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The Use of Geophysical Monitoring Systems and Data to Identify and Designate Ocean Sites for Disposal of Low-Level Radioactive Wastes

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THE USE OF GEOPHYSICAL MONITORING SYSTEMS AND DATA TO IDENTIFY AND DESIGNATE OCEAN SITES FOR DISPOSAL OF LOW-LEVEL RADIOACTIVE WASTES

by

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FOREWORD

In 1972 Congress enacted the The Marine Protection, Research and Sanctuaries Act (PL 92-532). The Act required the Environmental Protection Agency (EPA) to develop regulations to control ocean disposal of all wastes, including low-level radioactive wastes (LLW). The EPA Office of Radiation Programs (ORP) initiated specific studies to develop criteria directly applicable to ocean disposal of LLW.

The ORP has conducted feasibility studies to determine whether present-day technologies could be applied to determine effects from previous (1946 to 1970) U.S. disposals of radioactive wastes in the oceans. After successfully locating LLW containers in three previously used disposal sites, the ORP initiated characterization studies to: (1) determine the biological, chemical, and physical parameters within each of the sites; (2) monitor for the presence and distribution of radionuclides in each site, including their concentration levels; and, (3) assess the performance of past packaging techniques and materials.

The purpose of this report is to provide information applicable to using geophysical instruments and survey methods, and the data collected, in the process of designating sites for ocean disposal of LLW. The geophysical ocean survey methods described in this report are envisioned as preceding any sediment sampling required to characterize disposal sites.

The Agency invites all readers of this report to send any comments or suggestions to Mr. David E. Janes, Director, Analysis and Support Division, Office of Radiation Programs (ANR-461), Washington, D.C. 20460.

Richard J. Guimond, Director
Office of Radiation Programs

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I also wish to thank Mr. Robert S. Dyer and Mr. William Curtis of the Office of Radiation Programs, U.S. Environmental Protection Agency, for critical review of this report and for the many helpful suggestions and discussions during the course of this work. The critical review and comments also provided by Dr. William Forster of the U.S. Department of Energy and Dr. James Booth of the U.S. Geological Survey are gratefully acknowledged. Typing of this document by Ms. Phoebe H. Suber is also acknowledged with appreciation.

1. Introduction

The Environmental Protection Agency (EPA) is currently revising its 1977 Ocean Dumping Regulations. The revised regulations will incorporate criteria applicable to any ocean disposals of low-level radioactive wastes (LLW), as recommended by the International Atomic Energy Agency (IAEA). The IAEA recommends, pursuant to Annexes I (Sec. 6) and II (Sec. B.) of the London Dumping Convention (LDC), that any LLW disposed in the oceans should be properly packaged and disposed in deep ocean sites where the average water depth exceeds 4000 meters. Thus, the Agency, in revising the regulations for all wastes, will also include waste package performance and site designation criteria that are specific to LLW.

In addition to including siting and packaging performance criteria in the revised regulations, the Agency is preparing a series of technical reports that provide LLW disposal site monitoring recommendations. Sediment monitoring requirements for ocean disposal of all wastes, as listed in Part 228 of the existing Ocean Disposal Regulations (42 FR 2462 of January 11, 1977), include organic carbon, texture, particle size distribution, major mineral constituents, and settling rate. Because of the unique character of LLW, their potential for migration in sediments, and the different environmental stresses that the waste packages will be subject to from disposal in the deep ocean, additional disposal site sediment monitoring parameters are recommended. These include determining: (a) the sorptive distribution coefficient (Kd) of radionuclides; (b) sediment redox potential by the nitrate method and other supporting techniques; (c) pH; (d) geotechnical parameters; and (e) the composition of sediment core samples by the x-radiograph technique. Specific rationale for recommending each of these additional sediment monitoring parameters, and disposal site characterization data applicable to immobilizing LLW, are presented in two of the referenced technical reports (Neiheisel, 1988 and U.S. EPA, 1988). In general, determining these additional sediment parameters in LLW disposal sites will provide data for predicting the capability of sediments to retain radionuclides. Calculating the radionuclide retention factor of sediments in potential LLW disposal sites is very important because it can indicate whether a sufficient natural barrier to radionuclide migration exists in case the primary, engineered-barrier (waste container) fails.

This report is another in the Agency's series of technical documents that provide specific recommendations applicable to any future ocean disposal of LLW. It provides information about using geophysical instrumentation and survey methods in designating disposal sites.

In March 1987, the EPA Office of Radiation Programs (ORP) participated in the U.S. Geological Survey (USGS) mapping of the mid-Atlantic Exclusive Economic Zone (EEZ) using the geological, long-ranged inclined asdic (GLORIA) system to obtain sonographs (rough images) of the sea floor. Data from that survey shows that use of the GLORIA system can significantly improve the process for locating and designating potential LLW disposal sites. Within those portions of the mid-Atlantic EEZ (33.5^{O}N to 39^{O}N latitudes), where water depths exceeded 4000 meters, the GLORIA data identified no less than three sites with little or no indication of debris flow or other detrimental phenomena. Smaller-scale geophysical surveys, at each of the three sites identified from the GLORIA data, could provide more specific resolution of seafloor topography and a better assessment of environmental conditions within each site. The more specific data could be obtained from detailed sonographs provided by high-resolution seismic reflection profilers, from sea floor photographs, and from sediment characterization studies.

2. Geophysical Instruments

State-of-the-art geophysical instruments used to obtain reconnaissance plan-view imagery of large sections of the ocean floor have been compared to the first high-resolution photos of earth taken from space by the Landsat satellite (Hill, 1986). Side-scan sonars, seismic profilers and other geophysical instruments, supplemented by in-situ sediment monitoring, provide a means for assessing potential LLW disposal sites in the deep ocean. The full potential for applying such instruments to locating possible LLW disposal sites began in 1984 when the USGS initiated monitoring surveys of the EEZ, which extends to 200 nautical miles offshore. During these surveys, the long-range side-scan sonar system GLORIA mapped the seafloor. The first phase of GLORIA mapping in the EEZ, off the U.S. west coast, was completed in 1984. The data from the initial surveys, including interpretations of seafloor topography at a scale of 1:500,000, were published in atlas format (EEZ - SCAN 84, 1986). Mapping of the EEZ off the U.S. east coast was completed in 1987. Publication of that data is expected in 1989. The EPA participation in the mapping of the mid-Atlantic EEZ was motivated by an opportunity to obtain supplemental data pertinent to earlier EPA studies at the previously used 2800m and 3800m LLW disposal sites that are located in the mid-Atlantic EEZ. The insight gained on the capabilities and limitations of geophysical instruments during the USGS mid-Atlantic survey was invaluable in preparing this report.

The remainder of this report briefly discusses various side-scan sonar systems and seismic profilers that can be used to identify geologically stable, deep-water areas for potential designation as LLW disposal sites.

2.1. Side-Scan Sonar Systems

The GLORIA system is a specialized side-scan sonar capable of large-scale reconnaissance mapping of deep-ocean seafloor topography. GLORIA can map seafloor areas of approximately the same size as the state of New Jersey in a single day (MacGregor and Lockwood, 1984), while towed by ship at a speed of 8 - 10 nautical miles per hour (knots). Developed into a digital data collection system in 1981 by the United Kingom Institute of Oceanographic Sciences, this unique side-scan sonar operates at a nominal frequency of 6.5 kHz and a 100 Hz band width from a transducer array towed at 50 meters depth. The recorded pulses received are corrected in real time aboard the ship and used to produce sonographs which are images that show entire surfaces of topographic features at 50-m resolution. The advantages of the GLORIA mapping over conventional mapping techniques is that correlations and trends of features such as ridges and channels can be made with confidence between seismic profiles, and that the patterns of such features as meandering channels and dendritic canyons can be clearly defined (Cacchione, et al, 1988).

As the GLORIA imagery on the mid-Atlantic EEZ survey was being assembled aboard the RV FARNELLA in March 1987, it became apparent that major slumping areas and submarine canyons with interconnecting drainage patterns were more numerous and more complex than had been previously depicted on existing contoured bottom charts. Local tectonic structures and tonal differences that reflected a variation in sediment types also added to the interpretation of the bottom topography. The detailed GLORIA imagery provided an interpretative means of identifying areas of transport and erosion that could reflect on the suitability of considering an area for LLW disposals.

The GLORIA data obtained from the mid-Atlantic EEZ, in locations deeper than 4000 m, reveals three areas (one off New England and two off the Carolinas) that show relatively static geologic environs, free from debris flows or other indications of instability. These three areas, observed in unprocessed GLORIA data made available to EPA by the USGS, will be assessed in greater detail after final processing of all data which should provide improved resolution over the unprocessed imagery. These areas could be candidates for potential LLW disposal sites. Further study of these locations would require the use of more detailed, narrower ranged side-scan sonar and other geophysical instruments.

The National Oceanic and Atmospheric Administration (NOAA) utilizes a hull-mounted side-scan sonar system, SEA BEAM, that maps a smaller seafloor area, but in more detail, than the GLORIA system. The 5 km mapping "swath" of SEA BEAM is much narrower than the 30 km trackline spacing of the GLORIA system but the resultant map is much more detailed.

In addition to using GLORIA, the USGS has deployed the SEA MARK I, a mid-range side-scan sonar, to collect detailed topographic data of slump zones on the continental slope and rise off North Carolina (Cashman and Popenoe, 1985) and for surficial geological studies in the Northern Baltimore Canyon (Robb et al, 1982).

Seafloor maps provided by the SEA BEAM and SEA MARK I side-scan sonar systems, in conjuction with data obtained from high-resolution seismic profilers, have yielded excellent details of bottom features in selected areas of mapping. The use of SEA MARK I or SEA BEAM is recommended to enhance bottom features observed in GLORIA data and especially in the process of characterizing a site for consideration as a potential LLW disposal site.

The long-range (GLORIA) and medium-range (SEA BEAM and SEA MARK I) side-scan sonar imagery systems are valuable tools to the researchers, enabling them to focus on ocean bottom features that can indicate the degree of geologic stability in deep ocean environments. Areas of bottom surface stability or active areas of erosion and deposition can be identified from the sonograph imagery. Vertical stability of a seafloor area is not always discernable from side-scan sonar imagery, but the use of high-resolution seismic profilers can provide vertical stability data. The fact that six times as many seismic data profiles are available from SEA BEAM or SEA MARK I surveys, as compared to GLORIA, is a decided advantage with the more detailed surveys.

2.2. Seismic Profiling Systems

Continuous seismic profiling methods complement the side-scan sonar imagery and permit a more certain interpretation of the geological stability of a potential LLW disposal site. Combined use of a 3.5-kHz Sub-Bottom Profilier with a deep penetrating seismic system, using a 160 in^3 air gun or similar sound source, provides a detailed resolution of sediment layering and subsurface geologic structures, extending from the seafloor surface to underlying basement rock.

2.2.1. Airgun Profiler

During the GLORIA survey of the mid-Atlantic EEZ, deep penetration mapping of the ocean sediments and basement rock was obtained by using a 160 in^3 airgun with a hydrophone streamer of French-Italian design. The airgun was fired at 10-second intervals and at a 6-second sweep. Incoming data was fed in parallel to a special USGS computer (MASSCOMP) which digitized and displayed the data in real time on a monitor and recorded the data on nine-track magnetic tape. This type of deep penetrating seismic profiling is considered essential to assessing the stability of a candidate LLW disposal site and adjacent areas.

Deep penetrating seismic profiling provides a means of correlating surface bottom relief with reflectors found in the subsurface geology. Structures have been identified by the deeper penetrating seismic reflection systems that could eliminate a potential site for LLW disposal. An example is seen in data from the Atlantic continental slope and rise off North Carolina where a salt diapir complex was observed (Cashman and Popenoe, 1985). Salt diapirs are related to instability as they normally indicate areas of extensive slumping. The slumping appears to be a result of uplift and faulting associated with the vertical intrusion of the diapir.

Seismic reflection profile data, from along the edges of buried rift basins in the Long Island Basin, show low-angle border faults, tilted sedimentary horizons, and high-angle cross faults (Hutchinson et al, 1986). Such structures of instability are reported from Nova Scotia to South Carolina in the Atlantic continental margin. Although these structures were observed in shallower areas than the 4000-m depth recommended by the IAEA for LLW disposal sites, they are examples of utilizing deep penetration seismic profilers to obtain interpretative data.

Preliminary releases of Atlantic GLORIA survey data by the USGS (Ocean Science, 1987) report two fields of apparent salt domes off the Carolinas and northern New Jersey. These salt dome fields, and other features observed in the seismic profile data that will be published in the forthcoming EEZ Atlas of the Atlantic, will likely exclude otherwise potentially favorable LLW disposal sites from further consideration.

2.2.2. High-Resolution Profiler

A high-resolution 3.5-kHz profilier provides a graphic view of sediment layering in the upper 25-100 m of bottom sediment. The 3.5-kHz system is sometimes termed the sediment profiler since it presents a vertical profile of layered soft sediment. A 12-kHz system is also used with the 3.5-kHz profiler to obtain bathymetry data.

A typical 3.5-kHz system consists of a transceiver (transmission and receptor device) towed from the bow, and a recorder aboard ship. A 3.5-kHz sediment profile, recorded aboard the RV FARNELLA during the USGS mapping survey of the mid-Atlantic EEZ, is shown in Figure 1. This profile was obtained from an area in the lower seaward portion of the Baltimore Canyon. The profile shows the continuity and regularity of multiple layers in the upper 25 m of bottom sediments along a section of the ship's track in this area. Using Figure 1 as an example, one can readily see the utility of using geophysical instruments during LLW site selection or designation surveys to evaluate the degree of geologic stability and sediment uniformity in a prospective deep-sea location.

3. Disposal Site Monitoring

Monitoring surveys to select deep-ocean candidate LLW disposal sites should include the use or collection of geophyscial data and sediment samples. Identification of relatively large-scale, static or stable seafloor areas can be made by examining available USGS reconnaissance imagery data obtained from the GLORIA surveys of the EEZ. More detailed and smaller scaled data (for example, from the SEA BEAM and SEA MARK I mid-range side-scan sonar systems) can then be used, in conjunction with extensive seismic reflection profiling data, to delineate bottom features in potentially static areas identified by the GLORIA data. It should be noted here, however, that, although a relatively large volume of side-scan sonar and seismic relection profile data has been collected in the U.S. east and west coast EEZ areas, one of the criteria for designation of LLW disposal sites requires an average water depth in excess of 4000 meters. This depth is recommended by the IAEA and is accepted by the United States as a signatory to the LDC. Thus, potential areas for consideration as LLW disposal sites will be limited by this criterion within the U.S. EEZ, particularly in the Atlantic Ocean.

It is also important to note that assessments of potential LLW disposal sites should not be based solely upon side-scan sonar and seismic profile data. Site selection/designation processes will require in-situ sediment sampling. Accordingly, the EPA has prepared a report recommending sediment monitoring methods for LLW disposal sites (U.S. EPA, 1988).

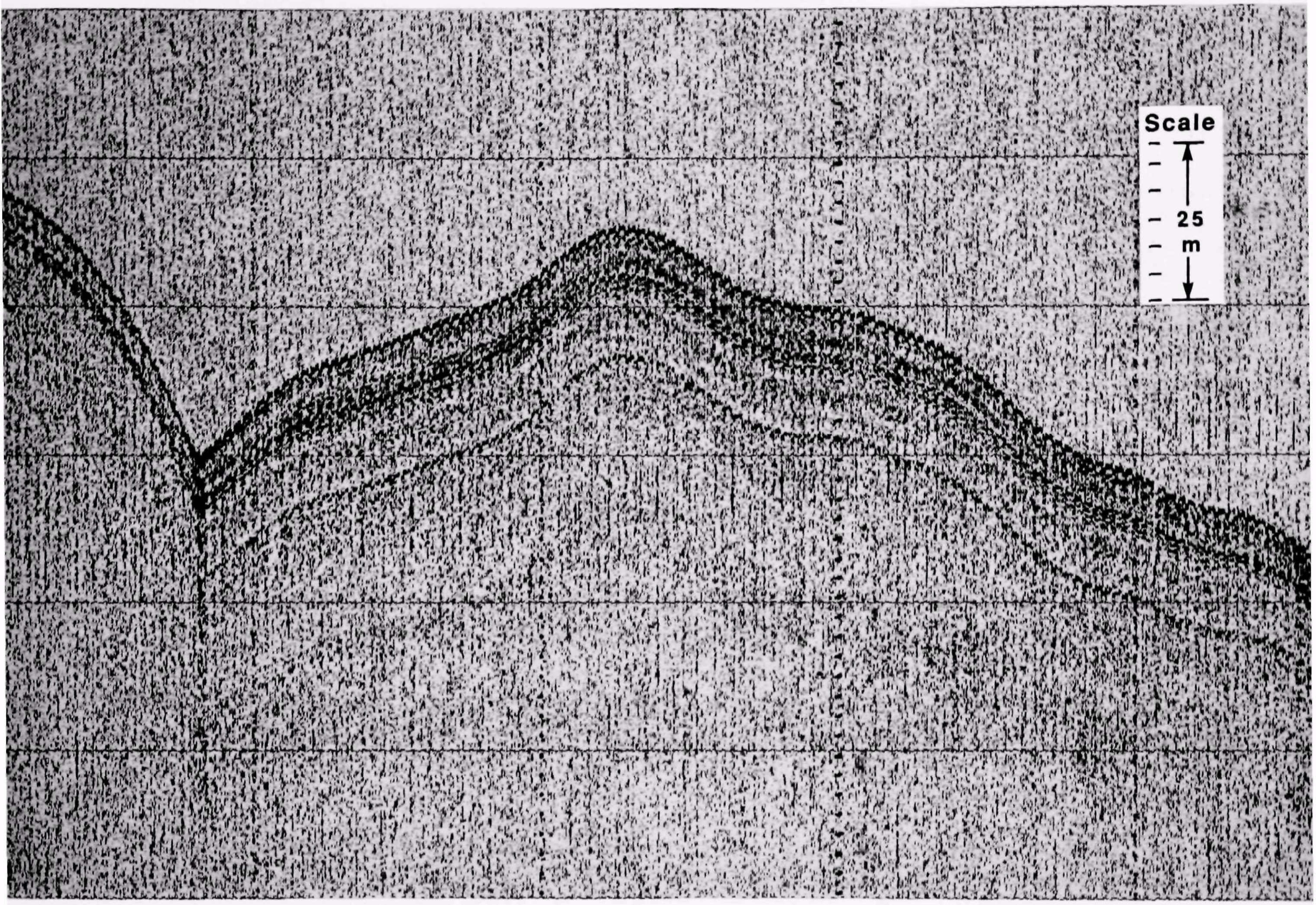

Figure 1. A graphic 3.5-kHz, high-resolution profile of sediment layers along the continental slope in the lower reaches of the Baltimore Canyon. Data obtained on March 12, 1987, during a USGS survey of the mid-Atlantic EEZ.

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