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GEOLOGIC AND HYDROLOGIC CONSIDERATIONS IN THE DISPOSAL OF LOW-LEVEL RADIOACTIVE WASTES

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INTRODUCTION

In view of the possible need for disposal of low-level radioactive waste in Delaware under the Nuclear Waste Policy Act of 1982, the Delaware Geological Survey has prepared this report to assist the citizens of our State in understanding this complex subject.

Emphasis here is on geologic and hydrologic aspects of disposal. Health, social, and economic factors are outside the scope of this report and are not discussed. However, they are very important integral parts of the safe disposal of low-level radioactive waste, and must be considered when selecting suitable disposal sites.

The material presented in the report has been compiled from numerous publications of the Department of Energy (DOE), Environmental Protection Agency (EPA), U. S. Geological Survey (USGS), and other sources.

This report is one of a Delaware Geological Survey series on disposal of different types of wastes. Reports on disposal of highly radioactive waste and solid waste have already been published (Spoljaric, 1981 and Spoljaric and Talley, 1982).

FEDERAL PROGRAMS AND RESPONSIBILITIES

On February 12, 1980, President Carter directed the Department of Energy to develop a national low-level radioactive wastes program. The stated purpose of the program is to ensure the safety of the public through appropriate management of low-level radioactive waste.

In developing the program, the Department of Energy has initiated technical assistance to the States and is coordinating state and federal waste management activities. DOE selected E. G. & G. Idaho, Incorporated as the lead contractor for the Low-Level Radioactive Waste Management Program.

In December of 1980, the Congress passed the Low-Level Radioactive Waste Policy Act (Public Law 96-573). The Act makes every State responsible for providing for the disposal of commercial low-level radioactive waste generated within its boundaries. The States are also authorized and encouraged to participate in interstate compacts to carry out this task.

In December 1982, the Nuclear Regulatory Commission (NRC) issued new licensing regulations for land disposal of radioactive waste. These regulations will become effective on December 27, 1983. They will amend previous regulations and provide very specific requirements for disposal of low-level radioactive waste.

In January 1983, the U. S. Congress passed the Nuclear Waste Policy Act of 1982 (Public Law 97-425) which covers disposal and storage of spent nuclear fuel, high-level radioactive waste, and low-level radioactive waste.

Several federal departments and agencies are directly involved in the handling and disposal of low-level radioactive waste.

The Nuclear Regulatory Commission is responsible for licensing and regulating all commercial users and handlers of radioactive materials.

The Department of Transportation (DOT) is responsible for regulating transport of low-level radioactive wastes. This includes safety requirements for packaging, shipping, storing, and handling of wastes.

The Environmental Protection Agency is responsible for developing criteria and standards for management of low-level radioactive wastes. All federal and State agencies are required to comply with these criteria and standards.

Several other federal agencies are involved, primarily in advisory capacities: the U. S. Geological Survey, the Bureau of Land Management, the National Oceanic and Atmospheric Administration, and the Federal Emergency Management Agency.

In some cases, the U. S. Coast Guard, Interstate Commerce Commission, and individual States may be involved in regulating the packaging and transport of low-level radioactive waste.

BACKGROUND

Types of Radiation

Radiation is manifested either as energy particles or waves generated by heat, light, sound, and ionized particles of matter. The last kind of radiation is associated with radioactive wastes.

There are three main types of radioactive radiation: alpha, beta, and gamma radiation.

Alpha radiation consists of highly energized positively charged particles. They quickly lose their energy when passing even through air (Figure 1). This type of radiation is generated by naturally occurring elements such as uranium and radium. Low-level radioactive wastes generally contain insignificant amounts of materials producing alpha radiation.

Beta radiation particles are negatively charged and are much smaller than particles of alpha radiation. They can penetrate farther through certain types of matter than alpha particles (Figure 1). However, an aluminum or glass sheet several millimeters thick stops this type of radiation. Many radionucleides, including tritium (radioactive hydrogen) produce beta radiation. This type of radiation is commonly found in low-level radioactive wastes.

Gamma radiation is a type of electromagnetic radiation. It can travel great distances and easily pass through different materials. A two-inch thick sheet of lead or a three-foot thick layer of concrete almost completely stops gamma radiation (Figure 1). Most types of low-level radioactive wastes contain components emitting this radiation.

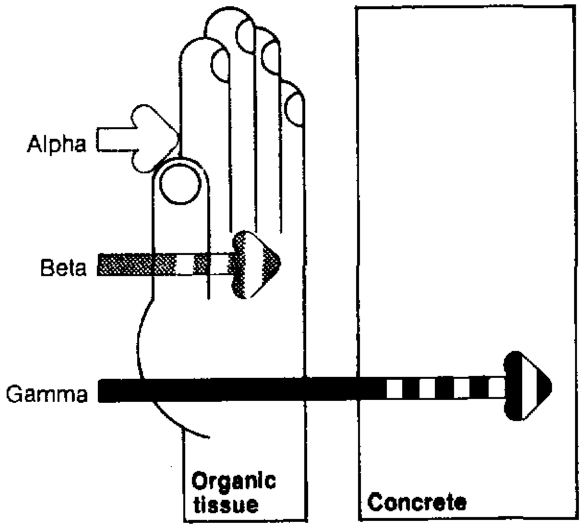

Figure 1. Examples of penetration abilities of different types of radioactive rays. (Source: U. S. Department of Energy, 1980).

What is Low-Level Radioactive Waste?

Legally defined, low-level radioactive waste is any radioactive material that is not classified as high-level radioactive waste, and is contaminated with less than 10 nanocuries* per gram of transuranic** elements (Public Law 97-425, January 7, 1983).

Low-level radioactive waste does not include wastes from the mining or milling of uranium ores. Generally, it includes by-products of industrial manufacturing and scientific, medical, or other research. The major specific sources of low-level radioactive wastes are nuclear power plants, industries utilizing radioactive materials, medical centers, hospitals, research institutions, and military installations.

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*One billionth of a currie; the unit for measuring radioactivity.

**An element with an atomic number greater than 92 (uranium).

Commercial power plants account for about 43 percent of all low-level radioactive waste. Research and medical institutions contribute about 25 percent, industry about 24 percent, and the U. S. Government (primarily military) the remaining 8 percent (National Low-Level Waste Management Program, 1980). The States in which the largest quantities of waste are generated are shown in Figure 2.

The waste itself consists of various materials containing radioactive contaminants, for example: discarded machinery or tools, clothing, plastics, grease, oil, and glass.

In most cases low-level radioactive waste does not require special shielding. In fact, some wastes have no more radioactivity than the natural background radioactivity.

Low-level radioactive waste is classified into three categories. This classification is based on concentrations of both long-lived and short-lived radionucleids. The specific criteria for classification are complex and described in detail in the Federal Register (Vol. 47, No. 248, December 27, 1982, p. 57473).

The most highly radioactive waste is Class C waste. This must meet the most rigorous requirements of disposal. Class B waste is an intermediate type of waste, and Class A needs to meet only the minimal requirements. Class A waste is usually separated from Class B and Class C wastes at the disposal site.

Production and Quantity of Low-Level Radioactive Waste

Low-level radioactive waste has been generated for many years. The U. S. Government has been producing the waste in significant quantities since the beginning of research and production of nuclear weapons in World War II. At present, the U. S. Government, primarily through its military programs, generates about 50,000 cubic meters of waste annually (National Low-Level Waste Management Program, 1980).

Since about 1950, through various industrial and research activities, mainly nuclear power plants and medical institutions, additional low-level radioactive wastes have been generated. On the average a medium-size hospital generates about 50 cubic meters of waste annually, a large one up to

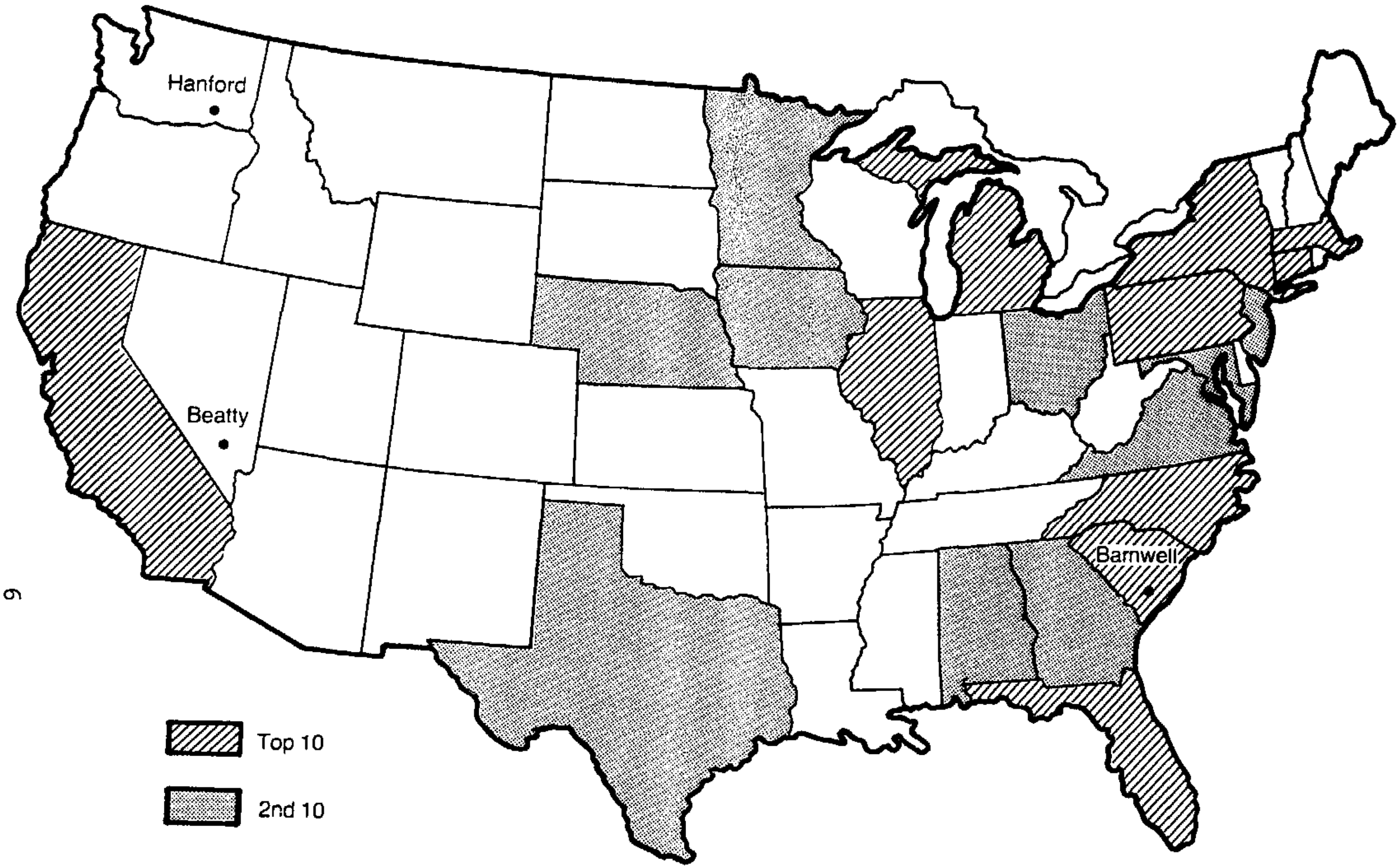

Figure 2. The major States that produced low-level radioactive waste in 1978. The locations of the three active disposal sites are also shown (Richland or Hanford, Beatty, and Barnwell). (Source: National Low-Level Waste Management Program, 1980.)

200 cubic meters. A large nuclear power plant (1,000 megawatts) generates about 1,000 cubic meters of waste annually. In 1980, nuclear power plants produced a total of about 100,000 cubic meters of low-level radioactive waste.

Treatment of Waste

The main purpose of treatment of low-level wastes is to reduce the quantity for disposal. Several methods are currently used, depending on the type of waste.

Liquid waste is reduced in volume by evaporation. The remaining liquid is thus concentrated and is solidified with cement, for example, as a binding material.

Filtration is employed to remove suspended solid particles from solutions. Ion exchange, on the other hand, is used to remove dissolved materials, primarily radioactive components, from solutions. Resins, which are used as ion exchangers, are then disposed. They may contain large amounts of radioactive contaminants.

Solid low-level radioactive wastes are usually compacted before disposal.

Military low-level wastes are basically treated the same way as commercial wastes. Most of the military waste is in a solid form.

Packaging and Transportation

Before being transported to disposal sites, low-level radioactive wastes are packaged in special containers: metal drums, metal tanks, fiberglass-reinforced plywood boxes, or strong cardboard and wooden boxes (National Low-Level Waste Management Program, 1980).

The type and size of the container is determined on the basis of the degree of radiation measured just outside of the container. The maximum allowable radiation is 1,000 millirem* per hour measured about 3 feet from the container. The containers must carry special markings and labels as required by federal regulations.

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*One-thousandth of a rem; the unit of radiation.

The containers of low-level radioactive waste are transported mainly by trucks from the facility where the waste was generated to the disposal site. The trucks must comply with all federal safety regulations. The transportation route must be selected in advance taking into consideration local and State requirements and appropriate officials and authorities must be notified.

SELECTION OF DISPOSAL SITE

The purpose of a disposal site is to isolate the waste from the environment for hundreds of years. Therefore, the site should be carefully selected and designed so that the isolation is maintained for such long periods of time.

Before a specific site is selected in Delaware, it is important to develop a detailed understanding of both geology and hydrology of the area. This includes knowledge of (1) the composition, characteristics, and distribution of surface and subsurface geologic units; (2) surface and ground-water flows; and (3) the effect of geologic units on flow of water (Fig. 3). All this information should be acquired before the final decision on the site selection is made so that all the necessary precautionary measures for the safe disposal of waste can be incorporated into the design of the site.

One of the most important criteria in accepting or rejecting a potential disposal site is permeability of the materials in which the site is to be located. The materials with low permeabilities, such as clays, are the most suitable because they can filter out some contaminants and contain radioactive liquids in case they escape from the disposal site.

The selected site must be surrounded and underlain by a buffer zone, i.e., undisturbed, low porosity, and low permeability geologic units. The site must be in a geologically stable area with minimal surface erosion, no flooding, and predictable climatic changes.

The possible migration paths of radionucleid carrying liquids from the waste must be determined before the site is used.

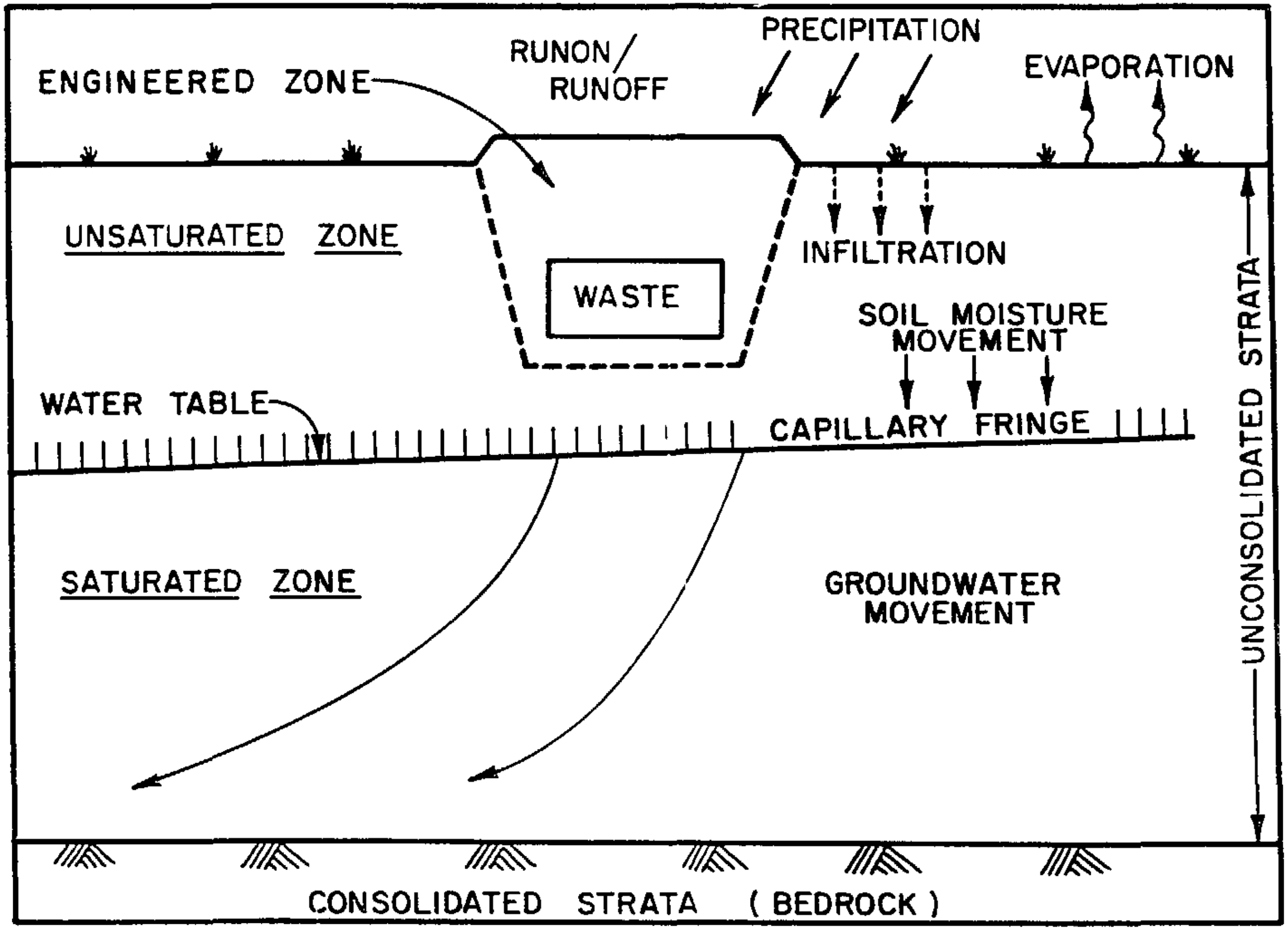


Figure 3. Schematic diagram of a disposal site with hydrologic variables that must be considered in determining suitability of an area for low-level radioactive waste disposal. (Source: Caswell, 1983).

The waste must be buried either above the water table or entirely in the water-saturated zone below the zone of water-table fluctuation. In the latter case, the site must be composed of fine sedimentary material (clays) with very low permeability.

DISPOSAL OF WASTE

Low-level radioactive wastes are generally buried in shallow trenches usually about 40 feet wide at the top, 25 feet at the bottom, 20 feet deep, and up to about 600 feet long. Trenches are spaced about 20 feet apart, and the whole disposal area is surrounded by a buffer zone. In addition to the buffer zone there are other barriers between the waste and the environment. The first barrier is the container which is made of material resistant to deterioration. The impermeable soil (clay) that surrounds the container is an additional barrier. Thus the environment is protected from the waste by at least three barriers. Containers with waste are placed in trenches and covered with soil, some of which may be compacted clay (Fig. 4). This type of disposal has been in use since the 1940's.

At present, there are three active commercial disposal sites: Barnwell in South Carolina, Beatty in Nevada, and Richland in Washington (Fig. 5). All three sites have been licensed by the corresponding States and the Nuclear Regulations Commission's Agreement State Program.

The Barnwell site is not licensed to accept organic liquid waste. In addition it will accept only 34,000 cubic meters of waste annually. The Richland site has not accepted organic liquids since December 1982.

The Beatty site accepts liquids only if they are contained in special vials.

The restriction imposed at both the Richland and Barnwell sites will most likely result in increasing amounts of waste being disposed in the Beatty site. This could result in the Beatty site being filled to capacity within the next several years. Consequently, the remaining two sites would not be able to accomodate all commercial low-level radioactive waste produced in the country.

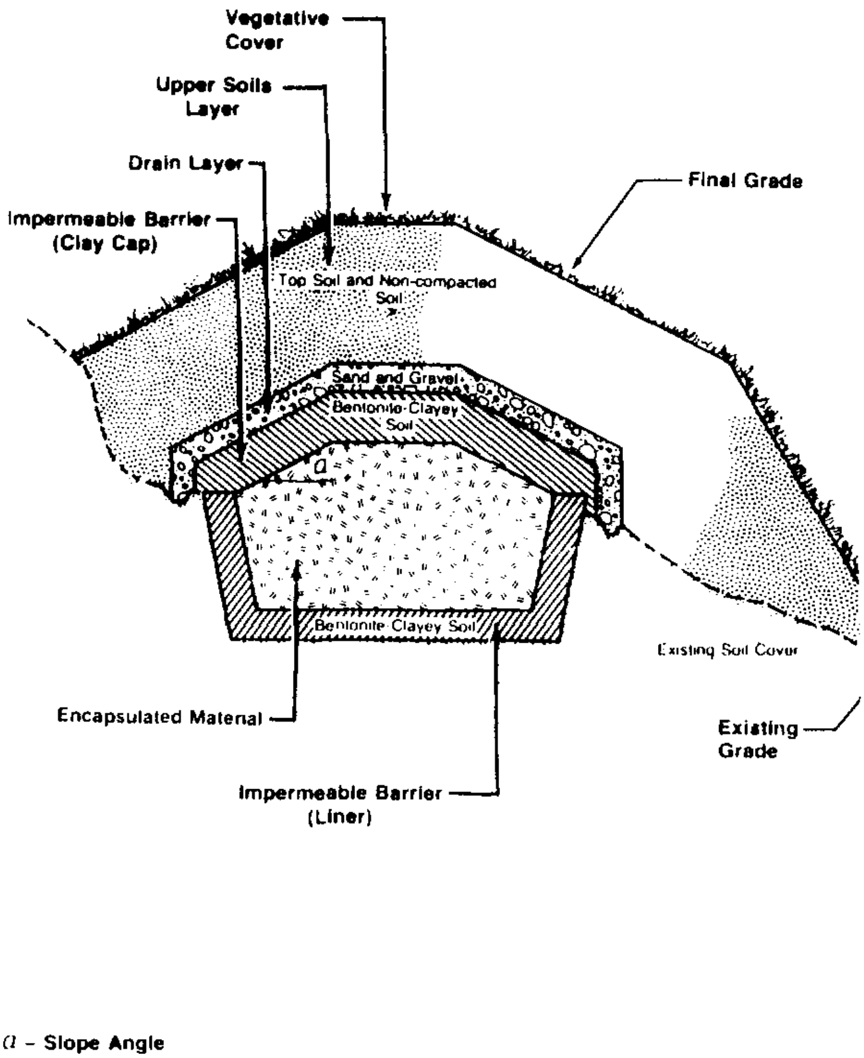


Figure 4. Cross-section of a disposal trench for low-level radioactive waste. (Source: Metry and Corbin, 1983.)

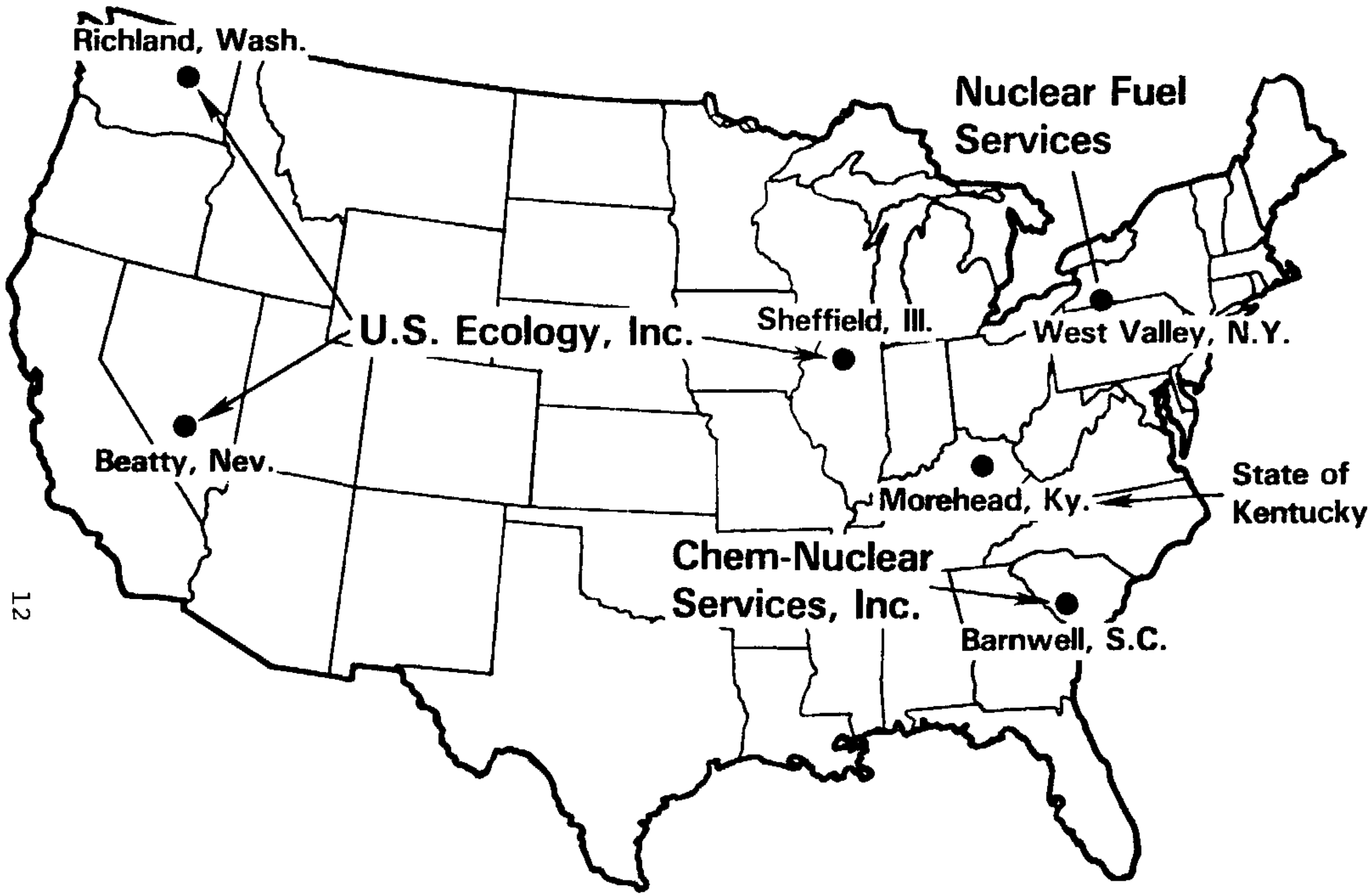


Figure 5. Original commercial low-level radioactive waste disposal sites. Only Richland, Beatty, and Barnwell are still open. (Source: Ramsey, 1982.)

The federal (Department of Energy) facilities appear to be adequate for the near future. There are 14 active waste disposal sites (Fig. 6). Eight of these are quite small and are used exclusively for the disposal of depleted uranium (Ramsey, 1982).

ENVIRONMENTAL MONITORING

The low-level radioactive waste disposal sites must be monitored to detect early any possible leaks of radioactive contaminants into the surrounding environment. Early detection is important so that remedial measures can be implemented before actual damage occurs.

The monitoring involves collecting and analyzing samples of both surface and ground water (Fig. 7), as well as gasses (air). The samples are analyzed for a variety of radioactive elements that are contained in the waste.

Even when the disposal site is full and closed to further waste disposal, the monitoring must continue to the same extent as when the site was active. If no problems, i.e., no escape of radionucleids into the surrounding environment occurs after several years, the monitoring is reduced in scope, but continues for about an additional 100 years.

CONCLUDING REMARKS

Although low-level radioactive waste is hazardous if not handled, treated, and disposed of in a safe and proper manner, it is not nearly as potent as high-level radioactive waste.

The major immediate problem seems to be insufficient disposal sites. Delaware is a "non-agreement State" which means that all licensing regarding radioactive material is administered by the federal government. In 1981, there were 37 facilities in the State holding Nuclear Regulatory Commission licenses (Centaur Associates, Inc., 1981).

Low-level radioactive waste is and will be generated in the future in the State by industry and educational and medical institutions. In January 1981 the Governor assigned the task of coordinating activities associated with waste in the State to the Department of Natural Resources and Environmental Control.

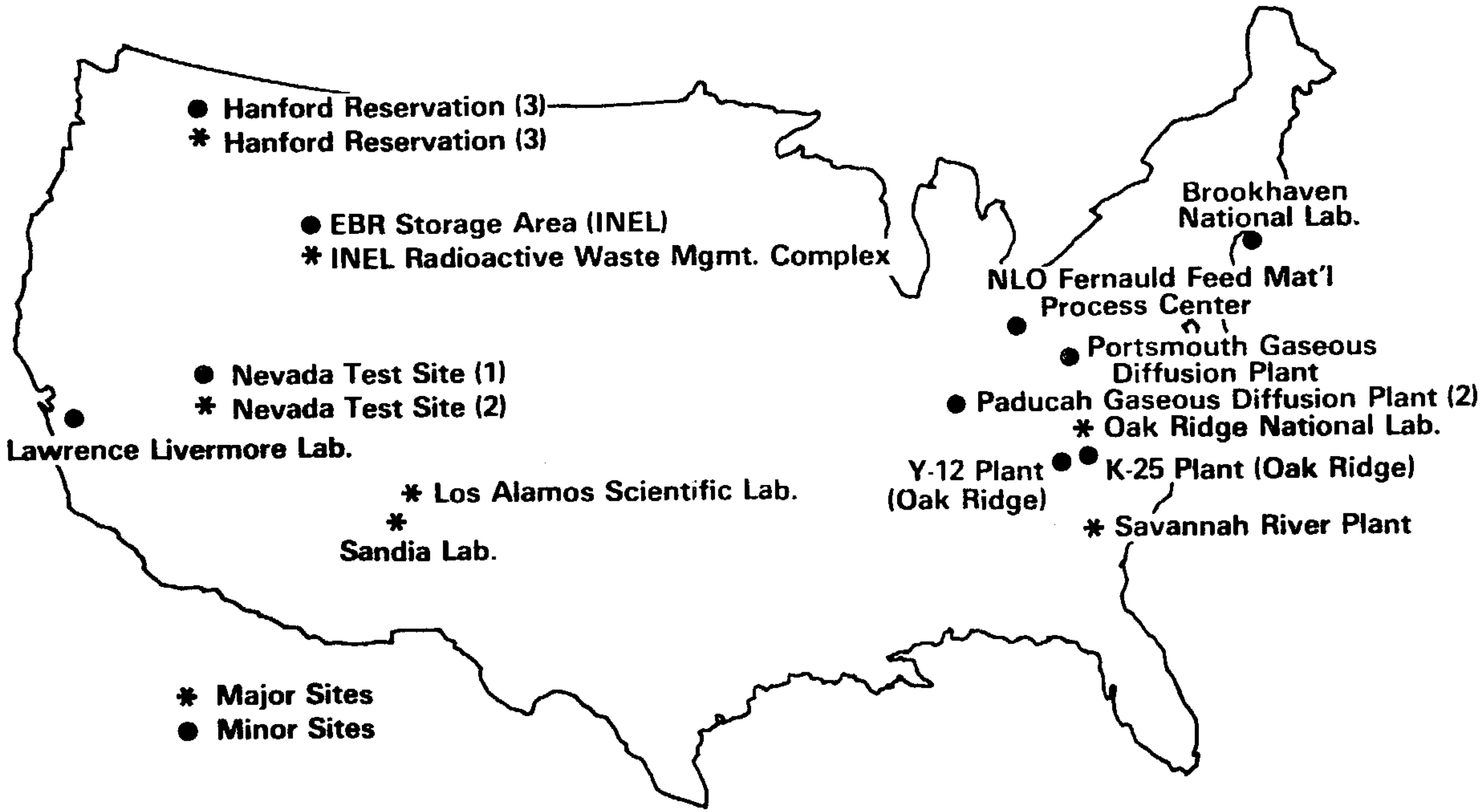
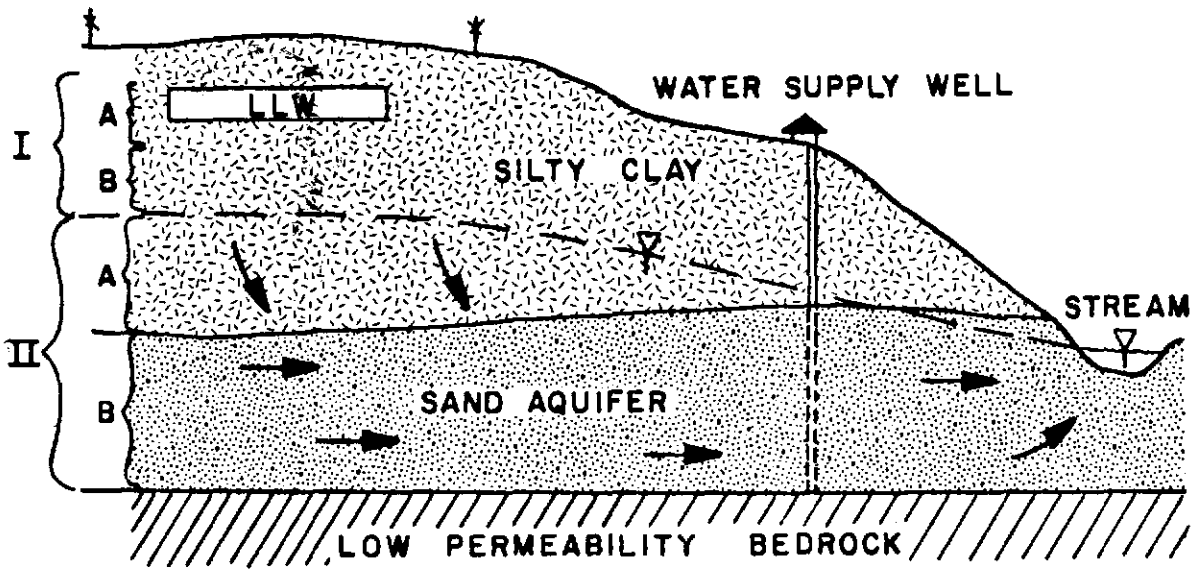


Figure 6. Locations of the Department of Energy low-level radioactive waste disposal and storage sites. (Source: Ramsey, 1982.)

Recent developments indicate a possibility that at least some of the waste generated in our State will be disposed of in the State as well.



I. UNSATURATED ZONE

A. EARLY DETECTION ZONE - IN-SITU TESTING NEAR THE WASTE.

B. SOIL MOISTURE SAMPLING BETWEEN WASTE AND WATER TABLE.

II. SATURATED ZONE

A. NEAR THE WATER TABLE, PARTICULARLY FRACTURED OR HIGH PERMEABILITY ZONES.

B. WATER SUPPLY AQUIFERS.

Figure 7. Cross-section of a disposal site indicating ground-water zones that must be monitored. LW = low-level radioactive waste disposal trench. (Source: Johannsen and Nichols, 1983.)

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