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ABSTRACT

This guide is Unit 3 of the four-part series, Science, Society, and America's Nuclear Waste, produced by the U.S. Department of Energy's Office of Civilian Radioactive Waste Management. The goal of this unit is to identify the key elements of the United States' nuclear waste dilemma and introduce the Nuclear Waste Policy Act and the role of the public in the development of a high-level waste management program. Particular attention is focused on activities to enable students to develop insight into the difficult task of siting, storing, transporting, and disposing of high-level nuclear waste. The first section of Unit 3 includes five lesson plans about risk assessment and the Nuclear Waste Policy Act. The second section provides a lesson plan about probability. Activity sheets for students and transparencies for the lesson plans and background notes are included in the third section followed by the unit test. Answers keys and a glossary are also included. Contains 12 references. (DDR)

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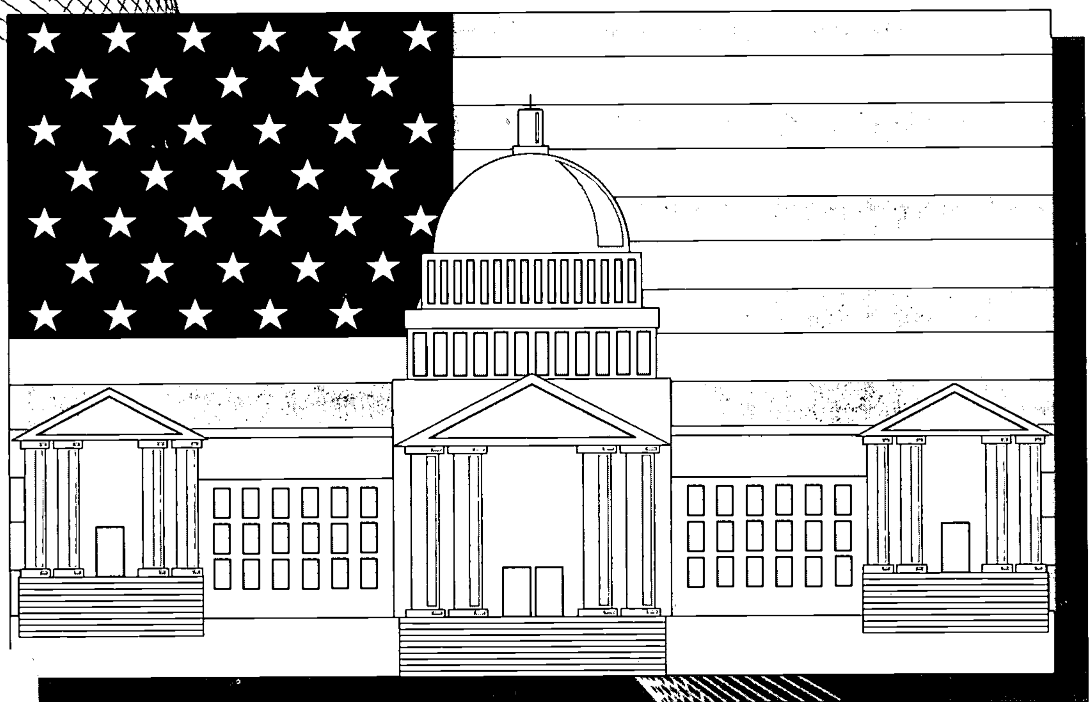
Science, Society, and America's Nuclear Waste



The Nuclear Waste Policy Act

Unit 3 Second Edition
Teacher Guide

"Science, Society and America's Nuclear Waste" is a four-unit secondary curriculum. It is intended to provide information about scientific and societal issues related to the management of spent nuclear fuel from generation of electricity at nuclear powerplants and high-level radioactive waste from U.S. national defense activities. The curriculum, supporting classroom activities, and teaching materials present a brief discussion of energy and electricity generation, including that produced at nuclear powerplants; information on sources, amounts, location, and characteristics of spent nuclear fuel and high-level radioactive waste; sources, types, and effects of radiation; U.S. policy for managing and disposing of spent nuclear fuel and high-level radioactive waste and what other countries are doing; and the components of the nuclear waste management system. The four units are:

Unit 1 - Nuclear Waste

Unit 2 - Ionizing Radiation

Unit 3 - The Nuclear Waste Policy Act

Unit 4 - The Waste Management System

In the study of nuclear waste management, or any other scientific and social subject, individuals are encouraged to seek differing perspectives and points of view.

This resource curriculum was produced by the U.S. Department of Energy's (DOE) Office of Civilian Radioactive Waste Management (OCRWM) and has been reviewed by selected staff, faculty, and/or workshop participants from: Louisiana State University; the University of Nevada, Reno and Las Vegas; the University of Tennessee; Pennsylvania State University; Hope College in Michigan; the University of South Florida School of Medicine; the New York State Department of Education, Science, Technology, and Society Education Project; the Nevada Science Project; the National Council for the Social Studies, Science and Society Committee; and the First International Workshop on Education in the Field of Radioactive Waste Management — At the Crossroads of Science, Society, and the Environment — co-sponsored by the multinational Organization for Economic Cooperation and Development/ Nuclear Energy Agency, U.S. Department of Energy's OCRWM, and the Swiss National Cooperative for the Storage of Radioactive Waste (NAGRA). The international workshop was attended by educators and information specialists from Austria, Belgium, Canada, Finland, France, Germany, Japan, the Netherlands, Spain, Sweden, Switzerland, the United Kingdom, and the United States. This curriculum was field tested through team-teaching by science and social studies teachers in Alabama, Florida, Georgia, Louisiana, Mississippi, South Carolina, and Texas.

For further information about this curriculum, please call 1-800-225-6972 (within Washington, DC, 202-488-6720) or write to:

OCRWM National Information Center
Attention: Curriculum Department
600 Maryland Ave., SW
Suite 760
Washington, DC 20024

The 1977 DOE Reorganization Act authorizes education and training activities necessary to ensure that the Nation has an adequate technical work force in energy-related research and production fields. These fields include mathematics, physics, geology, chemistry, zoology, biology, and other areas of basic and applied research. The DOE Science Enhancement Act (part of the 1991 National Defense Authorization Act) expands the Department's authorization to support science education and amends the 1977 legislation to make support for science education a major mission of the Department. Traditionally, the DOE educational emphasis has been on university-level education, with the agency providing graduate student fellowships and research appointments at DOE facilities. More recently, the education mission was expanded to include precollege education and science literacy.

DOE has been working diligently to make its contribution toward achieving our National Education Goals since their development following the 1989 Education Summit in Charlottesville, Virginia. Although DOE's work indirectly supports all the goals, DOE is especially involved in Goal # 4: "By the year 2000, U.S. students will be first in the world in science and mathematics achievement."

DOE sponsors a number of national and local energy education programs, in addition to this curriculum, through its national laboratories, energy technology centers, and various DOE program elements. For further information about these programs, please write to: U.S. Department of Energy, Office of Science Education and Technical Information, Washington, DC 20585.

Science, Society, and America's Nuclear Waste

The Nuclear Waste Policy Act

Unit 3 Second Edition
Teacher Guide

July 1995

Department of Energy
Washington, DC 20585

To the Teacher:

This Second Edition of the Teacher Guide accompanies the resource curriculum *Science, Society, and America's Nuclear Waste*. The curriculum, produced by the United States Department of Energy's (DOE's) Office of Civilian Radioactive Waste Management (OCRWM), is designed to assist science and social studies teachers in presenting issues related to the safe management and disposal of America's nuclear waste. The curriculum was developed, reviewed, and tested by teachers for use in grades 8 through 12.

The *Science, Society, and America's Nuclear Waste* curriculum provides information and background on energy and waste-management issues. It is suitable for use in technology and environmental science classes and in social studies classes in middle, high school, and advanced lower grades. Its content and focus are consistent with national goals to strengthen and update math and science curriculum and broaden public science literacy.

Since the curriculum was first made available to the public in 1992, and as of August 1995, more than 20,000 Teacher Guides and approximately 200,000 Student Readers have been requested by and distributed to educators of diverse disciplines in all 50 States and in 48 foreign countries.

Ancillary materials, such as videotapes, a computer diskette, and other materials referenced in the document, may be obtained by calling the OCRWM National Information Center at 1-800-225-6972 (in Washington, D.C., 202-488-6720).

Sincerely,

E.Y. Deshields

Evangeline Deshields, Manager
Office of Civilian Radioactive Waste Management
National Information Center

Printed with soy ink on recycled paper

Notice To Educators

These **Second Edition Teacher Guides** contain statistical updates that are current as of October 1, 1994. **First Edition Student Readers** are available upon request. Since very few statistical changes were required in the Student Readers, **Second Edition Student Readers** were <u>not</u> printed. Minor differences between the two editions are underlined in your Student Reader material contained in these Teacher Guides.

References to a Monitored Retrievable Storage (MRS) Facility and the Office of the Nuclear Waste Negotiator

You will note that throughout units 3 and 4 of the curriculum references are made to the concept of a Monitored Retrievable Storage (MRS) facility. The Nuclear Waste Policy Amendments Act of 1987 (the Act) authorized the siting, construction, and operation of such a storage facility as an integral part of the Federal waste management system. The Act gave the Secretary of Energy the authority to survey and evaluate sites for a storage facility then designate one. The Act also created the Office of the Nuclear Waste Negotiator to seek a State or Indian Tribe willing to volunteer a technically suitable site, under reasonable terms to be approved by Congress.

To counter a concern that interim central storage on the surface might become permanent, Congress linked the selection of a storage site to the recommendation of a repository site to the President by the Secretary. Under this limitation, construction of a storage site cannot begin until the Nuclear Regulatory Commission issues a license for construction of a repository. In 1989, the Department of Energy announced a delay in the recommendation of a repository site until 2001, and a delay in the expected date of repository operations until the year 2010. The Secretary also told Congress that if the linkage between the MRS facility and the repository were modified, then waste acceptance at the facility could begin by 1998. This was based on the assumption that a site would be available by then. However, the linkage remains in place, the Nuclear Waste Negotiator has not been able to find a volunteer candidate site, and accumulated political experience suggests that a volunteer site for interim storage is not likely. In the absence of interim central storage, waste acceptance and offsite transport could not occur until the start of repository operations in 2010.

The Fiscal Year 1995 budget does not provide funding to OCRWM for activities related to interim storage, and the statutory authority for the Office of the Nuclear Waste Negotiator expired in January 1995. However, references to an MRS facility are still included in the Second Revision, as the concept is still included in the Nuclear Waste Policy Act, as mentioned.

Because of the changes mentioned above, this edition's lesson in Unit 4, formally titled *The Role of the Monitored Retrievable Storage Facility*, has been replaced with the lesson *The Role of the Multi-Purpose Canister*. However, most of the other references to an MRS facility found throughout the curriculum have remained intact, most notably in Unit 3. Please take special note of this new information as you plan lessons around the concept of an MRS facility.

Please note that referenced videotapes and support materials can be obtained free of charge through the **OCRWM National Information Center at 1-800-225-6972 (in Washington, DC, 202-488-6720).**

THE NUCLEAR WASTE POLICY ACT

Text/Lessons

Enrichment

Transparency Masters/Activities

UNIT III: The Nuclear Waste Policy Act

Lesson	Focus	Activities/Materials Provided	Content Area/ Grade Level
The Nuclear Waste Policy Act (two 50-minute class periods)	Introduces students to the Nuclear Waste Policy Act and our Nation's plans for managing high-level nuclear waste.	Reading Lesson Activity Sheet Videotape (11 minutes) Enrichments (3) • Original Source Research • Role Play • Newspaper Research	Social Studies & Science (Grades 8-12)
Approaching a Complex Task (one 50-minute class period)	Helps students understand steps involved in approaching a complex task and provides insight into the challenge that developing a waste management system presents.	Flow Chart	Social Studies & Science (Grades 8-12)
Nulcear Waste Challenges and Solutions (one 50-minute class period)	Requires students to analyze the provisions of the Nuclear Waste Policy Act and the nature of our Nation's nuclear waste dilemma.	Transparency Activity Sheets (4) Discussion Questions Enrichments (7) • Essay Writing • Newspaper Research • Role Play • Simulation	Social Studies & Science (Grades 8-12)

UNIT III: The Nuclear Waste Policy Act

Lesson	Focus	Activities/Materials Provided	Content Area/ Grade Level
Risk Perception and Judgment (two 50-minute class periods)	Introduces factors people consider in determining risk and the concept that every human activity involves some degree of risk.	Transparency Activity Sheets (4) Discussion Questions Computer Activity/Diskette Enrichments • Transparency • Ranking • Computer Activity • Graphing • Reading Lesson • Reading Review • Math Exercises • Challenge Level Math Exercises	Social Studies & Science (Grades 8-12)

THE NUCLEAR WASTE POLICY ACT

Unit Purpose:

This unit of study will identify the key elements of our Nation's nuclear waste dilemma and introduce the Nuclear Waste Policy Act and the role of the public in the development of a high-level waste management program.

An introductory study of the Nuclear Waste Policy Act makes use of several media including a videotape, reading lesson and review, analytical essay writing, discussion on participatory democracy, development of a schematic, and the possibility for original document research and role-play.

Through participation in a "hands-on" activity, students will begin to develop insight into the difficult task we face in the development of nuclear waste management technology. This activity will enhance appreciation for the complexity of the task of siting, storing, transporting, and disposing of high-level nuclear waste.

Risks specifically associated with nuclear waste will be explored and students will examine their own risk judgments through use of pencil-paper and computer activities. Additionally, students will look into how scientists and decision-makers who are involved in determining methods of protecting health or improving safety quantify relationships among risks by developing mathematical probabilities. By exploring the issue of nuclear waste in this broader perspective, students will begin to appreciate the complex societal and technical challenges faced by the Nation. This awareness will help students become better informed citizens and future decision-makers. Student apprehensions regarding nuclear waste technology may surface during the discussions on risk and probabilities. It is important to probe for, acknowledge, and address these concerns as they are expressed.

Unit Concepts:

A national challenge exists because there is an accumulation of nuclear waste.

1. Many solutions have been explored over a 30-year period. Today, the majority of informed technical opinion holds that disposal in deep geologic repositories is the preferred method of permanent isolation.
2. The purpose of the Nuclear Waste Policy Act (NWPA) of 1982 and its amendments is to provide for the safe handling, storage, and disposal of our Nation's spent fuel and high-level nuclear waste.
3. The U.S. Congress has established that the management of nuclear waste is the responsibility of the present generation and should not be left for future generations.
4. Those involved with the program are dedicated to making technically sound decisions, working with affected parties to identify potential negative impacts and to avoid, mitigate, or compensate for such impacts.
5. The NWPA provides for independent oversight and review.
6. Many steps must be identified and addressed in planning and completing a complex task.
7. Complex technical and societal challenges must be addressed and solved in making decisions about the management of nuclear waste.

8. In making decisions about the management of nuclear waste, both technical and societal aspects of the challenge must be addressed.
9. In a democratic society, national challenges are solved through striving for legitimate and acceptable decisions arrived at through open and balanced dialogue.
10. Societal decisions are shaped by human values, perceptions, and analysis of facts.
11. The Nuclear Waste Policy Act of 1982 and amendments established a plan for the safe handling, storage, and disposal of our Nation's spent fuel and high-level radioactive waste.
12. State and public participation in the planning and development of the system is essential in order to promote public confidence in the safety of disposal of high-level nuclear waste and spent fuel.
13. Despite the controversy associated with the managing of our Nation's nuclear waste, it is imperative that this growing national challenge be addressed promptly and responsibly.
14. Risk has many dimensions.
15. Every human activity involves some degree of risk.
16. In making decisions about managing nuclear waste, public risk perception and the distribution of risk must be considered.
17. Both risk management and risk assessment are important aspects of the waste management program.
18. Scientists quantify relationships among risks by developing mathematical probabilities.
19. Judgment is an inevitable element in selecting criteria for quantifying risk.
20. Someone has to make the decision of whether or not a level of risk is acceptable.

Duration of Unit:

Seven 50-minute class periods

Unit Objectives:

As a result of participation in this unit of study, the learner will be able to:
1. name the key provisions of the Nuclear Waste Policy Act;
2. identify the key agencies involved in the high-level radioactive waste management program;
3. discuss whether this generation or future generations should provide for disposal of nuclear waste currently in storage;
4. identify specific attempts to allow for participation of affected parties;
5. identify ways in which independent oversight of DOE is provided for;
6. explain how and why the Nuclear Waste Policy Act provides for public participation;
7. explain the Federal role in the management of nuclear waste;
8. identify major steps involved in completing a complex project;
9. draw a conclusion about the complexity of the task DOE is faced with regarding the nuclear waste management program;
10. identify challenges and solutions associated with nuclear waste;
11. differentiate between technical and societal issues related to disposing of nuclear waste;
12. state ways in which people living in a democratic society make decisions about risks related to technology;
13. explain why he/she ranked the various items on the risk activity as he/she did;
14. discuss risk and what can be done to reduce it in his/her own life;

15. discuss both positive and negative results of risk management limitations;
16. discuss probabilities and risk assessment on an introductory level; and
17. discuss limitations of using probabilities in making societal decisions.

Unit Skills:

Analyzing, comparing and contrasting, concluding, critical thinking, decision-making, describing, designing, discussing, drawing conclusions, evaluating, explaining, graphing, group dynamics, note taking, rank ordering given items, reading, summarizing, synthesizing, viewing

Unit Vocabulary:

Acceptable level of risk, affected parties, Benefits Agreement, certification, democracy, distribution of risk, environmental impact statement, EPA, flow chart, global, judgment, MRS, MRS Review Commission, NIMBY, notice of disapproval, Nuclear Waste Fund, Nuclear Waste Policy Act of 1982, Nuclear Waste Policy Amendments Act of 1987, Nuclear Waste Technical Review Board, OCRWM, probabilities, quantify, risk assessment, risk management, risk perception, site characterization, societal, technical, trade-off, Yucca Mountain

Unit Materials:

Reading lessons

The Nuclear Waste Policy Act: An Overview, p. SR-1
Probability: The Language of Risk Assessment, p. SR-15

Activity sheets

Overview – Nuclear Waste Policy Act, p. 53
Swimming Pool Construction Flow Chart, p. 55
Nuclear Waste Challenges and Solutions (Parts 1 & 2), pp. 57, 59
Risk, p. 61
Risk Perception Computer Activity, p. 63
Probability: The Language of Risk Assessment, pp. 65, 66

Videotapes

Managing the Nation's Nuclear Waste (11 minutes)
Worldwide Waste Management (3 minutes, 25 seconds)
The Monitored Retrievable Storage System (8 minutes, 15 seconds)
(order all tapes free of charge from the OCRWM National Information Center at 1-800-225-6972; within Washington, DC, 488-6720)

Masters for transparencies

Nuclear Waste Challenges and Solutions (Part 1), p. 47
Ordering of Perceived Risk, p. 49
Factors for Locating Hazards, p. 51

Computer diskette (IBM or IBM compatible only in 5.25 and 3.5 inch disks)
Risk Perception and Judgment **(order free of charge from the OCRWM National Information Center at 1-800-225-6972; within Washington, DC, 488-6720)**

Background Notes
Risk Perception and Judgment, p. 25
The Debate About Risk, p. 26

Enrichment:
Probability: The Language of Risk Assessment, pp. 65, 66
Factors Affecting Risk Judgments , p. 67
Location of Hazards, p. 69
Probability Exercises, p. 71
Probability Exercise: Challenge Level, p. 73
Metric and U.S. Unit Conversions, p. 75

"Roles for Citizens," The Nuclear Waste Primer **(order free of charge from the OCRWM National Information Center at 1-800-225-6972; within Washington, DC, 488-6720)**

INTRODUCTION

Environmental Issues

High on the list of concerns shared by many Americans are environmental issues, protecting the parts of the environment that are unspoiled, and preventing unnecessary disturbances in the future. More and more, decisions that affect the long-term well-being of society and the environment involve the use of science and technology. The wise use of technology is one of the best tools Americans have to safeguard the environment. The safe disposal of nuclear waste is a good example. Making informed decisions about how to manage and dispose of nuclear waste requires us to have some understanding of the science involved, and also to consider how decisions about waste management will affect people and the environment.

Technical Questions

In Units 1 and 2, you learned about what nuclear waste is and why it needs special disposal. You learned about radiation — what it is, where it comes from, and some of its properties. You have also begun to look at some of the technical aspects of nuclear waste management — the nature of the waste, radiation, and radioactivity. In this unit, you will examine key elements of our Nation's nuclear waste dilemma, the Nuclear Waste Policy Act, and the role of the public in the development of a high-level waste management program. You will also look at how probability is used as one tool to determine acceptable levels of risk when using technology. Society also weighs consequences and values in making decisions about risk.

Decisions in a Democracy

One big concern for most people is how decisions about nuclear waste management will be made in a democracy like ours. This question is important because nuclear waste creates potential risk and requires safe and environmentally acceptable methods of disposal.

The U.S. Congress passed the Nuclear Waste Policy Act of 1982 and amendments which established U.S. law for the permanent disposal of high-level nuclear waste. The law made the U.S. Department of Energy responsible for developing and operating a system that will provide safe storage, transportation, and permanent disposal of these wastes. The law also requires participation of States, Indian Tribes, and the public in the waste management program.

National Energy Strategy

In February 1991, the National Energy Strategy was published by the U.S. Department of Energy. It presents a comprehensive strategy for producing and using energy in the future and contains more than a hundred initiatives whose implementation is a shared responsibility with the American public, the private sector, academia, and all levels of government. Among other things, it establishes a national commitment and strategies to ensure implementation of the Nuclear Waste Policy Act of 1982 and its amendments to establish an effective U.S. nuclear waste management program.

This unit includes a discussion of the initiatives contained in the Strategy and progress made during the first year of implementation.

In this unit, you will examine key elements of our Nation's nuclear waste management program and gain an understanding of how complex the challenge of waste disposal is. You will be introduced to provisions of the laws and examine questions of equity, burdens, and benefits related to nuclear waste disposal. You will examine the language of risk and probability. You will examine the roles of the Federal Government, States, and Indian Tribes. Finally, you will examine the role that people like you, your family, and friends can play in the development of a high-level waste management program.

THE NUCLEAR WASTE POLICY ACT

Purpose:

This lesson will introduce students to the Nuclear Waste Policy Act (NWPA) and our Nation's plans for managing high-level nuclear waste. Students will gain insight into the U.S. Congress's legislation that addresses the complex task of siting, transporting, and disposing of this waste.

Concepts:

1. Many solutions have been explored over a 30-year period. Today the majority of informed technical opinion holds that disposal in deep geologic repositories is the preferred method of permanent isolation.
2. The purpose of the Nuclear Waste Policy Act of 1982 and its amendments is to provide for the safe handling, storage, and disposal of our Nation's high-level nuclear waste.
3. The Federal Government has established that the management of nuclear waste is the responsibility of the present generation and should not be left for future generations.
4. Those involved with the program are dedicated to making technically sound decisions and to work with affected parties to identify potential negative impacts and to avoid, mitigate, or compensate for such impacts.
5. The NWPA provides for independent oversight and review.

Duration of Lesson:

Two 50-minute class periods

Objectives:

As a result of participation in this lesson, the learner will be able to:
1. name key provisions of the Nuclear Waste Policy Act;
2. identify key agencies involved in the high-level radioactive waste management program;
3. discuss whether this generation or future generations should provide for disposal of nuclear waste currently in storage;
4. identify specific attempts to allow for participation of affected parties; and
5. identify ways in which independent oversight of DOE is provided for.

Skills:

Analyzing, critical thinking, discussing, taking notes, reading, summarizing, viewing

Vocabulary:

Affected parties, Benefits Agreement, certification, environmental impact statement, EPA, MRS, MRS Review Commission, notice of disapproval, Nuclear Waste Fund, Nuclear Waste Policy Act of 1982, Nuclear Waste Policy Amendments Act of 1987, Nuclear Waste Technical Review Board, OCRWM, site characterization, Yucca Mountain

Materials:

Reading Lesson

The Nuclear Waste Policy Act: An Overview, p. SR-1

Activity Sheet

Overview – Nuclear Waste Policy Act, p. 53

Videotapes

Managing the Nation's Nuclear Waste (11 minutes)

Worldwide Waste Management (3 minutes, 25 seconds)

The Monitored Retrievable Storage System (8 minutes, 15 seconds)

(order all tapes free of charge from the OCRWM National Information Center, 1-800-225-6972; within Washington, DC, 488-6720)

Suggested Procedure:

Part I

1. You may wish to introduce this topic by showing the videotape entitled *Managing the Nation's Nuclear Waste*. It might be wise for students to take notes as they view the film to facilitate discussion of the video's key themes.

Sample videotape discussion questions - *Managing the Nation's Nuclear Waste*

a) Where is nuclear waste stored now? How is it stored?

b) Why is permanent disposal considered necessary?

c) What disposal option has been chosen? Others considered?

d) How is nuclear waste transported safely? Give evidence to support your answer.

e) What site has the U.S. Congress directed the Department of Energy (DOE) to investigate for its potential suitability for the Nation's first geologic repository? What steps are being taken to study this site?

(It is important that students understand that no site has been selected for a permanent repository. The Yucca Mountain Site has been selected by Congress for site characterization. Extensive studies will be conducted to determine whether the site is appropriate for a repository. Additionally, the State of Nevada has received grants from the Nuclear Waste Fund, which enables it to monitor DOE's activities and study the issues independently.)

f) The Department of Energy, Department of Transportation, Environmental Protection Agency, Nuclear Regulatory Commission, State and local governments, Indian Tribes, and the general public have all been involved in the implementation of the Nuclear Waste Policy Act. Why do you think so many different bodies, agencies, and individuals have been involved in this?

2. Assign the reading lesson and reading review entitled *The Nuclear Waste Policy Act: An Overview* to be completed in class or as homework.

Part II

1. Review the assignment *Overview – Nuclear Waste Policy Act.*
2. In 1820 Thomas Jefferson wrote:

   "I know of no safe depository of the ultimate powers of the society but the people themselves; and if we think them not enlightened enough to exercise their control with a wholesome discretion, the remedy is not to take it from them, but to inform their discretion by education."

   a) Have students write an essay analyzing the provisions of the Nuclear Waste Policy Act and its amendments and the Department of Energy's plans for management of our Nation's high-level waste in reference to the Jefferson quotation given above.

   b) Ask students what they think Thomas Jefferson would have thought of the provisions of the 1982 law and the 1987 Amendments Act, as well as DOE's plan for the fulfillment of the directives issued to them.

   c) This analysis could also be used as the starting point for a class discussion on participatory democracy with the NWPA and Amendments Act of 1987 serving as a current affairs example.
3. Draw a schematic of the process that occurs if the site being investigated is found suitable for the construction of a geologic repository. Have students assume for this exercise that the State or affected Indian Tribe disapproves and Congress must decide whether to uphold or override the disapproval. Be sure the students include the following in their schematic:

   a) DOE recommendation to the President

   b) Recommendation of the President to Congress

   c) Notice of Disapproval

   d) Congress decides whether or not to override the disapproval

   e) DOE applies to the Nuclear Regualtory Commission (NRC) for authorization to construct a repository (assuming Congress has overridden the disapproval)

   f) Begin construction

   Ask students what effect there would be on the above-listed process if the affected State or Indian Tribe had entered into a Benefits Agreement as provided for in the law.
4. Students may be interested in the efforts of other countries toward managing nuclear waste. You may want to conclude this lesson by watching and discussing the brief video entitled *Worldwide Waste Management.*

Sample Videotape Questions - *Worldwide Nuclear Waste Management*

a) Which country relies most heavily on nuclear power for electricity?

b) What are some of the benefits of using nuclear energy? What are some challenges?

c) How do other countries plan to dispose of spent fuel?

Teacher Evaluation of Learner Performance:

Student completion of reading review and participation in group activity will indicate level of comprehension.

Enrichment:

1. Have students research the *Code of Federal Regulations*, Volume 10, CFR Part 960. **(Order free of charge from the OCRWM National Information Center at 1-800-225-6972; within Washington, DC, 488-6720.)** This might include preparation of a short paper discussing what the *Code of Federal Regulations* is and an application of this to the NWPA and Amendments Act. Students should be asked to discuss the difference between a guideline and a regulation, between a guideline and a law, what process took place in order for this law to pass, what steps were necessary for passage, who voted, etc.
2. The League of Women Voters publication, *The Nuclear Waste Primer*, chapter entitled "Roles for Citizens," includes readings on the role of the public in the high-level waste management program and what citizens can do to stay informed on the issues and influence the development of the program. The readings on low-level waste management concern what citizens can do at both the State and national level. You may wish to have students read this and prepare a role-play activity to simulate interaction of the public and the various government agencies involved with the execution of the NWPA and Amendments Act of 1987. This role-play could be combined with the enrichment activity described at the end of the next lesson entitled *Nuclear Waste: Challenges and Solutions*. The Nuclear Waste Primer may be **ordered free of charge from the OCRWM National Information Center at 1-800-225-6972; within Washington, DC, 488-6720**.
3. Newspaper clippings, magazine articles, etc., expressing various points of view regarding nuclear waste issues may be used in any number of different ways. For example:
   a) Assign a different article to each student. Have students share the point of view expressed in their article with the class and discuss whether they agree or disagree with the author.
   b) Have students role-play the authors of the newspaper articles they have read.
   c) Conduct a mock public hearing with students representing the point of view expressed in the article they have read. You may wish to ask students with very strong opinions on the matter to present the opposing point of view at the hearing.
   d) Communicate the point of view expressed in a student's article by creating an editorial cartoon.
   e) Discuss the role of the media in addressing controversial issues in a democratic society.
   f) If you have required students to keep a nuclear waste issues scrapbook during this course of study, you may prefer to direct them to use these scrapbooks to aid in the preparation for a mock public hearing, role-play and class discussions.

   A selection of newspaper articles and press releases expressing various points of view on this issue may be **ordered free of charge from the OCRWM National Information Center at 1-800-225-6972; within Washington, DC, 488-6720**.
4. The videotape titled *The Monitored Retrievable Storage System* may be viewed and discussed to enhance understanding of the various components of the waste management system.

THE NUCLEAR WASTE POLICY ACT: AN OVERVIEW

The Nuclear Waste Policy Act of 1982 and amendments set forth U.S. policy for disposal of spent fuel from nuclear powerplants and high-level radioactive waste from our Nation's defense programs. Our law requires the U.S. Department of Energy to develop and operate a system that provides safe storage, transportation, and final disposal of these wastes deep underground in a geologic repository. A geologic repository is basically a mine with a special purpose.

3.1 The Laws

What is the Nuclear Waste Policy Act?

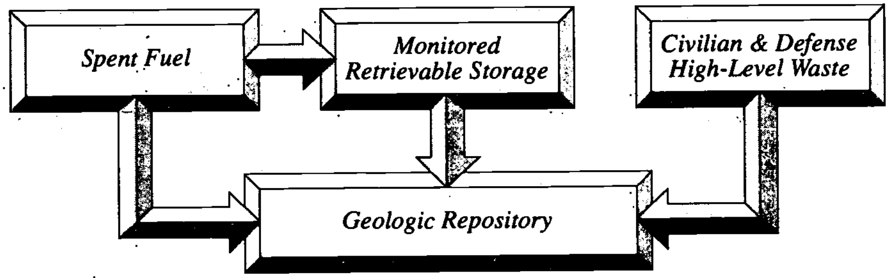
Passage of the Nuclear Waste Policy Act of 1982 (NWPA) was a major milestone in the Nation's management of high-level nuclear waste. The Act was signed into law by President Reagan in January 1983. In December 1987, Congress amended it by passing the Nuclear Waste Policy Amendments Act of 1987.

> Milestone —
>
> A significant event in history...*Getting a driver's license is an important milestone for most teenagers.*

What do the laws require?
What agency is responsible for developing the system?

These laws set forth the national policy for safely storing, transporting, and disposing of spent nuclear fuel and other high-level radioactive waste. They made the Department of Energy (DOE) responsible for carrying out the requirements of the law and created the Office of Civilian Radioactive Waste Management within DOE to do the job. DOE must develop, manage, and operate a waste system to protect the public health and the environment. Specifically, DOE must site, construct, and operate a deep, mined geologic repository. In addition, DOE is authorized to:

- site, construct, and operate one monitored retrievable storage (MRS) facility, under certain conditions; and
- develop a system for transporting high-level nuclear waste to an MRS facility and repository.



The United States has a national policy for safe transport, storage, and final disposal of spent fuel and other high-level nuclear waste.

3.2 Geologic Disposal

When did studies begin?

Planning and working toward final disposal of high-level nuclear wastes is not new. The United States began studies for isolating high-level nuclear waste in 1957 when the National Academy of Sciences first recommended deep geologic disposal. Study of thick deposits of salt as possible repository sites started in the 1960's. During the 1970's, scientific research began in basalt and welded tuff (types of volcanic rock) on lands owned by the Federal Government. In the late 1970's, scientists also began to investigate granite and similar types of rock.

> Isolate —
>
> To set apart from a group or whole... *When he had chicken pox, he was isolated from the other children so they wouldn't catch the disease.*

3.3 History of Finding a Site

How many potential sites were first named?

In February 1983, as required by the law, the Department of Energy named nine potentially acceptable sites for a permanent geologic repository. The sites were in:

Louisiana	(1)	Texas	(2)
Mississippi	(2)	Utah	(2)
Nevada	(1)	Washington	(1)

Are there guidelines for site evaluation?

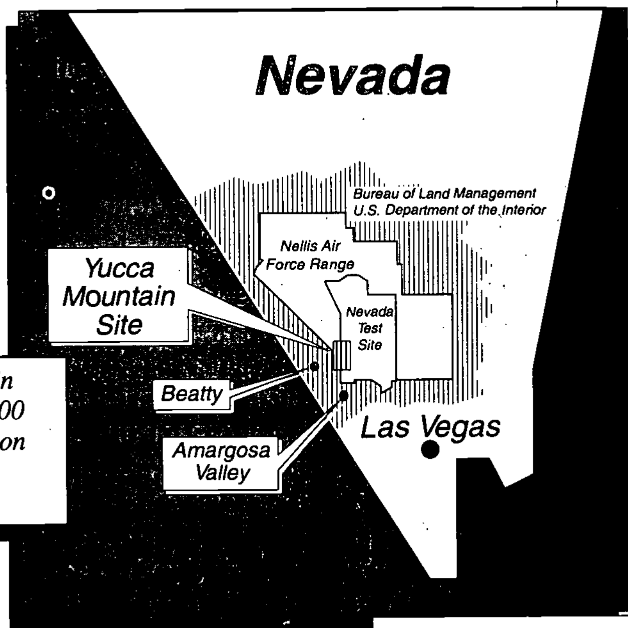
The law also required DOE to issue guidelines that explain how any site will be evaluated to determine whether it is suitable for a repository and that identify specific factors that would disqualify a site. In December 1984, DOE issued guidelines that reflected much consultation, input, and review from the public, States, and Federal agencies. Also, the Nuclear Regulatory Commission (NRC) agreed to the guidelines. This is significant because the NRC must grant a license before any construction can begin on a repository.

Narrowing the Search

What sites were named in 1986?

In 1986, following environmental assessment of all nine sites, the search for a site narrowed. Following the law, DOE recommended three sites to the President for very detailed studies. Following approval, these studies (called site characterization) began at Yucca Mountain, Nevada; Deaf Smith County, Texas; and Hanford, Washington. Congress became concerned with delays and rising costs of this program and, in late 1987, amended the law, directing DOE to focus site characterization efforts only on Yucca Mountain, Nevada. This amendment directed DOE to end studies at the other sites.

What is the only site being studied now? Who named this site?



The Yucca Mountain site is located in Nye County about 161 kilometers (100 miles) northwest of Las Vegas. It is on land already owned by the Federal Government.

Geology — Structure of a specific region of the Earth...*The class studied the geology of the area by looking at the rocks along the Interstate.*

3.4 Site Characterization

Detailed site studies of Yucca Mountain will include both surface and underground studies. These in-depth studies will help determine the capability of the underground site to keep nuclear waste isolated from the environment.

What will happen during site characterization?

Hydrology —

The scientific study of the properties, distribution, and effects of water in the atmosphere, on the Earth's surface, and in rocks and soils...*To understand the hydrology of the area the students studied both surface water and ground water.*

What do we need to know? Many studies will concentrate on the geology and hydrology of the site. What does that mean? It means we need to know as much as possible about the rocks, rock formations, and water at Yucca Mountain. Some specific questions are:

- What is the depth, thickness, and extent of the "host" rock?

What will be studied?

- What is the structure of the "host" rock? What is the rock made of? How did it form? How do the elements that make up the rock respond to heat? To water?

Ground water –

Water found underground in porous rock strata and soils, as in a spring.

- What about ground water? How much water is actually present? Where does it come from? How far is it from the surface to the water table? In what direction does ground water flow? How fast?
- How much surface water is there? Where does it come from? How does it flow? How fast?
- What is the terrain at the site?
- What is the potential for volcanic activity? For earthquakes?
- Are potential resources, like minerals, present?
- What was the climate like in the past? What might it be in the future? How might climate change affect a repository?

Data –

Information, especially information organized or used as the basis for decision-making.... *They collected and analyzed data about the site.*

Goals of Site Characterization

- To determine whether Yucca Mountain is suitable to be developed as a repository.

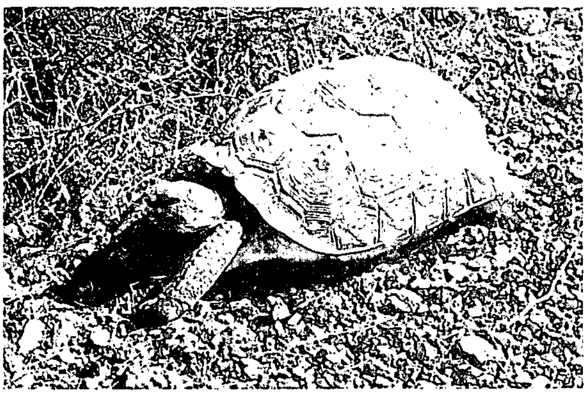
Data collection activities

- To gather information about geology, hydrology, geochemistry, and other conditions of the candidate site.
- To provide data for design of the waste package and the repository itself.
- To provide data needed to assess the performance of the proposed repository system.
- To provide data for recommendation of the site, if it is found suitable through site characterization.
- To provide information to license the repository, if the site is suitable.

3.5 Environment, Society, and Economy: How Are They Affected by the Repository?

What else will be studied?

In addition to conducting purely scientific studies, DOE will also study possible positive and negative impacts of the repository. Special research will focus on impacts on the environment, society, and its economy. For example, are there any species of animals or plants that could be lost as a result of building and operating a repository at this site? Will jobs be created for people living in the area? If sited in Nevada, will a repository have any effect on tourism or economic development and growth within Nevada? Consideration will be given to these and many other questions during site characterization. Ways of lessening adverse impacts will also be considered.



The impact on the desert tortoise will be considered.

Impact –

The effect of one thing on another....*Doing his homework instead of watching TV has a good impact on his grades.*

A report called an *Environmental Impact Statement (EIS)* is required before a license can be issued and construction can begin for the geologic repository. DOE has been collecting environmental data for several years to use in preparing the EIS. Once a site is selected, the U.S. Environmental Protection Agency (EPA) will review and comment on the environmental impact statement, and public hearings will be held to address any questions that are raised.

3.6 Site Selection

If the Site Is Found Unsuitable

What happens if the site is unsuitable?

If, at any time, the site is found unsuitable, site characterization activities will stop. DOE will then report to the Congress and to the Governor and State Legislature of Nevada, detailing reasons for such a decision.

If the Site Is Found Suitable

What happens if the site is suitable?

If, on the other hand, site studies should determine that the Yucca Mountain site is suitable for a repository, DOE can recommend it to the President. If it recommends the site, DOE must notify the Governor and State Legislature of Nevada at the same time. If the President approves, the recommendation goes to the Congress for consideration.

What can Nevada do?

What happens next depends on whether or not the State of Nevada has entered into a Benefits Agreement. By law, unless the State of Nevada has previously entered into a Benefits Agreement with DOE, it may submit a Notice of Disapproval to Congress within 60 days. If it decides to do this, disapproval prevents the use of the site for a repository, ***unless*** Congress passes a Joint Resolution to override the State's disapproval. Congress must act within the next 90 days of continuous session.

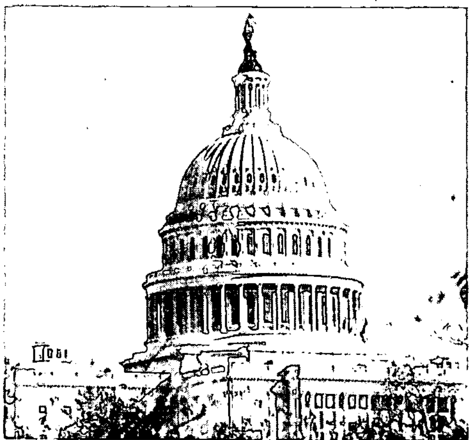
What if there is a Benefits Agreement?

Benefits Agreement
and the Site Selection Process

How does the existence of a Benefits Agreement between the State and DOE affect the site selection process? If a Benefits Agreement exists, the State receives certain payments and other benefits, such as involvement in planning the repository. But if a State enters into a Benefits Agreement, it gives up its right to disapprove a recommendation of the site.

What is the role of Congress?

If no Notice of Disapproval is submitted, or if Congress overrides a Notice of Disapproval, the site designation becomes effective. At that time, DOE can apply to the Nuclear Regulatory Commission for authorization to construct the repository.



Congress must approve the site recommmended for a repository before selection is final.

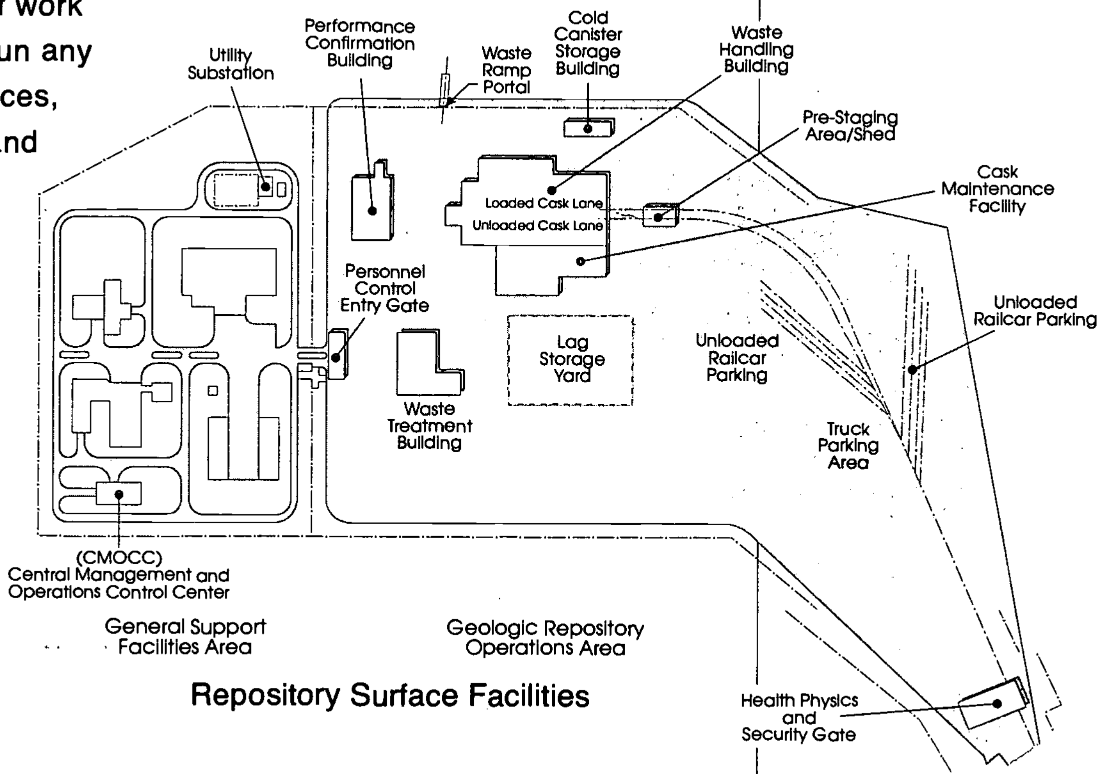
If a State or Tribe Volunteers

There is one other way a location for a repository may be determined. In 1987, Congress established the Office of Nuclear Waste Negotiator. This office is not a part of any other Federal agency or department and reports to the President and Congress. In 1993, Richard H. Stallings was selected as the Negotiator after David Leroy, who had served as Negotiator from 1990-93. His job was to seek a State or Indian Tribe willing to host a repository or storage facility. If a host volunteered, he would work out the terms or conditions under which the State or Indian Tribe would accept a repository or storage facility and submit those terms or condition to Congress for approval. A volunteered site could be used only if it was found suitable. Note: Statutory authority for the Office of the Nuclear Waste Negotiator expired in January 1995. See "Notice to Educators" in the front of this Unit.

3.7 What Might the Repository Look Like?

Should Yucca Mountain be approved as the repository site, the facility will include structures located both on the surface and underground. The surface buildings will cover 150 to 400 acres. Special facilities for receiving, unloading, and handling the containers of spent fuel and other high-level nuclear wastes will be built. There will also be buildings for the kinds of work necessary to run any industry — offices, maintenance and repair shops, warehouses, etc.

How much surface land is needed?



Repository Surface Facilities

The subsurface facility will resemble a large mine of about 567 hectares (1,400 acres). It will include ramps and passageways for moving the waste containers from the surface into permanent disposal within the tunnel floors.

How large will the subsurface area be?

3.8 Monitored Retrievable Storage

Educators, please refer to the "Notice to Educators" at the beginning of this Unit for current information on the concept of a Monitored Retrievable Storage facility. The law also authorizes DOE to site, construct, and operate a monitored retrievable storage (MRS) facility, subject to certain conditions. For

Who can site, construct, and operate an MRS facility?

example, the MRS facility cannot be located in Nevada. Another condition is that construction of the MRS facility cannot begin until a repository is licensed by the Nuclear Regulatory Commission. There is also a limit on the amount of waste that can be stored at any one time in the MRS facility.

What is the purpose of the MRS facility?

How would the MRS facility improve the total system?

To get an independent evaluation on the need for an MRS facility, Congress appointed an MRS Review Commission to study the need for an MRS facility as part of the total system. The Commission recommended that Congress provide for interim storage before permanent disposal. DOE considers an MRS facility to be a key part of the entire nuclear waste management system. That's because it would receive and package spent fuel from some nuclear powerplants and temporarily store it until a repository is ready. From an MRS facility, the waste would be shipped by special trains to the permanent geologic repository. The MRS facility would give the total system flexibility that would enable DOE to meet its goals of timely acceptance and disposal of waste.

A Place for the MRS Facility

Where will the MRS facility be located? What is the job of the Negotiator?

The location for an MRS facility has yet to be identified. One job of the Negotiator, appointed by the President, is to search for a State or Indian Tribe willing to host an MRS facility. The Negotiator will work with interested States or Indian Tribes to find a suitable location.

Waste from some nuclear powerplants could be stored temporarily at an MRS facility.

3.9 Transporting Nuclear Waste

What is the safety record for nuclear waste shipments?

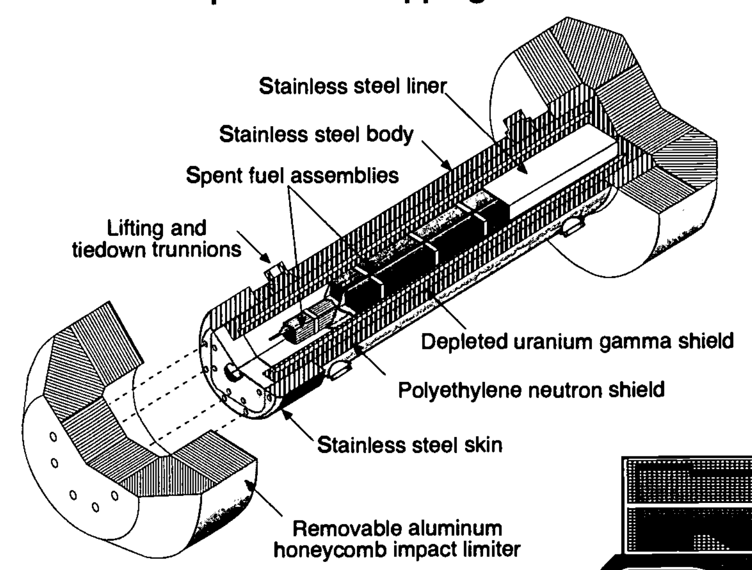
Safe transportation of spent fuel and other high-level nuclear waste is crucial to the success of our waste management system. Fortunately, the United States has 40 years of experience in transporting radioactive materials. Working together, the U.S. Departments of Transportation and Energy and the Nuclear Regulatory Commission have an excellent record of safely transporting highly radioactive material.

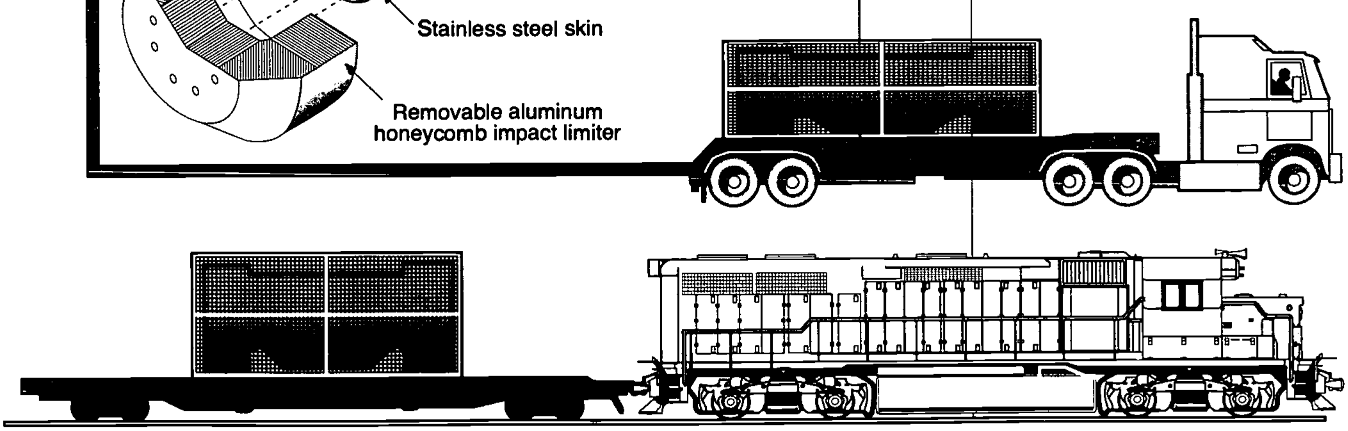
Casks for Spent Fuel

What about casks? Why will new casks be designed?

Spent fuel shipping casks have passed tests that measured their ability to protect their contents even under the most severe conditions. New shipping casks are being developed to minimize the need for handling spent fuel and to carry more spent fuel per cask.

Spent Fuel Shipping Cask





Spent fuel shipping casks may be transported by rail or on interstate highways by flatbed truck.

Who certifies casks?

Certified –

To guarantee as meeting a standard...*Before I got the job, the coach certified that I had passed the lifeguard test.*

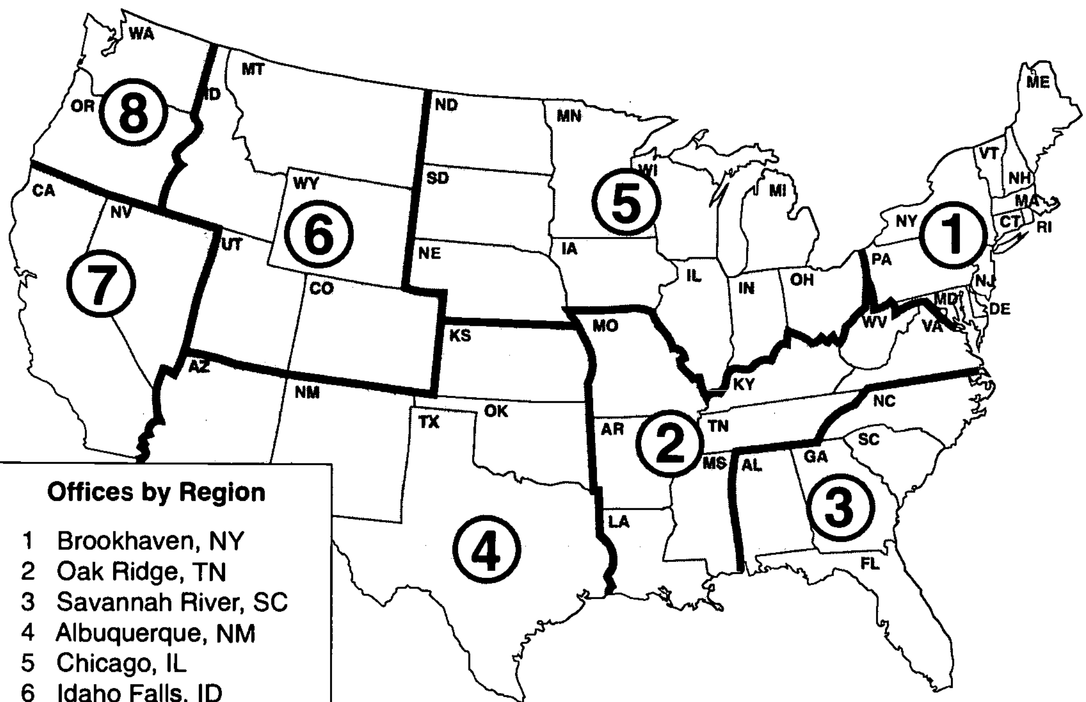
Shipping cask designs must undergo testing and be certified by the Nuclear Regulatory Commission before they can be used.

Other Transportation Issues

Are State, local, and Tribal governments involved?

Federal guidelines apply to transportation of all hazardous materials, including radioactive materials. DOE consults with local, Tribal, and State governments as well as the general public about transportation issues. Existing laws and regulations concerning spent fuel and other high-level nuclear waste shipments will be enforced by local, State, and Federal agencies.

U.S. Department of Energy Emergency Operations Centers



Offices by Region

1 Brookhaven, NY
2 Oak Ridge, TN
3 Savannah River, SC
4 Albuquerque, NM
5 Chicago, IL
6 Idaho Falls, ID
7 San Francisco, CA
8 Richland, WA

There are eight DOE Regional Coordinating Offices and Emergency Operations Centers that can dispatch radiological assistance teams to support State and local responders.

Source: DOE/Oak Ridge Regional Coordinating Office and Emergency Operations Center, 1994.

DOE will provide funding for and assist States in training their local and/or Tribal public safety officials. Procedures for safe transport of high-level nuclear waste will also include rapid response to emergency situations through Energy Emergency Response Centers.

Who will pay for training for safety officials?

3.10 Financial Assistance and Benefits Agreement

The NWPA provides for financial assistance to offset the impacts from siting and/or developing a repository or MRS facility. For example, funds have been provided to the State of Nevada to study issues related to the repository.

Is there financial aid?

Also, the 1987 amendments permit the Secretary of Energy to enter into a Benefits Agreement with a State or Indian Tribe hosting a repository or MRS facility. A Benefits Agreement entitles the State or Indian Tribe to receive certain benefits, including payments. However, a State or Tribe entering into a Benefits Agreement gives up its right to disapprove the site. Annual payments would begin before receipt of the waste and continue until the repository closed. At least one-third of payments would go to those units of local or Tribal governments affected by the facility.

What about the right to disapprove the site?

Will affected local governments be paid?

Benefits Agreement Annual Payments

	Before Waste Is Received	After Waste Is Received
Repository	$10 Million	$20 Million
MRS Facility	$5 Million	$10 Million

How much can Benefits Agreements pay?

A Benefits Agreement also provides for a review panel. The law requires members to be selected to give fair representation to the State, Tribal, and local governments; those paying for the system; and other public interests. The panel would carefully examine and evaluate all phases of the facility — from design and construction to operation and closing. The review panel would: 1) advise the Secretary of Energy, 2) present State, Tribal, and/or local points of view, and 3) participate in planning.

Can the State or Tribe have a review panel?

What would a review panel do?

3.11 The Nuclear Waste Technical Review Board

What is the Technical Review Board? What does it do?

The amended NWPA established a Nuclear Waste Technical Review Board to provide independent technical and scientific evaluation. The members were nominated by the National Academy of Sciences and appointed by the President. Members are people who have distinguished themselves in the fields of science and engineering. The Board examines and evaluates the DOE activities in site characterization and the packaging and transporting of high-level nuclear waste. It reports to both Congress and DOE at least twice each year until disposal begins.

3.12 The Nuclear Waste Fund

Who pays for disposal?

The Nuclear Waste Fund makes it possible for the Federal Government to pay for the development and operation of the high-level nuclear waste management system. Established by the NWPA, the Fund collects money from those who own or generate the waste. Each nuclear powerplant pays a fee for every kilowatt-hour of electricity it produces using nuclear energy. Currently, the fee is one-tenth of one cent for each kilowatt hour of electricity produced. Like all costs of doing business, this cost is typically passed along to the utility company's customers. The Federal Government will pay all costs of defense waste disposal.

3.13 Progress in Implementing the Law and the National Energy Strategy

What is the National Energy Strategy?

Who published it?

Who is responsible for its implementation?

In February 1991, the National Energy Strategy (NES) was published by the U.S. Department of Energy. It presents a comprehensive strategy for producing and using energy in the future and contains more than a hundred initiatives whose implementation is a shared responsibility with the American public, the private sector, academia, and all levels of government. Among other things, it establishes a national commitment and strategies to ensure implementation of the Nuclear Waste Policy Act of 1982 and its amendments to establish an effective U.S. nuclear waste management program.

What does the NES have to do with nuclear waste management?

Specific nuclear waste management actions called for in the Strategy are:

- Ensure that all Federal agencies carry out their activities consistent with the initial operation of a monitored retrievable storage facility to begin accepting spent nuclear fuel by 1998; and,

- Allow the timely characterization of the candidate repository site at Yucca Mountain, Nevada, and achieve the licensing and operation of a high-level nuclear waste repository at a suitable site as expeditiously as possible.

In addition, the Strategy included the commitment by the Department of Energy to develop processes that ensure focused, productive dialogues with all interested parties, and to strive to see that all program managers are aware of and responsive to issues that concern the public.

In February 1992, one year later, the U.S. DOE published a report on the progress that has been made in implementing the strategy. In the area of nuclear waste management and implementation of the Nuclear Waste Policy Act, the following progress was made:

- After a 3-year legal dispute that ended in favor of continuing congressionally mandated studies to determine whether Yucca Mountain, Nevada, is a suitable site for a repository, the Department of Energy received initial environmental permits from the State of Nevada and in mid-1991 began new site investigation work.

- Following discussions with the former Nuclear Waste Negotiator, by February 1992, seven municipalities and Indian Tribes had applied for DOE grants to study the feasibility of siting in their jurisdiction an MRS facility for temporary aboveground storage of nuclear waste. As of October 1994, twenty-four municipalities and Indian Tribes had applied for feasibility study grants, approximately half were awarded.

Who has applied for DOE grants to study the feasibility of siting an MRS in their jurisdiction?

3.14 An Evolving Program

Can the laws change? Why is this important to us?

Unlike many subjects you study, the nuclear waste management program is an evolving program still in the decision-making stages. Many questions remain. One of the strengths of our system of government is that it is structured so that Congress can respond to new or changed circumstances as they arise by amending laws. It is important, therefore, to realize that Congress can amend the laws described here. For this reason, it is necessary not only to learn about the law that governs nuclear waste today, but also to be aware that the law can change. It will be important for you to keep up with current events so that, if and when the law changes, you will continue to be an informed citizen.

OVERVIEW — NUCLEAR WASTE POLICY ACT

Directions: Match the response with the term it *most nearly* describes or defines by placing the appropriate letter on the line provided. Use each response only once.

TERM	RESPONSE
_c_ 1. Site Characterization	a. Nevada may file this if Yucca Mountain is found suitable for a geologic repository
_d_ 2. Nuclear Waste Fund	b. reviews and comments on environmental impact statement needed for licensing and constructing a geologic repository
_k_ 3. Nuclear Regulatory Commission	c. determines if an area is suitable for a geologic repository
_a_ 4. Notice of Disapproval	d. enables the Federal Government to recover costs of developing a disposal system for spent fuel and high-level waste
_g_ 5. NWPA & Amendments Act	e. offers financial aid to offset impacts from siting and developing a repository or MRS; requires forfeiture of right to veto
_i_ 6. EIS	f. seeks State or Indian Tribe to host an MRS facility
_f_ 7. Negotiator	g. established national policy for safely storing, transporting, and disposing of spent fuel and high-level radioactive waste
_h_ 8. Certification	h. spent fuel shipping casks must go through this process before they're approved for use
_b_ 9. EPA	i. required before a license can be issued and construction can begin for the geologic repository
_e_ 10. Benefits Agreement	j. determined by Congress, through passage of the Amendments Act
	k. agreed to DOE guidelines on how sites are evaluated to determine suitability for a repository

39

APPROACHING A COMPLEX TASK

Purpose:

This lesson will help students gain insight into steps involved in approaching a complex task.

Concept:

1. Many steps must be identified and addressed in planning and completing a complex task.
2. Complex technical and societal challenges must be addressed and solved in making decisions about the management of nuclear waste.

Duration of Lesson:

One 50-minute class period

Objectives:

As a result of participation in this lesson, the learner will be able to:
1. identify major steps involved in completing a complex project;
2. design a flow chart illustrating the steps necessary for completion of a complex project;
3. compare and contrast his/her perception of the complexity of a large scale project before and after participation in the design of the activity flow chart; and
4. draw a conclusion about the complexity of the task DOE is faced with regarding the nuclear waste management program.

Skills:

Analyzing, comparing and contrasting, concluding, decision making, designing, discussing, evaluating, graphing

Vocabulary:

Flow chart, societal, technical

Materials:

Activity Sheet

Swimming Pool Construction Flow Chart, p. 55

Suggested Procedure:

1. Explain to students that a decision has been made to build an inground swimming pool. Students are responsible for building this pool. They must consider everything that must be done to complete this project from the time the decision is made until the first swim. Point out to students that there are

a number of steps which should be considered prior to breaking ground for a project of this size. Be sure students understand that they own the land the pool is to be built on and have the necessary money for this project.

2. Because students will be asked to create a flow chart documenting their swimming pool design, you may wish to draw an example of a flow chart, such as the one appearing on the activity sheet entitled *Swimming Pool Construction Flow Chart,* on the chalkboard. Discuss, as a class, the flow chart they will use to help them organize their planning. Be sure students understand that the flow chart is to serve as a planning aid for this complex project; it is to be used to illustrate the steps they have decided are necessary for completion of this project. A number of examples of suggested steps follows.

    a) decision to build
    b) someone in charge
    c) budget
    d) design
    e) cost estimate
    f) builder/contractor
    g) Q/A* inspector
    h) license to build
    i) license to operate
    j) State guidelines
    k) safety regulations
    l) buy supplies
    m) buy equipment
    n) make schedule
    o) connect to water source
    p) design test
    q) fill pool
    r) new bathing suit
    s) suntan lotion
    t) lifeguard
    u) fencing
    v) restrooms
    w) lawn furniture
    x) pool chemicals
    y) State inspection
    z) first swim

3. Break students into small groups and allow them 15 minutes to discuss their approach and gather ideas. Have each group use the activity sheet entitled *Swimming Pool Construction Flow Chart* to create a chart illustrating the steps they have decided are necessary for completion of this project.

    Ask each group to share their flowcharts with their classmates; explaining the steps they have decided are necessary for completion of the swimming pool project.

    If you have time, ask students to identify which of these steps are purely technical considerations, which are purely societal considerations, and which are combinations of both technical and societal considerations. Students should be prepared to discuss why it is necessary to consider both technical and societal challenges in the development of a swimming pool or other complex structure.

4. Ask students if they think this particular project was more complicated than they would have previously thought.

5. Ask students to compare their perception of the magnitude of the technical and societal challenges involved in the completion of their swimming pool construction activity with those involved in the construction of a geologic repository for the storage of high-level nuclear waste.

* Quality Assurance

What follows is a list of guidelines that the U. S. Department of Energy (DOE) must adhere to in their construction of a geologic repository. Briefly discuss these guidelines stressing that all these criteria must be considered and met prior to the construction of a geologic repository for the purpose of permanent disposal of high-level nuclear waste. Be sure to compare the complexity of the geologic repository construction project with that of the swimming pool project just completed.

a) Responsibility — The organizational structure, functional responsibilities, levels of authority, and lines of communication for activities affecting quality must be documented.

b) Quality Assurance Program — A documented quality assurance program shall be planned, implemented, and maintained.

c) Design Control — The design shall be defined, controlled, and verified.

d) Procurement Document Control — Applicable design bases and other requirements necessary to assure adequate quality shall be included or referenced in documents for procurement of items and services. Suppliers must have a quality assurance program consistent with the minimum standards required here.

e) Instructions, Procedures, and Drawings — Activities affecting quality shall be prescribed in accordance with instructions, procedures, or drawings of a type appropriate with the circumstances.

f) Document Control — The preparation, issue, and change of documents that specify quality requirements or prescribe activities affecting quality shall be controlled to assure that correct documents are being used.

g) Control of Purchased Items and Services — The procurement of items and services shall be controlled to assure conformance with specified requirements.

h) Identification and Control of Items — A system shall be established for the identification and control of all materials, parts, and components. (This system should be designed to prevent the use of incorrect or defective material, parts, and components.)

i) Control of Special Processes — A system should be developed which guarantees that only fully qualified personnel will perform specialized jobs such as welding, heat treating, etc.

j) Inspection — A program for inspection of activities affecting quality should be established and carried out to verify adherence to instructions. These inspections should be performed by people other than those who are doing the work.

k) Test Control — A test program should be established to assure that all structures, systems, and components work satisfactorily and in compliance with the design specifications.

l) Control of Measuring and Test Equipment — A system should be instituted to assure that all equipment used in testing is in proper working order.

m) Handling, Storage, and Shipping — A system shall be instituted to control the handling, storage, cleaning, and preservation of material and equipment to prevent damage or deterioration.

n) Inspection, Test, and Operating Status — A system shall be established which clearly indicates the status of inspections and tests performed on individual items used in construction.

o) Control of Nonconforming Items — A system shall be established to control materials, parts, or components which do not conform to requirements in order to prevent their inadvertent use or installation.

p) Corrective Action — A system should be established to assure that conditions adverse to quality are promptly identified and corrected.

q) Quality Assurance Records — Records should be maintained to provide evidence of any activities affecting quality.

r) Audits — A system of planned and periodic audits should be carried out to verify compliance with all aspects of the quality assurance program and to determine the effectiveness of the program.

6. Students should be asked to draw a conclusion regarding the degree of difficulty of the task DOE is faced with in the nuclear waste management program and share this with their classmates.
7. If time is short you may wish to assign suggested procedure 6 for homework.

Teacher Evaluation of Learner Performance:

Discussion and group activity participation will indicate comprehension.

NUCLEAR WASTE CHALLENGES AND SOLUTIONS

Purpose:

This lesson provides students with an opportunity to analyze the provisions of the Nuclear Waste Policy Act and the nature of our Nation's nuclear waste dilemma.

Concepts:

1. In making decisions about the management of nuclear waste, both technical and societal aspects of the challenge must be addressed.
2. In making decisions about managing nuclear waste, public risk perception and the distribution of risk must be considered.
3. In a democratic society, national challenges are solved through striving for legitimate and acceptable decisions arrived at through open and balanced dialogue.
4. Societal decisions are shaped by people's values, perceptions, and analysis of facts.
5. The Nuclear Waste Policy Act of 1982 and amendments established a plan for the safe handling, storage, and disposal of our Nation's spent fuel and high-level radioactive waste.
6. State and public participation in the planning and development of the system is essential in order to promote public confidence in the safety of disposal of high-level nuclear waste and spent fuel.
7. Despite the controversy associated with the managing of our Nation's nuclear waste, it is imperative that this growing national challenge be addressed promptly and responsibly.

Duration of Lesson:

One 50-minute class period

Objectives:

As a result of participation in this lesson, the learner will be able to:
1. identify challenges and solutions associated with nuclear waste;
2. differentiate between technical and societal issues related to disposing of nuclear waste;
3. state ways in which people living in a democratic society make decisions about risks related to technology;
4. explain how and why the Nuclear Waste Policy Act provides for public participation; and
5. explain the Federal role in the management of nuclear waste.

Skills:

Analyzing, discussing, explaining, evaluating, group dynamics, reading, synthesizing

Vocabulary:

Democracy, NIMBY, risk perception, societal, technical

Materials:

Reading Lesson

The Nuclear Waste Policy Act: An Overview, p. SR-1
(Reference)

Activity Sheet

Nuclear Waste Challenges and Solutions (Parts I & II), pp. 57, 59

Transparency

Nuclear Waste Challenges and Solutions (Part I), p. 47

Suggested Procedure:

1. This activity lends itself well to group discussion, but can be equally as effective when assigned as an individual lesson. The suggested procedures that follow relate to presentation of this lesson as a group activity or as a class discussion.

2. Ask students to complete Parts I and II of the activity *Nuclear Waste Challenges and Solutions.* Before they do the activity, it may be helpful to discuss Question a). After students complete the activity, stimulate group discussion by inviting students to share their answers to the questions on the activity sheet. The questions which follow may be used to stimulate further class discussion.

Note:

Part I: *There are no "right" or "wrong" answers to Part I but students should be able to defend their answers by explaining their reasons for placing check marks.*

Part II: *Answers are indicated for Part II. However, students may have different answers that may be acceptable if they can defend their reasoning.*

For Small Group Discussion

a) Before dividing students into groups, review the nature of the Nation's nuclear waste dilemma and how the Nuclear Waste Policy Act addresses these issues. Be sure to discuss the differences between *challenges* and *solutions* and the terms *societal* and *technical* as they relate to the nuclear waste issue.
b) Divide students into groups of 3-5. Go over the instructions for the work sheet and have them work as a group on Part I of the activity *Nuclear Waste Challenges and Solutions.*
c) When all groups have completed their assignment, discuss this activity using the transparency "Nuclear Waste Challenges and Solutions."
d) Assign Part II of the activity to be completed individually during class. Discuss.
e) To culminate your discussion of Parts I and II, ask students if they can identify additional challenges and solutions and categorize them as technical or societal.

For Class Discussion

a) The activity entitled *Nuclear Waste Challenges and Solutions* asks you to identify challenges and solutions as either technical or societal. What do these two terms mean?

(Technical challenges and solutions are those that depend on mechanical or scientific practicability or whether the solution will work or not. For example, a technical challenge is designing casks that will keep radioactive materials from reaching the environment. Societal challenges and solutions are related to human society and interactions among people. The political and economic impacts and effects on people of the environmental impacts of solving the challenge of disposing of high-level nuclear waste are examples of the societal aspects.)

b) Although the technical and the societal aspects have been distinguished for the purposes of this activity, you may want to discuss whether students can think of ways in which these aspects interact, e.g., design decisions will have societal implications if they affect the number of or timing of need for construction workers required to build a facility. Societal aspects of a community will have technical implications, e.g., the presence of workers with the necessary skills to construct and operate the facility.

c) How does the way the Nuclear Waste Policy Act and amendments are written take into account both technical and societal aspects of nuclear waste disposal? Why is this important?

(The NWPA requires that every aspect of the technical plans for the repository and the entire waste management system be thoroughly studied. For example, site characterization is designed to study all important factors of the Yucca Mountain site to ascertain whether the site meets guidelines established for the repository. The findings will be used to design the repository and the waste canister to maximize safety. The NWPA also requires extensive testing of the cask that will be used for transportation. In addition to the characterization of the site, the potential impact of the repository on the economy and environment is being considered and ways of mitigating impact are being developed. The participation of the affected State and local governments and the public that is mandated by the NWPA shows the importance of addressing the societal aspects of nuclear waste management. One reason this participation is important is that it is part of the democratic process and will promote confidence in the safety of disposal of high-level waste and spent fuel. Furthermore, local people may have insights to contribute that might otherwise be overlooked.)

d) One challenge encountered in planning for the disposal of nuclear waste is that there is no accumulation of experience against which the calculations of analysts can be verified, and the time frame for predicting and preventing risk extends thousands of years into the future. How do you feel about this?

(Answers will vary)

e) Experts acknowledge that there are and will be risks in disposing of nuclear waste. In your opinion, are there risks associated with doing nothing about disposing of the existing accumulation of nuclear waste? Explain.

(Answers will vary)

f) How does the fact that the United States is a democracy influence the way we solve national challenges? How does the way the Nuclear Waste Policy Act of 1982 (NWPA) and the Amendments Act are written take into account the fact that this is a democracy?

(In a democratic society, national challenges are solved through striving for open and balanced dialogue in arriving at legitimate and acceptable decisions. When Congress drafted the NWPA and the Amendments Act, it took this into account by providing for participation by affected States, Indian Tribes, and local governments and also by the public.)

g) Societal decisions involve questions of values and people's values differ. A major challenge is distribution of risk. How does the NWPA address the question of distribution of risk?

(In our democracy, insistence on basing decisions only on facts developed by experts will not work very well. Technical information is critically important. However, the experts and various publics have to engage in a two-way exchange of ideas and opinions in settling difficult challenges. It is inevitable that the risk cannot be distributed to everyone in the Nation in the same way. This is also the case with many other risks in our society. The NWPA makes special provision for input from those who will bear the greatest burden of risk and also provides for some mitigation of risk in the form of benefits.)

h) Discuss the NIMBY (Not In My Back Yard) phenomenon. Ask students to identify controversial situations in their community or State and relate their thinking about the resolution of the controversy, including the process and how their personal values influence their thinking.

(Answers will vary)

i) Why are Indian Tribes named specifically by the NWPA? How could they be affected by the siting of a geologic waste repository?

(Indian Tribes have a unique status with relationship to individual States and to the Federal government. They have treaty rights with the U.S. Government that could be affected by the repository and the transportation of waste. Therefore, Congress decided to include Indian Tribes in the NWPA and gave them equal status with the States.)

j) What are some societal and economic challenges and benefits associated with siting a nuclear waste repository in an area?

(The most important concern people have about siting a nuclear waste repository relates to the health and safety of their families. They want to be sure the facility will not harm them, others in the community, or the environment. An increase in the number of people in an area can create challenges, especially in rural areas where services are limited. The area would need more housing, shopping areas, schools and classrooms, hospital beds, etc. The area would need more teachers, doctors, dentists, firemen, police, and services such as water supply and garbage pickup. The roads in the area would have more traffic and might need to be improved. Some people also are concerned about the particular effects that might occur; e.g., that using land for a repository might also have a negative impact on the area by discouraging new families or businesses from locating there or discouraging tourism. Others may be concerned more generally about how the repository might affect their present way of life.

A repository would also bring some benefits. Grants would compensate for expenses incurred by the community. Workers would be employed for construction of the repository. Afterward, workers would be employed to operate the facility. The wages earned by these people would add to the local economy. Some of their earnings would help pay taxes. They would spend money on housing, transportation, food, clothing, medical and dental care, and other goods and services. People already living in the area might welcome the positive changes that a repository might bring, such as better degree of cultural diversity. This would create additional jobs and strengthen the area economy.)

k) Why do you think the Federal Government is responsible for the high-level nuclear waste management program?

Have students write a brief summary of what they have learned in this lesson.

Teacher Evaluation of Learner Performance:

Teacher observation of group discussions, class debate, and completion of activities will indicate understanding.

Enrichment:

1. "...Furthermore, questions of acceptable risk, not so critical in other issues, will be paramount on science-related issues. Who gets to define acceptable risks where the people making the decisions and the people actually at risk are not the same? Or consider the dilemmas that arise when scientists preference for 'maybe' answers runs head-on into a political system that needs to decide 'yes' or 'no' — and make decisions more quickly than the pace of research might dictate."*

   Apply this quote in an essay or class discussion to what you have read and discussed so far in this Unit. Be sure to include consideration of the NWPA, the Amendments Act, and the questions discussed previously in this lesson.

2. Actual newspaper clippings **(order free of charge from the OCRWM National Information Center at 1-800-225-6972; within Washington, DC, 488-6720)** expressing various points of view regarding the site characterization of Yucca Mountain, Nevada, for purposes of determining suitability for a geologic repository may be used in any number of different ways. For example:

   a) Assign a different article to each student. Have students share the point of view expressed in their article with the class and discuss whether they agree or disagree with the author. Students should be able to defend their position.

   b) Have students role-play the authors of the newspaper articles they have read.

   c) Conduct a mock public hearing with students representing the point of view expressed in the article they have read.

* Source: Mathews, David. *The Promise of Democracy* (Dayton, Ohio: Kettering Foundation, 1988), p.109.

PART II

Managing our Nation's nuclear waste is a complex technical and societal issue. What is the U.S. government's planned response to this issue?

Directions: In the blank provided, write the number of the U.S. government's planned response to each challenge listed. There may be more than one response to a challenge.

CHALLENGE

5	A.	There was no national policy for safely storing, transporting, and disposing of spent nuclear fuel and high-level waste.
2,6,9, 10,12	B.	The site selected for the repository must meet strict guidelines developed to ensure safety of the environment and the public.
1,3,7 9,12	C.	High-level waste and spent nuclear fuel are major subjects of public concern.
8,11	D.	Disposing of spent fuel and high-level waste is expensive.
1,3,7, 9,12	E.	It is important that the public have confidence in the safety of disposal of spent fuel and high-level waste.
1,4,7	F.	Spent fuel and high-level radioactive waste must be transported safely.

PLANNED RESPONSE

1. following transportation regulations of Federal, State, and local agencies
2. studies to evaluate geologic formations
3. independent review of all aspects of the waste disposal program
4. shipping casks subjected to tests
5. The Nuclear Waste Policy Act and amendments passed by Congress
6. field and laboratory testing at potential site
7. transportation procedures being developed with State, Tribal, local governments, and public input
8. U.S. government required to pay costs for disposing of defense high-level waste
9. environmental assessments and environmental impact statements
10. detailed site characterization
11. utilities pay fee for all electricity generated by nuclear energy
12. State and local government and public participation in the planning and development of the repository required

RISK PERCEPTION AND JUDGMENT

Purpose:

This lesson introduces the concept that every human activity involves some degree of risk.

Concepts:

1. Risk has many dimensions.
2. Every human activity involves some degree of risk.
3. In making decisions about managing nuclear waste, public risk perception and distribution of risk must be considered.
4. Both risk management and risk assessment are important aspects of the waste management program.

Duration of Lesson:

Two 50-minute class periods

Objectives:

As a result of participation in this lesson, the learner will be able to:

1. explain why he/she ranked the various items on the risk activity as he/she did;
2. discuss risk and what can be done to reduce it in his/her own life; and
3. discuss both positive and negative results of risk management limitations.

Optional Objectives:

As a result of participation in the computer activity *Risk Perception*, the learner will be able to:

1. rank the 30 items on the diskette in accordance with his/her perception of degree of risk involved in each;
2. compare his/her ranking with that of the class as a whole and with rankings done by four other groups; and
3. speculate about why the rankings differ.

Skills:

Critical thinking, discussing, ranking given items

Vocabulary:

Distribution of risk, judgment, risk assessment, risk management, risk perception, trade-off

Materials:

Activity Sheet
Risk, p. 61

Transparency
Ordering of Perceived Risk, p. 49

Computer Diskette
Risk Perception and Judgment **(Order free of charge from the OCRWM National Information Center, 1-800-225-6972; within Washington, DC, 488-6720) (Available for IBM or IBM compatible PCs.)**

Background Notes
Risk Perception and Judgment, p. 25
The Debate About Risk, p. 26

Suggested Procedure:

1. Before passing out student copies of the activity entitled *Risk,* it may be helpful to explain to students that the activity they are going to be working on is an adaptation of a study conducted on risk perception in 1976. This particular study involved questioning four different groups of people. Three groups were from Eugene, Oregon; they included 30 college students, 40 members of the League of Women Voters, and 25 business and professional members of a group called the Active Club, which is a community service organization. The fourth group consisted of 15 persons selected nationwide for their professional involvement in risk assessment. This particular group of experts included a geographer, an environmental policy analyst, an economist, a lawyer, a biologist, a biochemist, and a government regulator of hazardous materials.

   Participants in this study rated 30 activities, substances, and technologies according to the present risk of death from each. These people were asked to consider the risk of dying (not just to themselves, but to anyone in society in general) as a consequence of the activity or technology being considered.

   The four groups of participants were given 30 index cards upon which a particular activity, substance, or technology was written. They were told to study the 30 items individually, thinking of all the possible ways someone might die from each. The next step was to order the items from least to most risky and then assign a numerical risk value to each by giving a rating of 10 to the least risky and making the other ratings accordingly. Respondents were given additional suggestions, clarifications, and encouragement to do as accurate a job as possible.

   The activity your students will engage in has been modified to make it more appropriate for classroom use. The modifications will influence results. Student interest should be piqued by comparing their results to the results of the other groups mentioned above. It is important that they understand that their results have been influenced by the modifications made in order to adapt the activity for classroom use. Students should also be aware that the table shown in the transparency is based on a very limited sampling.

   Additionally, it might be well to remind students that this study was conducted in 1976 and they should keep in mind while comparing responses that a great deal has happened and many things have changed since 1976 which cannot help but influence responses.

2. After allowing approximately 15 minutes for students to complete the activity, ask students to list their two most risky choices and their two least risky choices and write a few sentences explaining the rationale for their rankings.

3. Discuss student choices. You may wish to begin this discussion by pointing out that many authors prefer the term *judgment* to *perception*. Experts' and laypersons' assessments of risk both constitute judgments. But the separate groups may consider different factors to be relevant. (Perhaps students can better appreciate the last point if they are reminded that sometimes they and their parents have opinions that are divergent, at least in part because different factors are considered important.) Then discuss the question listed below.

Sample Discussion Questions:

a) What items did you rank high? Low? Why?

b) What do you think are the risks associated with the activities or technologies in the exercise? The benefits? What does the term "trade-off" mean? Why is the term "trade-off" often used in reference to risks and benefits of technologies?

c) What are the costs of reducing risk for the activities in this exercise? The benefits? (Do not limit your definition of cost to money. Consider such things as societal and environmental costs also.)

d) What can be done to reduce risk in our lives? What should be done to reduce risk in our lives? Should all methods be used? What should the role of the government be?

e) Do you think some level of risk in our lives is acceptable? Why or why not?

f) How should decisions to determine levels of acceptable risk be made? What should the role of the government be?

g) Should everyone be made to reduce his or her personal risk in activities? Should there be penalties if people don't? Are there examples in your life where this is occurring? Can you think of instances mentioned in the news? How do you feel about it?

h) What are some of the risks you face in your life? What could you do to reduce risk in your own life?

i) How has the development of technology affected risk? (Be sure to discuss both positive and negative effects.)

j) How can we measure risk?

k) Generally, making decisions about technology involves risk management. Risk management involves both (1) providing for safety (e.g., the design of technology, laws and regulations that affect design and operation, ensuring workers are properly qualified, plans made in case challenges should occur, etc.), and (2) striving for consensus in situations where people disagree about the riskiness of the technology or whether or where facilities should be constructed. Risk estimates are determined as part of a process called risk assessment. What are the positive results of risk management? What are the limitations of risk management?

(Performing risk assessment requires technical professionals, such as scientists and engineers, to identify challenges associated with the technology they are working on. After challenges are identified, ways of addressing the challenge can also be identified so as to provide safety. However, risk assessment cannot represent absolute truth. There is an inevitable element of judgment that selects or ignores particular aspects of a challenge being studied. These judgmental elements are incorporated into modeling and technical calculations and thus affect the knowledge that is produced.)

l) Explain the application of risk management to something you are familiar with, such as the automobile or sports. Does risk management guarantee absolute safety?

(For automobiles students may identify traffic laws, auto and highway design, driving lessons, etc. For sports they may identify such things as rules, equipment, coaching, etc.)

Following the discussion of the above questions, show students the transparency *Ordering of Perceived Risk*. (This list is taken by permission from "Perception of Risk," Paul Slovic, Vol. 236, pp. 280-285, Table 1, Science, April 17, 1987.) Ask students to compare their ranking with the rankings listed and speculate as to why the rankings are different.

If you have access to computers in your school or classroom, you may wish to make use of the computer diskette provided with this unit of study. This diskette can be used in conjunction with the written activity on risk. Students engage in the same ranking required by the risk activity; however, they receive immediate feedback relative to how their classmates and others have ranked each item on the activity. Specific instructions are included in this Teacher Guide.

m) Which activities or technologies were ranked about the same by all four groups? Why do you think this happened? Which ones were ranked very differently? Why? As part of this discussion, have students identify events that have occurred since 1976 when the other rankings were done. These events may have influenced their personal or class rankings.

n) How do you think each group "measured" risk?

o) What do you think is the significance of the fact that the different groups rank these items differently? Does this mean that the "experts" are right and the other groups are wrong? Of what importance is understanding that different groups see risk differently? How do you think we should deal with these differences in our democracy?

Have students write a short paragraph explaining the significance of this lesson to them.

> The computer program, student activities, and some teacher notes for the lessons on risk are based on information used by permission from "Facts and Fears: Understanding Perceived Risk" by P. Slovic, B. Fischhoff, and S. Lichtenstein, in *Societal Risk Assessment: How Safe is Safe Enough*, published by Plenum Publishing Corporation, New York, 1980.

Teacher Evaluation of Learner Performance:

Participation in class discussion, completion of the activity sheet entitled *Risk* and completion of the assigned paragraph explaining the significance of this lesson to them will indicate level of comprehension.

Enrichment:

Probability: the Language of Risk Assessment, pp. 65, 66
Reading Lesson and Activity

Factors Affecting Risk Judgments, p. 67
Activity

Read the following quotations, then consider and discuss just how one decides which experts to believe when opinions are divergent. Do you think that choosing which experts to believe should be a political decision? Why or why not?

"'Shipping high-level nuclear materials across the country to Yucca Mountain is not a gamble the public should allow the Department of Energy to take,' said the author of several books criticizing America's radioactive waste policies.' They should leave that kind of risk taking to the casinos,' said Marvin Resnikoff, a New York physicist and radioactive waste management consultant. 'Let them roll that kind of dice in the casinos and not on our highways.' " (Review-Journal, Las Vegas, Nevada 4/24/90)

" To date, most accidents and leakages in transit have involved low-level wastes, and no deaths or serious injuries have been traced to them. In fact, compared to transport of other hazardous materials, radioactive shipments have an excellent record...." (*The Nuclear Waste Primer, A Handbook for Citizens*. The League of Women Voters Education Fund, OCRWM National Information Center, Washington, DC, 1993)

RISK PERCEPTION AND JUDGMENT

The activity entitled RISK requires students to rank 30 specified activities according to their perception of an individual's risk of dying in any given year from these activities.

In the table below these same 30 activities are ranked according to their actual contributions to the number of deaths in the United States as they have been determined by actuarial estimates. That information appears in the first column; the remaining columns record geometric mean information for other groups questioned in the 1976 research.

Fatality Estimates and Disaster Multipliers for 30 Activities and Technologies

		Geometric Mean Fatality Estimates Average Year	
Activity or Technology	**Technical Fatality Estimates**	**League of Women Voters**	**Students**
1. Smoking	150,000	6,900	2,400
2. Alcoholic beverages	100,000	12,000	2,600
3. Motor vehicles	50,000	28,000	10,500
4. Handguns	17,000	3,000	1,900
5. Electric Power	14,000	660	500
6. Motorcycles	3,000	1,600	1,600
7. Swimming	3,000	930	370
8. Surgery	2,800	2,500	900
9. X-rays	2,300	90	40
10. Railroads	1,950	190	210
11. General (private) aviation	1,300	550	650
12. Large construction	1,000	400	370
13. Bicycles	1,000	910	420
14. Hunting	800	380	410
15. Home appliances	200	200	240
16. Fire fighting	195	220	390
17. Police work	160	460	390
18. Contraceptives	150	180	120
19. Commerical aviation	130	280	650
20. Nuclear power	100[a]	20	27
21. Mountain climbing	30	50	70
22. Power mowers	24	40	33
23. High school & college football	23	39	40
24. Skiing	18	55	72
25. Vaccinations	10	65	52
26. Food coloring	___[b]	38	33
27. Food preservatives	___[b]	61	63
28. Pesticides	___[b]	140	84
29. Prescrition antibiotics	___[b]	160	290
30. Spray cans	___[b]	56	38

[a] *Technical estimates for nuclear power were found to range between 16 and 600 annual fatalities. The geometric mean of these estimates was used here.*

[b] *Estimates were unavailable.*

THE DEBATE ABOUT RISK

Contributions to the debate about risk have increased dramatically over the past 10-15 years. Yet, a lack of agreement continues to exist in the academic community over how to define risk.

The concept *risk* is enormously complex. Our understanding of the complexity of the concept has increased as specialists from different disciplines have investigated what we mean when we say that a technology or activity is risky. Initially, engineering safety studies of nuclear reactors, which strongly influenced the emergence of modern-day risk analysis, defined risk in probabilistic terms. They defined risk as the product of the probability and consequences of an adverse event, and developed and compared quantitative estimates of the risk (i.e., probability) of dying from various technologies. This definition of risk began to change as new findings appeared.

Psychologists who subsequently studied the individual's response to risk discovered that the people whom they interviewed did not rate risk in the same way as experts in the field of probabilistic risk analysis. Experts' rating of various activities and technologies correlated highly with statistical frequencies of death; laypersons' judgments incorporated considerations other than annual fatalities. Factors such as whether the technology could have catastrophic consequences or whether the technology was unfamiliar appeared to influence the layperson's judgment of risk.

More recently, anthropologists and sociologists have pointed out that the issue of risk is more complex than studying people's responses. They emphasize that social factors affect the way we *select* risk and that these factors affect the judgment of both experts and members of the public. Thus, factors such as our educational, family, or occupational background affect our judgment of which dangers we are afraid of, which risks should be taken, and who should take them. These factors affect our judgment of what we need to examine in conducting risk analysis and our evaluation of the consequences.

As a result of these various studies, we are beginning to realize that making decisions about risk is much more complex than developing probabilistic estimates. The kinds of problems that we are facing are what Alvin Weinberg[1] has called *transscientific* problems—problems that cannot be answered by science because they involve questions of values as well as facts. A primary purpose of this classroom activity on risk is to facilitate students' awareness of the complexity of the risk concept and recognition that there is no one best *factual* answer to questions about risk. Hopefully, this unit will stimulate discussion of ways in which, in a democratic society, we can make decisions about risk.

[1] Former Director of the Institute for Energy Analysis of the Oak Ridge Associated Universities, Oak Ridge, TN.

RISK PERCEPTION COMPUTER ACTIVITY

For the Teacher:

Computer Equipment Required

This computer activity can be run on an IBM or IBM-compatible personal computer.

Student Directions

Directions for students are included in *Risk Perception Computer Activity* on the previous page.

For More Efficient Use of Computer Time

Before students sit down at the computer terminal, they should have access to a list of the 30 items they will be ranking. This will allow them to think over the options and compare them ahead of time. If each student does the entire exercise on-line, it will take a lot of time for the class to complete the activity.

Resetting the Program

At the beginning of each class, clear rankings of previous classes by typing INITCL <Enter>. This will delete the ranking of the previous class so the new class can see only its own class ranking.

Preparing the Computer

To begin the program, put the 3-1/2" or 5-1/4" disk in the drive that accepts these disks. Then change the directory to that drive. For example, put the 3-1/2" or 5-1/4" disk in drive A:> and then type A: at your C:> prompt so that you are working on the A:> drive. At the A:> prompt, type RANK and the program will begin to run.

Order disk free of charge

from the OCRWM National Information Center at 1-800-225-6972;

within Washington, DC, 488-6720

PROBABILITY

The Language of Risk Assessment

Purpose:

This lesson will demonstrate how scientists and decision makers, who are involved in determining methods of protecting health or improving safety, quantify relationships among risks by developing mathematical probabilities. Using probabilities facilitates discussion and comparison of risks related to science and technology in a more systematic manner. Students will develop an appreciation for the fact that (1) judgment is an inevitable element in selecting criteria for quantifying risk, and (2) someone still has to make the decision of whether or not this level of risk is acceptable.

Concepts:

1. Scientists quantify relationships among risks by developing mathematical probabilities.
2. Every human activity involves some degree of risk.
3. Judgment is an inevitable element in selecting criteria for quantifying risk.
4. Someone has to make the decision of whether or not a level of risk is acceptable.

Duration of Lesson:

One 50-minute class period

Objectives:

As a result of participation in this lesson, the learner will be able to:
1. discuss probabilities and risk assessment on an introductory level; and
2. discuss limitations of using probabilities in making societal decisions.

Skills:

Discussing, reading

Vocabulary:

Acceptable level of risk, probabilities, quantify, risk assessment

Materials:

Reading Lesson
Probability: The Language of Risk Assessment, p. SR-15

Activity Sheet
Probability: The Language of Risk Assessment, pp. 65, 66

Suggested Procedure:

1. A key factor in any discussion of risk assessment is calculation of the probability that an event will occur. It is important for students to understand that probabilities are simply that — probabilities — and offer no guarantees. Additionally, using probabilities has limitations.

2. You may wish to begin this study of probabilities by discussing the definition of probability. Once students feel comfortable with the terminology, assign the reading lesson entitled *Probability: The Language of Risk Assessment*. Allow approximately 15 minutes for reading and then discuss briefly.

Sample Discussion Questions:

a) Name a few ways in which you use probability or are affected by probability in your daily life.

(Deciding whether to carry an umbrella, wear a coat, evacuate your home in the face of a hurricane warning, etc. If you drive a car, the insurance rates are determined by insurance companies using probabilities.)

b) Why are probabilities involving health and safety risks to humans more difficult to determine than those dealing with card games?

(Probabilities involving health and safety risks to humans are more difficult to determine than many other types because a vast body of knowledge is often required before making predictions and testing of the whole system is not feasible.)

c) A common rule used in some cases by regulators involved in determination of human health risks is that a technology (new chemical, new industrial plant) is "safe" if exposure to the technology does not raise the health risk of the human population by more than one chance in one million. What do you think of this rule? What are some complications that might arise?

(Answers may vary; however, when discussing possible complications you should look for students to mention such things as the difficulty in knowing the rate of cancer or accidental deaths in a population before introducing a new exposure, background probability of health risks, use of animals in laboratory experiments, and the fact that biological differences between the test population [laboratory animals] and the human population introduce some uncertainties.)

d) Think of some event you have heard of recently (through the newspaper, TV, radio, family, friends, teachers, etc.) that could have been predicted through use of probabilities. Explain or illustrate why you think this particular event could have been predicted.

Note:

These questions might lend themselves to some good small group discussions with each group "reporting back" to the class on the results of their discussion.

When you have concluded the class discussion, assign the reading review entitled *Probability: The Language of Risk Assessment* to be completed in class or for homework.

Once students have completed the exercises, have volunteers go to the chalkboard to demonstrate how they worked specific problems. If you used this as a group activity, have each group choose a representative to share their answers.

As a culminating exercise for this lesson you may wish to have students discuss or write an essay on the function that risk assessment and probabilities serve in a technological society.

(Risk assessment and the development of probabilities are a blend of the predictive power of the sciences, which varies depending on the specific process, with analyses of human behavior. They attempt to bridge the gap between the sciences and the need for a decision-making tool in a technological society. The risks of a new or existing technology can be estimated and weighed against the benefits of that technology and the things the society values.)

Teacher Evaluation of Learner Performance:

Discussion participation and response to reading review will indicate level of comprehension.

Enrichment:

Probability Exercises, p. 71
Probability Exercises: Challenge Level, p. 73

PROBABILITY: THE LANGUAGE OF RISK ASSESSMENT

3.15 Introduction

One step in protecting public health and improving public safety is determining the risks involved with activities and technologies. To be able to discuss and compare risks, a common language is needed. For this reason, scientists and decision makers quantify relationships among risks by developing number values called mathematical probabilities.

How and why do scientists "quantify" relationships among risks?

3.16 Everyday Use of Probability

How "likely" something is to occur is known as "probability." Most people, including you, use probability in their everyday lives. For example, a local weather forecaster (or meteorologist) may forecast rain. The forecast is made by comparing scientific knowledge gained from observing similar conditions in the past to the existing weather conditions. Through this comparison, the meteorologist can tell us what percent chance of rain there is. Then you can decide whether or not to carry an umbrella. If you are cautious, you may decide to carry an umbrella if there is only a 30 percent chance of rain. Or you may wait until a 70 percent of rain is forecast.

What is probability?

What was the weather forecast?

Percentages and probabilities are related but not the same. Percentages are a mathematical statement of how many times out of 100 something happens. Probabilities refer to just one happening. For example, a 30 percent chance of rain at a particular weather station means that given these same weather

How are percentages related to probability?

conditions for 100 different days, it is expected to rain 30 of those days. The probability of rain for any one of those days is 30 divided by 100, which equals 30/100 or .30.

$$30 \div 100 = .30$$

Repeated Observations and Experiments

What is the mathematical formula for determining probability?

Most of the probabilities we use in every day life are determined from simply observing what happens every time certain conditions arise or from repeating an experiment many times. The number of times that a specific outcome occurs, divided by the total number of times the experiment is repeated, is the probability that the specific outcome will occur. This is useful for making predictions about what will happen in the future.

$$\frac{\text{Number of times outcome occurs}}{\text{Total number of repetitions}} = \text{Probability}$$

Let's use an example similar to the one above. The same weather conditions were observed and recorded for 100 days during the past 2 years. Forty of those 100 days were sunny and warm. This Tuesday, we expect the weather conditions to be very similar to those 100 days observed in the past 2 years. What is the probability that this Tuesday will be sunny and warm?

$$\frac{\text{40 sunny days}}{\text{100 repetitions}} = \frac{40}{100} = 0.40$$

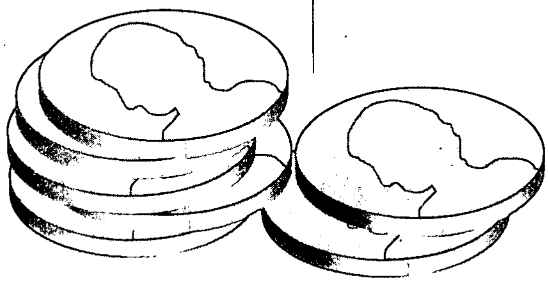
Common Sense

What is a .50 probability?

Some probabilities are common sense. For example, we know that when we flip a coin, there are only two possible outcomes —heads or tails. So there is a 50 percent chance (a 0.50 probability) that the coin will land heads up. There is also a 50 percent (0.50 probability) chance that it will land tails up. If we want to know how many times a coin is expected to land heads up on a certain number of flips, we don't have to actually flip the coin. We can simply multiply the probability of heads by the number of times we would flip the coin.

10 Flips?
10 x 0.50 = 5 Heads

2,000 Flips?
2,000 x 0.50 = 1,000 Heads



Heads or tails?

Random events like the coin flip cannot be predicted with certainty. Every time the coin is flipped, there is a 0.50 probability of heads and a 0.50 probability of tails. If a lot of flips in a row land heads up, the probability that the next flip will be tails is still 0.50. But the more total times the coin is flipped, the more likely it is that heads will occur 50 percent of the time and tails 50 percent.

Can outcome always be predicted with certainty?

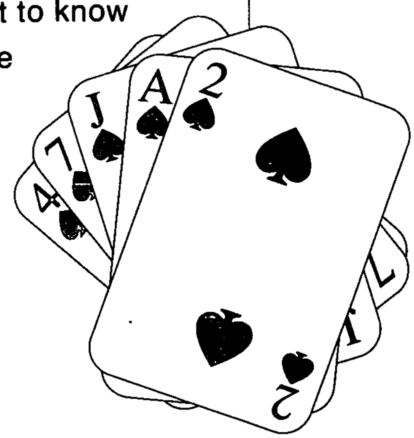
3.17 Figuring Probability

The same principles apply to other events. Suppose there are a certain number of possible outcomes to an event, and each event has an equal chance of happening. Then the probability of each outcome is 1 divided by the number of possible outcomes.

What is the probability of drawing the ace of spades from an ordinary deck of cards?

For example, the probability of drawing the ace of spades from an ordinary deck of cards is 1/52. Now, if we want to know the probability of drawing any ace on one draw, we add the probabilities of getting a particular ace together. There are four aces out of the 52 cards, or one ace per suit. The probability of drawing any of the four aces on a single draw is 1/13.

$$\frac{1}{52} + \frac{1}{52} + \frac{1}{52} + \frac{1}{52} = \frac{4}{52} = \frac{1}{13}$$



How many aces are there in a deck of cards?

For example, you may want to know the probability of drawing the ace of spades from an ordinary deck of cards. There is only 1 ace of spades in the deck of 52 total cards. That would be:

$$\frac{\text{1 favorable outcome}}{\text{52 possible outcomes}} = \frac{1}{52} = 0.02$$

If you want to know the probability of drawing any ace, you can apply the same formula. There are 4 aces out of 52 cards (1 ace for each suit). This means there are 4 favorable outcomes out of 52 possible outcomes.

$$\frac{4}{52} = \frac{1}{13} = 0.08$$

You could also add together the probabilities of getting a particular ace.

$$\frac{1}{52} + \frac{1}{52} + \frac{1}{52} + \frac{1}{52} = \frac{4}{52} = \frac{1}{13} = 0.08$$

How do we determine the probability of independent events occurring together?

Suppose you are playing cards and you want to know the probability of drawing a particular hand — 5 cards of the same suit (a flush). Think of each draw as a separate event. Remember also that the number of favorable and possible outcomes will be reduced by one after each draw.

First draw: There are 13 favorable cards out of 52 total cards

$$\frac{13}{52}$$

Second draw: There are now only 12 favorable draws out of

51 cards $\frac{12}{51}$

Third draw: There are 11 favorable cards remaining out of

50 cards $\frac{11}{50}$

Fourth draw: There are 10 favorable cards remaining out of

49 cards $\frac{10}{49}$

Fifth draw: There are 9 favorable cards remaining out of

48 cards $\frac{9}{48}$

To determine the probability of independent events happening together, you must multiply the individual probabilities together. So for drawing a flush:

$$\frac{13}{52} \times \frac{12}{51} \times \frac{11}{50} \times \frac{10}{49} \times \frac{9}{48} = \frac{154{,}440}{311{,}875{,}200}$$

$$= 0.000495$$

$$= \frac{495}{1{,}000{,}000} \text{ or 495 in 1 million}$$

Multiply by 4 to account for all 4 suits:

$$\begin{array}{r} 0.000495 \\ \times \quad\quad 4 \\ \hline 0.001980 \end{array} \quad \text{or} \quad \frac{198}{100{,}000}$$

The chance of drawing a flush in any suit in 5 draws is 198 in 100,000. If you drew five cards 100,000 times, you would be likely to draw a flush 198 times.

3.18 Health and Safety Risks

Why are probabilities involving health and safety risks to humans hard to determine?

Other probabilities, including those for health and safety risks to humans, are harder to determine. A lot of information may be needed to make a prediction. Or testing the whole system may not be possible. However, once the basic probability for each possible outcome is known, the same rules apply and can be used to make reasonable predictions.

For instance, suppose that, by law, a company cannot distribute a machine until certain safety standards are met. The company knows the machine will not operate safely if two particular parts break down at the same time. This situation could exist if one part is a backup for the other. The company couldn't wait until after the machines were distributed to see how many times out of 100 the two parts would break down at the same time.

However, the company could conduct tests on each part to find the probability for each part breaking down. Then these probabilities could be multiplied to determine the probability of both parts failing at the same time.

For example, suppose tests determined that the probability of part A breaking down was 0.05 and the probability of part B breaking down was 0.02. Then the probability of both parts breaking down is 0.05 x 0.02. This equals 0.001 or 1/1,000 (one in a thousand). If that level of risk is acceptable to the company and meets industry regulations, then the company could distribute the machine.

One in a Million

When is a technology considered "safe"?

In the case of human health risks, a rule used in some cases by regulators is that a technology (new chemical, new industrial plant, etc.) is "safe" if it does not increase the health risk of the population by more than 1 chance in 1 million. This is about the same chance each of us has of being struck by lightning or a meteorite.

Nuclear waste disposal is governed by a principle of minimizing risk to the public and environment to "as low as reasonably achievable" — ALARA. Many steps are taken in nuclear waste disposal, as with other nuclear power activities, to reduce public risk from radiation to at most one in a million.

Limitations

What is the difficulty with this rule?

One problem is that to know if risk increases, we have to know what the risk is before the "new risk" is introduced. Also, often increased risk is based on laboratory experiments using large numbers of animals. Large numbers of subjects are helpful, but the biological differences between the test population (often rats or mice) and humans introduce more uncertainties.

Probabilities do give us a way to determine a level of risk that is at least to some degree not subjective. But it is important to understand that personal judgment is still involved. For example, choosing what to consider in an experiment requires some judgment.

3.19 Consequences and Values

How do you determine the acceptability of risk?

Determining the acceptability of risk involves both the consequence of the action in question and values. If you decide not to carry an umbrella, the consequence may be that you get wet if it rains. How much risk you are willing to accept depends on whether you mind getting wet.

Human Health Risks

Why are situations involving technologies complicated?

Of course, in situations involving technologies, decision making is much more complicated. Difficulties can arise in determining an acceptable level of risk when the consequences could involve risk to human health or life. Still, since risk cannot be eliminated but may be reduced, it makes sense to quantify the risk in complex technologies. By identifying the risks of each event in the technology, events where risk can be reduced can be

How do you quantify risk in complex technologies?

identified. This may reduce the overall risk of the technology. In some cases, the costs of reducing risk to very low levels may be very expensive. A value judgment is then required to determine the level of risk considered acceptable.

Making Societal Decisions

Are there limitations to the usefulness of probability as a tool for discussing risk? Why?

Using probability as a tool for discussing risk is useful, but it is important to recognize that there are limitations in using probability for making decisions about the acceptability of risk. For example, most societal issues in which risk is a factor are complex. A significant problem may be discounted or underestimated. Also, many probabilities are estimated because it is not possible to perform controlled experiments to measure them. Furthermore, human behavior and human error are even less predictable than physical or biological events.

Other Aspects of Risk

Is probability the only aspect of risk?

Probability is only one aspect of risk. Societal risk decisions also involve consequences and values. What is the consequence of a failure — loss of money, illness, death? How large are the consequences? Do the risks and benefits fall on different people? Do the risks fall on the decision-makers or on others? How are decisions made? What are the alternatives?

PROBABILITY: THE LANGUAGE OF RISK ASSESSMENT

DIRECTIONS: After completion of the reading lesson answer the following questions in complete sentences. Use your own words whenever possible.

1. Besides using people's feelings about risk, what else do scientists do in order to "discuss and compare risks related to science and technology" in a more scientific manner?

   (Scientists quantify relationships among risks by developing mathematical probabilities.)

2. What is "probability"? How are most probabilities about everyday activities determined?

   (Probability is how likely something is to occur. Most probabilities that we use in everyday life have been determined from simply observing what happens every time certain conditions arise or from repeating an experiment many times.)

3. Why are the probabilities of health and safety risks to humans more difficult to determine than those of everyday activities? Give two reasons.

   (These are more difficult to determine because a large body of knowledge may be needed in order to make these predictions or testing of the whole system is not possible.)

4. What is the "common rule" used by regulators in determining the human health risks associated with a new technology? Based on your own experience, discuss one reason why this rule may not always be accurate or certain.

   (A technology [new chemical, new industrial plant] is "safe" if exposure to the technology does not raise the health risk of the human population by more than one chance in one million [1/1,000,000 or 0.000001], which is about the chance of being struck by lightning or a meteorite.)

5. Besides the "quantifiable" (countable) viewpoint provided by probabilities, how else is the "acceptability of risk" determined? (Use the example of the person and the umbrella for insight.)

   (Subjective judgment is an inevitable element in selecting criteria for determining probabilities and in determining whether or not a given level of risk is acceptable.)

6. Why are there limitations to using probability as a tool for discussing risk when it comes to making major societal decisions about risks?

(Most societal issues in which risk is a factor are so complicated and complex that a significant problem may be discounted or underestimated. Also, many probabilities are estimated because it is not possible to perform controlled experiments to measure them. Furthermore, human behavior, and therefore human error, are even less predictable than physical or biological events.)

SUMMARY

3.20 A National Problem

A national problem exists because of the accumulation of nuclear wastes. These wastes require special handling, storage, and final disposal to protect the public and the environment from hazards associated with high-levels of radiation.

Why is the accumulation of nuclear wastes a problem?

3.21 Congressional Mandate

The U.S. Congress has decided that the management of our Nation's nuclear wastes is the responsibility of the present generation and should not be left for future generations. Recognizing that a national problem has been created by the accumulation of spent fuel and high-level waste and that a safe and environmentally acceptable method of permanent disposal is needed, the U. S. Congress enacted the Nuclear Waste Policy Act of 1982 (NWPA) and amendments.

What law did Congress pass? Why?

3.22 The Nuclear Waste Policy Act

The NWPA and amendments established a national policy for safely storing, transporting, and disposing of spent nuclear fuel and high-level nuclear waste. The law gave responsibility for carrying out the law to the U.S. Department of Energy (DOE). DOE is required to:

- site, construct, and operate a deep, mined geologic repository.

In addition, DOE is permitted to:

- site, construct, and operate one monitored retrievable storage (MRS) facility; and
- develop a system for transporting the waste to a repository and MRS facility.

What does the NWPA do?

3.23 The Permanent Repository

What is the purpose of site characterization?

The United States began studies for isolating high-level radioactive waste in 1957 when the National Academy of Sciences first recommended deep geologic disposal. In 1987, Congress directed DOE to conduct in-depth site characterization studies at Yucca Mountain, Nevada, to determine whether the site is suitable for development as a geologic repository.

What happens if it is determined that the site is unsuitable?

If, at any time, it is determined that the Yucca Mountain site is unsuitable for development as a repository, all site characterization activities at the site will stop. Congress and the Governor and legislature of Nevada will be notified.

What happens if site characterization indicates the site is suitable?

If site characterization indicates that the Yucca Mountain site is suitable for development as a repository, the law spells out steps that the Secretary of Energy, President, Congress, and the State of Nevada can follow.

What is an MRS facility?

The amended law also directed DOE to site, construct, and operate an MRS facility, subject to certain conditions. For example, the MRS facility cannot be located in Nevada and construction of the MRS facility cannot begin until a repository is authorized by the Nuclear Regulatory Commission. An MRS facility would provide temporary storage for spent fuel from nuclear powerplants until shipment to a repository. In 1989, an independent MRS Review Commission reported to Congress on the contribution an MRS facility would make to managing spent fuel.

3.24 Safe Transportation

What will be done to ensure safe transportation?

Safe transportation is crucial to the management of nuclear waste. Spent fuel casks that must be certified by the Nuclear Regulatory Commission will be used for shipping. Extensive tests are conducted on casks before certification. Existing laws and regulations on shipments enforced by Federal, State, and local agencies will be followed during NWPA shipments. In addition, DOE is developing procedures for inspection, route selection, and other transportation issues in consultation with the affected States, Indian Tribes, local governments, and the public.

3.25 The Challenge of Nuclear Waste Disposal

How are technical challenges related to scientific inquiry?

Planning for the long-range disposal of our Nation's nuclear waste is a complex undertaking that presents many technical and societal challenges. The waste must be kept isolated for very long periods of time. Technical decisions will be based on scientific findings. But in science there are no absolute truths. Honest disagreements among scientists on correct interpretation of data are certain to occur, especially during the early stages of information gathering. Regardless of the ferocity of debate, however, it is important that open discussions take place and opposing views are fairly evaluated.

What societal challenges must be addressed?

Societal challenges must also be addressed. Every human activity involves risk. Important societal questions must be answered as part of the waste management program. Who will be most affected by nuclear waste disposal? What are the potential negative impacts? How can negative impacts be avoided or reduced? Will people affected by the waste management program be compensated? How?

How must decisions be made in our democracy?

Problems of nuclear waste management must be addressed democratically. Legitimate and acceptable decisions must be the product of open and balanced dialogue between Federal, State, Tribal, and local officials as well as the general public.

3.26 Probability and Risk

Every human activity involves some risk. Mowing the lawn, driving a car, flying in a commercial airliner, etc., all present some risk. Nuclear waste disposal is no exception. As with all other activities associated with nuclear power, preventing harm to the public and the environment is a priority. Many steps are taken to reduce public risk from radiation to at most one in a million — a risk much lower than that posed by most human activities, and certainly less than those named above.

Probability is an important tool in determining risk, but it is not the only one. The consequences of an event, as well as human values, are used to decide if a risk is acceptable.

ENRICHMENT

FACTORS AFFECTING RISK JUDGMENT

Purpose:

This lesson will encourage students to think about risk in ways that they may not have done before. Each individual must weigh various factors and make judgments/assessments based upon his/her own perception about an activity or technology. There are no right or wrong answers.

Concepts:

1. Research indicates that in thinking about risk, individuals consider identifiable factors such as controllability and outcome.
2. Societal decisions are shaped by people's values, perceptions, and analysis of facts.

Duration of Lesson:

One 50-minute class period

Objectives:

As a result of participation in this lesson, the learner will be able to:
1. rank activities/technologies taking into consideration two different, assigned factors which have been specifically defined; and
2. plot and discuss the results of his/her rankings on the grid entitled *Location of Hazards.*

Skills:

Analyzing, critical thinking, discussing, graphing

Vocabulary:

Catastrophic, dread, equitable, factor, global

Materials:

Activity Sheet
Factors Affecting Risk Judgments, p. 67
Locations of Hazards, p. 69

Transparency
Factors for Locating Hazards, p. 51

Suggested Procedure:

1. Research has been done to discover what factors people use in evaluating risk. Show students the transparency entitled *Factors for Locating Hazards*, which identifies factors that influenced one particular research group in ranking items according to their level of risk.

   (Information on this transparency is taken by permission from "Perception of Risk," Paul Slovic, Vol. 236, pp. 280-285, Figure 1, Science, April 17, 1987.)

2. Discuss the transparency with the class. Have students look back at items in the ranking they did for the activity entitled *Risk*. Ask students which of the factors described on the transparency they may have considered, consciously or unconsciously, in ranking the items. Ask them to explain how these factors influenced their rankings.

3. It might be helpful to remind students of the previous discussion on how they sometimes disagree with their parents based upon different factors being considered important in the decision-making or judgment process. We consider whether the risk is controllable, voluntary, fatal, catastropic, dreaded, or even known. These contribute to the risk assessment we give each of these technologies or activities.

4. You may wish to discuss at this point that there is no right or wrong answer when you are asking individuals to assess risk. Their assessment is based upon their judgment or perception of that technology or activity.

5. In the exercise entitled *Risk*, students were asked to rank 30 activities and technologies based upon their perceived risk with 1 being the most risky and 30 being the least risky. In this exercise entitled *Factors Affecting Risk Judgments,* the students will again be asked to rank activities and/or technologies. This time, however, they will rank each activity or technology considering two separate factors.

   Factor 1: considers whether the technology or activity is controllable or uncontrollable, voluntary or involuntary, fatal or not fatal

   Factor 2: considers whether the effect is observable or not observable, whether effects are known or unknown, has immediate effects or delayed effects

   Each activity or technology will be assigned a number, based upon a scale from 1 to 9, for each of the factors. The number each student assigns will represent his/her perception of the risk involved in the activity/technology being considered.

Perception of risk based upon a scale of 1 to 9 for Factor 1:

1 (low risk)		**9 (high risk)**
controllable	or	uncontrollable
voluntary	or	involuntary
not fatal	or	fatal

Perception of risk based upon a scale of 1 to 9 for Factor 2:

1 (low risk)		**9 (high risk)**
observable	or	not observable
know	or	unknown
immediate	or	delayed

FOR EXAMPLE: Scuba diving

Determine a value for Factor 1:

A sample thought process might be as follows:

Scuba diving is a controllable activity. Assign a low value (1-3). Scuba diving is a voluntary activity. Still a low value (1-3). Scuba diving could prove fatal. The assigned number should be higher based upon each individual student's assessment of that probability (3-6). The student will weigh these responses and decide on an overall ranking for Factor 1. So assume the student has determined that the final number value for Factor 1 should be a 4.

Determine a value for Factor 2:

Effects of scuba diving are observable. Assign a low value (1-3). Scuba diving has known effects. Assign a low value (1-3). The effects of scuba diving are immediate. The assigned number value should remain low (1-3).

In this case, you have determined that the final number value for Factor 2 should be a 2.

Have students enter the final number value for Factor 1 and the final number value for Factor 2 they have determined on the worksheet entitled *Factors Affecting Risk Judgments.*

Students should then rank the rest of the activities/ technologies listed on their worksheet in the same manner as the example above. You may wish to do one or two more to be sure students understand how to assign the number values. It may be necessary to reassure students, once again, that there are no right or wrong answers in ranking this list. Also, it might be well to advise students not to spend too much time "weighing" factors. In this particular exercise, a "gut" reaction is the best answer.

6. Once students have completed their rankings, distribute the graph entitled *Location of Hazards* and instruct students to plot the results of their worksheet rankings on this graph.

7. It might be helpful to plot the first item as a class in order to get students started. This also works well as a small group activity.

FOR EXAMPLE: Scuba diving

Using the results of the scuba diving example illustrated above, have students plot its location on their graph.

The number for Factor 1 should be located on the corresponding numbered line running left to right.

The number for Factor 2 should be located on the corresponding numbered line running up and down.

Place a dot on the point where the lines intersect and label it "scuba diving."

8. When students have finished with their grids, discuss the activity as a class.

9. Show the transparency entitled *Factors for Locating Hazards,* and discuss how others ranked specific items.

   Sample discussion questions:

   a) Where is radioactive waste located on *Factors for Locating Hazards*? Why?

   b) Are there any locations that surprise you? Would you locate some differently?

      If so, which?

   c) Where would you locate AIDS? Riding a roller coaster? Using drugs?

Teacher Evaluation of Learner Performance:

Student completion of the activities entitled *Factors Affecting Risk Judgments* and *Location of Hazards* should indicate level of comprehension.

> The computer program, student activities, and some teacher notes for the lessons on risk are based on information used by permission from "Facts and Fears: Understanding Perceived Risk" by P. Slovic, B. Fischhoff, and S. Lichtenstein, in *Societal Risk Assessment: How Safe is Safe Enough*, published by Plenum Publishing Corporation, New York, 1980.

Additional Enrichment:

Individual students or classes particularly interested in this activity may wish to rank and graph the following additonal items:

War (conventional)

AIDS

Cheerleading

Skateboarding

Amusement park rides

Nuclear weapons

Solid waste

Sunbathing

Global climate change

Dogs

Use of illegal drugs

This would be appropriate either after class discussion of the ranking and graphing of the items on the activity list or after discussing the transparency entitled *Factors for Locating Hazards*.

PROBABILITY EXERCISES

Things to Remember:

- The probability of any outcome is the number of times that outcome can occur divided by the total number of outcomes.
- If there are "n" equally likely outcomes to one event, then the probability of each outcome is 1 divided by n, 1/n.
- To determine the probability that any of several outcomes will occur for one event, such as the draw of one card, one spin of the roulette wheel, etc., add the separate probabilities together.
- To determine the probability of two separate events occurring at the same time, multiply the separate probabilities together.

Conversions:

Fraction to decimal

3/5 = 3 ÷ 5 = .6
3/20 = 3 ÷ 20 = .15

Decimal to fraction

.1 = 1/10	1 in ten
.01 = 1/100	1 in a hundred
.001 = 1/1000	1 in a thousand

Percent to probability

50% = 50/100 = .50 probability

Probability to percent

.50 probability = .50 x 100 = 50%
.35 probability = .35 x 100 = 35%

Conversion exercises

Convert to a decimal.

a) 1/2 = *1* ÷ *2* = *.5*

b) 1/3 = *1* ÷ *3* = *.33*

c) 3/4 = *3* ÷ *4* = *.75*

d) 2/3 = *2* ÷ *3* = *.67*

Convert to a fraction.

a) .25 *.25 x 100 = 25* *.25 = 25/100*

b) .60 *.60 x 100 = 60* *.60 = 60/100*

c) .934 *.934 x 1000 = 934* *.934 = 934/1000*

Convert from percent to probability.

a) 25% *25/100 = .25 probability*

b) 33% *33/100 = .33 probability*

c) 75% *75/100 = .75 probability*

Convert from probability to percent.

a) .2 *.2 x 100 = 20%*

b) .64 *.64 x 100 = 64%*

c) .934 *.934 x 100 = 93.4%*

Exercises

1. In flipping a coin six times, the following sequence was observed: H,T,T,T,T,T. What is the probability that on the seventh flip the coin will come up tails?

   Regardless of what happened on previous flips, the probability is .50 every time the coin is flipped.

2. Draw one card from an ordinary deck of cards. (Express answers as fractions and decimals.)

   a) What is the probability that it is the Queen of Hearts?

      1/52, 1 in 52 or .019

   b) What is the probability that it is either the King or the Queen of Hearts?

      1/52 + 1/52 = 2/52 = 1/26 or .038

3. Draw two cards from an ordinary deck. What is the probability of getting both the King and Queen of Hearts?

For the first card drawn, there is a 2 in 52 chance of getting one of the two cards. For the second card, there is a 1 in 51 chance. The probability of drawing both the Queen and King of Hearts on two draws is (2/52) x (1/51) = (2x1)/(52x51) = 2/2652 = 1/1326 = .00075

4. Draw five cards. What is the probability of drawing the A,K,Q,J,10 of Hearts? What is the probability of drawing any royal flush?

There are 5 cards we want to choose from the deck. For the first card, there is a 5 in 52 chance (5/52) of drawing one of the cards we want. For the second card, there are 4 cards left in the 51 remaining cards in the deck, so a 4 in 51 chance (4/51) for the second card. Using the same method, there is a 3 in 50 chance for the third card, a 2 in 49 chance for the fourth card, and a 1 in 48 chance for the fifth card. So, the probability of drawing that hand is 5/52 x 4/51 x 3/50 x 2/49 x 1/48 = (5x4x3x2x1)/(52x51x50x49x48) = 120/311,875,200 = .000000384. This is the probability of drawing one royal flush. Since there are four possible royal flushes, one for each suit, we need to multiply this probability by 4, giving us a .00000154 probability for drawing a royal flush or approximately 1.5 in a million.

5. Two basketball teams of equal skill are involved in a four-game tournament. What is the probability of one of the teams winning the tournament in four straight games?

Each team has a one in two chance of winning each game. Therefore, the probability of winning four straight games is (1/2)x(1/2)x(1/2)x(1/2) = 1/16 = .0625 or approximately 6%.

PROBABILITY EXERCISES
Challenge Level

1. A typical roulette wheel has 38 slots that are numbered 1, 2, 3,..., 34, 35, 36, 0, and 00. The 0 and 00 slots are green. Of the remaining slots, half are red and half are black. Also half of the integers from 1 to 36 are even and half are odd. 0 and 00 are defined as neither even or odd. A ball is rolled around the wheel and ends up in one of the slots. We assume that each slot has an equal chance.

   a) What is the probability of each slot?

   There are 38 slots, each with an equal chance. Therefore, each slot has a 1/38 probability.

   b) What is the probability of the ball landing in a green slot? A red slot? A black slot?

   2 of the 38 slots are green, so, the probability of the ball landing in a green slot is 2/38 or 1/19. Of the 36 remaining slots, half are red and half are black. So, there are 18 red and 18 black slots. The probability of red = the probability of black = 18/38 or *9/19.*

   c) What is the probability of the ball landing on an even number?

   Half of the numbers from 1 to 36 are even, so, there are 36/2 = 18 even slots. Therefore, the probability of getting an even number is 18/38 or 9/19.

   d) What is the probability of getting a 1, 12, 24, or 36?

   The probability for each of these numbers is 1/38 so the probability of getting one of these four is 1/38 + 1/38 + 1/38 + 1/38 = 4/38 or 2/19.

For the following questions, to calculate the "expected" value of an event multiply the consequence (profit or loss) under each outcome by the probability of the outcome and add them together. For example, if you bet $1.00 on the flip of a coin, there is a .50 probability that you win and a .50 probability that you lose. The expected value of this game is .50($1.00) + .50(0) = $.50 + $0 = $.50

2. In a particular lottery 2,000,000 tickets are sold each week for $.50 each. Each week there are 12,009 tickets drawn and awarded prizes: 12,000 people receive $25; 6 people win $10,000; 2 people win $50,000; and 1 person wins $200,000.

   a) Determine the probability of winning each prize.

Prize	*# of prizes awarded*	*Probability of each prize*
$25	12,000	12,000/2,000,000 = .006
$10,000	6	6/2,000,000 = .000003
$50,000	2	2/2,000,000 = .000001
$200,000	1	1/2,000,000 = .0000005

b) If you play this game, what is your "expected" payoff?

Prize x Probability	=	
25(.006)	=	*.15*
10,000(.000003)	=	*.03*
50,000(.000001)	=	*.05*
200,000(.0000005)	=	*.10*
Expected winnings	=	*$.33*

But, don't forget you spent $.50 on the ticket.
Adjusted "winnings" $.33 - .50 = - $ -.17

3. Suppose you must choose between two products to sell in your shop. Your choice depends on what the economy is going to do. If the economy goes up, you will make a profit of $100,000 on (product A) or $60,000 on (product B). If the economy stays the same, you will earn a profit of $50,000 on (product A) and $40,000 on (product B). And if the economy goes down, you will lose $20,000 on (product A) but can still earn $10,000 on (product B).

You don't know for sure what the economy is going to do, but you might know the probabilities of these things happening. Suppose the probability of the economy going up is .4, the probability of it staying the same is .4, and the probability of it going down is .2.

Determine the expected profit for each product. Which product would you choose and why?

Product A: .4(100,000) + .4(50,000) + .2(-20,000) =
40,000 + 20,000 - 4,000 = 56,000

Product B: .4(60,000) + .4(40,000) + .2(10,000) =
24,000 + 16,000 + 2,000 = 42,000

The average business professional would choose (product A). However, a very conservative or cautious business professional would be willing to sacrifice some of the profit in order to avoid any risk of losing money. So, he or she would choose (product B).

Glossary

acceptable level of risk — A determination that considers both the consequences of an action and personal values in deciding whether or not to act.

affected parties — The designation as established by the Nuclear Waste Policy Act as amended that a State, Indian Tribe, or unit of local government is a potential host for a repository or MRS facility. The term also applies to an Indian Tribe that the Secretary of the Interior finds would experience substantial and adverse effects from a MRS facility or a repository. Such term may at the discretion of the Secretary include contiguous units of local government.

Benefits Agreement — A legal understanding between DOE and a State that outlined the specific conditions under which a State or Indian Tribe might host a repository or monitored retrievable storage facility.

certification — The act of assuring that something is certain.

democracy — Government exercised directly by the people or through elected representatives.

Environmental Impact Statement (EIS) — A formal report on the environmental impacts of a projected activity. The National Environmental Policy Act of 1969 (NEPA) mandated an in-depth study of the environmental impacts associated with any new large activity that might involve the Federal Government.

EPA (Environmental Protection Agency) — An agency of the Federal Government responsible for the protection of the environment and the enforcement of environmental legislation; formed in December 1979 under Public Law 97-604.

equitable — Characterized by fairness.

flow chart — A diagram consisting of a set of symbols and connecting lines that shows step-by-step progression through a complicated procedure or system.

global — Of or pertaining to the whole world, worldwide.

ground water — Water found underground in porous rock strata and soils, as in a spring.

joint resolution — Resolution passed by both houses of a bicameral legislature.

judgment — A considered decision or evaluation.

MRS (Monitored Retrievable Storage) facility — A temporary surface storage system that was studied by the U.S. Department of Energy as a potential part of an integrated system for disposing of spent nuclear fuel.

MRS Review Commission — A group of three experts appointed to evaluate the need for a monitored retrievable storage facility as part of the system for disposing of the Nation's high-level nuclear waste; required by the 1987 amendment to the NWPA.

NIMBY (Not In My Back Yard) — An abbreviation or acronym used to describe opposition to siting a facility in one's area or neighborhood.

non-ionizing radiation — Low energy radiation such as radio and television waves.

Notice of Disapproval — A formal expression in writing to the U.S. Congress of an unfavorable response by a State or Indian Tribe following a recommendation to the President of a repository or monitored retrievable storage site within the State or Tribal land.

Nuclear Waste Fund — The fund established by the Nuclear Waste Policy Act of 1982 to ensure that the costs of high-level radioactive waste management and disposal are borne by the owners and generators of the waste. Utilities generating electricity at nuclear powerplants pay 1 mill (1/10 of a cent) per kilowatt-hour of electricity generated by nuclear powerplants. Costs of disposing of nuclear waste from defense activities will be paid by the Federal Government.

Nuclear Waste Negotiator — The individual whose primary responsibility was to identify and negotiate with a State or Indian Tribe willing to host a repository or a MRS facility. The Office of the Nuclear Waste Negotiator was created by the Nuclear Waste Policy Amendments Act to identify alternative sites for potential nuclear waste management facilities. The Office was terminated in January 1993. In June 1993, President Clinton directed Secretary O'Leary to continue the work until January 1995.

Nuclear Waste Policy Act of 1982 (NWPA) — A Federal law that designates how the Nation's high-level nuclear waste is to be permanently disposed of. Amended by Congress in 1987 and 1988.

Nuclear Waste Policy Amendments Act of 1987 — A Federal law that amended the NWPA. Among other provisions, it named Yucca Mountain, Nevada, as the only site to be characterized for the repository.

Nuclear Waste Technical Review Board — A panel of 11 members, with distinguished service in science or engineering, nominated by the National Academy of Sciences and appointed by the President to evaluate the technical and scientific validity of activities of DOE in site characterization or transportation of spent fuel; provided for by the 1987 amendment to the NWPA.

OCRWM (Office of Civilian Radioactive Waste Management) — The office created in the U.S. Department of Energy by the Nuclear Waste Policy Act of 1982 (NWPA) to implement provisions of the NWPA governing the permanent disposal of high-level radioactive waste and nuclear spent fuel.

probability — A number expressing the likelihood of occurrence of a specific event.

quantify — To measure or express a quantity.

relative hazard — The apparent or perceived danger of a particular activity compared to other hazards.

risk assessment — An estimate of the frequencies and consequences of undesirable events and evaluation of the risks in quantitative terms; also the study of risk.

risk management — Decision making which involves both providing safety and striving for consensus.

risk perception — One's estimate of undesirable consequences and likelihood of occurrence of undesirable consequences associated with some activity or technology.

site characterization — Activities, collection of information, and studies (whether in the laboratory or in the field) undertaken to evaluate the suitability of a site for a geologic repository.

societal — Relating to the structure or organization of society.

technical — Of the mechanical and applied sciences; requiring specialized knowledge.

trade-off — Accepting one result in order to gain another.

Yucca Mountain, Nevada — The site designated by Congress in the amended Nuclear Waste Policy Act as the site to be characterized to determine whether it is suitable for a geologic repository.

Index

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UNIT 3

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Science, Society, and America's Nuclear Waste

Transparency Masters & Student Activities

Nuclear Waste Challenges & Solutions

Ordering of Perceived Risk

Factors for Locating Hazards

Overview – Nuclear Waste Policy Act

Swimming Pool Construction Flow Chart

Nuclear Waste Challenges and Solutions (Activity)

Risk

Risk Perception Computer Activity

Probability: The Language of Risk Assessment

Factors Affecting Risk Judgments

Location of Hazards

Probability Exercises

Metric & U.S. Unit Conversions

The Nuclear Waste Policy Act

Unit 3 Second Edition
Teacher Guide

NUCLEAR WASTE CHALLENGES AND SOLUTIONS

PART I

Managing the Nation's nuclear waste is a complicated challenge with both technical and societal aspects that must be addressed. After reading the Overview – Nuclear Waste Policy Act, consider the statements written below and decide if each statement is a challenge or a solution (or both) and if it is societal or technical (or both). For each statement, put a check in the appropriate box or boxes.

	Challenge?	Solution?	Technical?	Societal?
1. There is an accumulation of spent fuel and high-level waste that requires permanent disposal.				
2. The Nuclear Waste Policy Act of 1982 (NWPA) and the Nuclear Waste Policy Amendments Act of 1987 established a national policy for safely storing, transporting, and disposing of spent nuclear fuel and high-level waste.				
3. The NWPA requires utilities using nuclear reactors for generating electricity to pay a fee that covers their share of all costs of disposal of spent fuel. Also, the Federal Government is required to pay costs of disposing of high-level waste that results from defense activities.				
4. Radioactive waste is a potential hazard to public health and safety and the environment.				
5. State and local governments and the public will participate in planning for disposal of waste.				
6. Spent fuel and high-level waste must be safely transported to the repository				
7. The Federal Government is planning a deep underground geologic repository for permanent disposal of spent fuel and high-level waste.				
8. Spent fuel and high-level waste will remain radioactive for thousands of years.				
9. The Federal Government will assist utilities in providing storage of spent fuel until a repository is ready.				
10. Spent fuel and high-level radioactive waste is thermally hot.				
11. In the Amendments Act, Congress directed DOE to conduct site characterization studies at Yucca Mountain, Nevada, for purposes of determining its suitability as a site for a geologic repository.				
12. Many Nevada residents are opposed to a geologic repository being constructed in their State.				

ORDERING OF PERCEIVED RISK

Ordering of perceived risk for 30 activities and technologies. The ordering is based on the geometric mean risk ratings within each group. Rank 1 represents the most risky activity or technology.

Source: "Facts and Fears: Understanding Perceived Risk" by Paul Slovic, Baruch Fischoff, and Sarah Lichtenstein in Societal Risk Assessment: How Safe is Safe Enough? *Plenum Publishing Corp., New York, 1980, permission granted.*

Activity or technology	League of Women Voters	College students	Active club members	Experts
Nuclear power	1	1	8	20
Motor vehicles	2	5	3	1
Handguns	3	2	1	4
Smoking	4	3	4	2
Motorcycles	5	6	2	6
Alcoholic beverages	6	7	5	3
General (private) aviation	7	15	11	12
Police work	8	8	7	17
Pesticides	9	4	15	8
Surgery	10	11	9	5
Firefighting	11	10	6	18
Large construction	12	14	13	13
Hunting	13	18	10	23
Spray cans	14	13	23	26
Mountain climbing	15	22	12	29
Bicycles	16	24	14	15
Commercial aviation	17	16	18	16
Electric Power (non-nuclear)	18	19	19	9
Swimming	19	30	17	10
Contraceptives	20	9	22	11
Skiing	21	25	16	30
X-rays	22	17	24	7
High-school and college football	23	26	21	27
Railroads	24	23	20	19
Food preservatives	25	12	28	14
Food coloring	26	20	30	21
Power mowers	27	28	25	28
Prescription antibiotics	28	21	26	24
Home appliances	29	27	27	22
Vaccinations	30	29	29	25

FACTORS FOR LOCATING HAZARDS

Factor 2

Not observable
Unknown to those exposed
Effect delayed
New risk
Risks unknown to science

Controllable
Not dread
Not global catastophic
Consequences not fatal
Equitable
Individual
Low risk to future generations
Easily reduced
Risk decreasing
Voluntary

Uncontrollable
Dread
Global catastophic
Consequences fatal
Not equitable
Catastrophic
High risk to future generations
Not easily reduced
Risk increasing
Involuntary

Observable
Known to those exposed
Effect immediate
Old risk
Risks known to science

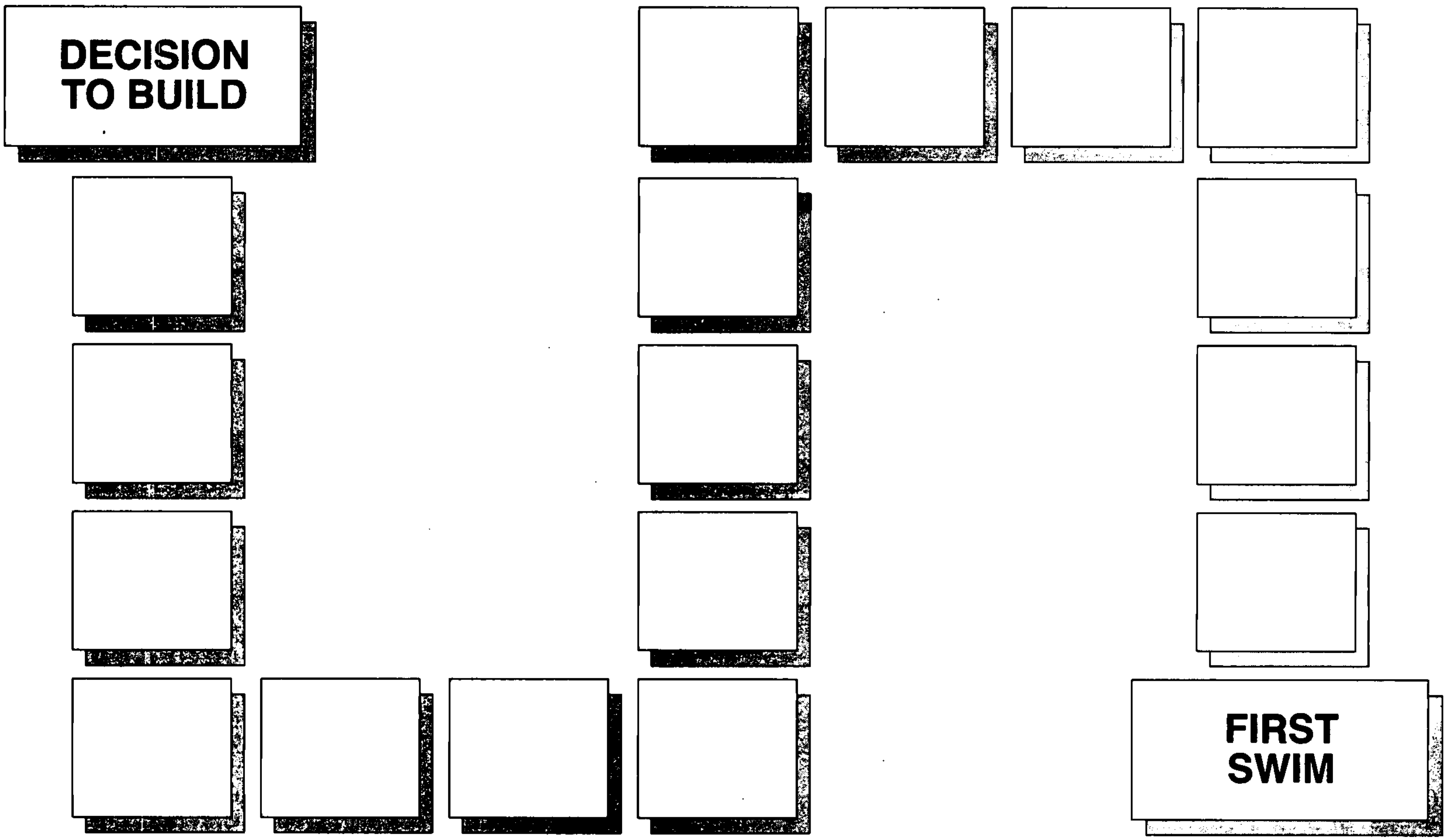
Source: *"Facts and Fears: Understanding Perceived Risk" by Paul Slovic, Baruch Fischoff, and Sarah Lichtenstein in* Societal Risk Assessment: How Safe is Safe Enough?, *permission granted.*

OVERVIEW — NUCLEAR WASTE POLICY ACT

Directions: Match the response with the term it *most nearly* describes or defines by placing the appropriate letter on the line provided. Use each response only once.

TERM	RESPONSE
____ 1. Site Characterization	a. Nevada may file this if Yucca Mountain is found suitable for a geologic repository
____ 2. Nuclear Waste Fund	b. reviews and comments on environmental impact statement needed for licensing and constructing a geologic repository
____ 3. Nuclear Regulatory Commission	c. determines if an area is suitable for a geologic repository
____ 4. Notice of Disapproval	d. enables the Federal Government to recover costs of developing a disposal system for spent fuel and high-level waste
____ 5. NWPA & Amendments Act	e. offers financial aid to offset impacts from siting and developing a repository or MRS; requires forfeiture of right to veto
____ 6. EIS	f. seeks State or Indian Tribe to host an MRS facility
____ 7. Negotiator	g. established national policy for safely storing, transporting, and disposing of spent fuel and high-level radioactive waste
____ 8. Certification	h. spent fuel shipping casks must go through this process before they're approved for use
____ 9. EPA	i. required before a license can be issued and construction can begin for the geologic repository
____10. Benefits Agreement	j. determined by Congress, through passage of the Amendments Act
	k. agreed to DOE guidelines on how sites are evaluated to determine suitability for a repository

SWIMMING POOL CONSTRUCTION FLOW CHART



NOTE: You are not limited by the number of boxes on this chart. You may feel free to use fewer boxes than provided or add more boxes if you feel this is necessary.

NUCLEAR WASTE CHALLENGES AND SOLUTIONS

PART I

Managing the Nation's nuclear waste is a complicated challenge with both technical and societal aspects that must be addressed. After reading the Overview—Nuclear Waste Policy Act, consider the statements written below and decide if each statement is a challenge or a solution (or both) and if it is societal or technical (or both). For each statement, put a check in the appropriate box or boxes.

	Challenge?	Solution?	Technical?	Societal?
1. There is an accumulation of spent fuel and high-level waste that requires permanent disposal.				
2. The Nuclear Waste Policy Act of 1982 (NWPA) and the Nuclear Waste Policy Amendments Act of 1987 established a national policy for safely storing, transporting, and disposing of spent nuclear fuel and high-level waste.				
3. The NWPA requires utilities using nuclear reactors for generating electricity to pay a fee that covers their share of all costs of disposal of spent fuel. Also, the Federal Government is required to pay costs of disposing of high-level waste that results from defense activities.				
4. Radioactive waste is a potential hazard to public health and safety and the environment.				
5. State and local governments and the public will participate in planning for disposal of waste.				
6. Spent fuel and high-level waste must be safely transported to the repository.				
7. The Federal Government is planning a deep underground geologic repository for permanent disposal of spent fuel and high-level waste.				
8. Spent fuel and high-level waste will remain radioactive for thousands of years.				
9. The Federal Government will assist utilities in providing storage of spent fuel until a repository is ready.				
10. Spent fuel and high-level radioactive waste is thermally hot.				
11. In the Amendments Act, Congress directed DOE to conduct site characterization studies at Yucca Mountain, Nevada, for purposes of determining its suitability as a site for a geologic repository.				
12. Many Nevada residents are opposed to a geologic repository being constructed in their State.				

PART II

Managing our Nation's nuclear waste is a complex technical and societal issue. What is the U.S. government's planned response to this issue?

Directions: In the blank provided, write the number of the U.S. government's planned response to each problem listed. There may be more than one response to a problem.

	PROBLEM	PLANNED RESPONSE
______	A. There was no national policy for safely storing, transporting, and disposing of spent nuclear fuel and high-level waste.	1. following transportation regulations of Federal, State, and local agencies
		2. studies to evaluate geologic formations
______	B. The site selected for the repository must meet strict guidelines developed to ensure safety of the environment and the public.	3. independent review of all aspects of the waste disposal program
		4. shipping casks subjected to tests
		5. The Nuclear Waste Policy Act and amendments passed by Congress
______	C. High-level waste and spent nuclear fuel are major subjects of public concern.	6. field and laboratory testing at potential site
______	D. Disposing of spent fuel and high-level waste is expensive.	7. transportation procedures being developed with State, Tribal, local governments, and public input
______	E. It is important that the public have confidence in the safety of disposal of spent fuel and high-level waste.	8. U.S. government required to pay costs for disposing of defense high-level waste
______	F. Spent fuel and high-level radioactive waste must be transported safely.	9. environmental assessments and environmental impact statements
		10. detailed site characterization
		11. utilities pay fee for all electricity generated by nuclear energy
		12. State and local government and public participation in the planning and development of the repository required

RISK

Directions: Everything we do involves some risk, but some things are riskier than others. Below is an alphabetical list of 30 activities and technologies. Rank the risk of an individual (not necessarily you, but anyone) of dying in any year from these activities and technologies, with #1 as the most likely and #30 as the least likely.

Alcoholic beverages	high school and college football	power mowers
bicycles	home appliances	prescription antibiotics
commercial aviation	hunting	railroads
contraceptives	large construction	skiing
electric power (non-nuclear)	motorcycles	smoking
firefighting	motor vehicles	spray cans
food coloring	mountain climbing	surgery
food preservatives	nuclear power	swimming
general (private) aviation	pesticides	vaccinations
hand guns	police work	X-rays

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________
6. ______________________
7. ______________________
8. ______________________
9. ______________________
10. ______________________
11. ______________________
12. ______________________
13. ______________________
14. ______________________
15. ______________________
16. ______________________
17. ______________________
18. ______________________
19. ______________________
20. ______________________
21. ______________________
22. ______________________
23. ______________________
24. ______________________
25. ______________________
26. ______________________
27. ______________________
28. ______________________
29. ______________________
30. ______________________

RISK PERCEPTION COMPUTER ACTIVITY

Directions: This computer activity will allow you to rank 30 activities or technologies according to their risk and then compare your rankings to rankings done by:

- members of your class,
- members of a professional business club,
- members of a League of Women Voters group,
- a group of college students, and
- a group of risk assessment experts.

1. To begin, type RANK and then press <Enter>.

2. The program will automatically assign you a student number and prompt you to rank each item listed.

   Rank the activities and technologies in the order of their risks. Use numbers "1" through "30" with "1" as the most risky and "30" as the least risky. You must rank each item. Use each number only once.

   The cursor will go down only. If you want to go back to an item you have already passed, run the cursor all the way through the list and it will return to the top of the first column.

   To change a ranking, put the cursor at the correct position and type in the new ranking. You do not need to delete the old number.

   Hit F2 if you need help, want to start over, or have ranked all the items.

3. By hitting the F2 key, you will be able to get help, start over, save your ranking, or quit the program. DO NOT QUIT UNLESS YOUR INSTRUCTOR TELLS YOU TO DO SO.

   When you have finished, save your ranking. The computer will then check to be sure you have not left any item out or used a number more than once. If you have, numbers you forgot to use or numbers you used more than once will be listed and you can make corrections.

4. When you have finished and saved your rankings, the computer will show you on screen how your rankings compare with others. The results will be displayed for:
   - your ranking,
   - the ranking of your class so far,
   - experts, and
   - others who have ranked the items.

5. If you want a printed copy of the rankings, enter "Y" in response to the prompt "DO YOU WANT A PRINTED COPY OF THE RANKINGS? [Y/N]".

6. The screen will say "IS THERE ANOTHER STUDENT? [Y/N]". Respond "Y" for another student to use the program.

PROBABILITY: THE LANGUAGE OF RISK ASSESSMENT

DIRECTIONS: After completion of the reading lesson answer the following questions in complete sentences. Use your own words whenever possible.

1. Besides using people's feelings about risk, what else do scientists do in order to "discuss and compare risks related to science and technology" in a more scientific manner?

____

____

2. What is "probability"? How are most probabilities about everyday activities determined?

____

____

____

3. Why are the probabilities of health and safety risks to humans more difficult to determine than those of everyday activities? Give two reasons.

____

____

4. What is the "common rule" used by regulators in determining the human health risks associated with a new technology? Discuss one reason why this rule may not always be accurate or certain.

____

____

____

5. Besides the "quantifiable" (countable) viewpoint provided by probabilities, how else is the "acceptability of risk" determined? (Use the example of the person and the umbrella for insight.)

____

____

6. Why are there limitations to using probability as a tool for discussing risk when it comes to making major societal decisions about risks?

111

112

FACTORS AFFECTING RISK JUDGMENTS

Studies have been conducted to discover what factors people link with risk. One such study indicates that we consider whether the risk is controllable, voluntary, fatal, catastrophic, dreaded, or even known.

Part I

In this exercise, rank each activity or technology considering two separate factors. Using a scale from 1-9, with 1 being low and 9 being high, determine a value for Factor 1 and a value for Factor 2 for each activity or technology listed below. When you have completed your rankings, you will plot the results on the grid entitled *Location of Hazards.*

ACTIVITY	FACTOR 1 *1...9* *controllable or uncontrollable?* *voluntary or involuntary?* *not fatal or fatal?*	FACTOR 2 *1...9* *observable or unobservable?* *known or unknown?* *immediate effects or delayed effects?*
Autos		
Handguns		
Alcohol		
Swimming		
Vaccination		
Antibiotics		
X-ray		
Football		
Bicycling		
Nuclear power		
Pesticides		
Electric power (non-nuclear)		

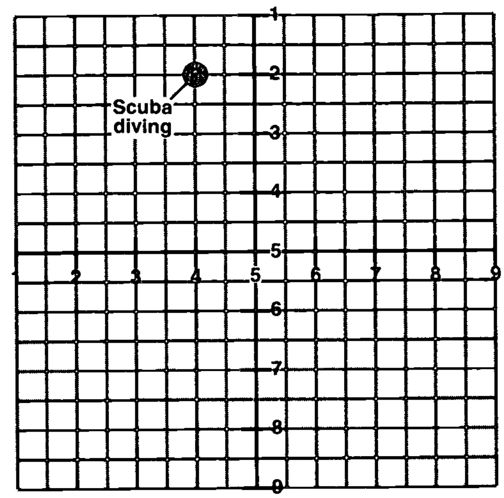
LOCATION OF HAZARDS

Part II

Directions: Plot the results of your ranking on the activity entitled *Factors Affecting Risk Judgements.*

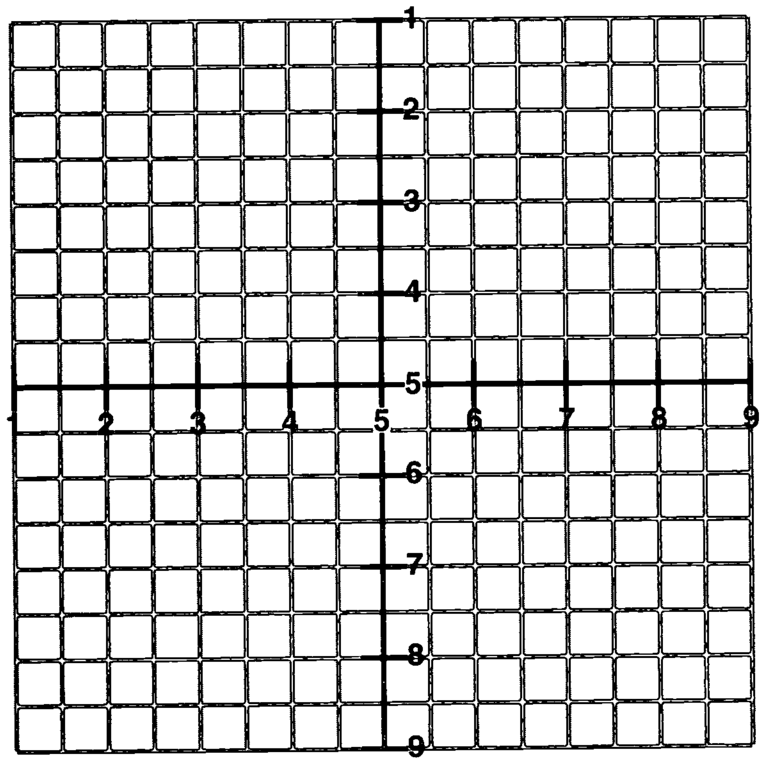
1. Mark the intersection of Factor 1 and factor 2.
2. Label the point with the appropriate activity or technology.

Example:



Factor 2
Not observable
Unknown effects
Effects delayed

Factor 1
Controllable
Consequences not fatal
Voluntary



Uncontrollable
Consequences fatal
Involuntary

Observable
Known effects
Effects immediate

PROBABILITY EXERCISES

Things to Remember:

- The probability of any outcome is the number of times that outcome can occur divided by the total number of outcomes.
- If there are n equally likely outcomes to one event, then the probability of each outcome is 1 divided by n, $\left(\frac{1}{n}\right)$.
- To determine the probability that any of several outcomes will occur for one event, such as the draw of **one** card, **one** spin of the roulette wheel, etc., **add** the separate probabilities together.
- To determine the probability of two separate events occurring at the same time, **multiply** the separate probabilities together.

Conversions:

Fraction to decimal

$\frac{3}{20} = 3 \div 5 = 0.6$

$\frac{3}{20} = 3 \div 20 = 0.15$

Decimal to fraction

0.1 = 1/10	1 in ten
0.01 = 1/100	1 in a hundred
0.001 = 1/1000	1 in a thousand

Percent to probability

$50\% = \frac{50}{100} = 0.50$ probability

Probability to percent

0.50 probability = 0.50 x 100 = 50%
0.35 probability = 0.35 x 100 = 35%

Convert to a fraction.

a. 0.25 =
b. 0.60 =
c. 0.934 =

Convert from percent to probability.

a. 25% =
b. 33% =
c. 75% =

Convert from probability to percent.

a. 0.2 =
b. 0.64 =
c. 0.934 =

Exercises

1. In flipping a coin six times, the following sequence was observed: H,T,T,T,T,T. What is the probability that on the seventh flip the coin will come up tails?

2. Draw one card from an ordinary deck of cards. (Express answers as fractions and decimals.)

   a) What is the probability that it is the Queen of Hearts?

   b) What is the probability that it is either the King or the Queen of Hearts?

3. Draw two cards from an ordinary deck. What is the probability of getting both the King and Queen of Hearts?

4. Draw five cards. What is the probability of drawing the A,K,Q,J,10 of Hearts? What is the probability of drawing any royal flush?

5. Two basketball teams of equal skill are involved in a four game tournament. What is the probability of one of the teams winning the tournament in four straight games?

PROBABILITY EXERCISES

Challenge Level

1. A typical roulette wheel has 38 slots that are numbered 1, 2, 3,..., 34, 35, 36, 0, and 00. The 0 and 00 slots are green. Of the remaining slots, half are red and half are black. Also half of the integers from 1 to 36 are even and half are odd. 0 and 00 are defined as neither even or odd. A ball is rolled around the wheel and ends up in one of the slots. We assume that each slot has an equal chance.

   a) What is the probability of each slot?

   b) What is the probability of the ball landing in a green slot? a red slot? a black slot?

   c) What is the probability of the ball landing on an even number?

   d) What is the probability of getting a 1, 12, 24, or 36?

For the following questions, to calculate the "expected" value of an event multiply the consequence (profit or loss) under each outcome by the probability of the outcome and add them together. For example, if you bet $1.00 on the flip of a coin, there is a 0.50 probability that you win and a 0.50 probability that you lose. The expected value of this game is 0.50($1.00) + 0.50(0) = $.50 + $0 = $0.50

2. In a particular lottery 2,000,000 tickets are sold each week for $0.50 each. Each week there are 12,009 tickets drawn and awarded prizes: 12,000 people receive $25; 6 people win $10,000; 2 people win $50,000; and 1 person wins $200,000.

   a) Determine the probability of winning each prize.

   b) If you play this game, what is your "expected" payoff?

3. Suppose you must choose between two products (A and B) to sell in your shop. Your choice depends on what the economy is going to do. If the economy goes up, you will make a profit of $100,000 on product A or $60,000 on product B. If the economy stays the same, you will earn a profit of $50,000 on product A and $40,000 on product B. And if the economy goes down, you will lose $20,000 on product A but can still earn $10,000 on product B.

You don't know for sure what the economy is going to do, but you might know the probabilities of these things happening. Suppose the probability of the economy going up is 0.4, the probability of it staying the same is 0.4, and the probability of it going down is 0.2.

Determine the expected profit for each product. Which product would you choose and why?

METRIC AND U.S. UNIT CONVERSIONS

Both metric and U.S. equivalent units have been used in this curriculum, as appropriate to the issues being discussed. For example, inventories of spent fuel are routinely reported in the United States in terms of metric tons,* even though most Americans are familiar with the short ton (2,000 pounds). Classroom experiments are usually conducted using metric units as well. Yet the standards and tests for spent fuel transportation casks are written using temperature in degrees Fahrenheit, miles per hour, and other similar units.

While the United States is working to increase its use of the metric system, both systems will be used during the transition period. To familiarize yourself with potentially unfamiliar metric units, conversion charts are provided here. Use Table 1 to convert a metric unit into its U.S. equivalent. To convert an U.S. unit into its metric equivalent, use Table 2.

For example, using Table 1 to convert 1,000 kilograms into its equivalent in pounds, multiply by 2.205 to get 2,205 pounds (1,000 kg X 2.205 lb/kg = 2,205 lb). Alternately, using Table 2, 2,000 pounds is equivalent to 907.2 kilograms (2,000 lb X 0.4536 kg/lb).

* One metric ton is equal to 1,000 kilograms (or 2,205 pounds).

Table 1. Approximate Conversions from Metric to English Units

If you know...

Length →	multiply by →	to get
millimeters (mm)	0.03937	inches (in)
centimeters (cm)	0.03281	feet (ft)
centimeters (cm)	0.3937	inches (in)
meters (m)	39.37	inches (in)
meters (m)	3.281	feet (ft)
meters (m)	1.094	yards (yd)
kilometers (km)	3,281.0	feet (ft)
kilometers (km)	0.5396	nautical miles (mi)
kilometers (km)	0.6214	statute miles (mi)
Area		
hectares (ha)	2.471	acres
hectares (ha)	1.076 X 105	square ft (ft^2)
Weight (mass)		
grams (gm)	0.03527	ounces (oz)
grams (gm)	0.002205	pounds (lb)
kilograms (kg)	2.205	pounds (lb)
metric tons (t)	1.102	short tons
metric tons (t)	0.984	long tons
Pressure		
kilopascals (kPa)	6.9	pounds/square inch (lb/in^2)
Volume		
cubic centimeters (cm^3)	0.06202	cubic inches (in^3)
cubic meters (m^3)	3.531	cubic feet (ft^3)
cubic meters (m^3)	1.307	cubic yards (yd^3)
liters (L)	2.113	pints* (pt)
liters(L)	0.2642	gallons* (gal)
Temperature		
Celsius	9/5, [then add 32]	Fahrenheit
Electric Current		
ampere (A)	1	ampere (A)
Energy, Work, Heat		
joule (J)	9.480×10^{-4}	BTU
Power		
watt (W)	1	watt (W)
watt (W)	3.4129	BTU per hour
watt (W)	1.341×10^{-3}	horsepower

Common Prefixes for Metric Units:

mega = million = 10^6	deci = one-tenth
kilo = thousand	centi = one-hundredth
hecto = hundred	milli = one-thousandth
deka = ten	micro = one-millionth
Examples:	kilogram = 1,000 grams milliliter = 1/1,000 liter

*liquid measure

Table 2. Approximate Conversions from English to Metric Units

If you know...

Length →	**multiply by** →	**to get**
inches (in)	2.54	centimeters (cm)
feet (ft)	30.48	centimeters (cm)
feet (ft)	0.3048	meters (m)
miles (mi)	1.609	kilometers (km)
yards (yd)	0.9144	meters (m)
Area		
square inches (in^2)	6.5	square centimeters (cm^2)
square feet (ft^2)	0.09	square meters (m^2)
square yards (yd^2)	0.8	square meters (m^2)
acres	0.4047	hectares (ha)
square miles (mi^2)	2.6	square kilometers (k^2)
Weight (mass)		
ounces (oz)	28.349527	grams (gm)
pounds (lb)	0.4536	kilograms (kg)
tons (long)	1.016	metric ton (t)
Pressure		
pounds per square inch	70.31	grams per square centimeter
pounds per square inch	0.145	kilopascals
Volume		
cubic feet (ft^3)	0.02832	cubic meters (m^3)
cubic inches (in^3)	16.387	cubic centimeters (cm^3)
cubic yards (yd^3)	0.765	cubic meters (m^3)
gallons* (gal)	3.785	liters (L)
pints* (pt)	0.473	liters (L)
quarts* (qt)	0.946	liters (L)
Temperature		
Fahrenheit	[subtract 32, then multiply by 5/9]	Celsius
Electric Current		
ampere (A)	1	ampere (A)
Energy, Work, Heat		
BTU	1,055	joules (J)
Power		
watt (W)	1	watt (W)
BTU per hour	0.293	watt (W)
horsepower	745.712	watt (W)

*liquid measure

TEST

NAME ______________________________

Directions: Circle the letter of the answer that best completes the statement given.

1. The Nuclear Waste Policy Act of 1982 and Amendments Act of 1987 are laws that establish a national policy for the:

   a. future of nuclear power generation in the United States
   b. storing, transporting, and disposing of high-level nuclear waste.
   c. environmental clean-up of our Nation's defense facilities.
   d. disposal of low-level nuclear waste and mill tailings.

2. United States scientific researchers currently favor __________ as the preferred long-term method of high-level waste disposal.

   a. shallow land burial
   b. underground tanks
   c. deep geological burial
   d. above-ground barrels

3. Studies that will NOT be a part of the U.S. Department of Energy's (DOE's) site characterization process at Yucca Mountain, Nevada, are:

   a. hydrologic, geologic, and geochemical characteristics of the site.
   b. social impacts of the repository.
   c. economic impacts of the repository.
   d. feasibility of a monitored retrievable storage facility at the site.

4. If the president recommends Yucca Mountain to the Congress as the site for the repository, and Nevada has NOT entered into a Benefits Agreement, the State of Nevada can:

   a. appeal to the Nuclear Regulatory Commission (NRC).
   b. submit a notice of disapproval to the Congress.
   c. appoint a special prosecutor to investigate the U.S. Government.
   d. conduct its own study of the site.

5. A Benefits Agreement between the State of Nevada and the DOE would:

   a. result in Nevada's giving up its right to disapprove the site recommendation.
   b. create a mechanism by which Nevada could also host a monitored retrievable storage system.
   c. result in the creation of a Nuclear Waste Technical Review Board.
   d. ensure that DOE will comply with existing transportation laws and regulations.

6. The purpose of the monitored retrievable storage facility is:

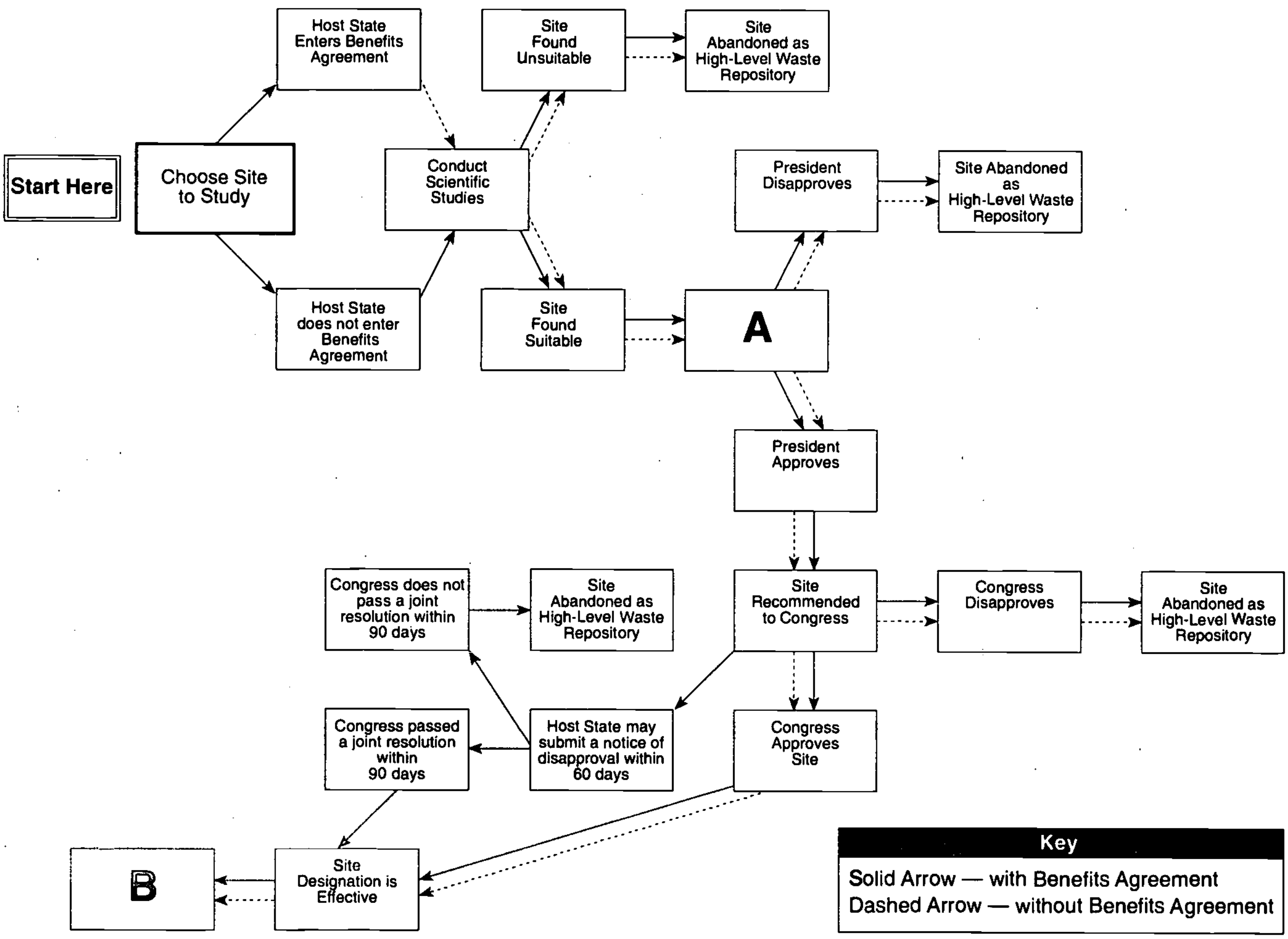
   a. to reprocess spent fuel.
   b. to provide interim storage of spent fuel.
   c. for permanent disposal of spent fuel.
   d. to serve as a regional storage facility for low-level waste.

7. Spent fuel will be transported to storage facilities in:

   a. tanks.
   b. barrels.
   c. casks.
   d. crates.

8. The source of the funds that will cover the costs of disposal of spent fuel from nuclear powerplants is:

   a. State taxes
   b. the U.S. Internal Revenue Service
   c. utilities using nuclear powerplants
   d. income taxes



Use the flow chart above to answer questions 9 and 10.

9. Which of the following would be appropriate in box A?

   a. site abandoned as a high-level waste repository
   b. DOE applies to the NRC for construction authorization
   c. DOE recommends the site to the President
   d. the President disapproves the site

10. Which of the following would be appropriate in box B?

   a. site abandoned as a high-level waste repository
   b. DOE applies to the NRC for construction authorization
   c. DOE recommends the site to the President
   d. the President disapproves the site

11. Present laws governing the disposal of nuclear waste:

   a. cannot ever be changed.
   b. can be amended by DOE.
   c. can be amended by the President.
   d. can be amended by Congress.

12. Casks for transporting spent fuel must be certified by the:

   a. Nuclear Regulatory Commission (NRC).
   b. Department of Energy (DOE).
   c. Department of Transportation (DOT).
   d. Environmental Protection Agency (EPA).

13. New shipping casks with increased fuel carrying capacities are being designed because:

   a. they may be less expensive than existing casks.
   b. they may be more expensive than existing casks.
   c. they will decrease the total number of waste shipments necessary.
   d. they will increase the total number of waste shipments necessary.

14. The Office of the Nuclear Waste Negotiator was established to:

   a. find a volunteer State of Indian Tribe to host a repository and/or an MRS facility.
   b. pick a State to host an MRS facility.
   c. oversee the transportation of high-level nuclear waste.
   d. represent radiation workers in contract talks with DOE.

15. Disposing of spent fuel and high-level waste is expensive. What is one way that the U.S. Government plans to respond to this problem?

    a. requiring all States to contribute funds to the civilian radioactive waste management program.
    b. charging hazardous materials carriers an insurance fee for transporting high-level nuclear waste.
    c. increasing State income taxes.
    d. requiring the U.S. government to pay the costs for disposing of defense high-level waste.

16. An example of a technical issue relating to the disposal of nuclear waste is:

    a. designing a cask that will keep radioactive material from reaching the environment.
    b. concern of local residents for the health of themselves and their families.
    c. improved local economy.
    d. increased local population.

17. An example of a societal issue relating to the disposal of nuclear wastes is:

    a. designing a cask that will keep radioactive material from reaching the environment.
    b. concern of local residents for the health of themselves and their families.
    c. developing models of groundwater movement patterns.
    d. understanding host rock response to thermally hot waste canisters.

18. Constructing the Nation's first high-level nuclear waste repository is a complex task and involves all of the following EXCEPT:

    a. a detailed program for the safe storage of low-level waste.
    b. a program for inspection of activities affecting quality on the site.
    c. a program to test that all structures and systems work satisfactorily.
    d. a defined, controlled, and verified repository design.

19. Ensuring public confidence of the safety of disposal of spent fuel and high-level nuclear waste is part of the complex of managing and disposing of high-level waste. Which of the following will help ensure public confidence?

    a. monitoring the transportation of low-level waste
    b. requiring utilities to pay a fee for all electricity generated by nuclear energy
    c. requiring independent review of all aspects of the waste disposal program
    d. regulating the disposal of transuranic waste

20. What will be studied to determine the impact of a repository on the economy of the host State?

    a. endangered animals and plants in the vicinity of the site
    b. groundwater flow patterns at the site
    c. geologic formations at the site
    d. numbers and types of jobs that will be created of lost

1. B	11. D
2. C	12. A
3. D	13. C
4. B	14. A
5. A	15. D
6. B	16. A
7. C	17. B
8. C	18. A
9. C	19. C
10. B	20. D

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