth, activists shaped their risk perceptions by drawing on knowledge and information from their own research or from sources they believed to be independent from the DOE and BNL.

4.3.6 Influencing Other Peoples' Risk Perceptions

One way to depict this controversy is to see it as a battle between BNL and the Long Island Activists for public opinion. The Friends of BNL network wanted the public to believe that the risk from the tritium was minimal, that the Lab was responsible, and that the Lab cared about how it affected the environment. The Long Island Activist network, on the other hand, wanted the public to believe that radioactive contamination of any level was unsafe and that radiation did not belong in this sensitive and heavily populated region of Long Island. One interviewee from the Friends of BNL network expressed it this way:

But there's not a [. . .] public health problem for members of the community. That was basically our message. And the basic message of the people that were opposed to us was primarily, "Any level of radiation is bad for you and there's a risk to you." And so there was a very strong dichotomy in our messages.

The activists made moral arguments about the insanity of nuclear weapons, but their most effective strategy was to scrutinize BNL's behavior and to reveal to the public signs

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of incompetence, inconsistency, or uncaring on the part of the Lab, knowing that such revelations would lessen public trust in the Lab.

The Lab's strategy at first was to engage in the moral argument, espousing the benefits of science. They also took issue with what they saw as inconsistencies in the activists' arguments, as this quote from a BNL employee exemplifies:

They were just bent on an anti-nuclear front and all nuclear is bad. Meanwhile you don't see anti-nuclear groups trying to shut down hospitals, which rely very heavily on nuclear medicine.

However, it soon became clear that the Lab was losing public trust rapidly, and, to their credit, they switched their strategy to focus on establishing a constructive conversation with the civic organizations immediately around the Lab.

4.3.7 Creating a Climate of Distrust and Anger Between Friends of BNL and Long Island Activists

Activists we interviewed objected to several different tactics that BNL used during the controversy. One activist reported how BNL employees would attempt to discredit him in front of other members of the public. The following quote refers to a meeting where an activist tried to connect with a local citizen who expressed fear and outrage at the Lab. When he approached this woman after the meeting and was speaking with her he noticed:

And these people walking by who were obviously from the lab, were walking by saying [to her], "Don't listen to him. He doesn't know what he's talking about." You know, it's just that kind of attitude, you know, after awhile it grates on you.

Such behavior indicates a fundamental lack of respect on the part of these Lab employees for this individual. In addition to this we heard other anecdotes about BNL employees threatening or intimidating activists at public meetings. One activist recounted a public meeting she attended at a local library:

I mean like lab people were screaming at community people. There was almost a fight in the hallway. It was like . . . really surreal. This one scientist came up to me

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and there was a picture of Alec Baldwin like on the front of like Cigar magazine and he's sticking it in my face and going, "See that? See that? What the hell kind of guy is this that you're working with?"

To be sure, intimidation of this nature was prevalent on all sides. A videotape of a public meeting captures a community member insulting a BNL manager with incredibly vulgar language. Another Lab employee was set up by the local media and embarrassed in public. Many community members claimed that people at BNL lied outright. People at BNL claim that people accused them of lying in the most rude, direct, uncivil manner. Certainly people from all sides behaved in what is commonly believed to be inappropriate civic behavior. Others mentioned that this is simply the nature of Long Islanders:

We are have a real "in your face" mentality here.

A similar encounter, this time with a community resident, not an activist, also ended up discrediting Brookhaven in the long run. Apparently, an employee at the Lab attempted to discourage a local citizen from listening to local activists. The citizen recounted the interaction with the BNL person:

I remember [BNL employee] saying something to me that really, it really bothered me, and it really, it probably set me in motion more than anything, [BNL employee] said to me, "You can't trust [names activist]" "Don't trust him. Stay away from him. And don't trust [another activist]. And don't trust [a third activist]."

BNL employees would attempt to infiltrate activist organizations covertly by presenting themselves as merely "interested citizens," and not mention that they worked for the Lab.

We had one situation where at a Citizens for a Clean Brookhaven meeting, a woman showed up that we didn't recognize and she just said, "Well I'm just a community member." And, so, we made her feel welcome. Then at the next meeting at the Brookhaven lab, we saw her there. And she turned out to be an employee that just got transferred over to the community end of it. She blatantly lied to us. And said that she

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had no affiliation with Brookhaven lab or anything. So, it's very difficult to have a good rapport with people that are not honest with you.

Additionally, BNL employees would attempt to participate in local government decision making about the Lab while disguising the fact that they work for the Lab. Perhaps they were concerned that, if they revealed their affiliation, their opinion might not carry as much weight as that of an impartial "concerned citizen." In one instance recounted to us, a BNL manager wrote a letter to the Suffolk County Task Force, suggesting they stop exploring a radiation issue with the Lab.

The county legislator, Judy Fields, who sponsored the bill funding the Suffolk County Task Force, got a letter from an independent citizen who questioned the validity of the Task Force, and why would we would waste money on the task force looking into this issue, and why we would listen to people that don't know what they're talking about. So I asked her, I said, "Well, who would write such a letter?" She said, "Well, a citizen from Stonybrook." Actually it was [names town]. I go, "What is his name?" She answered, "Well, his name's [name removed]." And I say, "Oh, he is one of the top people at Brookhaven lab." In the letter he failed to mention that he also worked for Brookhaven lab! And he was high up in the management of Brookhaven lab! You know, every time you'd walk into a meeting, he'd come up and greet you and shake your hand, and be as nice as anything to you. And when you're not looking he's stabbing you in the back.

Stacking public meetings was another tactic of which Brookhaven was accused. Moreover, there were claims that BNL not only stacked meetings, but attempted to mask this stacking.

I went to another meeting where one of their [the Lab's] people was holding the meeting and a common tactic that Brookhaven Lab would do is when they would have a community meeting, they'd fill the room with Brookhaven lab employees. And they would say they are also part of the community. You would be outnumbered 10 to 1. And at one particular meeting I raised my hand and I said, "Could I have a count of all the people here who work at Brookhaven lab?" And the guy, he refused

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to do that, he refused to do a head count because I knew we were outnumbered by 95 to 5.

Another argument was that Brookhaven succeeded in getting placed on its community boards citizens who either were married to Lab employees, who were retired Lab employees, or who were independent contractors paid by the Lab. This, in essence, gave the Lab more representation than some people thought was proper.

And so the funny thing is some of the community boards, or the community groups were made up of Brookhaven lab employees. Or, the wives of . . . you know, friends of Brookhaven, which the wives or the people who work there. Or another fellow, [names person], was a former employee of Brookhaven lab who now was an independent contractor, and all his work was funded through Brookhaven lab. He called himself a community leader, and he had vote on it. So it was the DOE having a vote, it was Brookhaven lab having a vote, and then these different community groups that all had ties to the laboratory.

Another complaint had to do with the way that BNL tried to limit public input by producing thick reports and asking the public comment on it in an unreasonably short period of time. This interviewee speculated that, while this may have been a strategy of the Lab's to limit public involvement, and while the Lab may have succeeded in doing so in this instance, the cost was actually quite dear.

They've taken two years to fill out a document that thick, and give it to the public and say you've got a ten-day review period. Huh? So it takes them two years and they want you to review it and comment on it in ten days?!! So if that doesn't generate cynicism, I don't know what does.

All of these phenomena helped to contribute to establishing a relationship between the Friends of BNL Network and the Long Island Activists Network that was characterized as distrustful. It was a relationship filled with anger, outrage, and suspicion. What is remarkable is that the people engaged in this controversy were able to get beyond these confrontations and still find a way to communicate with each other, as the next section describes.

Box 4-4. Summary of the Three Main Social Networks and Their Stance Toward the Tritium Controversy

Network	Initial Position	Logic	Principles
Friends of BNL	Probably not dangerous, don't look into it unless we have to	We would have known about it much earlier if something big had gone wrong	Trust science Trust lab Science is good for society Presumption of Lab's innocence
Community residents	It may be a dangerous, look into it immediately as if it were	Organizations tend to be irresponsible. BNL has a lot to lose, they may be hiding something	Good environmental practices need to be enforced with good leadership and good oversight No presumption of Lab's innocence or guilt
Long Island activists	It certainly is dangerous, and it's probably only the tip of the iceberg	BNL and DOE don't care about local place or people. They only care about advancing the use of radiation	Radiation is deadly Presumption of Lab's guilt

4.4 Convergence Network: The Community Working Group

The three networks described above interacted, argued, cooperated, and competed with each other during the course of this controversy. Of course, this event should be interpreted as one in an ongoing history of interaction among these three networks. Nevertheless, the three networks formed very different stances and opinions about the risk, as summarized in the Box 4-4 below.

Members from these three networks came together in many places. Indeed, some individuals participated in more than one network, although no one participated in both the Friends of BNL and the Long Island Activist networks.

One of the most important places where these networks originally came together and interacted was in the Community Working Group. The CWG has its origins in the days before the tritium was discovered (see section on CWG in Section 3), but, as with many things, it was the tritium that accelerated its development and demise. The purpose for discussing the CWG in this report is to comment on its importance as a setting where people from the different networks came together to discuss the risk controversies at the Lab. Some of the data we gathered in our interviews refer to the year 1996, a time before the tritium was discovered. But since the same people were involved throughout the chemical controversy of 1996 and the tritium controversy of 1997, it is difficult to untangle the two events.

Unlike other DOE Labs, Brookhaven did not have a Site Specific Advisory Committee. In fact, the Lab had no regular contact with citizens, activists, and local government in a form that might be considered a citizens advisory committee. As the controversy matured, the Lab quickly realized the benefits such a committee might hold. Membership in the CWG was open to anyone, but certain individuals were invited to attend.

4.4.1.1 As a Venue for Discourse and Information Gathering

A fair depiction of this controversy is to see two sides in opposition to each other with the community residents watching the debate, acting as a jury, trying to decide

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which side to believe. But the representation in this picture does not credit the community residents with taking the initiative to research and learn about the risk and the Lab, which many of them did do. Several community residents who we interviewed mentioned that they not only listened to both sides make their arguments, they also did their own research in order to figure out which side was right.

The CWG became the main venue where BNL and the activists interacted directly and where unaffiliated members of the local community could listen to both sides discuss the issues. This was not the case in the other roundtables being hosted at Brookhaven. The Brookhaven Executive Roundtables did not create the same type of space. The Poster Sessions that BNL held for the purpose of educating people were also discounted by many interviewees as ineffective discourse spaces:

You were supposed to kind of like walk through . . . they signed you in, kind of gave you the greeting. Showed you the posters. And you could interact with everybody all along the way, but there wasn't an opportunity to say . . . you know, okay this is the responsible person, this is who we're asking questions of what's going on. I want answers to these things. And that's what so many people that I saw there, were getting frustrated with it. There was no ultimately accountable person. There was no interaction. It was this kind of, very controlled, assembly line type, come look, here's the picture, everything's okay, get the hell out of here.

The reasons why the CWG turned out the way it did probably have to do with: (1) letting the membership be open to anyone who wanted to attend, (2) BNL not taking over the process, but instead let the participants run their own meetings, (3) allowing there to be an authentic discussion among the participants.

The chief reason people went to the CWG was to get information. It was a matter of expediency. At the meetings, people could not only request specific reports be made available, but they could also learn about the kinds of reports and information that were available. For example, STAR was able to announce it was hosting a workshop that everyone could attend. BNL could announce the availability of a new document for public comment. And community residents could tell the activists about things they had

uncovered, things such as the Tiger Team report mentioned above. All the community residents we interviewed who attended these meetings reported that they were very helpful, as did many of the activists we interviewed.

In addition to raw information, people at the CWG meetings could also ask for and receive responses or reactions to information or comments. They reported that they were able to ask questions directly to the people who knew the answers, whether they be Lab employees, Lab management, or activists. In other words, residents could quiz STAR and BNL and compare their answers immediately. Residents or activists routinely asked BNL to comment on one thing or another. In turn, BNL used the CWG to receive feedback about their information or how they were being perceived in the community. But in the end, in the competition between BNL and the activists for public opinion, it was BNL who came out on top — for many of the residents with whom we spoke. The activist groups like STAR and so forth were appreciated for their information and perspective, but residents reportedly felt that the activists often overstated the case or made accusations that they were unable to support. This was not always the case. Activists also were able reveal insights that the residents appreciated. Residents also reported that BNL “clearly lied to us.” However, over time, they came to feel that BNL was now telling the truth, that BNL had changed their ways, and that BNL was acting with consistency, caring, and competence.

People who participated in the CWG reported it was a valuable experience because they learned a lot. So far we have focused on their learning about the technical side of the issue and learning about the attitude, perspective, intention, and reaction of the other participants and groups. This later topic was by far the most important for the CWG participants risk perceptions. The most notable change we detected in the risk perceptions of our interviewees came from the community residents. Both other groups — BNL and the activists — had their perceptions hardened by the interaction

4.4.1.2 Difficulties Maintaining the CWG

While the CWG apparently served a positive purpose for many people involved in the controversy, it was not easy to maintain as an organization.

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One of the problems that some people raised with the CWG had to do with its inefficiency. Because the membership was always open, it was difficult for the group to maintain any sense of progress. Instead, old discussions were repeated for the benefit of new members, something old members found annoying.

Like I said, you could have group of twenty people at one of these committee meetings sit through a three hour presentation on Long Island hydrology. And then the next meeting comes, and the person right by you in the room, who wasn't at the last one, and you go over it all again. And then the more people that came . . . it just became crazy after awhile.

Another problem was that of control and representation. The CWG never developed rules for establishing a head or a moderator. It was difficult to understand if the CWG was capable of speaking in one voice. And there was clearly a desire among some in the organization to be able to speak to the Lab with the authority of the entire CWG. The first meeting was, by some accounts, quite remarkable. The participants told all BNL members to leave and set about organizing themselves. They chose a moderator and came up with a list of items they wanted BNL to address. But as time went by, differences of opinion within the group challenged it. The breaking point was when two members accepted a grant from BNL, which paid a small salary and established an office in the Lab for the CWG. Activist members were appalled at what they saw as betrayal, claiming those two people did not have the authority to take money on behalf of the CWG. BNL asserted that it could give money to whomever it pleased and it would not rescind its decision. This squabbling drove out several community and civic members who only wanted to keep learning, to keep the dialogue moving forward, as the following paraphrase from a community member expresses:

Everyone was pursuing their own agenda. I got sick and tired of it all!

In the end the group splintered apart. The activists went off to set up CALA, which BNL initially attempted to attend, but were not permitted. Other individuals set up NEAR and used the grant to get that organization off the ground. Still others used the opportunity to exit the whole process. Later, Brookhaven would establish a formal CAC,

bringing together many of the original members of the CWG in a more formal and lasting organization.

5. Results on Standards and Stigma Across Networks

5.1 Regulatory Standards

An important theme for our study was the role that drinking water standards play in shaping perceptions of the tritium risk. The most prominent and significant drinking water standards for this case are those encoded in the Federal Government's Safe Drinking Water Act. This is Federal legislation that establishes maximum concentration limits for a range of common drinking water contaminants. States and counties are free to establish more strict limits, which they sometimes do, but not in Suffolk County. Tritium is regulated in drinking water by the EPA at a level of 20,000 pCi/l (US EPA 2000).

This afforded risk managers the opportunity to establish the seriousness of the risk by comparing measured levels of contamination against the quality standards. Indeed many risk messages issued by the Lab did interpret the severity of the risk in this way. Measurements were taken at hundreds of monitoring wells inside and outside of the Lab, as well as at the taps of private homes. At some of the monitoring wells tests revealed the concentration of tritium did rise above the drinking water standard.

These water quality standards not only provided a baseline for expressing the level of potential harm, they also provided risk managers with a management objective. The implicit assumption made by the Lab was that, if the water contamination levels would be brought below those of the Safe Drinking Water Act, then the contamination would be acceptable. Brookhaven could argue it was doing nothing illegal. Several people we interviewed, such as this resident of the local area, accepted the logic of this approach, but were still wary:

Q: So these standards that they have . . . they're always comparing the levels with the standard.

A: That's right.

Q: What do you think of using that as a yardstick?

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A: I mean, what are they going to do? They have to do something. You have contamination. It has to be cleaned up. Well, what do you clean it up to? And so they look for guidance from the federal government. I understand they have to have some standard. But on the flip side, as I just explained, those standards are not necessarily based on science. Sometimes they're based on politics. So when you look for a standard. You want a standard that's going to protect your health, not get through Congress. So these standards, there's a political angle woven into these standards that may not be a health protective measure.

Those at the Lab responsible for communicating about the risk to the public also agreed that they needed to use the standard as a yardstick. However, the argument never carried much weight because so many members in the audience rejected the validity of the standard.

It was often very important for us to say, this is a standard. This is where we are on the standard. And every time we could make that comparison, we would be at a very small fraction of the standard. But you get very little credit because in general there's a lack of trust in the community about standards and federal government.

5.1.1 Understanding Where Standards Come From

Even the technical management at BNL admitted it was difficult to understand the origin of standards. Several attempts were made to bring in health experts to explain to BNL management how standards are arrived at. One manager (a scientist) concluded that:

It is very difficult to talk about just how the numbers are generated. The source data is very nebulous. And the extrapolation from acute doses to lifetime small doses is really gray. It is really a stretch. I never heard anyone explain it effectively.

Activists and community residents we interviewed all agreed that they did not understand how standards were computed. Much mention was made of the fact that tritium standards in Canada are different (higher) than those in the United States. Since Canada's standards are higher, activists generally avoided discussing them. Lab people,

however, used that comparison to argue that the U.S. standards were probably over-protective.¹⁵

5.1.2 Believing the Standards Are Protective

Among the Friends of BNL network, people generally believed that the standards did relate to a level of acceptable risk, even if they did not really understand how the standards were computed. For instance, although this individual admittedly did not comprehend how standards were arrived at, he did indicate acceptance of the standards. He mentioned that he trusted the people who set the standards, based on his limited experience with regulatory agencies.

I accept standards as the best guess of what is protective of human health. And I recognize that they can change. It's the best we can come up with now. In the cases I've been involved in, the regulatory agencies err on the side of being very protective, rather than taking a chance. "What the hell, let's make it 50 instead of 5." They just don't do that. And so I trust that the people doing this type of work think along those lines.

This suggests that this professional risk manager accepts standards as protective because personal experience with standard setting agencies and other professional individuals in standard setting activities leads him to trust the standard setting practice as a whole. There is also represented here a certain trust in the profession of regulatory science. This is grounded in his personal experiences with those professionals, but is probably also established by virtue of his relationship with the profession of science, in the broadest terms. He identifies himself as a scientist, thus any culpability for regulatory scientists is also a charge against his own identity. Thus to protect his identity as a scientist who does good in the world, he necessarily must ascribe to certain tenets. One of those is that people in the profession are competent and honest.

¹⁵ We learned from one interviewee that the standard for tritium in drinking water was set at a concentration computed to match an expected dose. That dose is 1 millirem. The background dose for radiation on the average in America is about 350 millirem. Therefore, drinking water with 20,000 pCu/l radiation will increase your dose by about one day's worth of normal background radiation.

Although they believe the standards provide adequate protection, people in the Friends of BNL network mentioned that the public was not likely to think the same way:

A. Even though we detected levels hundred times less than standard, it was still considered bad. “Why is that in my water? I don’t want it in my water!”

Q. So the only acceptable thing would be no incidence.

A. None. Zero. Yeah. Particularly with radiation. [. . .] With radiation zero is acceptable and that’s the only thing that is acceptable. You know, I heard that loud and clear from a number of people.

5.1.3 Believing Standards Are Arbitrary, Bogus, or Inadequate

Interestingly, we heard from both Friends of BNL and Long Island Activists that the standards are more or less arbitrary and products of political haberdashery and little else. This Lab employee mentioned:

Oh the standard is a political thing. They have wanted to change the standard for years. It’s a political hot potato. There is no credible evidence to set the standard at 20,000 pCu/l. Other countries are much higher. Canada is at 50,000. They want to easily move it to 60,000. In reality, if you really look at it, that’s assuming that low levels are bad for you. The number of disintegrations we are talking about, compared to the normal demise of cells in the body is absolutely trivial. The body is getting rid of cells at a rate of 10,000,000 in a period of time and from radiation like this we are talking about maybe two. For me the standard is based on nothing but political stuff.

Which can be likened to this exchange we had with an activist:

Q. Well what’s your take on the standards, are they . . . too high . . . or are they too . . .

A: They’re bullshit. In a word, basically, I think that standards across the board are set by industry to do what they want and I think that standards are a sham, essentially for the most part.

Other people in the community were suspicious of the standards because they do not trust the Federal Government, much to the chagrin of this BNL employee:

I remember one meeting at Mastic Beach where [names person] was explaining standards. This guy just challenged him on it. "The government tells you that? Why do we trust the government." [laughs] Typically, if the community knew we were adhering to state or EPA standards, there was a general acceptance, I think. In this case there was just a total lack of trust in government.

A third perspective we heard was that standards were inadequate because they are based on the assumption that all contaminants act on the body independently of each other. This ignores the fact that synergistic effects of compounds have been documented. This community resident felt that standards were a pragmatic way to try and set limits, but the standards do not necessarily accurately depict the health risks because they don't consider the synergistic effects of two or more contaminants.

Q. Do you trust that they can determine a safe level. . .?

A. Well, yeah, I'd say that that's reasonable to set limits. But I think where they ran into problems is when they can't tell you what happens when you combine it with other things. Yeah, they got a problem. We sat through endless meetings on VOC's and they tell you, ok, you've got five parts per billion in your drinking water, TCA. And then somebody says, well what happens when there's this one, this one, and this one?

5.1.4 Changing the Standards

One theme we explored in the interviews was what would happen if the government increased the drinking water standard from 20,000 pCu/l to a higher number. Some people, like this community resident said they would accept the change out of deference to expertise:

Q: What if they said well we did some more research and now we think that 50,000 pCu/l is safe?

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A: I would go along with that because I don't know. I can't argue with them. I can't say why did you use 20 and now you're going to 50? [. . .] I assume that there's more than 1 person involved in that operation and for me to say that 20 different scientists are wrong and coming up with 50,000, would be ludicrous, I'd be stupid to say that because I don't know. I have no idea.

Lab personnel, scientists, and other people who trust in the institution of science and regularly decision making would probably accept the new standard for the same reasons that they accept the present standards.

However, many people we interviewed indicated that they and others would respond very very negatively to change that made standards more lenient. This lab employee was speculating about what the general public would think:

Q. What do you think would happen if EPA made the standards less stringent.

A. I think there would be a revolt among people who follow that sort of thing. "You are putting us at more risk." There would be a negative response.

5.1.5 The Perception of the Standard

Two individuals at the Lab suggested that one of the biggest problems with using the standard is that it is expressed in the form of a large number. Since 20,000 picocuries/l could be expressed as 20 nanocuries/l or 0.02 microcuries per liter, was there a disadvantage or advantage to using one notation over another? This person went back and forth on the question:

A. The standard for tritium in drinking water is 20,000 picocuries per liter. If you don't know what a picocurie is, that doesn't help. Just the mere number 20,000 sounds like a lot. If we could all have \$20,000 sitting in our pocket, it's a lot of money. 20,000 picocuries is a lot. So, from a standards perspective it's difficult to communicate. You know if we could have talked about that in curies, it's a pretty small number in curies.

Q: So if they presented the standard, just in terms of 0.02 microcuries, you think that would make a difference in how the risk is perceived by most people in the community?

A: Yeah, I do. Yeah, I do. Absolutely. Numbers make a difference.

[then, later in the interview the person revisited this issue . . .]

A. You know, it's interesting that you ask that question with changing the standards. I question in my own mind, if you said it's .02 millicuries, maybe that they'd think it was such a deadly substance that you have to make the standard so low. I don't know. The mind's a funny thing — perception. But big numbers made a big difference, maybe if it were 2, or something like that, I think it would make a difference.

5.2 Stigma and Its Importance in the Controversy

Clearly the stigma associated with radiation propelled a controversy that was originally about VOCs into the big leagues of risk conflicts. Radiation is a keyword that the media and activists used to trigger interest in readers.

The controversy over tritium in groundwater was never just a controversy about dangers to human health, although for some people involved that was surely a major consideration. Different people attempted to frame the controversy in ways that suited them. For instance, the Lab attempted to frame it as purely a concern about health risk, while the community residents and the activists tended to include the attitude and behavior of BNL management and employees in handling dangerous substances, the attitude and behavior of BNL management and employees in relating to the communities living around the Lab, and about the moral rightness of nuclear weapons, nuclear power, and nuclear research. As the conflict matured, BNL found itself fighting for its survival. While the DOE probably never seriously contemplated shutting down the Lab, the suggestion did receive coverage in the *New York Times*. People associated for the Lab began to highlight the economic benefits of the Lab's existence in the county and the social benefits of their research. Their trump card was nuclear medicine.

When people associated with the Lab, or sympathetic to the Lab spoke in broader terms, it was to defend the institution of science. According to this argument, science is valued for the products and techniques it produces. Nuclear medicine was the most frequently mentioned. X-rays, CAT scans, PET and NMR imaging are all benefits paid off from years of research into high energy physics. Cancer treatments that rely on radiation were also cited. The general strategy here was to break the stigma associated with radiation by pointing out that some radiation had positive social benefits

5.2.1 Secrecy and Openness at Brookhaven

From people working at the Lab we heard about how the Lab had been open Sundays for years and years, that busloads upon busloads of school children came to tour the science museum, that the facility readily welcomed anyone who wished to visit and tour the site. However, this stands in stark contrast to the depiction of the Lab by dozens of our interviewees. Even community residents who came to trust the Lab acknowledged to us that, before the whole controversy began, the Lab was a big unknown to the local community.

The local perception of a closed, secret lab lead to stigma. The fence, the guards with guns at the gate all contributed to a perception of the Lab as a secret government facility. People complained that no one knew what went on in there. One interviewee mentioned that this came up at a civic association meeting:

People talked about what was going on over there, what they were doing and how concerned... you know they had *green glows* going on over there with the nuclear (*sic*) reactors and images of unknowns, so you think of aliens and all the rest.

The fence, the guard booth, the secrecy all contributed to a public image of a facility ignorant of its local context.

I had a neighbor who lived near me, and she said, well, “You work there at the lab? They make atom bombs over there.” And no matter what I would say, she would not be convinced that we did not make atom bombs.

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The most significant aspect of stigma in this case was that the Lab reached out to the local public and, over time, managed to overcome stigma and build a positive image of the Lab in the community. The Lab invited local civic groups to come to the Lab, to attend roundtable meetings, poster sessions, citizen working group meetings, etc.

They had committees about clean-up, committees about budget. And they were asking people from the community to go in and talk.

And the Lab also packed up its overhead projectors and headed out to the community to explain about the Lab and the controversy. They worked to teach people about the Lab, to make them feel comfortable with the kind of research happening there.

5.2.2 Does Tritium Have Its Own Stigma?

One of the questions that emerges from this study is whether or not tritium is developing its own stigma, distinct from the stigma associated with radiation in general. One clue suggesting this may be so is the ubiquitous comprehension and use of the term across all segments of the population versed in the controversy.

A second clue is the negative association people have with the term. People probably know that tritium is a radioactive compound, but they are also coming to associate the term with pollution. In other words, people in this controversy did not recognize tritium as a useful or desired product.

A third clue suggesting this question comes from a related controversy in California last year (Withgott 2001). A tritium-labeling facility at Lawrence-Berkeley National Lab was shut down by the NIH. Although NIH claims the facility was closed for budgetary reasons and because it was not performing adequate scholarship, others cited a strong citizen and local government opposition to the facility. Local government had passed resolutions asking that the facility be closed out of concern for the health effects of releases of tritiated water and tritium gas. In this instance, tritium was being produced for the benefits it provided researchers.

Just what associations people have with tritium will need to be the subject of future research. But the BNL case and the Lawrence-Berkeley case suggest that tritium has

entered the vocabulary of people active in radiation controversies. At this point it is unclear just what effect this may have for future controversies.

6. Conclusions

6.1 Trust as a Dimension of Risk

The tritium controversy of 1997 at Brookhaven National Lab is a rich case study for scholars interested in risk conflicts and for citizens, activists, and lab staff who are interested in how to prevent or avoid controversies or to resolve them more favorably the next time around.

This report has focused on the way that individuals who became engaged in this controversy came to develop perceptions of the risk posed by the tritium in the groundwater. We learned that people's risk perceptions were truly multidimensional. Human health and ecosystem quality were of interest.

However, the most salient dimension of risk for this controversy was the publics' lack of trust in the Lab. To a large extent this controversy centered around the relationship between the Lab and the local population. A host of factors including: a lack of knowledge about the Lab, media stories and hyped concern, activists who captured public attention, poor public relations on the part of Lab leadership early on in the event, and host of past and present environmental contamination events caused by the Lab all led to a situation where the local people came to suspect the worst of the Lab.

Perceptions of risk from the tritium were never merely about the tritium alone. They also included fear or concerns that tritium was not the only radioactive contaminant that the Lab had lost sight of. If the Lab could be so careless with tritium, what else was sitting out there just waiting to be discovered? People's risk perceptions about the tritium in the groundwater came to include perceptions of the Lab's competence and the Lab's interest in protecting the local community.

It is doubtful that the public trusted the Lab before the tritium or the chemical contamination was found. Over and over and over again, people told us that no one knew anything about the Lab. It was a big secret that no one minded, until there came a reason

to become concerned. But a situation of benign neglect became damaging to the Lab when members of the local population — not just activists, but citizens and civic leaders — came to be critical of the Lab. At the very least, people became concerned that the Lab was acting incompetently and was uncaring. Reasons offered as to why this was so ranged from poor management and poor oversight to sheer indifference to the environment and surrounding population on the part of Lab personnel.

Scholars have identified four key dimensions of trust. These are: competence, commitment, caring, and predictability (Kasperson, Golding, Tuler 1992). In the first half of 1997, when the tritium controversy was at its worst, citizens, activists, and civic leaders felt that the Lab was not exhibiting any of these characteristics. The public perception of *competence* of the Lab was affected by the announcement of the contamination and the realization that the Lab never thought to investigate whether the spent fuel pool was leaking. Suspicions of incompetence were later confirmed when DOE fired the Lab contractor. The *commitment* of the Lab to protecting the safety of employees and the environment was challenged when the public became aware of the Tiger Team report that concluded the Lab put science before safety. People came to question whether the Lab *cared* about the surrounding community when they heard Lab management say they were not at all surprised to hear the spent fuel pool was leaking for the last 15 years and nothing was ever done about it. Finally, the public was unable to see *predictability* in the Lab's action, partly because the event seemed out of control, but also because the Lab went through many changes in leadership and because DOE exerted its own control over the Lab's actions.

This case study suggests that one additional dimension should be added to this depiction of trust — openness to sharing information. Our interviewees from the Community Residents Network and the Long Island Activists Network frequently claimed that BNL was not being open about sharing information. This lack of openness was perceived as an attempt to disguise past failures or to cover up inappropriate behavior. One community resident told the story of how surprised and angry a BNL employee became when he revealed that he had obtained a copy of the Tiger Team report (which had found many problems with environmental and safety protection at the Lab in

the 1980s). He recounted how this BNL employee remarked with worry and amazement, “Where did you get *that*? How did you get that?” as if the report was something BNL had been attempting to keep buried.

Distributing information freely and openly is still an issue between Long Island Activists and the Lab. At a CAC meeting I attended during the course of this research the Lab was making available a new report about environmental performance. A Lab manager presented to the CAC the highlights of the report, but refused to distribute the report until the end of the meeting, despite requests from several CAC members to see the report during the presentation. I interviewed a member of the CAC later — a member of the Long Island Activist Network — who cited that experience as a sign that the Lab still has problems with sharing information. “It’s like pulling teeth to get anything out of them,” this person remarked. Based on this case study, it can be concluded that reluctance to share information can enhance the perception that the institution is not being trustworthy.

Associated with the topic of trust is the notion of independent validation. An important issue in this case study was the validity of information. One anecdote from an interview with a community resident captures this point well. This individual felt strongly that while the data from the Lab was essential to forming a sound judgment about the seriousness of the risk, nothing given by the Lab should be trusted without first being independently verified. Community residents active in the controversy attempted to verify Lab data and conclusions in two ways. First, they asked other governmental agencies to perform independent testing. For example, water samples were split and given to the Suffolk County Water Authority for independent assessment. BNL performed its own analysis on the sister samples. The samples were distributed to the two labs in a blind manner. Only the residents had the key that showed which sample was which so that the results could be compared. This certainly does not represent a relationship of trust. Perhaps it is better described as “trust but verify.” The second way in which people attempted to validate the Lab’s assertions was to examine them for consistency and reasonableness. For example, an individual recounted how he studied BNL reports about the source of the chemical contamination. BNL sought to blame the

contamination on an industrial park to the south of the Lab. This individual laughed when he found that, to pin the blame on this industrial park, BNL had to make the assumption that the chemical plume migrated in the opposite direction of the groundwater flow, a notion he found completely illogical. Later on, of course, BNL admitted it was the main source of the plume.

With time local citizens came to accept the Lab as a trustworthy neighbor and their perceptions of the risk were diminished. First, there was a period of *atonement*, where the firing of the Lab's operator and the hiring of a new operator and a new director indicated to citizens that BNL had been doing something wrong, and that the DOE had acted to solve the problem. Also, BNL leadership apologized to the community for its mistakes. Second, *predictability* became higher when no new controversies arose. The tritium seems to have been where it was thought to be, the pumping and recharge seem to be keeping it there, and nothing new was going wrong. This gave people the sense that the problem was contained to just the tritium. Third, and most important for the establishment of trust, was that individuals came to believe that BNL did *care* about the environment and the local population. There were several reasons why this came about. First, BNL admitted the mistake, took responsibility for it, and took actions to mitigate it. Second, the Lab took the time and effort to listen to the public. And the people at the Lab listening were at the highest levels. Not only that, but people felt that the Lab heard what they said and that the Lab changed its behavior in response to the input it received. Third, were the personal relationships that Lab employees formed with the involved public. Through face-to-face contact, citizens came to know individuals working at the Lab. They felt comfortable about telephoning and asking for information or explanations. When answers were forthcoming and honest, people felt positive about the relationship.

In summary, peoples' perceptions of risk in this controversy were tightly linked to their assessments of how much trust they could put in BNL and the DOE. On the four key dimensions of trust — commitment, competence, caring, and prediction — the Lab fared poorly in many eyes. In addition to these we recognize that an openness to sharing and examining information is another dimension of trust. Finally, as the controversy ensued

and people realized a need to work together, the principle of interaction with the Lab came to be “trust but verify.”

6.2 How Social Networks Shape Risk Perceptions

One finding from this study is that not all social networks influence the formation of individuals’ risk perceptions in the same manner. People in the Friends of BNL Network generally adopted the perception that the risk was acceptable whereas people in the Long Island Activist Network generally saw the risk as unacceptable. And in these two different perceptions different dimensions of risk were emphasized quite differently. Despite these substantive differences it is possible to draw some basic conclusions about the ways in which networks operate to shape individuals’ risk perceptions.

Belonging to a network shapes risk perceptions in two main ways. First, the network serves as a means to distribute and interpret information. The network provides means for information to be made available to all members of the network. Specific individuals in the network assume communal responsibilities such as anticipating the knowledge needs and interests of the other network members. They then take actions to ensure that people in the network receive the relevant information. They photocopy reports. They pass along notices of meetings. They clip newspaper articles. And so on. This was especially noticeable in the Friends of BNL Network where individuals were formally assigned this role, but it also seemed to hold true for the Long Island Activist Network where STAR took on the information gathering and distribution role. This role was least formalized in the Community Residents Network, which was also the network with the lowest degree of uniformity.¹⁶ Some community residents were more inclined to trust the Lab, others to trust the activists. As a result, information sharing within that network tended to be more discontinuous and based on friendships.

Second, because the members of the network share a number of premises, the interpretation and evaluation of information can be definitive. This means that

¹⁶ It may be true that within the Friends of BNL Network there was more discontent and discord than we were able to discern in this case study. We have already admitted the difficulties of getting the National Weather Service employees to speak with us. It could well be that, among certain segments of Lab employees, there was a great deal of difference about risk perception.

uncertainties about how to interpret information are often resolved by ideological forces. Thus, the Long Island Activist Network would tend to assert a precautionary interpretation of the data (guilty until proven innocent) while the Friends of BNL Network would adopt an innocent until proven guilty presumption. This is definitive because it leaves little or not room for uncertainty or indeterminateness. Only in the Community Residents Network was there a greater degree of uncertainty of multiple interpretations of data. For individuals in networks that were highly structured and which emphasized ideological or philosophical beliefs (such as “science is good” for the BNL Network and “the precautionary principle” for the Activist Network), the network provided clear and precise interpretations of data. Members of these networks might not even be aware that there are different ways to interpret the data.

Third and finally, people use peer relationships in networks to “try out” explanations and interpretations that they may be considering believing. This was especially true for individuals in the Community Residents Network who asserted that they approached the controversy with an open mind. These individuals wanted to reach conclusions based on the most convincing argumentation, not on philosophical or ideological grounds. The diversity of opinion within this network was actually an asset for members who sought to explore these multiple interpretations. The same may be true for the Friends of BNL Network or the Long Island Activists Network. For example, an employee at the lab might let drop to a colleague a number of different notions associated with the risk perception. For example, imagine this hypothetical statement made by one Lab employee to another:

Boy the Lab sure has gone overboard with drilling monitoring wells.

Such a statement might inspire a variety of responses from:

- a) What’s the matter with you? Don’t you know the Lab is doing the right thing here?
- b) And how! Why is the Lab kowtowing to those crazy activists?
- c) Why do you think so? I was wondering the same thing.

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The first reply would serve to stifle dissent within the network and condemn people who dare to entertain a point of view in opposition to the one sanctioned by Lab leadership. The second response might indicate the presence of sub-culture within the Lab who takes issue with the Lab leadership. The third response might signify to the original speaker the rightness of entertaining critical thoughts and encourage further exploration.

In sampling peer attitudes, the hypothetical employee above is investigating the social consensus within the network. Certainly not everyone in a network needs to believe the same thing. There is some degree of tolerance for different beliefs and members of the network try to identify the boundaries of what beliefs are considered acceptable. At the same time, the network serves to reinforce some beliefs. At times in the controversy it might be more or less important for the network to be unified. For example, consider the effect this answer might have on the person who posed the first question above:

We've got to drill these wells in order to understand the exact location of the tritium in the groundwater. Otherwise we'll look really stupid to the community.

Such an answer would, of course, indicate to the first employee that the "correct" stance for people in this network is to support the well drilling program. It brings people's beliefs into alignment and defines a clear position for the network. While the above example is purely hypothetical and we have situated it in the Friends of BNL network as a means of example, the same could be true for the other networks as well.

People in very tight social networks may find it difficult to adopt risk perceptions that are different or in tension with the network's perceptions. For instance, we would expect it to be much more difficult for a BNL physicist to adopt a perception of the tritium risk more in line with the Long Island Activist network, and vice versa. For one thing, their colleagues would ridicule or ostracize them for "defecting to the enemy." However, in a looser network, such as the Community Residents network, there is more latitude for diversity. We found this to be so in this case. Some community residents were very understanding and trustful of the Lab, others are, to this day, still resentful and distrusting. What makes this possible is simply that the Community Residents network is not as tightly coupled as the other networks are. The people who disagree with each other

in the Community Residents network rarely have to interact. Therefore they can tolerate different perceptions more readily than a group whose survival depends on consensus — at least consensus on fundamental principles.

A possible hypothesis emerging from this research then is that people who are tightly linked to a high solidary network are more likely to form risk perceptions that are consistent with most others in the network.

Another interesting question to ponder is: Are the risk perception factors outlined in the Boxes 4-1, 4-2, and 4-3 determined by the network and imposed upon the participants of that network? Or do people who think alike join the same network? Reflection leads me to suggest it is a bit of both. People who think alike do join similar organizations. But it is also true that people with different views, if those views are not strongly held, can develop a consistent rationality through communicative interaction. Members of the network learn from each other and, over time, come to adopt as their own rationality. New people who are attracted by the network are quick to learn this rationality. Thus, it is likely that, at least some networks pressure individuals to conform with the accepted style of thinking. Of course, some networks will be more tolerant of dissent and diverse points of view than will others. The extent to which the network demands conformity may be related to the decision stakes involved.

This suggests a second hypothesis. When the decision stakes are high, social networks organized around the controversy will demand higher conformity from their members.

6.3 Standards and Stigma in Risk Perceptions

A third hypothesis to emerge from this research is that, if BNL had been able to say there was a “safe” level of radiation exposure (a “no adverse effect level” or NOAEL), and if they had succeeded in getting the public to accept this level as safe, the controversy would have been much lessened.

Results from this case study suggest that we would find this hypothesis to be untrue. In this instance, the controversy did not revolve around the safety dimension of risk alone. Instead, the trust dimension of risk became salient along with other dimensions

such as the connection between nuclear weapons and nuclear research. These would have remained the salient dimensions regardless of whether or not the tritium was considered “safe” or not.

Opponents to the Lab frequently noted that, although the tritium contamination was small, no level of radiation pollution was acceptable to the public. This is obviously because the public stigmatizes radiation as inherently dangerous. This opinion is supported by scientists such as Helen Caldicott and Jay Gould and others who argue there is a scientific basis for this position. It is not clear that the controversy about the low dose effects of radiation is a purely scientific question, but, as long as controversy persists among reputed scientists, the controversy will remain alive in the public sphere.

Stigma in the sense of a community image blighted with negativity probably never came widely into play in the tritium controversy at BNL. In general, the public opinion about BNL is positive. People are generally proud to have the Lab and its renown scientists as neighbors. A survey of the population of Suffolk County would probably reveal BNL is held in a positive light. Stigma was certainly relevant to some of the Long Island Activists involved in this event. For them, and for a number of people in the general population as well, nuclear reactors are associated with negative images. Once the HFBR was shut down for good, most of the stigma associated with this case also disappeared.

6.4 Final Conclusions

This exploratory case study investigated the ways in which people’s situatedness in social networks helped shape their perceptions of a low dose radiation risk. It also explored how this particular risk controversy played out and the role that scientific information, regulatory standards, and stigma played.

The results suggest that social networks do affect the way an individual forms risk perceptions. Such networks provide means for information to be distributed and interpreted for the members of the network. They also provide opportunities for people to test out rationales about the risk and about the controversy through a process of informal “peer review.” In this instance, regulatory standards were used by some parties to try and

establish some “hard ground” where risk perceptions could take root. However, for many participants in this controversy such risk comparisons were irrelevant or ancillary because the most salient risk dimensions had to do with institutional trust and philosophical principles (against lying and for honesty and openness, and against the nuclear weapons culture). Thus this research suggests the hypothesis that in instances where damage is not the most salient risk dimension, changes in regulatory standards will have no effect on people’s risk perceptions.

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Low Dose, Risk, Decisions, & Risk Communication

Community Surveys

Low Dose Radiation

Fernald, Ohio and Rocky Flats, Colorado

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A REPORT

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Abstract

This report is intended to present a basic description of the data from the two community surveys and to document the text of the questions; the methods used for the survey data collection; and a brief overview of the results. Completed surveys were conducted at local communities near the Rocky Flats, Colorado and the Fernald, Ohio sites; no survey was conducted for the Brookhaven, New York site.

Fernald. The Fernald sample was randomly selected from 98% of all potential residential telephones in the townships of Ross, Morgan, and Crosby. The only telephone exchanges not used for the Fernald study had 4%, or fewer, of the holders of the telephone numbers actually living in either of the three target townships. Surveying started on July 24, 2001 and finished on August 30, 2001. A total of 399 completed interviews were obtained resulting in a CASRO¹ response rate of 41.8%. The average length of an interview was 16.5 minutes.

Rocky Flats. The sample was randomly selected from all potential residential telephones in Arvada and from 99% of the potential telephones in Westminster. Surveying started on August 10, 2001 and finished on September 25, 2001. A total of 401 completed interviews were obtained with a CASRO response rate of 32.5%. The average length of an interview was 15.7 minutes.

Overall, respondents hold favorable views of science. They indicate an interest in developments in science and technology, feel that the world is better off because of science, and that science makes our lives healthier, easier, and more comfortable. However, respondents are divided on whether science should decide what is safe or not safe for themselves and their families. The majority of the respondents think that standards for exposure to radiation should be based on what science knows about health effects of radiation and on what is possible with today's technology. Although few respondents had visited the sites, most had heard or read something about Fernald or Rocky Flats in the media. Impressions of the sites tend to be negative. Most respondents feel that overall their community would be better off without the site. However, when asked about the economic future of their community after cleanup and closure of the site, only 31–43% thought that it will be better, 47–56% thought their local economy will be about the same.

¹ The CASRO response rate equals completed interviews divided by (completed interviews + partial interviews) + (all other known forms of contact) + an estimate of the numbers for which nothing is known.

1. Introduction

Research consistently shows that expert evaluations of the risks from low-dose radiation exposure are considerably different from those of the lay public. This is important because lay risk evaluations determine attitudes, preferences, and behaviors related to how nuclear facilities should be managed. The conclusions about the potential hazards, the sources of evidence, interpretation of information, the values applied to outcome and policy options, and confidence in organizational management are displayed within the context of local communities. The result has been considerable opposition to expert-recommended actions to manage radiation exposures. Risk communication has been put forward as a means for bridging the gaps between expert and lay perspectives and thereby gaining support for public radiation-control programs and policies. Natural background radiation, including radon, raises only limited public concern and there is widespread public approval for the use of radiation isotopes in basic research and in medicine. Some industrial uses have been accepted only grudgingly as absolutely necessary (nuclear weapons) or as a *fait accompli* (existing nuclear power and radioactive waste sites). The primary disputes between experts and the public are with the industrialized sources of radiation.

This report is intended to present a basic description of the data from the two community surveys and to document the text of the questions; the methods used for the survey data collection; and a brief overview of the results. More detailed analyses will appear in final reports of the community studies and in future manuscripts resulting from this research project.

Scientific evidence exercises only a limited influence over public opinion even when the debate about specific cases is put into scientific and risk terms. The nature of science itself is often misunderstood and the inherent conditions of uncertainty and the inevitable development of new questions about the nature of radiation that results from science experiments prohibit the kinds of clear, unambiguous, and final answers that will settle questions about the potential risks to human health and the environment for lay people who have strong moral, ethical, or cultural values at stake. Thus, a difficult situation results. Society invests enormous time, resources, and effort into producing scientific and technical solutions to manage radiation risks only to have the best available advice rejected by individuals, groups, and communities at all social levels.

Table 1. ***Approaches to Communicating Risk***

Approach	Reference	Strategy
1. Communication Process Approach	(See Chapter 2)	Message source sent through available channel to intended audience (with feedback if necessary).
2. National Research Council Approach	NRC 1989; NRC 1996	An interactive exchange of information and opinion between experts and lay people.
3. Mental Models Approach	Gueter, G., and A.L. Stevens, 1983; Morgan, et al., 2002	Compares mental model for audience with expert models for evaluating risks
4. Crisis Communication Approach	(See Chapter 5)	Provides immediate action messages and directions
5. Convergence Communication Approach	Rogers and Kincaid, 1981	Long term “cycling” of information between groups to slowly converge onto common ground
6. Three-Challenge Approach	Rowan, 1991	Addresses the challenges of knowledge, process, and communication skills
7. Social Constructionist Approach	Waddell, 1995	Considers the flow of information as modified by understanding, values, beliefs, and emotions.
8. Hazard Plus Outrage Approach	Sandman, 1989	Based on premise that risk communication often must address the condition of hazard + outrage

Note. From *Risk Communication: A Handbook for Communicating Environmental, Safety, and Health Risks* (PAGE NUMBER NEEDED), by R. Lundgren and A. McMackin, 1998, Columbus OH and Richland, WA: Battelle Press.

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Communication and education long have been considered the means for closing the differences between the experts and the public. The basic problem is how to provide the public with scientific evidence, confidence in the analysis, trust in the policies and programs, and willingness to support specific projects. To address the risk communication issues² — over the past half century a series of different conceptual approaches to risk communication have developed. Lundgren and McMakin (1998, chap. 2) summarized eight approaches. As shown in Table 1, these approaches have become more complex as they have accumulated evidence of psychological, social, cultural, economic, and political factors. An overriding additional complication is added with the power and variety of communication means that are exercised in contemporary life.

As the Lundgren and McMakin book shows, the tendency for risk communication is to develop in response to a series of social studies of public risk responses. Beginning with some rather simple, linear and mechanistic descriptions during the 1960s and early 1970s, risk communication moved on to incorporate work from social psychology and decision-making and somewhat later included sociological, cultural, and anthropological research.

² The potential for science-based education constitutes an additional area of research that is addressed in other studies undertaken by this research project.

Figure 1. A model of impact for unfortunate events. Adapted from Kasperson, “Social Amplification of Risk.”

Roger Kasperson and his colleagues initiated an important direction of social analysis with the formulation of the Social Amplification of Risk as a conceptual framework to describe public responses to risk information (Kasperson et al., 1988; Kasperson & Kasperson, 1996).³ Figure 1 outlines this framework and shows a series of social-cultural conditions that influence the range of public behavioral outcomes. One of the key outcomes is the development of technological stigma for certain types of hazards and hazardous conditions. Stigmatization serves as a socially developed “sign” or “prompt” to guide the public’s risk evaluations. It also functions as a feedback loop within the social amplification of risk framework to inform decision-makers about public acceptability (Gregory, Flynn, & Slovic, 1995; Flynn, forthcoming; Satterfield, Slovic, Gregory, Flynn, & Mertz, 2001). Another important line of research considers the performance of organizations designated as risk managers, a matter that was included in the first wave of studies done on the social amplification of risk (Burns, 1993; see also U.S. Secretary of Energy Advisory Board, 1993).

The response to radiation risks is most obvious at the community level as repeatedly demonstrated with recent attempts to site nuclear waste facilities. When federal agencies have attempted to locate and develop high-level waste sites the responses at the community and state levels have taken a variety of political and social responses, inevitably in opposition to these proposals (Dunlap, Kraft, & Rosa, 1993; Slovic et al., 1991; Flynn, 1992). The futile effort over two decades to locate low-level waste sites, undertaken by more than 20 states and multi-state (compact) programs shows how difficult it is to overcome public resistance at the community level (U.S. General Accounting Office, 1999; Weingart, 2001). In varying degrees these public responses apply to nuclear power and weapons production sites. Concerns extend to transportation routes used for moving wastes and to atmospheric fallout that took place several decades ago (*City of Santa Fe v. Komis*, 1992; U.S. Department of Health and Human Services, 2001).

³ The Social Amplification of Risk has been the subject of about 100 articles and one forthcoming book (Pidgeon, Kasperson, & Slovic, forthcoming).

Figure 2. Social geography of risk communication.

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The early models of risk communication lacked the ability to construct science-based messages that addressed public concerns and moderated public attitudes toward radiation exposure and its management. This limitation affected decisions in two directions. It did not provide the public with the information used to make decisions on their behalf and it did not provide decision-makers with appropriate understanding of the public concerns. The result was a long series of contentious differences between radiation managers and the public expressed at the local, state and national levels. The early communication failures prompted the more recent models, which recognizes that earlier simple models did not adequately inform either managers or the public. It was necessary to move on toward more inclusive approaches, ones that took account of the full range of human social interactions that bear on the subject. The survey research reported here is part of a larger study of communities and the many roles of risk communication. It attends to the ways that communities learn about specific sources of potential radiation exposure and how they respond. It looks at the social construction of information, attitudes, and opinions that frame the evaluation of new scientific information. Certainly at this point, few people will be surprised to discover that science does not have the impact upon public opinion and behaviors that experts hope for. The goal of these surveys and case studies is to describe some key conditions in selected communities as a part of developing a better understanding of community-level opportunities and constraints to risk communication. Can science have an effective voice in the social world of radiation policies and programs? If so, how can that voice be heard and what outcomes could be expected under specific conditions?

Social Geography of Risk Communication. In order to address the issues involved with risk communication in the existing societal structures with their many overlapping and contending elements, we developed a conceptual framework entitled the Social Geography of Risk Communication. It builds on the past quarter century of work on risk issues and their social consequences. It is oriented to spatial conditions to identify communities, jurisdictions, and spheres of influence. The basic approach is shown in Figure 2. As a guide to research, it is used to identify the major arenas for social action. It is within these arenas, as they display local issues and the many connections with other levels of society, that important responses to risk issues are formed and actions take place. Risk communication must be capable of understanding the community context in order to comprehend the primary social effects on public perceptions and

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behaviors. To do this, it also must understand the broader societal forces that bear on community issues.

Community Site Selection. Nuclear facilities with the potential for low-dose radiation exposure are located in more than a hundred communities across the country. The case study researchers have considerable experience with the community issues from earlier case studies, going back to the 1970s, and from siting issues related to nuclear power, the DOE weapons complex, and various levels of radioactive waste siting. Team meetings reviewed the potential communities from these categories and selected 14 sites and communities for preliminary visits.⁴ From these 14 sites, three were selected. The lead researchers were Dr. Thomas Webler for Brookhaven New York, Dr. Seth Tuler for Fernald, Ohio, and Dr. Theresa Satterfield for Rocky Flats, Colorado. The area of influence for each of these three facilities is quite large. The next step was to define a study community within that large geographic area.

Our approach to this task was to identify a “study” community, one that was concise enough to support in-depth, field-level research with access to both inside-the-community responses and the networks that connect it with other groups, jurisdictions, and communities. This core community has geographical and political boundaries. It has a significant role in project, program, or policy decision-making in response to potential low dose radiation exposure. It serves as a viable unit of social analysis for study on the subject of risk communication.

A number of conditions in the community are examined. These include the role of established communication media, ad hoc communication sources, and groups that provide ancillary and perhaps more personal messages (organizations like churches, lodges, unions, environmental groups, neighborhood groups, local governments, schools, PTAs, etc.). The research looks at sources of differential effects: How individuals and groups responded to specific media, personal, and in-group messages. The key informant work focused on community groups that played a notable role in responding to the sources of radiation risk. The additional survey results, outlined in this descriptive report, are important to understand the community studies by providing a context for the field work and the key informant interviews as

⁴ More than 50 sites were researched through the literature and 14 sites were visited in the community selection process including: Lawrence Livermore NL, CA, Lawrence Berkeley NL, CA, Rancho Seco, CA, Rocky Flats, CO, West Valley, NY, Plymouth, MA, Fernald, OH, Millgram, VT, Brookhaven, NY, Allegany County, NY, +++++]

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well as providing a statistically valid set of perspectives on the conditions underlying risk communications.

Completed surveys were conducted at local communities near the Rocky Flats, Colorado and the Fernald, Ohio sites; no survey was conducted for the Brookhaven, New York site.

1.1 A Brief History of the Two Survey Community Sites

DOE's Rocky Flats facility is located in Jefferson County approximately 16 miles northwest of Denver. It began operations in 1953 to produce "plutonium pits," the triggers for nuclear weapons and operated as a production facility until 1989. In 1992, Rocky Flats was closed as a weapons plant and designated as the Rocky Flats Environmental Technology Site as part of the DOE program to manage and clean up former nuclear weapons facilities. During its 35 year history there were a number of risk events brought to public attention including a major fire in the 1950s, protests by anti-nuclear activists during the 1970s, and reports of off-site contamination at various times. The most startling event was a raid by the FBI on June 6, 1989 with a warrant charging violations of environmental laws. This resulted in charges against the contract operator of the facility, Rockwell International, the investigations of a Federal Grand Jury, and in 1992 the guilty plea by Rockwell, who paid a fine of \$18.5 million. The cleanup efforts and a class action suit asking for health and property damages from earlier operations contributed to stories about the facility over the past decade with various levels of news media attention. The issues at Rocky Flats involve the acceptable levels of clean up, especially of plutonium contamination, and the future uses of the production portions of the site and its buffer zone.

The Fernald facility, located in a rural, residential area 18 miles northwest of Cincinnati, Ohio, began production in 1952 to produce uranium metal products for the nation's nuclear weapons programs. Production was officially ended in 1991, 40 years after construction began, and the site was renamed the Fernald Environmental Management Project. Since that time it has focused on site clean-up and restoration. Many events and news media stories about Fernald have kept the facility in front of the public since the mid-1980s. These have dealt with on and off-site contamination. One notable event was the settlement of a class action lawsuit by Fernald neighbors in 1989 for \$78 million for property damages and initiation of a medical monitoring program. The remediation of the site, which is ongoing, has been carried out with publicly

accountable regulation and considerable public attention so the issues of various degrees of radiation risk have been widely discussed. There has been considerable discussion about waste management alternatives and the future uses of the site.

2. The Community Surveys

2.1 Survey Content

The surveys were designed to assess the public's awareness of and concern with issues related to radioactive waste and the potential for exposure to low-level radiation. The survey included questions about:

- Science and technology, particularly radiation;
- The adequacy of standards for radiation exposure and how standards should be set;
- Perceptions of risk to public health from different types of radiation;
- Familiarity with the sites and past events; general impressions of the site;
- Sources of information;
- Perceptions of the community in general and the influence of the site on the community;
- Evaluations of specific proposals for future use of the site; and
- Levels of environmental concern.

The surveys collected basic social-demographic data about the respondents (i.e., gender, age, educational background, income, ethnicity, and political affiliation).

2.2 Survey Development and Administration

Most of the questions were the same for both the survey instruments with only some variation for items that asked about site-specific issues. In those cases, the questions were parallel. The instruments were based upon question sets asked in the more than 100 surveys developed by Decision Research personnel over the past two decades with many specific questions drafted with direct input from field-work researchers who were conducting studies in the subject communities. A copy of the survey instrument is attached as an appendix to this report. All telephone interviews were conducted by Northwest Survey & Data Services. Prior to the start of telephone data collection internal pre-testing and extensive pre-test interviews were

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completed with respondents from the target communities. Interviewer training was on July 23, 2001, preceding the first survey, for Fernald.

Fernald. The Fernald sample was randomly selected from 98% of all potential residential telephones in the townships of Ross, Morgan, and Crosby. The only telephone exchanges not used for the Fernald study had 4%, or fewer, of the holders of the telephone numbers actually living in either of the three target townships. Surveying started on July 24, 2001 and finished on August 30, 2001. A total of 399 completed interviews were obtained resulting in a CASRO⁵ response rate of 41.8%. The average length of an interview was 16.5 minutes.

Rocky Flats. The sample was randomly selected from all potential residential telephones in Arvada and from 99% of the potential telephones in Westminster. The only telephone exchanges not used for Westminster had 2%, or fewer, of the actual Westminster residents. Additionally, because the two communities are not completely contiguous and because the telephone exchanges in this urban area cover more communities than just Arvada and Westminster, potential respondents were asked to identify which of the two communities they lived in and if they did not live in either community they were coded as ineligible and were not interviewed. Surveying started on August 10, 2001 and finished on September 25, 2001. A total of 401 completed interviews were obtained with a CASRO response rate of 32.5%. The average length of an interview was 15.7 minutes.

For both surveys, the confidence interval or sampling error is plus or minus 4.9% for a 50-50 proportional split, at the 95% confidence level.

⁵ The CASRO response rate equals completed interviews divided by (completed interviews + partial interviews) + (all other known forms of contact) + an estimate of the numbers for which nothing is known.

**Table 2. *Demographic Characteristics of Samples:
Comparison of Fernald and Rocky Flats***

	Fernald	Rocky Flats
Gender		
Male	38.1	42.6
Female	61.9	56.9
No Answer	0	0.5
Race		
White	94.0	82.3
Black or African American	1.8	0.8
Asian	0.3	2.7
Native Hawaiian or other Pacific Islander	0.5	0.0
American Indian or Alaskan Native	0.5	0.8
Hispanic or Latino	0.3	9.0
Other	1.8	3.5
Don't Know/No Answer	1.0	1.0
Education		
Less than HS Graduate	9.3	2.2
HS Graduate	38.6	23.2
Some college	30.1	37.9
College Graduate	22.1	36.4
Don't Know/No Answer	0.0	0.3
Income		
Less than \$25,000	14.0	9.5
\$25,000 to \$50,000	32.6	32.4
\$50,000 to \$75,000	25.6	24.4
\$75,000 or more	15.5	27.4
Don't Know/No Answer	12.3	6.2
Mean Age	45.0	46.0

Note. Cell entries are percentages.

2.3 Participants

Fernald. The Fernald sample consisted of 399 respondents ranging in age from 18 to 87 with a mean age of 45. Sixty-two percent were female. Respondents were predominately white (94%); slightly over half (52%) had received at least some college or more. Forty-one percent had annual household income of \$50,000 or more. About 38% indicated they were affiliated with Republican Party and 25% reported they were Democrats. Sixteen percent reported that either they or a family member now worked at the Fernald site or had in the past.

Rocky Flats. The Rocky Flats sample was comprised of 401 respondents ranging in age from 18 to 88 with a mean age of 46; 57% were female. Approximately 82% of respondents were white and 74% of the sample had received some college education or more. Fifty-two percent of the respondents had annual household incomes of \$50,000 or more. About 27% reported being affiliated with the Republican Party and 30% Democratic. Only 11% of the respondents reported that either they or a family member worked at Rocky Flats now or in the past. Fifty-four percent of the sample resided in the Westminster area. The average length of time respondents had lived in the Denver area was 21.6 years. Arvada residents were more likely to have lived in the area longer; 61.4% had lived in the area 16 years or more compared to 49.3% of Westminster residents.

Table 2 displays the demographic characteristics for both samples.

Table 3. **Attitudes About Science and Radiation:
Comparison of Fernald and Rocky Flats**

		Not interested	Slightly	Somewhat	Very interested	Don't know/ No answer
<hr/>						
RAD003. How interested are you in new developments in science and technology?						
	<i>Fernald</i>	12.0	20.8	44.1	22.8	0.3
	<i>Rocky Flats</i>	11.2	10.2	38.4	39.7	0.5
<hr/>						
			Better	Worse	Other	Don't know/ No answer
<hr/>						
RAD004. All things considered, would you say that the world is better off or worse off because of science?						
	<i>Fernald</i>	77.7	11.8	9.3	0.3	
	<i>Rocky Flats</i>	77.8	7.2	13.2	0.5	
		Strongly agree	Agree	Disagree	Strongly disagree	Don't know/ No answer
<hr/>						
RAD005. Science is making our lives healthier, easier and more comfortable						
	<i>Fernald</i>	21.8	66.4	9.8	1.0	1.0
	<i>Rocky Flats</i>	21.0	72.6	5.2	0.5	0.8
<hr/>						
RAD006. Most scientists want to work on things that will make life better for the average person.						
	<i>Fernald</i>	13.8	67.4	14.8	1.0	3.0
	<i>Rocky Flats</i>	15.2	65.8	16.2	1.0	1.8
<hr/>						
RAD007. Science can decide what is safe or not safe for you and your family.						
	<i>Fernald</i>	7.5	47.9	33.3	8.0	3.3
	<i>Rocky Flats</i>	6.5	42.9	41.4	5.7	3.5
<hr/>						
RAD008. Most radioactivity is human-made.						
	<i>Fernald</i>	10.0	46.4	25.1	2.0	16.5
	<i>Rocky Flats</i>	9.0	43.4	32.2	3.7	11.7
<hr/>						
RAD009. Radiation from the natural environment is less harmful than human-made.						
	<i>Fernald</i>	6.3	43.1	32.6	3.5	14.5
	<i>Rocky Flats</i>	7.5	39.2	31.9	3.7	17.7
<hr/>						
RAD010. Science can decide whether radiation exposure is safe or unsafe for you and your family.						
	<i>Fernald</i>	10.5	61.9	21.8	4.3	1.5
	<i>Rocky Flats</i>	8.0	61.6	25.7	3.0	1.8

Note. Cell entries are percentages.

3. Results

3.1 Attitudes about Science and Radiation

The first section of the survey elicited attitudes and opinions about science and radiation in general. Table 3 contains the questions and responses for these items. The first question asked respondents how interested they were in new developments in science and technology. Most respondents in both samples indicated at least some interest in such new developments with only 11-12% of either sample reporting they were not interested. Rocky Flats respondents reported greater interest with over three-quarters (78.1%) being somewhat or very interested in science and technology compared to 66.9% of the Fernald respondents. The Rocky Flats sample showed 39.7% as “very interested” compared to 22.8% for Fernald. This may be a reflection of the higher educational background of the Rocky Flats sample.

Over three-quarters of the respondents (78%) believed that when all things are considered, the world is better off because of science. Only 7.2% to 11.8% (in Rocky Flats and Fernald, respectively) thought the world was worse off. The majority of respondents in both samples agreed that “science is making our lives healthier, easier and more comfortable. Rocky Flats respondents were somewhat more likely to agree with this statement (93.5%) compared to Fernald (88.2%). Most respondents (81%) in both samples agreed that “most scientists want to work on things that will make life better for the average person.”

Respondents were divided on whether “science can decide what is safe or not safe for you and your family” with Rocky Flats respondents at 49.4% and Fernald at 55.4% agreement. However, when asked if “science can decide whether *radiation exposure* is safe or unsafe for you or your family” agreement increased with 69.6% for Rocky Flats respondents and 72.4% for Fernald. See Table 3.

Table 4. **Attitudes about Radiation Safety Standards:
Comparison of Fernald and Rocky Flats**

		Too high	About right	Too low	Don't know/ No answer
<hr/>					
RAD011. Do you think the safety standards for radiation exposure are generally too high, too low, or about right?					
	<i>Fernald</i>	11.3	45.9	32.6	10.3
	<i>Rocky Flats</i>	6.2	45.4	36.9	11.5
		How much radiation people receive from nature	What science knows about health effects of radiation	Both (if volunteered)	Don't know/ No answer
<hr/>					
RAD012. If you were in charge of setting the standards for exposure to radiation, would you base the standards on how much radiation people receive from nature or what science knows about the health effects of radiation?					
	<i>Fernald</i>	14.3	74.2	6.3	5.3
	<i>Rocky Flats</i>	14.2	68.8	12.7	4.2
		What is possible with today's technology	What can be achieved without excessive costs	Both (if volunteered)	Don't know/ No answer
<hr/>					
RAD013. Would you set the standards for environmental cleanup of radiation sites based on what is possible with today's technology, or what can be achieved without excessive or unreasonable costs?					
	<i>Fernald</i>	68.2	22.3	4.3	5.3
	<i>Rocky Flats</i>	74.3	17.0	5.7	3.0
<hr/>					

Note. Cell entries are percentages.

A little over half of the respondents thought most radioactivity is human-made; 56.4% of the Fernald sample and 52.4% in Rocky Flats agreed with this statement. A relatively high proportion of respondents answered “don’t know” to this question, 11.7% in Rocky Flats and 16.5% in Fernald. Respondents were divided on whether “radiation from the natural environment is less harmful than human-made.” Almost half (49.4% in Fernald and 46.6% in Rocky Flats) agreed that natural radiation is less harmful, but 14.5% (Fernald) to 17.7% (Rocky Flats) indicated that they didn’t know.

3.2 Attitudes about Radiation Safety Standards

The next set of survey items elicited respondents’ attitudes about radiation safety standards. See Table 4. About 45-46% of the respondents thought that the safety standards for radiation exposure are generally “about right,” 33-37% thought the standards were too low. Ten to twelve percent said they didn’t know. Few respondents thought the safety standards were too high, 6.2% in Rocky Flats and 11.35 in Fernald.

Another question asked if standards for exposure to radiation should be based on how much radiation people receive from nature or on what science knows about the health effects of radiation. The majority of the respondents (68.9% for Rocky Flats and 74.2% for Fernald) said standards should be based on what science knows about health effects of radiation.

When asked about how standards for environmental cleanup of radiation should be established, most respondents (68.2% to 74.3%) thought standards should be based on what is possible with today’s technology. Only 17.0 to 22.3% thought standards should be based on what could be achieved without excessive costs.

Table 5. ***Different Approaches for Determining Level of Cleanup at Site: Comparison of Fernald and Rocky Flats***

The U.S. Department of Energy is currently doing environmental cleanup at the [Fernald/Rocky Flats] site. We would like your opinion about different approaches for determining the level of cleanup. I'm going to read you four different approaches and I'd like you to tell me which standard is the most important one for the cleanup to meet.

	Current regulatory standards	A standard agreed to by local residents	A standard set by science	A standard set by costs	Don't know/No answer
Most important approach					
<i>Fernald</i>	15.3	41.1	36.6	4.5	2.5
<i>Rocky Flats</i>	16.2	32.7	46.9	2.2	2.0
Second most important approach					
<i>Fernald</i>	28.3	30.3	32.1	9.0	0.3
<i>Rocky Flats</i>	29.5	29.5	31.6	8.4	1.0
Third most important approach					
<i>Fernald</i>	44.3	19.9	21.1	14.2	0.5
<i>Rocky Flats</i>	41.4	24.2	16.2	17.5	0.8

Note. Cell entries are percentages.

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Next, respondents were asked to rank four different approaches for determining the level of environmental cleanup at their site. The four approaches were: current regulatory standards, a standard agreed to by local residents, a standard set by science, or a standard set by costs. Table 5 displays the results. The majority of respondents in both samples indicated that either a standard agreed to by local residents or a standard set by science were the most important approaches to determining cleanup levels. For Fernald respondents, 41.1% reported that a standard agreed to by local residents was the most important approach followed by 36.6% saying a standard set by science was the most important. In Rocky Flats, 46.9% thought a standard set by science was the most important approach for determining the level of cleanup; 32.7% reported that a standard agreed to by local residents was the most important approach. A standard set by costs received very little support with less than five percent in either sample selecting that option. Only 15-16% said that current regulatory standards were the most important way to determine cleanup level.

Figure 3. Risks to you and people in your community: Comparison of Fernald and Rocky Flats. Source: Fernald and Rocky Flats Radiation Surveys (2001). Sorted by Fernald risk score.

3.3 Perception of Risk

In one segment of the survey, respondents were asked to indicate the degree of risk to public health in their community associated with 16 sources of radiation. Figure 3 shows the 16 items and the mean risk responses by sample; Table 6 displays the percentage distributions for each item. The five items perceived as posing the highest risk for the public were: nuclear waste, fallout from nuclear weapons testing, radiation from nuclear weapons manufacturing, nuclear power plants, and sun tanning. Over seventy percent of both samples rated these five sources as moderate or high risk. Radioactive waste from uranium mines, radiation from medical waste, and radioactive materials used in research were also considered as moderate or high risk by over sixty percent of the respondents. The sources seen as least risky were microwave ovens, food irradiation, cell phones, and natural background radiation.

Respondents seem less sure of the risk associated with natural sources of radiation. Natural background radiation, cosmic radiation, and radon received over 10% “don’t know” responses from both samples. In addition, Rocky Flats respondents gave over 10% “don’t know” responses to radioactive waste from uranium mines and food irradiation.

Perceptions of risk were similar in both sites. As previous research has found (Flynn, et al., 1994) women had higher risk perceptions than men. This held true in both samples. In Fernald, women provided higher risk assessments for 14 of the 16 items. They were significantly higher on seven of the items. Men had significantly higher risk perceptions for only one item, medical x-rays. In Rocky Flats, women had higher risk perceptions on all items and were significantly higher on 14 of the items. The only items for which they were not significantly higher were medical x-rays and cell phones.

3.4 Familiarity with Site and Events

The next segment of the interviews asked questions about familiarity with the site and impressions with specific events that had occurred there in the past. Over 80% of the respondents in both samples were at least slightly familiar with the site and over half (50.9% in Fernald and 55.6% in Rocky Flats) reported they were somewhat or very familiar with the site (see Table 7). Most respondents indicated that they had heard or read about the site in the media. This was particular true in Rocky Flats with 91% reporting that they had heard or read something

Table 6. *Risks to you and people in your community: Distributions by Sample*

Item		High risk	Moderate risk	Slight risk	Almost no risk	Don't know/No answer
31. Nuclear waste	<i>Fernald</i>	61.7	21.3	8.8	5.0	3.3
	<i>Rocky Flats</i>	61.1	18.2	13.2	4.7	2.7
33. Fallout from nuclear weapons testing	<i>Fernald</i>	56.1	19.6	13.0	7.8	3.5
	<i>Rocky Flats</i>	53.4	22.0	12.5	7.5	4.7
32. Radiation from nuclear weapons manufacturing	<i>Fernald</i>	49.9	23.3	14.0	7.8	5.0
	<i>Rocky Flats</i>	48.4	24.9	15.2	6.5	5.0
30. Nuclear power plants	<i>Fernald</i>	47.4	24.6	16.3	9.0	2.8
	<i>Rocky Flats</i>	46.6	23.7	16.5	9.2	4.0
26. Suntanning	<i>Fernald</i>	46.6	33.3	15.3	3.8	1.0
	<i>Rocky Flats</i>	50.9	34.2	9.5	3.5	2.0
34. Radioactive waste from uranium mines	<i>Fernald</i>	41.6	25.1	14.5	9.8	9.0
	<i>Rocky Flats</i>	39.4	29.2	14.0	5.0	12.5
29. Radiation from medical waste	<i>Fernald</i>	38.4	28.1	21.8	7.0	4.8
	<i>Rocky Flats</i>	37.2	26.2	20.5	9.2	7.0
28. Radioactive materials used in research	<i>Fernald</i>	34.8	28.8	23.6	7.0	5.8
	<i>Rocky Flats</i>	34.9	28.9	21.5	9.2	5.5
24. Radon	<i>Fernald</i>	17.5	29.3	28.8	11.8	12.5
	<i>Rocky Flats</i>	16.5	33.7	23.9	11.5	14.5
35. Electromagnetic fields	<i>Fernald</i>	16.8	36.3	32.3	9.0	5.5
	<i>Rocky Flats</i>	15.7	37.7	27.7	13.0	6.0
27. Medical X-rays	<i>Fernald</i>	12.8	36.8	37.1	11.5	1.8
	<i>Rocky Flats</i>	12.2	38.7	33.4	13.2	2.5
25. Cosmic rays	<i>Fernald</i>	11.5	25.8	30.3	18.3	14.0
	<i>Rocky Flats</i>	11.5	25.4	28.7	18.5	16.0
23. Natural background radiation	<i>Fernald</i>	9.5	24.6	35.3	16.0	14.5
	<i>Rocky Flats</i>	5.5	24.9	30.7	18.5	20.5
37. Cell phones	<i>Fernald</i>	7.5	23.1	43.9	20.6	5.0
	<i>Rocky Flats</i>	7.7	24.7	36.9	23.4	7.2
38. Food irradiation	<i>Fernald</i>	6.3	24.1	37.6	23.1	9.0
	<i>Rocky Flats</i>	11.7	19.0	29.2	27.9	12.2
36. Microwave ovens	<i>Fernald</i>	3.3	23.6	44.4	27.8	1.0
	<i>Rocky Flats</i>	3.5	21.7	44.4	27.7	2.7

Source: Fernald and Rocky Flats Surveys (2001).

Table 7. **Familiarity with Site: Comparison of Fernald and Rocky Flats**

	Not familiar	Slightly familiar	Somewhat familiar	Very familiar	Don't know/No answer
39. How familiar are you with [Fernald/Rocky Flats]?					
<i>Fernald</i>	17.5	31.6	34.1	16.8	0.0
<i>Rocky Flats</i>	15.2	28.9	38.7	17.0	0.3
			Yes	No	Don't know/ No answer
40. Have you ever heard or read anything about [Fernald/Rocky Flats] in the media?					
<i>Fernald</i>			82.0	18.1	0.0
<i>Rocky Flats</i>			91.0	8.5	0.5
41. Have you ever visited the [Fernald/Rocky Flats] site?					
<i>Fernald</i>			20.8	79.2	0.0
<i>Rocky Flats</i>			20.0	79.8	0.3
	Very negative	Negative	Neutral (if volunteered)	Very positive	Don't know/No answer
42. When you think about the [Fernald/Rocky Flats] site, is your personal impression generally....					
<i>Fernald</i>	14.5	47.1	13.8	18.1	3.5
<i>Rocky Flats</i>	11.0	44.4	16.7	24.7	1.8
43. When you think about how people in your community view the site, is it generally...					
<i>Fernald</i>	19.6	52.1	7.0	9.5	1.8
<i>Rocky Flats</i>	13.2	57.1	7.7	12.2	0.8

Note. Cell entries are percentages.

Table 8. **Recall of Specific Events at Fernald**

Now I am going to describe some events that have occurred at the Fernald site, and I would like you to tell me if you recall them.

	Not at all	Vague recollection	Clear memory	Don't know/No answer	N
In 1989 a class action lawsuit by Fernald neighbors was settled for \$78 million, including a medical monitoring program.	22.6	39.1	38.4	0.0	399
In 1991 DOE officially ended production and the site was renamed the Fernald Environmental Management Project, or FEMP.	37.6	36.3	26.1	0.0	399
In 1997 the first waste materials were placed into an on-site disposal "cell." Contaminated soil and debris from the site that are below specific acceptance criteria are being placed into the disposal cell.	35.8	38.6	25.3	0.3	399

	TV/Radio	Newspapers	Word of mouth	Other	Don't know/No answer	N
How did you learn about event?						
1989 class action lawsuit	13.9	22.0	23.0	41.1	0.0	309
1991 ending of production and renaming site	22.9	33.3	14.9	28.9	0.0	249
1997 placement of waste into on-site disposal "cell"	23.5	30.2	14.1	30.6	1.6	255

	Very negative	Negative	Neutral (if volunteered)	Positive	Very positive	Don't know/No answer	N
How did this event affect your impression of the Fernald site?							
1989 class action lawsuit	23.3	48.5	14.2	10.7	2.3	1.0	309
1991 ending of production and renaming site	12.1	34.9	17.3	32.1	2.4	1.2	249
1997 placement of waste into on-site disposal "cell"	14.1	41.2	14.1	25.9	3.5	1.2	255

Note. Cell entries are percentages.

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compared to 82% in Fernald ($p < .0001$). Only 20-21% of the respondents in either sample had visited the sites.

Respondents were then asked for their personal impression of the site. Impressions of both sites tended to be negative with 61.7% of Rocky Flats respondents reporting negative or very negative impressions compared to 55.4% in Fernald. Only 22% (Rocky Flats) and (26%) Fernald of the respondents had positive or very positive impressions of the sites. Respondents were even more likely to think that other people in their community held negative views of the sites with 72% (Rocky Flats) and 70% (Fernald) saying they thought other people had negative or very negative impressions.

Next, respondents were asked about three events that had taken place at their site since 1989 and whether they recalled the event. Those that recalled the event were asked how they learned about it, and how the event affected their impression of the site. Tables 7 and 8 display the events and responses for Fernald and Rocky Flats, respectively.

Fernald. The three events for Fernald were:

- In 1989, a class action lawsuit by Fernald neighbors was settled for \$78 million, including a medical monitoring program.
- In 1991, DOE officially ended production and the site was renamed the Fernald Environmental Management Project, or FEMP.
- In 1997, the first waste materials were placed into an on-site disposal “cell.” Contaminated soil and debris from the site that are below specific acceptance criteria are being placed into the disposal cell.

The 1989 class action lawsuit was remembered by a majority of the respondents. Three-quarters (77.5%) had at least a vague recollection of this event with 38.4% having a clear memory. For the other two events, 62 percent remembered the event occurring in 1991 and 64 percent the event of 1997, with about one-quarter of these recollections being “a clear memory.” Forty-six percent of the Fernald respondents had some recollection of all three events. Only 12.8% had no recall of any of the events.

Table 9. **Recall of Specific Events at Rocky Flats**

Now I am going to describe some events that have occurred at the Rocky Flats, and I would like you to tell me if you recall them.

	Not at all	Vague recollection	Clear memory	Don't know/No answer	N
44. In 1989 the FBI raided the Rocky Flats plant to investigate alleged violations of environmental law.	41.2	44.4	14.21	0.3	401
47. In 1992, nuclear weapons production came to an end at Rocky Flats.	19.0	35.4	45.1	0.5	401
50. In 2000, there was a controversy over a proposal to use controlled burning to manage vegetation in the buffer zone that surrounds the Rocky Flats plant.	50.6	22.7	26.2	0.5	401

How did you learn about event?	TV/Radio	Newspapers	Word of mouth	Other	Don't know/No answer
1989 FBI raid (N = 235)	28.5	28.9	11.5	30.2	0.9
1992 ending of production (N = 323)	29.7	19.8	16.7	32.8	0.9
2000 controlled burning proposal (N = 196)	34.7	27.6	5.6	32.1	0.0

How did this event affect your impression of the Rocky Flats?	Very negative	Negative	Neutral (if volunteered)	Positive	Very positive	Don't know/No answer
1989 FBI raid (N = 235)	13.6	56.2	25.5	2.1	1.3	1.3
1992 ending of production (N = 323)	4.6	17.7	22.0	48.9	6.5	0.3
2000 controlled burning proposal (N = 196)	15.8	42.4	28.6	11.2	2.0	0.0

Note. Cell entries are percentages.

Community Surveys

Respondents learned about the events through multiple communication channels — TV and/or the radio, newspapers and word of mouth, as exemplified by the spread of responses and the answers categorized as “Other” (see Table 8).

In rating the three events, the 1989 class action lawsuit elicited the most negative response with 71.8% reporting that this event had a negative or very negative affect on their impression of the Fernald site. Over half (55.3%) said the 1997 placement of waste into an on-site disposal cell had a negative or very negative affect. Almost half (47%) said the 1991 end of production and renaming of the site to FEMP had a negative or very negative affect on them. One-third (34.5%) thought the end of production had a positive affect; 17.3% thought the event had neither a positive or negative effect on their impression of the site. Neutral responses were offered by 14% of the sample for the other two events.

Rocky Flats: The three events at Rocky Flats were:

- The 1989 FBI raid at the Rocky Flats plant to investigate alleged violations of environmental law.
- The announcement in 1992 that nuclear weapons production was ended at Rocky Flats.
- The controversy in 2000 over a proposal to use controlled burning to manage vegetation in the buffer zone that surrounds the Rocky Flats plant.

Most respondents (80.5%) remembered when the nuclear weapons production came to an end in 1992 with 45.1% reporting a clear memory of the event. (See Table 9). Nearly sixty percent (58.6%) of the Rocky Flats respondents recalled the 1989 FBI raid of the plant. The 2000 controversy over the proposal to use controlled burning was remembered by almost half of the respondents (48.9%). Almost one-third (31.2%) had some memory of all three events. Only 10.5% could not remember any of the events.

Respondents learned about the events from a variety of sources including TV and radio, newspapers or a combination of these sources. Few respondents reported hearing about the events by “word of mouth” only with 5.6% hearing about controlled burning by that means to 16.7% for the 1992 ending of production.

Table 10. **Community Descriptions: Comparison of Fernald and Rocky Flats**

Now I'd like to ask you some questions about your community in general. I'm going to read you a number of different ways to describe communities, and I would like you to tell me how well each one describes your community.

		Very poor	Poor	Good	Very good	Don't know/No answer
53. Bedroom community						
	<i>Fernald</i>	2.5	13.5	47.1	36.3	0.5
	<i>Rocky Flats</i>	2.7	9.7	45.9	40.4	1.3
54. Industrial community						
	<i>Fernald</i>	19.3	52.1	24.1	4.3	0.3
	<i>Rocky Flats</i>	26.9	57.6	11.7	2.0	1.8
55. Recreational community						
	<i>Fernald</i>	8.3	37.3	43.6	9.3	1.5
	<i>Rocky Flats</i>	3.7	17.7	57.4	21.0	0.3
56. Agricultural community						
	<i>Fernald</i>	7.5	30.8	39.9	20.8	1.0
	<i>Rocky Flats</i>	10.0	62.3	22.2	4.2	1.3
57. Retirement community						
	<i>Fernald</i>	10.8	44.4	34.3	9.5	1.0
	<i>Rocky Flats</i>	6.2	42.6	40.9	7.5	2.7
58. Working class community						
	<i>Fernald</i>	3.0	7.3	49.9	39.1	0.8
	<i>Rocky Flats</i>	1.3	6.2	57.4	34.7	0.5

Note. Cell entries are percentages.

The 1989 FBI raid produced the largest proportion of negative affect on those recalling the event with 69.8% reporting that the raid had negative or very negative affect on their impression of Rocky Flats. The 2000 controlled burning controversy left 58.2% of those who remember it with a negative or very negative impression. On the other hand, 22.3% of those who recalled the 1992 ending of production said it had a negative affect on them while over half viewed this as a positive event (55.4%). Some respondents indicated the event had neither a positive or negative affect on them. Such neutral responses ranged from 22.0% for the 1992 production end to 28.6% for the 2000 controversy over controlled burning.

3.5 Attitudes about the Community

The next section of the interview asked for respondent views about their community. Six different ways to describe communities were read and respondents were asked to rate how well each description applied to their community. They were asked if it was a very poor, poor, good or very good description of their community. See Table 10 for the results.

Respondents in both communities overwhelmingly thought of their community as “working class” with 92.1% of the Rocky Flats and 89.0% of the Fernald respondents reporting it was a good or very good description of their community. Most respondents also thought of their community as a bedroom community with 83.4% (Fernald) to 86.3% (in Rocky Flats) saying this was a good or very good description. Rocky Flats respondents also thought of their community as recreational with over three-quarters (78.4%) reporting this was a good or very good description of their community. Fernald respondents were less likely to rate community as recreational with 52.9% reporting this was a good or very good description ($p < .0001$). Fernald respondents were much more likely than Rocky Flats respondents to think of their community as agricultural with 60.7% of the Fernald reporting agricultural as a good or very good description compared to only 26.4% of the Rocky Flats respondents ($p < .0001$).

Rocky Flats was considered a retirement community by 48.4% of the respondents compared to 43.8% of the Fernald respondents. Neither community was thought of as industrial. Although the Fernald sample was more likely to consider their community industrial with 28.4% reported this as a good or very good description compared to only 13.7% of the Rocky Flats sample ($p < .0001$).

Table 11. **Attitudes about Community: Comparison of Fernald and Rocky Flats**

	Improving rapidly	Improving slowly	Stable	Declining slowly	Declining rapidly	Don't know/No answer
59. Do you see the economy of your community as improving...						
<i>Fernald</i>	19.1	24.8	25.8	19.1	10.3	1.0
<i>Rocky Flats</i>	17.0	19.2	42.6	17.0	3.2	1.0
		Not at all concerned	Slightly concerned	Concerned	Very concerned	Don't know/No answer
60. Thinking about the community as a whole, how would you characterize it in terms of its concern about environmental problems?						
<i>Fernald</i>		6.3	30.1	43.6	17.3	2.8
<i>Rocky Flats</i>		4.7	23.7	46.6	21.2	3.7
	Much better	A little better	The same	A little worse	Much worse	Don't know/No answer
61. After cleanup and closure of the site, will the economic future of your community be....						
<i>Fernald</i>	15.0	25.6	47.4	5.0	1.3	3.8
<i>Rocky Flats</i>	11.2	20.0	55.9	7.7	0.8	4.5
	Strongly favor	Favor	(Volunteered) neutral	Oppose	Strongly oppose	Don't know/No answer
62. In general, do you strongly favor, favor, oppose or strongly oppose new development in your community?						
<i>Fernald</i>	24.1	52.4	3.8	16.3	2.8	0.8
<i>Rocky Flats</i>	8.7	41.9	8.0	30.7	9.5	1.3

Note. Cell entries are percentages.

Community Surveys

When asked about the economy of their community, responses were mixed. In Fernald, 43.9% thought the economy was improving, 29.4% thought it was declining, and one-quarter thought the economy was stable. In Rocky Flats, respondents were less likely to see their economy as improving (36.2%) and more likely say it was stable (42.6%). One-fifth thought the economy was declining (see Table 11).

When asked about the economic future of their community after cleanup and closure of the site, approximately half (47.4% in Fernald and 55.9% in Rocky Flats) thought the economy would be the same after cleanup and closure of the site. Fernald respondents were somewhat more optimistic with 42.6% indicating that the economy would be better compared to 31.2% in Rocky Flats. Fernald respondents were more likely to be pro-development than Rocky Flats with 76.4% favoring development compared to only 50.6% of the Rocky Flats sample.

Another question asked respondents how they would characterize the community in terms of its overall concern about environmental problems. Most believed their community to be concerned about environmental problems with 67.8% of the Rocky Flats sample and 60.9% of Fernald reporting the community to be concerned or very concerned about environmental problems.

Table 12. **Site's Influence on the Community:
Comparison of Fernald and Rocky Flats**

Now I'd like to ask you some questions about [Fernald/Rocky Flats] and your community.

	Not influenced	Slightly influenced	Somewhat influenced	Strongly influenced	Don't know/No answer
63. In general, how much do you think [Fernald/Rocky Flats] influences how you and your neighbors view your community?					
<i>Fernald</i>	41.6	30.8	15.5	8.3	3.8
<i>Rocky Flats</i>	45.6	29.2	16.7	6.5	2.0
64. When you think about people from outside your community, how strongly is their impression of your community influenced by [Fernald/Rocky Flats]?					
<i>Fernald</i>	29.1	26.6	22.8	15.3	6.3
<i>Rocky Flats</i>	32.4	28.2	20.7	10.0	8.7
	With	Without	(Volunteered) About the Same		Don't know/No answer
65. Overall, do you feel that your community is better off with, or better off without [Fernald/Rocky Flats]?					
<i>Fernald</i>	13.5	73.2	9.5		3.8
<i>Rocky Flats</i>	12.0	68.8	15.5		3.7

Note. Cell entries are percentages.

Community Surveys

The next set of questions addressed the site's influence on the community. The first question asked was: "In general, how much do you think [Fernald/Rocky Flats] influences how you and your neighbors view your community." While over half of both samples thought the site had at least a slight influence, neither set of respondents thought the site strongly influenced their personal or neighbors' view of the community (see Table 12). Respondents were more likely to think the site did not influence their own or their neighbors view of the community with 41.6% of Fernald and 45.6% of the Rocky Flats samples giving this response.

Respondents were more likely to think people outside the community were influenced by the site. In Fernald, 64.7% thought people outside the community were at least slightly influenced by the site; this percentage was 58.9% in Rocky Flats. Overall, respondents thought their community was better off *without* the site; 73.2% of Fernald and 68.8% of Rocky Flats respondents reported this opinion.

3.6 Proposals for Future Use of Site

In each community, a number of different proposals have been suggested for redeveloping and future use of the sites. Three proposals that had been widely discussed in each community for future use of the sites were selected for this survey. Respondents in each sample were presented with each proposal and asked if this use would be very positive, positive, neutral, negative, or very negative for their community.

Table 13. **Attitudes about Proposals for Future Use of Site:
Comparison of Fernald and Rocky Flats**

	Very positive	Positive	Neutral	Negative	Very negative	Don't know/No answer
<i>Fernald</i>						
66. A museum about the Cold War and Fernald's role in the production of nuclear weapons	10.0	41.6	26.8	16.0	3.5	2.0
67. A place for the reburial of remains of Native Americans.	4.5	23.3	29.8	22.1	16.8	3.5
68. A park, with nature walks and bike trails in areas restored with native vegetation.	17.6	36.3	14.8	17.3	12.5	1.5
<i>Rocky Flats</i>						
66. Clean site up so it can become a National Wildlife Refuge that would be fenced but with public access	34.4	41.2	12.7	6.2	4.2	1.3
67. Residential housing (after appropriate cleanup)	1.3	15.0	19.0	33.2	26.7	5.0
68. Clean site up so, in addition to becoming a fenced nature preserve, appropriate areas along the outside edge of the site will be open to industrial and highway development	4.0	30.9	22.4	26.4	15.2	1.0

Note. Cell entries are percentages.

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Fernald. The three proposals for future use of the Fernald site were:

- A museum about the Cold War and Fernald's role in the production of nuclear weapons;
- A place for the reburial or remains of Native Americans; and
- A park, with nature walks and bike trails in areas restored with native vegetation.

None of these proposals gained an overwhelming positive response. The museum and park proposals were viewed as most positive. A park with nature walks was considered a positive or very positive use of the site by 53.9% of the respondents; 29.8% thought this was a negative use of the Fernald site, and 14.8% were neutral. The museum proposal was viewed as positive or very positive by 51.6% of the Fernald sample. One-quarter of the sample (26.8%) held neutral feeling on this proposal; and 19.5% considered it a negative or very negative use of the site. A place for the reburial of Native American remains elicited the least positive response for future use of this land. Only 27.8% gave this proposal a positive or very positive rating; 38.9% considered it a negative use of this site and 29.8% were neutral (see Table 13).

Rocky Flats. The three proposals for the future of the Rocky Flats site were:

- A National Wildlife Refuge that would be fenced but with public access;
- Residential housing; and
- In addition to establishing the fenced nature preserve, appropriate areas along the outside edge of the site will be open to industrial and highway development.

The proposal calling for a National Wildlife Refuge received the most positive response by far. Three-quarters of the sample (75.6%) considered this a positive or very positive use of the site with one-third (34.4%) reporting it was a very positive use. The proposal to open the areas along the outside edge of the site to industrial and highway development (in addition to the fenced nature preserve) was viewed positively by only 34.9% of the sample; 41.6% viewed this as a negative or very negative use of the site. The proposal to reuse the site for residential housing was considered a negative or very negative use of the site by 59.9% of the respondents. Only 16.3 of the respondents thought residential housing was a positive use of this site; 19.0% were neutral.

Table 14. **Level of Concern about Site: Comparison of Fernald and Rocky Flats**

	Much more concerned about radiation	Somewhat more concerned about radiation	About the same	Somewhat more concerned about other contaminants	Much more concerned about other contaminants	Don't know/No answer
<hr/>						
69. How concerned are you about radiation at [Fernald/Rocky Flats] compared to other environmental concerns in your community.						
<i>Fernald</i>	15.5	20.8	30.3	19.1	13.5	0.8
<i>Rocky Flats</i>	14.2	20.5	37.4	16.7	10.2	1.0
			No effect	Slight effect	Moderate effect	Large effect
<hr/>						
70. If a small amount of radiation was present at [Fernald/Rocky Flats], how much do you think this would affect the future of your community?						
<i>Fernald</i>	13.0	36.8	29.6	17.3	3.3	
<i>Rocky Flats</i>	13.2	35.2	30.4	18.5	2.7	
			Yes	No	Don't know/No answer	
<hr/>						
71. In the normal course of conversations you might have at home, does [Fernald/Rocky Flats] ever come up?						
<i>Fernald</i>	34.8	65.2	0.0			
<i>Rocky Flats</i>	39.9	59.6	0.5			
	Very concerned	Slightly concerned	Not at all concerned	Don't know/No answer		
<hr/>						
72. How concerned are you and your family about [Fernald/Rocky Flats]?						
<i>Fernald</i>	36.0	52.5	10.8	0.7		
<i>Rocky Flats</i>	28.1	56.9	15.0	0.0		
			Yes	No	Don't know/No answer	
<hr/>						
73. Is it likely a discussion of [Fernald/Rocky Flats] would come up at any other social or community group you might be part of?						
<i>Fernald</i>	44.6	55.1	0.3			
<i>Rocky Flats</i>	49.6	49.9	0.5			

Note. Cell entries are percentages.

3.7 Level of Concern About the Site

Respondents were asked a series of questions about the level of environmental concern about the site. First, they were asked how concerned they were about radiation at Fernald or Rocky Flats compared to other environmental concerns (such as water or air pollution) in their respective community. They were asked if they were more concerned about radiation, or more concerned about other contaminants or about the same. Responses were divided. In Fernald, 36.3% were somewhat or much more concerned about radiation and 32.6% were somewhat or much more concerned about other contaminants. Thirty percent reported their level of concern was about the same for both. Responses were similar in Rocky Flats. About one-third (34.7%) expressed more concern about radiation than other types of environmental issues and 26.9% reported more concern for other contaminants. Thirty-seven percent expressed the same level of concern for both. See Table 14.

Another question asked respondents, if a small amount of radiation was present at the site, how much do you think this would affect the future of your community? Most of the respondents in both samples thought it would have some effect. Only 13% thought it would have no effect. Almost half (46.9% in Fernald and 48.9% in Rocky Flats) reported that it would have a moderate or large effect on the future of their community.

When asked about normal home conversations, 40% of the Rocky Flats sample said that the topic of Rocky Flats came up and 34.8% of the Fernald sample said Fernald came up. Discussions of Fernald and Rocky Flats are more likely at other social and community gatherings outside the home. Nearly half the Rocky Flats sample (49.6%) said the topic comes up outside the home; the percentage was 44.6% for the Fernald sample.

When asked how concerned the respondent and their family were about the site, most people (85-88%) said they were slightly or very concerned. See Table 14. Thirty-six percent of the Fernald and 28.1% of the Rocky Flats sample said they were *very* concerned about the site. Only 10.8% of Fernald and 15.0% of Rocky Flats sample said they were not at all concerned.

Table 15. *Distribution of Open-Ended Responses by Category: Comparison of Fernald and Rocky Flats*

Category	Fernald		Rocky Flats	
	f	%	f	%
2. Health/Safety concerns	24	23.5	11	11.1
6. General negative comments regarding site/mistrust of site	10	9.8	8	8.1
1. Concerns about hidden information	10	9.8	3	3.0
3. Legal concerns	4	3.9	0	0.0
4. Clean-up: Negative feelings	2	2.0	4	4.0
12. Negative feelings regarding wildlife refuge			11	11.1
11. Negative feelings regarding residential housing			9	9.1
5. Clean-up: Positive feelings	5	4.9	7	7.1
7. General positive comments toward site	2	2.0	2	2.0
8. Appreciative of survey being done	8	7.8	6	6.1
9. Relative/friend works or worked at site	4	3.9	0	0.0
10. Other miscellaneous comments	33	32.4	38	38.4
Total number of comments^a	102	100.0	99	100.0

^aFernald: 90 respondents made comments. Eleven respondents had more than one comment. Rocky Flats: 91 respondents made comments. Eight respondents had more than one comment.

3.8 Open-Ended Responses

At the close of the interview, respondents were given the opportunity to make comments, which were recorded, and content analyzed, resulting in 10 categories for Fernald and 12 categories for Rocky Flats, and content analyzed. Table 15 displays the results. Twenty-three percent of the respondents in each sample made comments. Nearly half of the comments were negative in nature (49.0% in Fernald and 46.4% in Rocky Flats). Negative comments included health and safety concerns, mistrust of what has happened at the site, concern that information about problems is hidden from the public, legal concerns, and so on. About one-quarter of the comments by Fernald respondents mentioned health and safety concerns about the site; 11.1% of the Rocky Flats comments fell in this category. Eight to ten percent of the comments (in Rocky Flats and Fernald, respectively) were general negative comments regarding the site and mistrust of the site. Comments included:

- “it [Fernald] has been a thorn in our side forever”
- “I will be glad when they do get rid of it”
- “I still feel distrust that whoever is in charge is dishonest and the public is not being told everything”
- “Fernald has laid a major scar on the area; people from outside who have moved in are very negative about it. Hope that the best is being done for the environment.”

Few comments were positive in nature, only 6.9% in Fernald and 9.1% in Rocky Flats. Examples of some of the positive comments were:

- I’m glad they’re cleaning it [Fernald] up and I hope they do a quality job of cleaning it up because if you are going to make it a park, it’s important for it to be clean.”
- I’m overall pleased with the way the cleanup has been as long as they don’t leave any radium at the site [Fernald].”
- “We needed the bombs, so I’m glad we had them made. Somebody had to do it. I am strongly in favor of atomic weapons.” [Rocky Flats respondent]

As shown in Table 15, about one-third of the comments (32.5 in Fernald and 38.4% in Rocky Flats) were miscellaneous in nature — neither positive nor negative.

4. Summary

Overall, respondents hold favorable views of science. They indicate an interest in developments in science and technology, feel that the world is better off because of science, and that science makes our lives healthier, easier, and more comfortable. However, respondents are divided on whether science should decide what is safe or not safe for themselves and their families. They were more confident on the specific issue of whether science can determine if *radiation exposure* is safe or unsafe for them and their families. When it comes to questions about radiation (whether most radioactivity is human-made or if radiation from natural environment is less harmful than human-made), responses are more divided and 12 to 18 percent said they did not know the answer.

The majority of the respondents think that standards for exposure to radiation should be based on what science knows about health effects of radiation and on what is possible with today's technology. Few people (6-11%) think safety standards for radiation are too high, most think they are about right (45-46%) or too low (33 -37%).

Although few respondents had visited the sites, most had heard or read something about Fernald or Rocky Flats in the media. Impressions of the sites tend to be negative. Few respondents report positive impressions of the site. Respondents were even more likely to believe other people in their community held negative views of the site than the survey results show for this sample.

In Fernald, a strong majority of the respondents (62-78%) remember the three events listed. The 1989 class action suit, in particular, is recalled by 77.5% of the respondents (77.5%). The class action suit had a negative affect on their impression of the Fernald site.

In Rocky Flats, the end of nuclear weapons production in 1992 is remembered by a majority of the respondents. This event tends to have a positive affect on respondents unlike the other two events that were considered more negative by the respondents who remembered them.

Responses are mixed on proposals for future use of the site. Developing Rocky Flats as a National Wildlife Refuge is the one proposal that was clearly viewed as positive by respondents with three-quarters indicating this is a positive or very positive future use of the site.

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Most respondents feel that overall their community would be better off without the site. However, when asked about the economic future of their community after cleanup and closure of the site, only 31 to 43 percent thought that it will be better, 47 to 56 percent thought their local economy will be about the same.

Even a small amount of radiation left at the site is felt to have some effect of the future of their community. Most respondents indicated they and their families have some concern about the site.

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Low Dose, Risk, Decisions, & Risk Communication

Community Surveys

Appendix A

Survey Instrument: Fernald, Ohio

RAD1IN1

Hello, this is _____. I am calling on behalf of Decision Research, a non-profit research institute. I would like ask any adult (18 years or older) in your household some questions about your community and radiation. The results are designed to help shape public policies on radiation. I want to assure you that I am not selling anything and that this survey is completely anonymous and voluntary. It will take about 15 minutes. Do you have any questions before we begin?

PRESS 1

RAD1003

First I would like to ask some questions about science. How interested are you in new developments in science and technology, not interested, slightly interested, somewhat interested, or very interested?"

- 1 NOT INTERESTED
- 2 SLIGHTLY
- 3 SOMEWHAT
- 4 VERY INTERESTED

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1004

All things considered, would you say that the world is better off or worse off because of science?

- 1 BETTER
- 2 WORSE
- 3 (IF VOLUNTEERED - NEUTRAL)
- 4 (IF VOLUNTEERED - NEITHER)
- 5 (IF VOLUNTEERED - BOTH)

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

Community Surveys Appendix A: Survey Instrument, Fernald, Ohio

RAD1005

Now I will read a few statements. For each one, please tell me if you strongly agree, agree, disagree, or strongly disagree. "Science is making our lives healthier, easier and more comfortable."

- 1 STRONGLY AGREE
- 2 AGREE
- 3 DISAGREE
- 4 STRONGLY DISAGREE

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1006

"Most scientists want to work on things that will make life better for the average person." Do you strongly agree, agree, disagree, or strongly disagree with that statement?

- 1 STRONGLY AGREE
- 2 AGREE
- 3 DISAGREE
- 4 STRONGLY DISAGREE

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1007

"Science can decide what is safe or not safe for you and your family." (Do you strongly agree, agree, disagree, or strongly disagree with that statement?)

- 1 STRONGLY AGREE
- 2 AGREE
- 3 DISAGREE
- 4 STRONGLY DISAGREE

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1008

"Most radioactivity is human-made." (Do you strongly agree, agree, disagree, or strongly disagree with that statement?)

- 1 STRONGLY AGREE
- 2 AGREE
- 3 DISAGREE
- 4 STRONGLY DISAGREE

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

Community Surveys Appendix A: Survey Instrument, Fernald, Ohio

RAD1009

"Radiation from the natural environment is less harmful than human-made radiation." (Do you strongly agree, agree, disagree, or strongly disagree with that statement?)

- 1 STRONGLY AGREE
- 2 AGREE
- 3 DISAGREE
- 4 STRONGLY DISAGREE

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1010

(How strongly do you agree or disagree with this statement) "Science can decide whether radiation exposure is safe or unsafe for you and your family." (Do you strongly agree, agree, disagree, or strongly disagree?)

- 1 STRONGLY AGREE
- 2 AGREE
- 3 DISAGREE
- 4 STRONGLY DISAGREE

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1011

Now I would like to ask about your opinions on radiation. Do you think the safety standards for radiation exposure are generally too high, too low, or about right?

- 1 TOO HIGH
- 2 ABOUT RIGHT
- 3 TOO LOW

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1012

If you were in charge of setting the standards for exposure to radiation, would you base the standard on how much radiation people receive from nature or what science knows about the health effects of radiation?

- 1 HOW MUCH RADIATION PEOPLE RECEIVE FROM NATURE
- 2 WHAT SCIENCE KNOWS ABOUT THE HEALTH EFFECTS OF RADIATION
- 3 (IF VOLUNTEERED: BOTH)

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

Community Surveys Appendix A: Survey Instrument, Fernald, Ohio

RAD1013

Would you set the standards for environmental cleanup of radiation sites based on what is possible with today's technology, or what can be achieved without excessive or unreasonable costs

- 1 WHAT IS POSSIBLE WITH TODAY'S TECHNOLOGY
- 2 WHAT CAN BE ACHIEVED WITHOUT EXCESSIVE COSTS
- 3 (IF VOLUNTEERED: BOTH)
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1014

The US Department of Energy is currently doing environmental cleanup at the Fernald site. We would like your opinion about different approaches for determining the level of cleanup. I'm going to read you four different approaches and I'd like you to tell me which standard is the most important one for the cleanup to meet.

PROBE FROM LIST

- 1 CURRENT REGULATORY STANDARDS
- 2 A STANDARD AGREED TO BY LOCAL RESIDENTS
- 3 A STANDARD SET BY SCIENCE
- 4 A STANDARD DETERMINED BY COSTS
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1015

What is the second most important?

(PROGRAMMED TO SHOW REMAINING CHOICES)

- 1 CURRENT REGULATORY STANDARDS
- 2 A STANDARD AGREED TO BY LOCAL RESIDENTS
- 3 A STANDARD SET BY SCIENCE
- 4 A STANDARD DETERMINED BY COSTS
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1016

What is the third most important approach?

(PROGRAMMED TO SHOW REMAINING CHOICES)

- 1 CURRENT REGULATORY STANDARDS
- 2 A STANDARD AGREED TO BY LOCAL RESIDENTS
- 3 A STANDARD SET BY SCIENCE
- 4 A STANDARD DETERMINED BY COSTS
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

Community Surveys Appendix A: Survey Instrument, Fernald, Ohio

RAD1018

Your top three ranked choices were CHOICE 1, CHOICE 2, and CHOICE 3. Now I would like you to rate each of the approaches in terms of how important it is. Imagine you have 100 dollars to divide between the three approaches. Out of 100 dollars, how much would you give to SHOW FIRST RANKED ITEM HERE?

ENTER EXACT NUMBER

- 997 REFUSED
- 998 DON'T KNOW
- 999 NO ANSWER

RAD1019

You have (100 - RAD018 ANS) dollars remaining. How much would you give to SHOW SECOND RANKED ITEM HERE?

ENTER EXACT NUMBER

- 9 97 REFUSED
- 998 DON'T KNOW
- 999 NO ANSWER

RAD1020

You have (100 - (RAD1018 ANS + RAD1019 ANS)) dollars remaining for the third ranked item. Are you satisfied with that?

- 1 YES (SKIPTO RAD1023)
- 2 NO

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1022

Since you are not satisfied with your ratings I will ask you to rate each item again

PRESS 1 --->SKIP BACK TO RAD1018

RAD1023

Now I am going to ask your opinion about risks to public health in your community For each item please tell me if you think there is almost no health risk, a slight health risk, a moderate health risk, or a high health risk to you and people in your community. How much of a health risk is natural background radiation? (Almost no risk, slight risk, moderate risk, or high risk?)

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW

Community Surveys Appendix A: Survey Instrument, Fernald, Ohio

9 NO ANSWER

RAD1024

What about radon? Is radon almost no risk to public health, a slight risk, moderate risk, or high risk?

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1025

What about cosmic rays? (How much health risk do they pose for the public?)

NOTE: COSMIC RAYS ARE NATURAL RADIATION FROM OUTER SPACE

PROBE FROM LIST

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1026

(What about) sun tanning? (How much risk does sun tanning pose to the public?)

PROBE FROM LIST

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1027

(What about) medical x-rays? (How much health risk do they pose for the public?)

PROBE FROM LIST

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

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- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1028

(What about) radioactive materials used in research? (How much health risk do they pose for the public?)

PROBE FROM LIST

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1029

(What about) radiation from medical waste? (How much health risk do they pose for the public?)

PROBE FROM LIST

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1030

(What about) nuclear power plants? (How much health risk do they pose for the public?)

PROBE FROM LIST

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1031

(What about) nuclear waste? (How much health risk does it pose for the public?)

PROBE FROM LIST

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- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1032

(What about) radiation from nuclear weapons manufacturing? (How much health risk does that pose for the public?)

PROBE FROM LIST

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1033

(What about) fallout from nuclear weapons testing? (How much health risk does that pose for the public?)

PROBE FROM LIST

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1034

(What about) radioactive waste from uranium mines? (How much health risk does that pose for the public?)

PROBE FROM LIST

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

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RAD1035

(What about) electromagnetic fields such as energy fields from power lines?
(How much health risk do they pose for the public?)

PROBE FROM LIST

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1036

(What about) microwave ovens? (How much health risk do they pose for the public?)

PROBE FROM LIST

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1037

(What about) cell phones? (How much health risk do they pose for the public?)

PROBE FROM LIST

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1038

(What about) food irradiation? (How much health risk does that pose for the public?)

PROBE FROM LIST

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED

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- 8 DON'T KNOW
- 9 NO ANSWER

RAD1039

Now I'd like to talk with you about the Fernald site. How familiar are you with Fernald?

PROBE FROM LIST

- 1 NOT FAMILIAR
- 2 SLIGHTLY FAMILIAR
- 3 SOMEWHAT FAMILIAR
- 4 VERY FAMILIAR

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1040

Have you ever heard or read anything about Fernald in the media?

- 1 YES
- 2 NO

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1041

Have you ever visited the Fernald site?

- 1 YES
- 2 NO

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1042

When you think about the Fernald site, is your personal impression generally very negative, negative, positive, or very positive?

- 1 VERY NEGATIVE
- 2 NEGATIVE
- 3 (IF VOLUNTEERED) NEUTRAL
- 4 POSITIVE
- 5 VERY POSITIVE

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1043

When you think about how people in your community view the site, is it generally very negative, negative, positive, or very positive?

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- 1 VERY NEGATIVE
- 2 NEGATIVE
- 3 (IF VOLUNTEERED) NEUTRAL
- 4 POSITIVE
- 5 VERY POSITIVE
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1044

Now I am going to describe some events that have occurred at the Fernald site, and I would like you to tell me if you recall them. First, in 1989 a class action lawsuit by Fernald neighbors was settled for \$78 million, including a medical monitoring program. How well do you recall this event?

PROBE FROM LIST

- 1 NOT AT ALL _(SKIPTO RAD1047
- 2 VAGUE RECOLLECTION
- 3 CLEAR MEMORY
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1045

How did you learn about this?

PROBE FROM LIST

CHOOSE ALL THAT APPLY

IF MORE THAN ONE, SELECT 4, ENTER EACH SELECTION, SEPARATED BY COMMA

- 1 TELEVISION / RADIO
- 2 NEWSPAPERS
- 3 WORD OF MOUTH
- 4 OTHER SPECIFY
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1045OTH

SPECIFY

RAD1046

How did this event affect your impression of the Fernald site? Did the event have a very negative, negative, positive, or very positive effect?

- 1 VERY NEGATIVE
- 2 NEGATIVE
- 3 (IF VOLUNTEERED) NEUTRAL
- 4 POSITIVE
- 5 VERY POSITIVE

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- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1047

Next, in 1991 the Department of Energy (or DOE) officially ended production and the site was renamed the Fernald Environmental Management Project, or FEMP. How well do you recall this event?

PROBE FROM LIST

- 1 NOT AT ALL (SKIPTO RAD1050
- 2 VAGUE RECOLLECTION
- 3 CLEAR MEMORY

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1048

How did you learn about this?

PROBE FROM LIST

CHOOSE ALL THAT APPLY

IF MORE THAN ONE, SELECT 4, ENTER EACH SELECTION, SEPARATED BY COMMA

- 1 TELEVISION / RADIO
- 2 NEWSPAPERS
- 3 WORD OF MOUTH
- 4 OTHER SPECIFY

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1048OTH

SPECIFY

RAD1049

How did this event affect your impression of the Fernald site? Did the event have a very negative, negative, positive, or very positive effect?

- 1 VERY NEGATIVE
- 2 NEGATIVE
- 3 (IF VOLUNTEERED) NEUTRAL
- 4 POSITIVE
- 5 VERY POSITIVE

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

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RAD1050

Finally, in 1997 the first waste materials were placed into an on-site disposal "cell." Contaminated soil and debris from the site that are below specific acceptance criteria are being placed into the disposal cell. How well do you recall this event?

PROBE FROM LIST

- 1 NOT AT ALL (SKIPTO RAD1053
- 2 VAGUE RECOLLECTION
- 3 CLEAR MEMORY

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1051

How did you learn about this?

PROBE FROM LIST

CHOOSE ALL THAT APPLY

IF MORE THAN ONE, SELECT 4, ENTER EACH SELECTION, SEPARATED BY COMMA

- 1 TELEVISION / RADIO
- 2 NEWSPAPERS
- 3 WORD OF MOUTH
- 4 OTHER SPECIFY

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1051OTH

SPECIFY

RAD1052

How did this event affect your impression of the Fernald site? Did it have a very negative, negative, positive, or very positive effect?

- 1 VERY NEGATIVE
- 2 NEGATIVE
- 3 (IF VOLUNTEERED) NEUTRAL
- 4 POSITIVE
- 5 VERY POSITIVE

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1053

Now I'd like to ask you some questions about your community in general. I'm going to read you a number of different ways to describe communities, and I would like you to tell me how well each one describes your community. First, a bedroom community. Is this a very poor, poor, good or very good description of your community?

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NOTE: A BEDROOM COMMUNITY IS A COMMUNITY THAT IS PRIMARILY RESIDENTIAL

PROBE: How well does this describe your community?

- 1 VERY POOR
- 2 POOR
- 3 GOOD
- 4 VERY GOOD

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1054

Second, an industrial community. Is this a very poor, poor, good or very good description of your community?

- 1 VERY POOR
- 2 POOR
- 3 GOOD
- 4 VERY GOOD

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1055

Third, a recreational community. (Is this a very poor, poor, good or very good description of your community?)

- 1 VERY POOR
- 2 POOR
- 3 GOOD
- 4 VERY GOOD

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1056

An agricultural community. (Is this a very poor, poor, good or very good description of your community?)

- 1 VERY POOR
- 2 POOR
- 3 GOOD
- 4 VERY GOOD

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1057

A retirement community (how well does this describe your community?).

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PROBE AS NEEDED FROM LIST

- 1 VERY POOR
- 2 POOR
- 3 GOOD
- 4 VERY GOOD
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1058

A working class community (how well does this describe your community?)

PROBE FROM LIST

- 1 VERY POOR
- 2 POOR
- 3 GOOD
- 4 VERY GOOD
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1059

We are now more than half way through the survey and I want to thank you for your cooperation. Next, do you see the economy of your community as improving rapidly, improving slowly, stable, declining slowly or declining rapidly?

- 1 IMPROVING RAPIDLY
- 2 IMPROVING SLOWLY
- 3 STABLE
- 4 DECLINING SLOWLY
- 5 DECLINING RAPIDLY
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1060

Thinking about the community as a whole, how would you characterize it in terms of its concern about environmental problems? Is your community not at all concerned, slightly concerned, concerned, or very concerned (about the environment)?

- 1 NOT AT ALL CONCERNED
- 2 SLIGHTLY CONCERNED
- 3 CONCERNED
- 4 VERY CONCERNED
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

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RAD1061

After cleanup and closure of the Fernald site, will the economic future of your community be much better, a little better, the same, a little worse, or much worse?

- 1 MUCH BETTER
- 2 A LITTLE BETTER
- 3 THE SAME
- 4 A LITTLE WORSE
- 5 MUCH WORSE

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1062

In general, do you strongly favor, favor, oppose or strongly oppose new development in your community?

- 1 STRONGLY FAVOR
- 2 FAVOR
- 3 (IF VOLUNTEERED) NEUTRAL
- 4 OPPOSE
- 5 STRONGLY OPPOSE

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1063

Now I'd like to ask you some questions about the Fernald site and your community. In general, how much do you think Fernald influences how you and your neighbors view your community? Is your opinion of your community not influenced, slightly influenced, somewhat influenced, or strongly influenced by the Fernald site?

- 1 NOT INFLUENCED
- 2 SLIGHTLY INFLUENCED
- 3 SOMEWHAT INFLUENCED
- 4 STRONGLY INFLUENCED

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1064

When you think about people from outside your community, how strongly is their impression of your community influenced by the Fernald site? Is it not influenced, slightly influenced, somewhat influenced, or strongly influenced?

- 1 NOT INFLUENCED
- 2 SLIGHTLY INFLUENCED
- 3 SOMEWHAT INFLUENCED
- 4 STRONGLY INFLUENCED

- 7 REFUSED

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- 8 DON'T KNOW
- 9 NO ANSWER

RAD1065

Overall, do you feel that your community is better off with, or better off without the Fernald site?

- 1 WITH
- 2 WITHOUT
- 3 (IF VOLUNTEERED) ABOUT THE SAME
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1066

A proposal for the future use of the Fernald site is to house a museum about the Cold War and Fernald's role in the production of nuclear weapons. Would this use be very positive, positive, neutral, negative or very negative for your community?

- 1 VERY POSITIVE
- 2 POSITIVE
- 3 NEUTRAL
- 4 NEGATIVE
- 5 VERY NEGATIVE
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1067

Another proposal for the future use of the Fernald site is a place for the reburial of remains of Native Americans. Would this use be very positive, positive, neutral, negative or very negative for your community?

- 1 VERY POSITIVE
- 2 POSITIVE
- 3 NEUTRAL
- 4 NEGATIVE
- 5 VERY NEGATIVE
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1068

Another proposal for the future use of the Fernald site is a park, with nature walks and bike trails in areas restored with native vegetation. Would this use be very positive, positive, neutral, negative or very negative for your community?

- 1 VERY POSITIVE
- 2 POSITIVE
- 3 NEUTRAL
- 4 NEGATIVE

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- 5 VERY NEGATIVE
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1069

How concerned are you about radiation at the Fernald site compared to other environmental concerns in your community, (such as water or air pollution)?

PROBE: Which are you more concerned about, water and air pollution from other contaminants, or radiation from the site?

PROBE FROM LIST

- 1 MUCH MORE CONCERNED ABOUT RADIATION
- 2 SOMEWHAT MORE CONCERNED ABOUT RADIATION
- 3 ABOUT THE SAME
- 4 SOMEWHAT MORE CONCERNED ABOUT OTHER CONTAMINANTS
- 5 MUCH MORE CONCERNED ABOUT OTHER CONTAMINANTS
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1070

If a small amount of radiation was present at the Fernald site, how much do you think this would affect the future of your community? Would it have no effect, a slight effect, a moderate effect, or a large effect (on the future of your community)?

- 1 NO EFFECT
- 2 SLIGHT EFFECT
- 3 MODERATE EFFECT
- 4 LARGE EFFECT
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1071

Next, we would like to know something about how important the Fernald site is to you and other people in your community. In the normal course of conversations you might have at home, does Fernald ever come up?

PROBE: Do you ever discuss the site at home?

- 1 YES
- 2 NO (SKIPTO RAD1073)
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

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RAD1072

How concerned are you and your family about the Fernald site? Are you very concerned, slightly concerned, or not concerned at all?

- 1 VERY CONCERNED
- 2 SLIGHTLY CONCERNED
- 3 NOT AT ALL CONCERNED

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1073

Is it likely a discussion of Fernald would come up at any other social or community groups you might be part of?

- 1 YES
- 2 NO (SKIPTO RAD1AGE

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1074

Where would that be? (What are the other social or community groups you are a part of where Fernald might come up in conversation?)

OPEN ENDED

RAD1AGE

Thank you. We are almost done. Now I would like to ask you some questions about yourself. In what year were your born?

ENTER EXACT NUMBER

- 9996 BEFORE 1890
- 9997 REFUSED
- 9998 DON'T KNOW
- 9999 NO ANSWER

RAD1SEX

Are you male or female (sorry I have to ask everyone)?

- 1 MALE
- 2 FEMALE

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1ETH

What is your race or ethnic identity?

NOTE: R MAY CHOOSE AS MANY AS APPLY IF VOLUNTEERED

IF MORE THAN ONE, SELECT 4, ENTER EACH SELECTION, SEPARATED BY COMMA

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PROBE FROM LIST

- 1 WHITE
- 2 BLACK OR AFRICAN AMERICAN
- 3 ASIAN
- 4 NATIVE HAWAIIAN OR OTHER PACIFIC ISLANDER
- 5 AMERICAN INDIAN OR ALASKAN NATIVE
- 6 HISPANIC OR LATINO
- 7 OTHER (PLEASE SPECIFY) _____

- 97 REFUSED
- 98 DON'T KNOW
- 99 NO ANSWER

RAD1ETHOTH

(PLEASE SPECIFY)

RAD1EDU

What is the highest level of education you have completed?

- 1 Doctorate (PhD, EdD) or Professional (MD, JD, DDS)
- 2 Masters (MA, MS, MBA, Med)
- 3 Bachelors (BA, BS, AB)
- 4 Associates (AA, AS)
- 5 Some college, no degree
- 6 High School Diploma or GED
- 7 9th - 12th Grade, no diploma (SKIPTO RAD175b)
- 8 5th - 8th Grade (SKIPTO INCOME1)
- 9 4th Grade or less (SKIPTO INCOME1)

- 97 REFUSED
- 98 DON'T KNOW
- 99 NO ANSWER

RAD175a

Have you ever taken a science course at the college level?

- 1 YES
- 2 NO

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD175b

Have you ever taken a science course at the high school level?

- 1 YES
- 2 NO

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

Community Surveys Appendix A: Survey Instrument, Fernald, Ohio

INCOME1

Is your total annual household income, from all sources, before taxes, over or under \$35,000?

PROBE: Include money from jobs (wages, salary, tips, bonuses),

interest, dividends, child support, alimony, welfare, social security, disability and retirement payments, net income from a business, farm or rent, or any other money income received by members of your family. Do not include lump-sum payments, such as money from an inheritance or sale of a home.

- 1 OVER \$35,000 ---> SKIPTO INCOME4
- 2 UNDER \$35,000
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

INCOME2

Is it over or under \$25,000?

PROBE: Is your total annual household income, from all sources, before taxes, over or under \$25,000?

- 1 OVER \$25,000 -->SKIPTO RAD1076
- 2 UNDER \$25,000
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

INCOME3

Is it over or under \$15,000?

- 1 OVER \$15,000 ---> SKIPTO RAD1076
- 2 UNDER \$15,000 ---> SKIPTO RAD1076
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

INCOME4

Is it over or under \$50,000?

- 1 OVER \$50,000
- 2 UNDER \$50,000---> SKIPTO RAD1076
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

INCOME5

Is it over or under \$75,000

- 1 OVER \$75,000
- 2 UNDER \$75,000
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

Community Surveys Appendix A: Survey Instrument, Fernald, Ohio

RAD1076

What political party are you affiliated with?

PROBE FROM LIST

- 1 REPUBLICAN
- 2 DEMOCRAT
- 3 LIBERTARIAN
- 4 OTHER SPECIFY: _____
- 5 (IF VOLUNTEERED) NOT A REGISTERED VOTER

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1076OTH

SPECIFY

RAD1077

Do you or any of your family or household members work at the Fernald site, now or in the past?

- 1 YES
- 2 NO

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1COM

Thank you. That is the end of the survey. Do you have any comments you would like to add?

OPEN ENDED

RAD1END

On behalf of Decision Research I would like to thank you for your participation. Good bye.

ENTER YOUR COMMENTS RELEVANT TO THE SURVEY

RAD1IID

ONE MORE DONE!!

ENTER YOUR INTERVIEWER ID - ALL 3 DIGITS

THANKS!!

Low Dose, Risk, Decisions, & Risk Communication

Community Surveys

Appendix B

Survey Instrument: Rocky Flats, Colorado

RAD1IN1

Hello, this is _____. I am calling on behalf of Decision Research, a non-profit research institute. I would like ask any adult (18 years or older) in your household some questions about your community and radiation. The results are designed to help shape public policies on radiation and the future of Rocky Flats. I want to assure you that I am not selling anything and that this survey is completely anonymous and voluntary. It will take about 15 minutes. Do you have any questions before we begin?

PRESS 1

RAD1001

First I would like to ask whether you live in Westminster or Arvada?

- 1 Westminster
- 2 Arvada
- 3 Neither --> SKIPTO NOQAL

RAD1002

How many years have you lived in the Westminster/Arvada or the greater Denver area?

ENTER EXACT NUMBER

96 96 OR MORE YEARS

- 97 REFUSED
- 98 DON'T KNOW
- 99 NO ANSWER

RAD1003

Now I would like to ask some questions about science. How interested are you in new developments in science and technology, not interested, slightly interested, somewhat interested, or very interested?"

- 1 NOT INTERESTED
- 2 SLIGHTLY
- 3 SOMEWHAT
- 4 VERY INTERESTED

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

Community Surveys Appendix B: Survey Instrument, Rocky Flats, Colorado

RAD1004

All things considered, would you say that the world is better off or worse off because of science?

- 1 BETTER
- 2 WORSE
- 3 (IF VOLUNTEERED - NEUTRAL)
- 4 (IF VOLUNTEERED - NEITHER)
- 5 (IF VOLUNTEERED - BOTH)

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1005

Now I will read a few statements. For each one, please tell me if you strongly agree, agree, disagree, or strongly disagree. "Science is making our lives healthier, easier and more comfortable."

- 1 STRONGLY AGREE
- 2 AGREE
- 3 DISAGREE
- 4 STRONGLY DISAGREE

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1006

"Most scientists want to work on things that will make life better for the average person." Do you strongly agree, agree, disagree, or strongly disagree with that statement?

- 1 STRONGLY AGREE
- 2 AGREE
- 3 DISAGREE
- 4 STRONGLY DISAGREE

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1007

"Science can decide what is safe or not safe for you and your family." (Do you strongly agree, agree, disagree, or strongly disagree with that statement?)

- 1 STRONGLY AGREE
- 2 AGREE
- 3 DISAGREE
- 4 STRONGLY DISAGREE

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

Community Surveys Appendix B: Survey Instrument, Rocky Flats, Colorado

RAD1008

"Most radioactivity is human-made." (Do you strongly agree, agree, disagree, or strongly disagree with that statement?)

- 1 STRONGLY AGREE
- 2 AGREE
- 3 DISAGREE
- 4 STRONGLY DISAGREE

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1009

"Radiation from the natural environment is less harmful than human-made radiation." (Do you strongly agree, agree, disagree, or strongly disagree with that statement?)

- 1 STRONGLY AGREE
- 2 AGREE
- 3 DISAGREE
- 4 STRONGLY DISAGREE

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1010

(How strongly do you agree or disagree with this statement) "Science can decide whether radiation exposure is safe or unsafe for you and your family." (Do you strongly agree, agree, disagree, or strongly disagree?)

- 1 STRONGLY AGREE
- 2 AGREE
- 3 DISAGREE
- 4 STRONGLY DISAGREE

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1011

Now I would like to ask about your opinions on radiation. Do you think the safety standards for radiation exposure are generally too high, too low, or about right?

- 1 TOO HIGH
- 2 ABOUT RIGHT
- 3 TOO LOW

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

Community Surveys Appendix B: Survey Instrument, Rocky Flats, Colorado

RAD1012

If you were in charge of setting the standards for exposure to radiation, would you base the standard on how much radiation people receive from nature or what science knows about the health effects of radiation?

- 1 HOW MUCH RADIATION PEOPLE RECEIVE FROM NATURE
- 2 WHAT SCIENCE KNOWS ABOUT THE HEALTH EFFECTS OF RADIATION
- 3 (IF VOLUNTEERED: BOTH)

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1013

Would you set the standards for environmental cleanup of radiation sites based on what is possible with today's technology, or what can be achieved without excessive or unreasonable costs

- 1 WHAT IS POSSIBLE WITH TODAY'S TECHNOLOGY
- 2 WHAT CAN BE ACHIEVED WITHOUT EXCESSIVE COSTS
- 3 (IF VOLUNTEERED: BOTH)

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1014

The US Department of Energy is currently doing environmental cleanup at Rocky Flats. We would like your opinion about different approaches for determining the level of cleanup. I'm going to read you four different approaches and I'd like you to tell me which standard is the most important one for the cleanup to meet.

PROBE FROM LIST

- 1 CURRENT REGULATORY STANDARDS
- 2 A STANDARD AGREED TO BY LOCAL RESIDENTS
- 3 A STANDARD SET BY SCIENCE
- 4 A STANDARD DETERMINED BY COSTS

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1015

What is the second most important?

(PROGRAMMED TO SHOW REMAINING CHOICES)

- 1 CURRENT REGULATORY STANDARDS
- 2 A STANDARD AGREED TO BY LOCAL RESIDENTS
- 3 A STANDARD SET BY SCIENCE
- 4 A STANDARD DETERMINED BY COSTS

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

Community Surveys Appendix B: Survey Instrument, Rocky Flats, Colorado

RAD1016

What is the third most important approach?

(PROGRAMMED TO SHOW REMAINING CHOICES)

- 1 CURRENT REGULATORY STANDARDS
- 2 A STANDARD AGREED TO BY LOCAL RESIDENTS
- 3 A STANDARD SET BY SCIENCE
- 4 A STANDARD DETERMINED BY COSTS

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1018

Your top three ranked choices were CHOICE 1, CHOICE 2, and CHOICE 3. Now I would like you to rate each of the approaches in terms of how important it is. Imagine you have 100 dollars to divide between the three approaches. Out of 100 dollars, how much would you give to SHOW FIRST RANKED ITEM HERE?

ENTER EXACT NUMBER

- 997 REFUSED
- 998 DON'T KNOW
- 999 NO ANSWER

RAD1019

You have (100 - RAD018 ANS) dollars remaining. How much would you give to SHOW SECOND RANKED ITEM HERE?

ENTER EXACT NUMBER

- 9 97 REFUSED
- 998 DON'T KNOW
- 999 NO ANSWER

RAD1020

You have (100 - (RAD1018 ANS + RAD1019 ANS)) dollars remaining for the third ranked item. Are you satisfied with that?

- 1 YES (SKIPTO RAD1023)
- 2 NO

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1022

Since you are not satisfied with your ratings I will ask you to rate each item again

PRESS 1 --->SKIP BACK TO RAD1018

Community Surveys Appendix B: Survey Instrument, Rocky Flats, Colorado

RAD1023

Now I am going to ask your opinion about risks to public health in your community. For each item please tell me if you think there is almost no health risk, a slight health risk, a moderate health risk, or a high health risk to you and people in your community. How much of a health risk is natural background radiation? (Almost no risk, slight risk, moderate risk, or high risk?)

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1024

What about radon? Is radon almost no risk to public health, a slight risk, moderate risk, or high risk?

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1025

What about cosmic rays? (How much health risk do they pose for the public?)

NOTE: COSMIC RAYS ARE NATURAL RADIATION FROM OUTER SPACE

PROBE FROM LIST

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1026

(What about) sun tanning? (How much risk does sun tanning pose to the public?)

PROBE FROM LIST

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

Community Surveys Appendix B: Survey Instrument, Rocky Flats, Colorado

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1027

(What about) medical x-rays? (How much health risk do they pose for the public?)

PROBE FROM LIST

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1028

(What about) radioactive materials used in research? (How much health risk do they pose for the public?)

PROBE FROM LIST

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1029

(What about) radiation from medical waste? (How much health risk do they pose for the public?)

PROBE FROM LIST

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1030

(What about) nuclear power plants? (How much health risk do they pose for the public?)

PROBE FROM LIST

Community Surveys Appendix B: Survey Instrument, Rocky Flats, Colorado

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1031

(What about) nuclear waste? (How much health risk does it pose for the public?)

PROBE FROM LIST

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1032

(What about) radiation from nuclear weapons manufacturing? (How much health risk does that pose for the public?)

PROBE FROM LIST

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1033

(What about) fallout from nuclear weapons testing? (How much health risk does that pose for the public?)

PROBE FROM LIST

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

Community Surveys Appendix B: Survey Instrument, Rocky Flats, Colorado

RAD1034

(What about) radioactive waste from uranium mines? (How much health risk does that pose for the public?)

PROBE FROM LIST

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1035

(What about) electromagnetic fields such as energy fields from power lines? (How much health risk do they pose for the public?)

PROBE FROM LIST

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1036

(What about) microwave ovens? (How much health risk do they pose for the public?)

PROBE FROM LIST

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1037

(What about) cell phones? (How much health risk do they pose for the public?)

PROBE FROM LIST

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED

Community Surveys Appendix B: Survey Instrument, Rocky Flats, Colorado

- 8 DON'T KNOW
- 9 NO ANSWER

RAD1038

(What about) food irradiation? (How much health risk does that pose for the public?)

PROBE FROM LIST

- 1 ALMOST NO HEALTH RISK
- 2 SLIGHT HEALTH RISK
- 3 MODERATE HEALTH RISK
- 4 HIGH HEALTH RISK

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1039

Now I'd like to talk with you about Rocky Flats. How familiar are you with Rocky Flats?

PROBE FROM LIST

- 1 NOT FAMILIAR
- 2 SLIGHTLY FAMILIAR
- 3 SOMEWHAT FAMILIAR
- 4 VERY FAMILIAR

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1040

Have you ever heard or read anything about Rocky Flats in the media?

- 1 YES
- 2 NO

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1041

Have you ever visited the Rocky Flats site?

- 1 YES
- 2 NO

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1042

When you think about Rocky Flats, is your personal impression generally very negative, negative, positive, or very positive?

Community Surveys Appendix B: Survey Instrument, Rocky Flats, Colorado

- 1 VERY NEGATIVE
- 2 NEGATIVE
- 3 (IF VOLUNTEERED) NEUTRAL
- 4 POSITIVE
- 5 VERY POSITIVE

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1043

When you think about how people in your community view the site, is it generally very negative, negative, positive, or very positive?

- 1 VERY NEGATIVE
- 2 NEGATIVE
- 3 (IF VOLUNTEERED) NEUTRAL
- 4 POSITIVE
- 5 VERY POSITIVE

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1044

Now I am going to describe some events that have occurred at Rocky Flats, and I would like you to tell me if you recall them. First, in 1989 the FBI raided the Rocky Flats plant to investigate alleged violations of environmental law. How well do you recall this event?

PROBE FROM LIST

- 1 NOT AT ALL _(SKIPTO RAD1047
- 2 VAGUE RECOLLECTION
- 3 CLEAR MEMORY

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1045

How did you learn about this?

PROBE FROM LIST

CHOOSE ALL THAT APPLY

IF MORE THAN ONE, SELECT 4, ENTER EACH SELECTION, SEPARATED BY COMMA

- 1 TELEVISION / RADIO
- 2 NEWSPAPERS
- 3 WORD OF MOUTH
- 4 OTHER SPECIFY

- 7 REFUSED
- 8 DON'T KNOW

Community Surveys Appendix B: Survey Instrument, Rocky Flats, Colorado

9 NO ANSWER

RAD1045OTH

SPECIFY

RAD1046

How did this event affect your impression of Rocky Flats? Did the event have a very negative, negative, positive, or very positive effect?

- 1 VERY NEGATIVE
- 2 NEGATIVE
- 3 (IF VOLUNTEERED) NEUTRAL
- 4 POSITIVE
- 5 VERY POSITIVE

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1047

Next, in 1992, nuclear weapons production came to an end at Rocky Flats. How well do you recall this event?

PROBE FROM LIST

- 1 NOT AT ALL (SKIPTO RAD1053
- 2 VAGUE RECOLLECTION
- 3 CLEAR MEMORY

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1048

How did you learn about this?

PROBE FROM LIST

CHOOSE ALL THAT APPLY

IF MORE THAN ONE, SELECT 4, ENTER EACH SELECTION, SEPARATED BY COMMA

- 1 TELEVISION / RADIO
- 2 NEWSPAPERS
- 3 WORD OF MOUTH
- 4 OTHER SPECIFY

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1048OTH

SPECIFY

Community Surveys Appendix B: Survey Instrument, Rocky Flats, Colorado

RAD1049

How did this event affect your impression of Rocky Flats? Did the event have a very negative, negative, positive, or very positive effect?

- 1 VERY NEGATIVE
- 2 NEGATIVE
- 3 (IF VOLUNTEERED) NEUTRAL
- 4 POSITIVE
- 5 VERY POSITIVE

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1050

Finally, in 2000, there was a controversy over a proposal to use controlled burning to manage vegetation in the buffer zone that surrounds the Rocky Flats plant. How well do you recall this event?

PROBE FROM LIST

- 1 NOT AT ALL (SKIPTO RAD1050
- 2 VAGUE RECOLLECTION
- 3 CLEAR MEMORY

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1051

How did you learn about this?

PROBE FROM LIST

CHOOSE ALL THAT APPLY

IF MORE THAN ONE, SELECT 4, ENTER EACH SELECTION, SEPARATED BY COMMA

- 1 TELEVISION / RADIO
- 2 NEWSPAPERS
- 3 WORD OF MOUTH
- 4 OTHER SPECIFY

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1051OTH

SPECIFY

RAD1052

How did this event affect your impression of Rocky Flats? Did it have a very negative, negative, positive, or very positive effect?

- 1 VERY NEGATIVE
- 2 NEGATIVE
- 3 (IF VOLUNTEERED) NEUTRAL

Community Surveys Appendix B: Survey Instrument, Rocky Flats, Colorado

- 4 POSITIVE
- 5 VERY POSITIVE
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1053

Now I'd like to ask you some questions about your community in general. I'm going to read you a number of different ways to describe communities, and I would like you to tell me how well each one describes your community. First, a bedroom community. Is this a very poor, poor, good or very good description of your community?

NOTE: A BEDROOM COMMUNITY IS A COMMUNITY THAT IS PRIMARILY RESIDENTIAL

PROBE: How well does this describe your community?

- 1 VERY POOR
- 2 POOR
- 3 GOOD
- 4 VERY GOOD
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1054

Second, an industrial community. Is this a very poor, poor, good or very good description of your community?

- 1 VERY POOR
- 2 POOR
- 3 GOOD
- 4 VERY GOOD
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1055

Third, a recreational community. (Is this a very poor, poor, good or very good description of your community?)

- 1 VERY POOR
- 2 POOR
- 3 GOOD
- 4 VERY GOOD
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1056

An agricultural community. (Is this a very poor, poor, good or very good description of your community?)

Community Surveys Appendix B: Survey Instrument, Rocky Flats, Colorado

- 1 VERY POOR
- 2 POOR
- 3 GOOD
- 4 VERY GOOD
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1057

A retirement community (how well does this describe your community?).

PROBE AS NEEDED FROM LIST

- 1 VERY POOR
- 2 POOR
- 3 GOOD
- 4 VERY GOOD
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1058

A working class community (how well does this describe your community?)

PROBE FROM LIST

- 1 VERY POOR
- 2 POOR
- 3 GOOD
- 4 VERY GOOD
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1059

We are now more than half way through the survey and I want to thank you for your cooperation. Next, do you see the economy of your community as improving rapidly, improving slowly, stable, declining slowly or declining rapidly?

- 1 IMPROVING RAPIDLY
- 2 IMPROVING SLOWLY
- 3 STABLE
- 4 DECLINING SLOWLY
- 5 DECLINING RAPIDLY
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1060

Thinking about the community as a whole, how would you characterize it in terms of its concern about environmental problems? Is your community not at

Community Surveys Appendix B: Survey Instrument, Rocky Flats, Colorado

all concerned, slightly concerned, concerned, or very concerned (about the environment)?

- 1 NOT AT ALL CONCERNED
- 2 SLIGHTLY CONCERNED
- 3 CONCERNED
- 4 VERY CONCERNED
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1061

After cleanup and closure of Rocky Flats, will the economic future of your community be much better, a little better, the same, a little worse, or much worse?

- 1 MUCH BETTER
- 2 A LITTLE BETTER
- 3 THE SAME
- 4 A LITTLE WORSE
- 5 MUCH WORSE
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1062

In general, do you strongly favor, favor, oppose or strongly oppose new development in your community?

- 1 STRONGLY FAVOR
- 2 FAVOR
- 3 (IF VOLUNTEERED) NEUTRAL
- 4 OPPOSE
- 5 STRONGLY OPPOSE
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1063

Now I'd like to ask you some questions about Rocky Flats and your community. In general, how much do you think Rocky Flats influences how you and your neighbors view your community? Is your opinion of your community not influenced, slightly influenced, somewhat influenced, or strongly influenced by Rocky Flats?

- 1 NOT INFLUENCED
- 2 SLIGHTLY INFLUENCED
- 3 SOMEWHAT INFLUENCED
- 4 STRONGLY INFLUENCED
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

Community Surveys Appendix B: Survey Instrument, Rocky Flats, Colorado

RAD1064

When you think about people from outside your community, how strongly is their impression of your community influenced by Rocky Flats ? Is it not influenced, slightly influenced, somewhat influenced, or strongly influenced?

- 1 NOT INFLUENCED
- 2 SLIGHTLY INFLUENCED
- 3 SOMEWHAT INFLUENCED
- 4 STRONGLY INFLUENCED

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1065

Overall, do you feel that your community is better off with, or better off without Rocky Flats?

- 1 WITH
- 2 WITHOUT
- 3 (IF VOLUNTEERED) ABOUT THE SAME

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1066

A proposal for the future use of the Rocky Flats site is to clean it up so that the site can become a National Wildlife Refuge that would be fenced but with public access. Would this use be very positive, positive, neutral, negative, or very negative for your community?

- 1 VERY POSITIVE
- 2 POSITIVE
- 3 NEUTRAL
- 4 NEGATIVE
- 5 VERY NEGATIVE

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1067

With an appropriate cleanup, one long-term outcome for Rocky Flats might include residential housing. Would this use be very positive, positive, neutral, negative, or very negative for your community?

- 1 VERY POSITIVE
- 2 POSITIVE
- 3 NEUTRAL
- 4 NEGATIVE
- 5 VERY NEGATIVE

- 7 REFUSED
- 8 DON'T KNOW

Community Surveys Appendix B: Survey Instrument, Rocky Flats, Colorado

9 NO ANSWER

RAD1068

Another proposal for the future use of the Rocky Flats site is to clean it up so, in addition to becoming a fenced nature preserve, appropriate areas along the outside edge of the site will be open to industrial and highway development. Would this use be very positive, positive, neutral, negative, or very negative for your community?

- 1 VERY POSITIVE
- 2 POSITIVE
- 3 NEUTRAL
- 4 NEGATIVE
- 5 VERY NEGATIVE
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1069

How concerned are you about radiation at Rocky Flats compared to other environmental concerns in your community, (such as water or air pollution)?

PROBE: Which are you more concerned about, water and air pollution from other contaminants, or radiation from the site?

PROBE FROM LIST

- 1 MUCH MORE CONCERNED ABOUT RADIATION
- 2 SOMEWHAT MORE CONCERNED ABOUT RADIATION
- 3 ABOUT THE SAME
- 4 SOMEWHAT MORE CONCERNED ABOUT OTHER CONTAMINANTS
- 5 MUCH MORE CONCERNED ABOUT OTHER CONTAMINANTS
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1070

If a small amount of radiation was present at Rocky Flats, how much do you think this would affect the future of your community? Would it have no effect, a slight effect, a moderate effect, or a large effect (on the future of your community)?

- 1 NO EFFECT
- 2 SLIGHT EFFECT
- 3 MODERATE EFFECT
- 4 LARGE EFFECT
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

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RAD1071

Next, we would like to know something about how important Rocky Flats is to you and other people in your community. In the normal course of conversations you might have at home, does Rocky Flats ever come up?

PROBE: Do you ever discuss the site at home?

- 1 YES
- 2 NO (SKIPTO RAD1073)
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1072

How concerned are you and your family about Rocky Flats? Are you very concerned, slightly concerned, or not concerned at all?

- 1 VERY CONCERNED
- 2 SLIGHTLY CONCERNED
- 3 NOT AT ALL CONCERNED
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1073

Is it likely a discussion of Rocky Flats would come up at any other social or community groups you might be part of?

- 1 YES
- 2 NO (SKIPTO RAD1AGE)
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1074

Where would that be? (What are the other social or community groups you are a part of where Rocky Flats might come up in conversation?)

OPEN ENDED

RAD1AGE

Thank you. We are almost done. Now I would like to ask you some questions about yourself. In what year were you born?

ENTER EXACT NUMBER

- 9996 BEFORE 1890
- 9997 REFUSED
- 9998 DON'T KNOW
- 9999 NO ANSWER

RAD1SEX

Are you male or female (sorry I have to ask everyone)?

Community Surveys Appendix B: Survey Instrument, Rocky Flats, Colorado

- 1 MALE
- 2 FEMALE
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1ETH

What is your race or ethnic identity?

NOTE: R MAY CHOOSE AS MANY AS APPLY IF VOLUNTEERED

IF MORE THAN ONE, SELECT 4, ENTER EACH SELECTION, SEPARATED BY COMMA

PROBE FROM LIST

- 1 WHITE
- 2 BLACK OR AFRICAN AMERICAN
- 3 ASIAN
- 4 NATIVE HAWAIIAN OR OTHER PACIFIC ISLANDER
- 5 AMERICAN INDIAN OR ALASKAN NATIVE
- 6 HISPANIC OR LATINO
- 7 OTHER (PLEASE SPECIFY) _____
- 97 REFUSED
- 98 DON'T KNOW
- 99 NO ANSWER

RAD1ETHOTH

(PLEASE SPECIFY)

RAD1EDU

What is the highest level of education you have completed?

- 1 Doctorate (PhD, EdD) or Professional (MD, JD, DDS)
- 2 Masters (MA, MS, MBA, Med)
- 3 Bachelors (BA, BS, AB)
- 4 Associates (AA, AS)
- 5 Some college, no degree
- 6 High School Diploma or GED
- 7 9th - 12th Grade, no diploma (SKIPTO RAD175b)
- 8 5th - 8th Grade (SKIPTO INCOME1)
- 9 4th Grade or less (SKIPTO INCOME1)
- 97 REFUSED
- 98 DON'T KNOW
- 99 NO ANSWER

RAD175a

Have you ever taken a science course at the college level?

- 1 YES
- 2 NO

Community Surveys Appendix B: Survey Instrument, Rocky Flats, Colorado

- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD175b

Have you ever taken a science course at the high school level?

- 1 YES
- 2 NO
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

INCOME1

Is your total annual household income, from all sources, before taxes, over or under \$35,000?

PROBE: Include money from jobs (wages, salary, tips, bonuses),

interest, dividends, child support, alimony, welfare, social security, disability and retirement payments, net income from a business, farm or rent, or any other money income received by members of your family. Do not include lump-sum payments, such as money from an inheritance or sale of a home.

- 1 OVER \$35,000 ---> SKIPTO INCOME4
- 2 UNDER \$35,000
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

INCOME2

Is it over or under \$25,000?

PROBE: Is your total annual household income, from all sources, before taxes, over or under \$25,000?

- 1 OVER \$25,000 -->SKIPTO RAD1076
- 2 UNDER \$25,000
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

INCOME3

Is it over or under \$15,000?

- 1 OVER \$15,000 ---> SKIPTO RAD1076
- 2 UNDER \$15,000 ---> SKIPTO RAD1076
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

INCOME4

Is it over or under \$50,000?

- 1 OVER \$50,000

Community Surveys Appendix B: Survey Instrument, Rocky Flats, Colorado

- 2 UNDER \$50,000---> SKIPTO RAD1076
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

INCOME5

Is it over or under \$75,000

- 1 OVER \$75,000
- 2 UNDER \$75,000
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1076

What political party are you affiliated with?

PROBE FROM LIST

- 1 REPUBLICAN
- 2 DEMOCRAT
- 3 LIBERTARIAN
- 4 OTHER SPECIFY: _____
- 5 (IF VOLUNTEERED) NOT A REGISTERED VOTER
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1076OTH

SPECIFY

RAD1077

Do you or any of your family or household members work at Rocky Flats, now or in the past?

- 1 YES
- 2 NO
- 7 REFUSED
- 8 DON'T KNOW
- 9 NO ANSWER

RAD1COM

Thank you. That is the end of the survey. Do you have any comments you would like to add?

OPEN ENDED

RAD1END

On behalf of Decision Research I would like to thank you for your participation. Good bye.

ENTER YOUR COMMENTS RELEVANT TO THE SURVEY

Community Surveys Appendix B: Survey Instrument, Rocky Flats, Colorado

RAD1IID

ONE MORE DONE!!

ENTER YOUR INTERVIEWER ID - ALL 3 DIGITS

THANKS!!

NOQUAL

I am sorry to have bothered you. We are only interviewing people in Westminster or Arvada at this time. Thank you and have a good (day/evening).

PRESS 1