



**STATENS
KÄRNBRÄNSLE
NÄMND**

NATIONAL BOARD FOR SPENT NUCLEAR FUEL

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Technical and

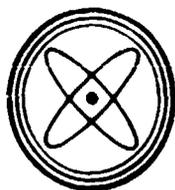
Socio-political Issues

in Radioactive

Waste Disposal

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Volume II
Subseabed Disposal



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NATIONAL BOARD FOR SPENT NUCLEAR FUEL

**TECHNICAL AND SOCIO-POLITICAL ISSUES
IN RADIOACTIVE WASTE DISPOSAL
1986**

**Volume II
Subseabed Disposal**

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of
The Royal Swedish Academy of Sciences**

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SUBSEABED DISPOSAL

A. IntroductionA.1. Background

Seventy percent of the earth's surface is covered by water. A global search for a high level waste and/or spent fuel disposal site under the site-selection guidelines outlined in Volume I, Chapter III would find that clay sediments under the oceans are among the most stable and homogeneous geological formations on earth. Eight countries¹ and the Commission of the European Communities (CEC) in the Seabed Working Group (SWG) of the Organization for Economic Cooperation and Development (OECD), Nuclear Energy Agency (NEA) had been actively pursuing research into the technical feasibility of developing one or more of these clay sediment areas into an international waste repository. For some of these countries subseabed disposal is the backup choice to a land-based national Mined Geological Repository (MGR) for high level waste.

In 1984 OECD-NEA published a report on the multinational studies in subseabed disposal (as of the end of 1982) (NEA, 1984a).

¹Canada, Federal Republic of Germany, France, Japan, Netherlands, Switzerland, United Kingdom, United States (Belgium, Italy, Sweden have observer status).

In 1983, the Seabed Working Group (SWG) prepared a five-year plan for producing a "Concept Assessment Report," which would have been published in 1988. The United States' national programme anticipated publishing its own feasibility assessment in 1990, as its scientists thought more extensive research was necessary. The sudden decision by the U.S. Department of Energy to drop funding from US \$8 million in 1986 to zero in 1987 has changed everyone's plans. The United States was the first to explore the subseabed disposal concept, and accounts for nearly half the research funds expended to date. Cancellation of the U.S. research programme and its withdrawal from the Seabed Working Group (SWG) has led to a decision by the SWG to reassess its programme.

In order to retain the information already available, the Seabed Working Group (SWG) intends to publish a final report in 1987 that will summarize national and international research and explicitly identify other research needed for a comprehensive assessment of the subseabed disposal concept. It will include a preliminary radiological risk assessment. The accuracy of this risk assessment will be limited, as the components of the integrated systems model will not be validated or, in some cases, verified. Estimated data values will be used where real data are not available. In some cases the data has been collected, but there is not enough time to analyze and prepare it for use in the model. The SWG's final report will also include a complete bibliography of publications relevant to the assessment of subseabed disposal.

A.2. Concept

Suitably packaged waste (processed waste or spent fuel) would be taken by ship to the disposal site and placed tens of meters deep in the

bottom sediments. The waste package, important during transportation and emplacement, would provide the first barrier to nuclide migration. Greater reliance is placed on the clay sediments, which would sorb radionuclides and delay their release long enough for them to decay to very low levels. Radionuclides escaping the sediments would be diluted and dispersed by the ocean waters, which would also protect the repository from human intrusion.

An artist's conception is shown in Figure 1 (J.K. Associates, 1985).

B. Site Selection and Assessment Studies

The purpose of these studies is to identify potential sites for the disposal of heat-generating wastes in the seabed. The United Kingdom Programme has also looked at the possibilities of disposal on the seabed. Generic site selection criteria for subseabed disposal are quite similar to those discussed in regard to the land-based Mined Geological Repository.

The Seabed Working Group reviewed information on fifteen areas in the North Atlantic and five areas in the Pacific Ocean. Analyzed specifically under the guidelines listed below, four Atlantic and three Pacific locations appeared to meet minimum specifications. For practical reasons, primarily accessibility and lesser political opposition, the Atlantic areas were chosen for further investigation. Since 1985 research has concentrated on two sites, the Southern Nares Abyssal Plain (SNAP), and the Great Meteor East (GME) location on the Madeira Abyssal Plain, shown in Figure 2 (Arup et al, 1985). The formal

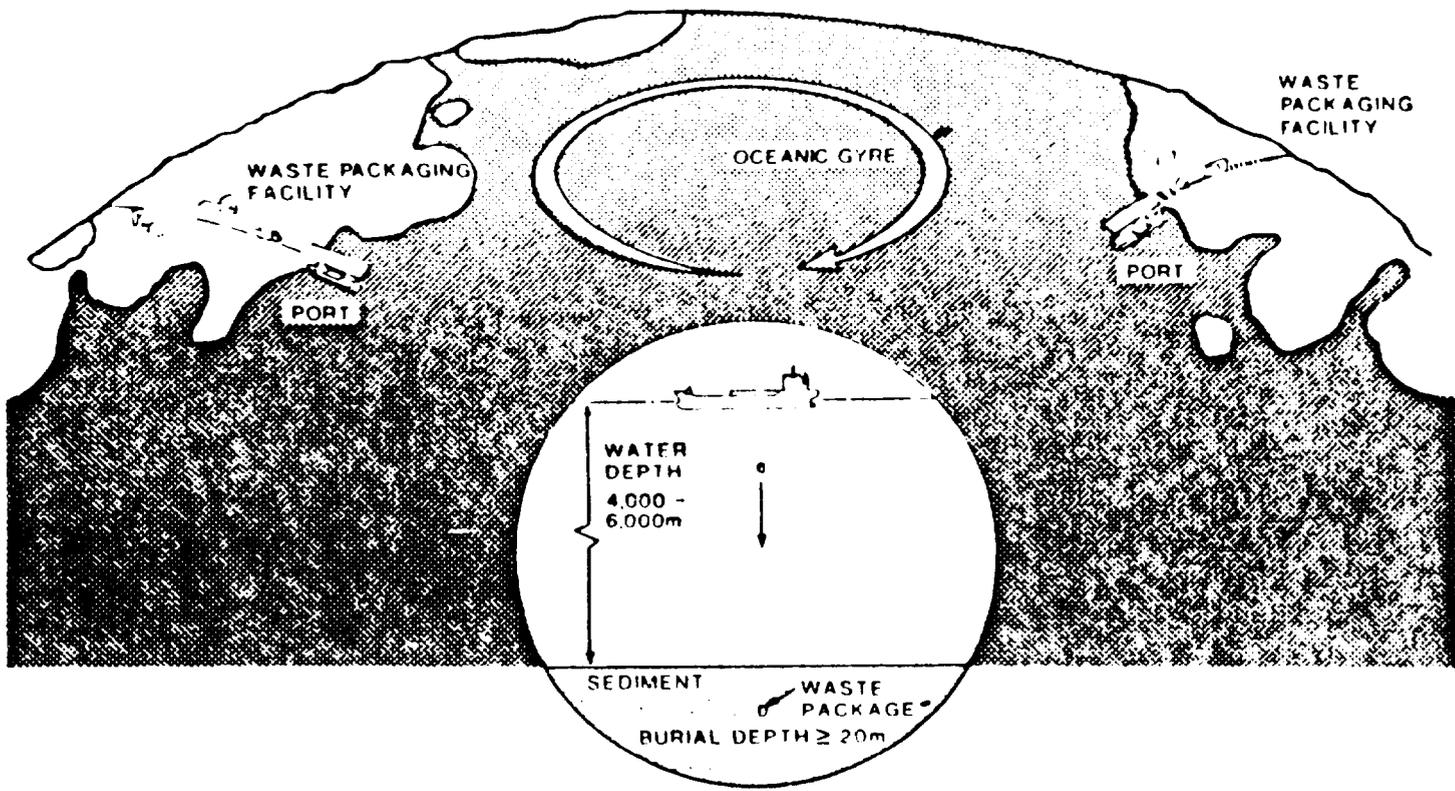
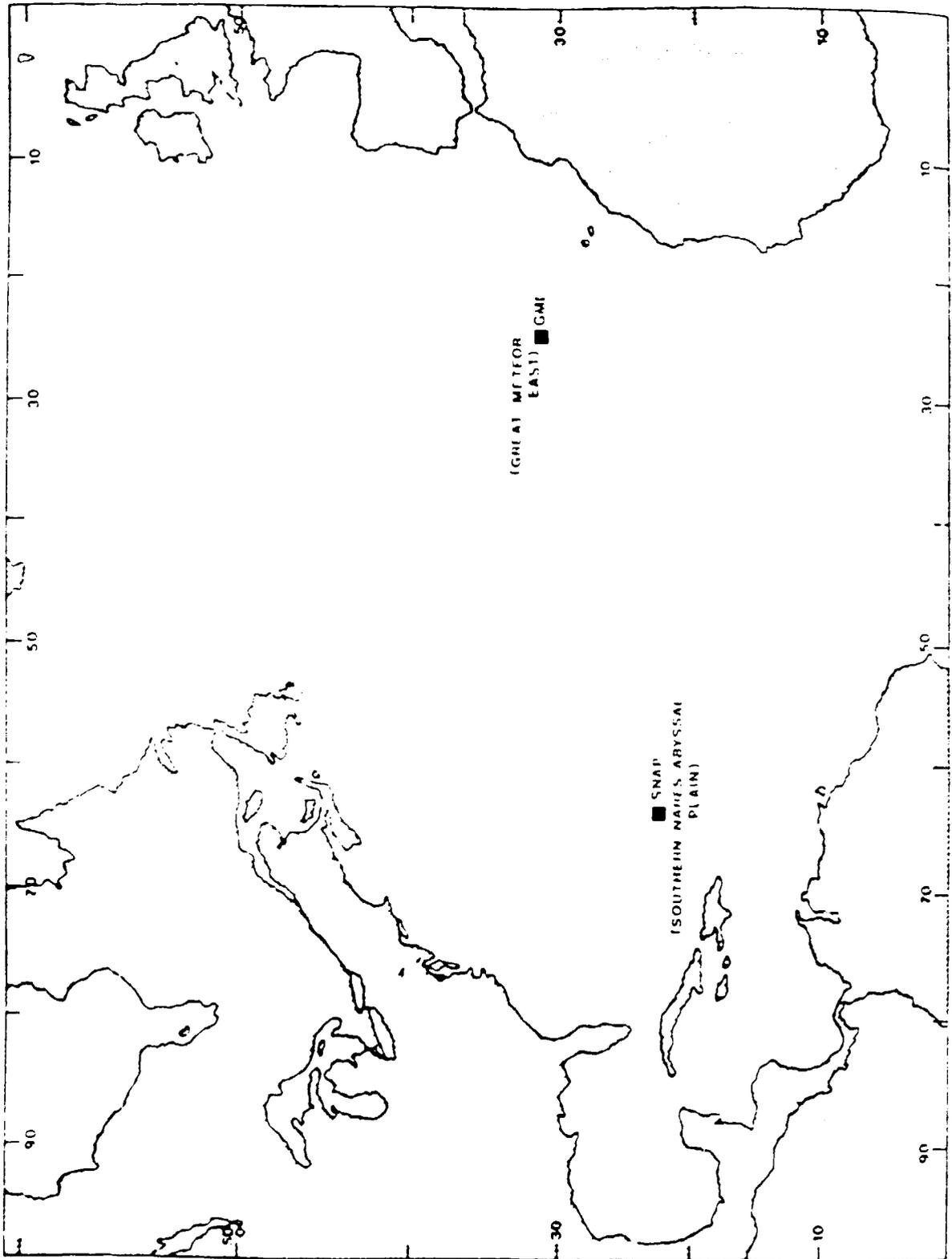


Figure 1. Artist's Conception. Source: J.K. Associates, 1985.

Figure 2. Seabed Working Group Study Areas. Source: Arup et al., 1988.



guidelines for assessment were based on three exclusionary criteria: stability, barrier and avoidance.

B.1. Stability and Predictability

The areas being considered for subseabed disposal of radioactive wastes are among the most stable formations on earth. Mid-plate, mid-gyre locations are far from the overlaps common in continental areas and are not affected by severe long-term climatic changes such as ice ages as shown in Figure 5-3. (Hinga et. al. 1982).

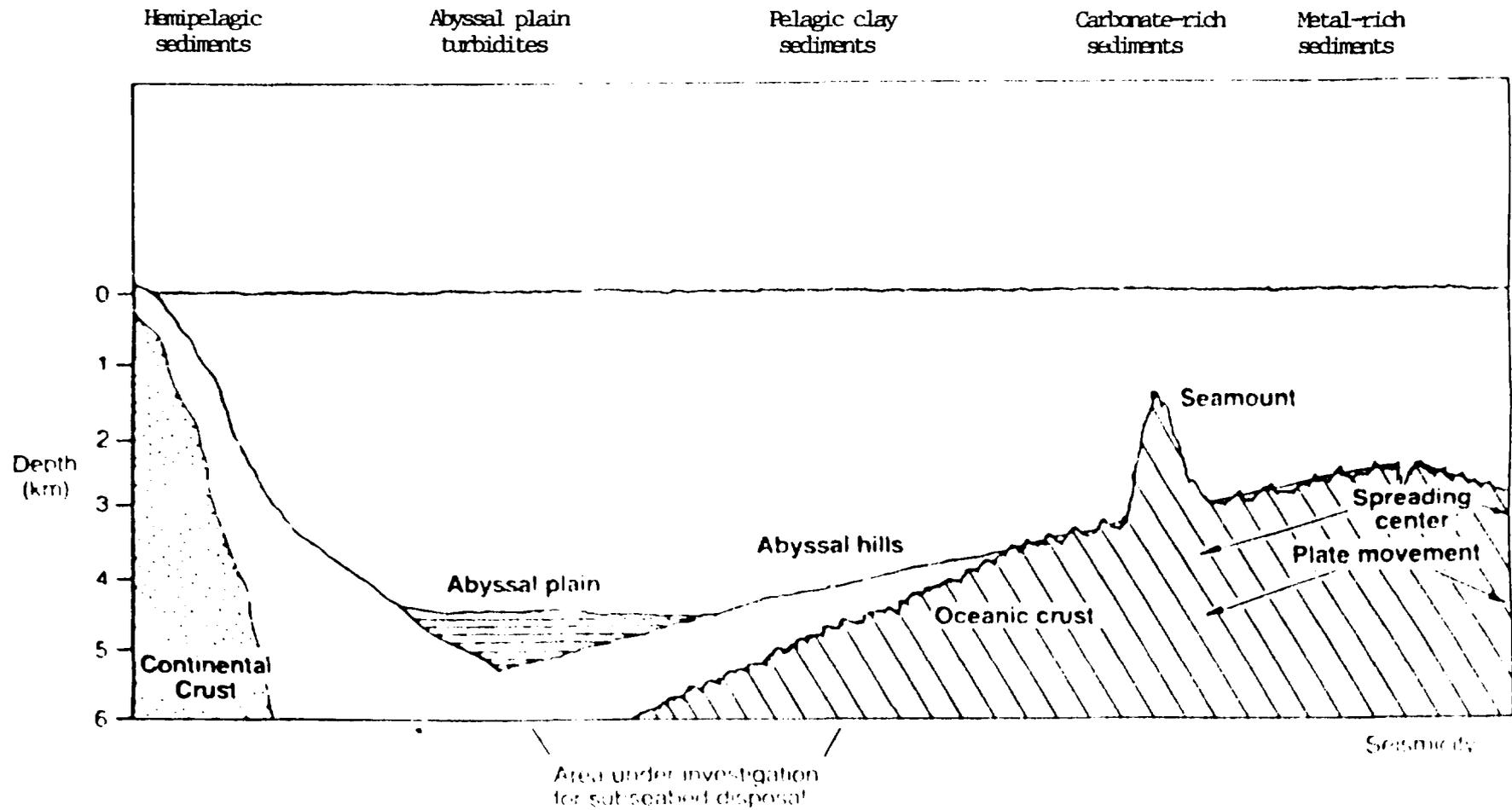
B.1.a. Size

In order to accommodate the roughly 100,000 canisters which could be available for disposal, the site chosen should be at least 100 km². The oceans cover 70% of the earth's surface; SWG investigations t 1982 involved twenty study areas from 1600 km² to 240,000 km².

B.1.b. Bathymetry

This is analogous to topography in land-based repositories. The sea floor should be nearly flat to ensure sediment stability, and distant from steep slopes that could introduce masses of coarse or erosive sediments into the site.

Figure 3. Mid-latitude profile of the Atlantic Ocean. Source: Hinge et al., 1982.



B.1.c. Sediment Thickness

Minimum sediment thickness required at a site is dependent on the anticipated placement method. For deep emplacement of several canisters per hole, 400 m is considered minimal. For shallow emplacement of single containers, predictability of sediment barriers mandates a minimum of double the assumed placement depth (50 m), i.e. 100 m. (Originally, had assumed 30m for emplacement depth). Emplacement techniques are discussed in section E, Engineering Studies.

B.1.d. Stratigraphy

A site should show horizontal uniformity and continuity. As with land-based geologic repositories, there should be evidence of stability over the Quaternary Period, as reflected in the sediment record. Evidence of continuous deposition over this long period, though desirable, is not absolutely necessary provided there is no evidence of erosion. Layers of sand within a column of fine-grained sediments complicates the prediction of pore-water advection, and, depending on total thickness within the penetrator zone, will adversely affect penetrator emplacement.

B.1.e. Physical Properties

In penetrator (free fall) and drilled emplacement methods, sediments need to be viscoelastic, retaining most of their original geotechnical properties after the emplacement process. The presence of erratic boulders in the upper 30 m of the sediment column could prevent successful penetrator emplacement.

B.2. Barrier

Like its land-based cousin, the subseabed repository depends on multiple barriers. Near field and far field properties of concern are those physical and chemical properties that prevent or delay release of radionuclides into the ocean environment.

B.2.a. Pore-Water Advection

Radionuclide migration from leached waste material is most likely to take place through sediment pore waters, driven by thermal or compaction processes, or both. Where this process transports radionuclides faster than other mechanisms (e.g. diffusion) it compromises the safety of the repository. Research has shown that pore-water movement is less than measurement levels for present conditions. If turbidity currents lay down too heavy a load of sediments, pore-water movement may increase considerably.

B.2.b. Redox Conditions

Potentially migratory radionuclides are in a variety of chemical forms. Solubility can be retarded, as low oxidation conditions decrease solubility of some ions and high oxidation conditions retain others. Therefore, a vertical sediment column with a range of oxidation/reduction conditions would be desirable, from oxidized conditions stabilizing manganese oxides to reducing conditions allowing ferrous iron to be mobilized in the pore water.

B.2.c. Sorptive Capacity

One of the primary benefits of subseabed areas under study is that the thick sedimentary clays with which they are covered are highly adsorptive of ions released from radionuclides. There are seven radionuclides, however, that do not adsorb readily to any material and/or have very long half lives; they will escape eventually from any containment system, including land-based repositories. They are technetium-99, carbon-14, iodine-129, neptunium-237, selenium-79, uranium-233 and palladium-107.

B.2.d. Bioturbation

The burrowing of animals living at the benthic boundary may cause uncertainty in predicting sediment barrier properties. Sites where open burrows exceed one percent of the total sediment volume to burial depth should be considered as less desirable.

B.3. Avoidance

Avoiding human interference is fairly simple for a subseabed disposal site. The logistics of locating and identifying the site are great. Specialized equipment for recovery of buried waste packages would be difficult to obtain and operate outside of regulated channels.

Avoiding unintentional disruption can be achieved by choosing a location that avoids established shipping lanes, undersea communications lines, and areas with significant or potentially significant resources, such as harvestable quantities of fish or exploitable resources.

C. Site Study Procedures

While several countries had carried out initial site examinations applying various procedures, intensive studies of a limited number of sites, coordinated by the Seabed Working Group (SWG), have been carried out since 1979. Data from reconnaissance surveys (involving several geophysical techniques and limited geological sampling) provided an information base which allowed recommendations of sites for further study. The procedure followed the schematic in Figure 4. (Sandia, 1984)

C.1. Screening

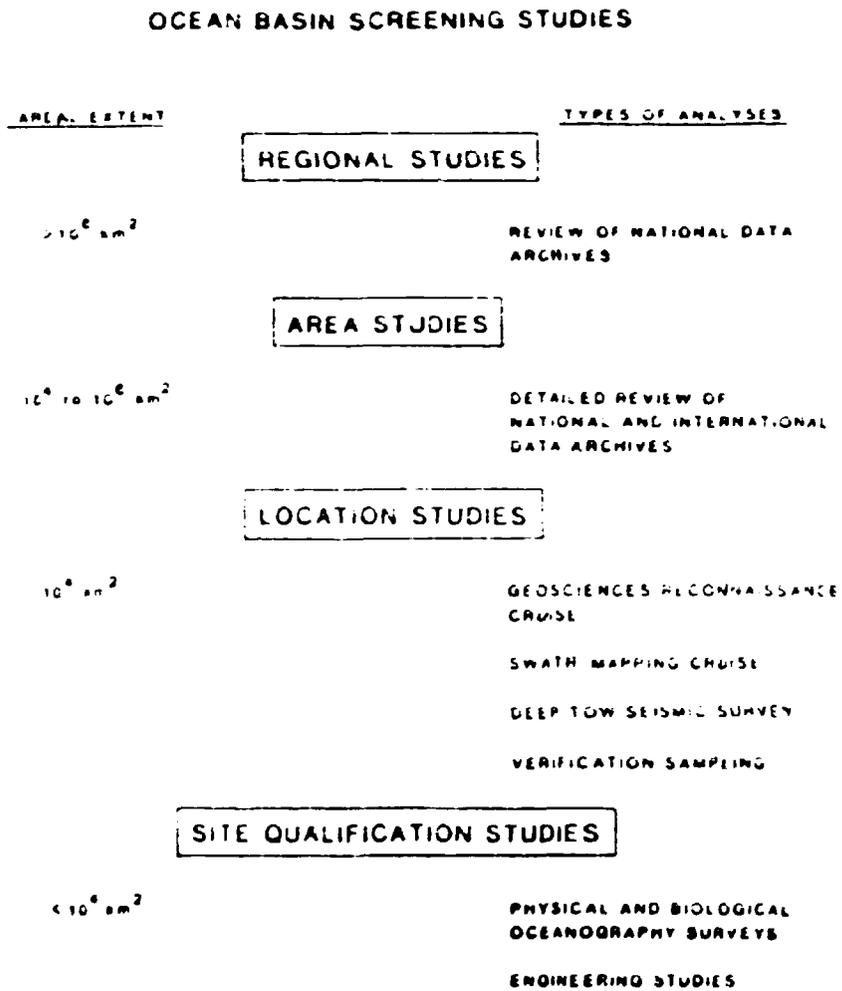
After eliminating areas of high oceanic primary productivity, a paper study of published maps and charts was used to eliminate areas of known rough bottom topography. At this stage areas of several degrees square were identified for further investigation. Existing geophysical records, where available, were examined to determine whether sufficiently thick sediments covered the basement crystalline rock. This could be determined from low-frequency seismic surveys or high-frequency acoustic profiles. Very few sites offered published information on sediment cores to indicate the types of sediments and their depositional history.

Where the paper study indicated potentially qualified sites based on bathymetry, stratigraphy, and area size, decisions were made to conduct further geoscience surveys.

C.1.a. Bathymetry and Stratigraphy

Bathymetric data were most commonly obtained from standard 12 KHz sounders operated at all times during standard reconnaissance geoscience

Figure 4.



Source: Sandia, 1983.

surveys carried out by research vessels operated by national organizations in member countries of the Seabed Working Group. Some bathymetric data was obtained from a multi-beamed high-frequency acoustic profiler. Seabed microtopography and near-surface stratigraphy information was also obtained from high-frequency sonifiers, which vary within a range of frequencies, revealing not only the sediment/water boundary but also subsurface changes in the texture, density, or water content of sediments.

C.1.b. Sediment Thickness

Low frequency seismic response from air and water guns allowed the recording of data showing the total thickness of sediment and regional altitudes of the sediment beds over the basaltic basement.

C.1.c. Size

Reconnaissance survey lines were spaced from 3 to 15 km apart. Cross lines assured navigational accuracy and allowed correlation into a 3-dimensional view of the acoustic stratigraphy. In some cases core samples were taken for verification, but such data, first limited by coring devices to 25 m, only extend 35 m into the sediment (except where the deep sea drilling project (DSDP) of the Glomar Challenger coincided with study areas).

C.2. Preliminary Site Selection

Attention has focused on the abyssal plain areas of the central North Pacific and North Atlantic Ocean. Here in mid-plate, mid-gyre regions, vast expanses of uniform sediments have been deposited continuously for millions of years. They are remote from seismic and volcanic

disturbances typical of the edges of the oceanic plates and are unaffected by glacial episodes. They lie beneath 4-6 km of water that biologically is the least productive of any in the ocean environment. No economically attractive mineral resources are present.

The clay sediments themselves are low in permeability and high in sorptive capacity. Their low strength would facilitate emplacement of a waste package while preventing the development of fractures. Temperature is essentially constant at approximately 2°C. The enormous hydrostatic head (60 MPa) ensures that porewater will not boil when subjected to moderate heating from radioactive decay.

As described below resolution of most issues raised in site qualification studies requires interactions among several research areas. For example, the sampling depth for a coring device will reflect canister burial requirements, and potential interactions among radionuclides, sediments, and the porewater will suggest the important geochemical properties to be measured. Studies to date reveal considerable range in sediment thickness, sorption coefficients, carbonate content and redox conditions. There is every indication, however, that sites of sufficient size with favourable physical and chemical characteristics do exist.

D. Multiple Barriers

The barrier segment of the Site Selection and Assessment section above dealt with natural sediment barrier properties. This section considers desirable and undesirable qualities in the other barriers--the waste package and the ocean.

D.1. Waste Package

The waste package consists of the treated waste matrix and its canister or container. The waste matrix that has been most intensively studied is the borosilicate glass vitrified waste package developed for land-based repositories. Spent fuel could also be disposed in the subseabed. Most models assume the waste is aged 50 years. The type of capsule in which this glass block is encased is dependent upon the emplacement method, drilled or free fall, and the heat-load of the vitrified waste. The waste capsule is discussed in some detail under Engineering Studies.

The United States programme currently favours a borosilicate glass matrix for the high level waste and a titanium alloy (TiCode 12) for the canister. The latter has a very low uniform corrosion rate (approximately 10^{-3} mm yr⁻¹) due to the ready formation of a thin external film of titanium oxide. It resists stress and crevice corrosion and is stable in radiation fields. Further data are required, however, to assess pitting characteristics and resistance to hydrogen embrittlement. The thickness of a titanium wall would be dictated more by requirements for mechanical strength during handling than by the corrosion rate. Preliminary analyses suggest that a canister lifetime of 100-300 years is ample for safety considerations. This requirement could be met by titanium walls only 2 mm thick, but handling stresses and accident scenarios dictate wall thicknesses of at least 6-7 mm.

Canister materials favored by the CEC Programme include Ti-0.2% Pd and Hasteloy alloys.

The CEC plans studies of the leaching behavior of borosilicate glass under subseabed conditions. Preliminary analyses indicate that the leaching rate is not a significant variable for cumulative radionuclide releases to the water column. The radionuclides that are responsible for most of the doses to man are long-lived and relatively mobile in marine sediments. Lowering their leaching rate would delay their introduction to the human environment, but would do little to diminish their ultimate impact on individual or total dose.

D.2. Thermal Transport

For conceptual purposes the cylindrical canisters are considered to be 0.3 m in diameter and 3.0 m long. Placement in clay sediments on 100 m spacings and at a depth of 30 m is assumed. Figure 5 shows the concept. (J.K. Associates, 1985). Theoretical models for heat transfer, canister migration, and diffusive radionuclide transport through porous media have been developed and calibrated by laboratory experimentation.

Some of the most sophisticated work has been done on thermal modelling. In one study thermal output of 1.5 kW per canister generated a maximum temperature of 250°C at the canister surface. This temperature will fall to 100°C after 40 years. Rayleigh numbers of 10^{-3} are forecast, ensuring that thermal transport will be dominated by conduction. Thermal transport is modelled by a transient, non-linear, two-dimensional, finite element code called MARIAH. MARIAH predicts that the maximum distance of the 100°C isotherm will not exceed 0.8 m. This code has been verified by laboratory experiments. A field test planned for 1986-87 has been cancelled due to the phase-out of the United States'

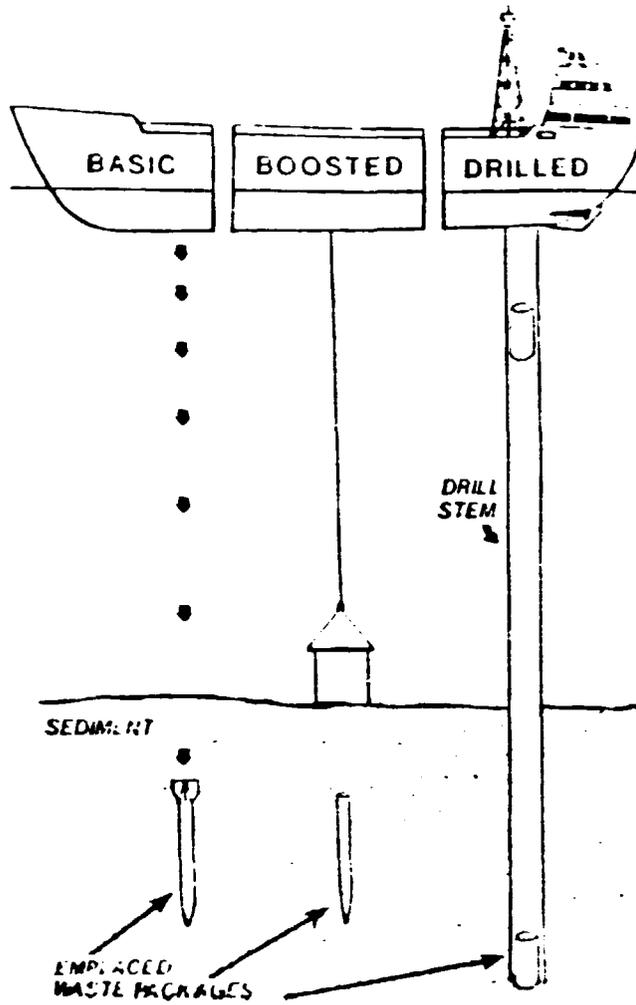


Figure 5. Schematic of Waste Emplacement.
 Source: J.K. Associates, 1985.
 (Not to Scale).

Subseabed Disposal Program (SDP). This test, the In-Situ Heat Transfer Experiment (ISHTE) was a major project of the SDP and would have explored radionuclide transport properties as well as thermal and pressure conditions. The ISHTE device is a 3 m x 4 m platform equipped with multiple probes for heat and radioactive tracer introduction and sensing equipment. The completed ISHTE platform, damaged during the Seabed Working Group (SWG) Component Test Cruise, was being refurbished when the U.S. Office of Civilian Radioactive Waste Management requested the SDP to store it for future use.

D.3. Canister Migration

Another major study is the prediction of canister migration in heated sediments. Canisters are expected to weigh 3 Mg and will be affected by temperature-induced changes in porewater buoyancy and thermomechanical stresses on the sediment skeleton. Data have been collected to try to validate a two-dimensional, finite-element code named NEPTUNE, which models the creeping motion of saturated media due to thermally driven porewater flow and skeletal deformation. Full confidence in the model would require an extended field experiment, perhaps twenty years in duration. No significant safety problems due to canister migration are expected. A rudimentary code, COUPLEFLO, has projected a maximum canister displacement of 1.0 m downward. Preliminary analyses suggest that the more realistic output of the NEPTUNE code may result in even smaller displacement.

D.4. Near-Field

The near-field environment is the region bounded by the 100°C isotherm. Never expected to extend more than 0.8 m from the canister, it is not considered a significant barrier to radionuclide mobility. Important near-field issues include local geochemical and hydrothermal responses to the heat and radiation fields generated by the waste package.

D.5. Dispersion

Following their release at the sediment and water column interface, radionuclides will be dispersed by ocean currents and influenced by a host of biological interactions. Modelling of these processes represents a major challenge to physical and biological oceanographers.

D.5.a. Physical Oceanography

Dispersion in the marine environment will eventually be depicted via three submodels, each relevant to a different physical scale. In the immediate vicinity of the repository, the lowest 10-100 m of the water column are portrayed by a benthic boundary layer model (BBLM). This layer is formed by the friction between the stationary seabed and the moving seawater. Turbulent mixing is so intense that properties such as density (and by analogy a radionuclide source term) are made vertically uniform within the benthic boundary layer. Above it water density decreases with height, limiting vertical exchange.

The regional eddy resolving model (REM) depicts flow and dispersion characteristics on 1000 km square domains. Grid sizes of 5 to 15 km are

employed in three dimensional, numerical simulations of fluid transport. Preliminary simulations have been run using a variety of realistic parameter values, and statistical evaluation of the results provides insight about the sensitivity of the model to various parameters. Comparison with field tracer data had been planned.

Large scale general circulation models attempt to capture oceanic flow and mixing properties on a global scale. Grid sizes range up to 200 km. Mixing due to eddies within individual grid compartments is described by a diffusivity parameter. Circulation of surface waters and vertical mixing are handled independently for each major ocean basin. Deep-water currents are less well understood and require modelling of transequatorial exchanges and circumpolar mixing. Two general approaches to large-scale physical oceanography are being explored. Some simulations, such as the Semtner-Bryan model, attempt to portray actual ocean geometries, accurate boundary conditions, realistic density distributions, etc. Their results can be compared directly with real ocean data. Less realistic but more flexible are idealized models whose simpler portrayal of marine conditions make sensitivity studies easier to conduct. British and German members of the Seabed Working Group (SWG) Physical Oceanography Task Group (POTG) are currently working with one of these models.

In their current state the oceanographic models outlined above are not yet suitable for estimating the global transport of radionuclides released from a subseabed repository. Additional data collection and analysis are necessary to define the most relevant parameters as identified by sensitivity studies. Particularly needed are model components

dealing with the effects of large relief bottom topography, exchange between coastal and mid-sea waters, Arctic upwelling and circumpolar mixing.

D.5.b. Biological Oceanography

There are two major questions to be resolved:

- 1) Can biological transport mechanisms return enough radioactive material to the surface to engender unacceptable individual or collective doses?
- 2) Would subseabed disposal cause widespread and/or long term damages to the oceanic biological community?

Large collective doses imply mass transfers of radioactive materials. Significant biological transfer of concentrated radioactive material relative to water transport would have to come from widespread contamination. There is no indication that there is large mass transport of radionuclides by biological means relative to physical means.

Individual doses would come from a critical pathway, which requires much smaller quantities of biomass and contaminant. A demonstration of safety in this regard would require proving that no critical pathway exists.

Both questions require an understanding of marine food webs, including the distribution and abundance of key faunal species and their bioaccumulation rates for important radionuclides.

E. Engineering Studies

Engineering studies cover the development and assessment of techniques for transporting wastes to the site and emplacing them beneath

the seabed. While several methods have been proposed, two have been the subjects of detailed feasibility studies: drilled emplacement (Bury, 1985) and free-falling penetrator emplacement (Arup et al, 1985). The studies, carried out by independent consulting firms and co-financed by the U.K. Department of the Environment (DoE) and the CEC show how wastes could be handled, transported and emplaced using present technology, where available, and highlighted areas requiring substantial further development and/or research. A preliminary cost analysis was also performed. Details of these studies are given in Appendix I.

Drilled emplacement would involve lowering strings of waste canisters into pre-drilled 1000 m deep holes from a concrete semi-submersible platform equipped with powerful engines to maintain its position. Vitrified high level waste in standard canisters would be delivered in transfer flasks and moved by a bridge-and-winch system to the disposal platform. Flasks would be opened inside a flooded compartment, where the canisters would be formed into strings, to be lowered by drill pipe through several kilometers of water and into the previously drilled hole. A single platform is expected to be able to dispose of up to 400 m³ per year, adding approximately 0.2 percent to the cost of generated electricity. This emplacement technique is favoured by those who insist on strict control of waste emplacement. However, much of the technology requires considerable further development, and the complexity of the operation creates many opportunities for malfunctions, the most serious being a dropped string of canisters. Most capitalization for this option is at the front end, and international use of a single platform would require uniform waste canisters. Mechanical aspects aside, the

scientific work that has been performed over the life of the Seabed Working Group (SWG) programme has concentrated on the first 35 m of sediments, whereas drilled emplacement would put the wastes 200 to 550 m below the seafloor. The additional depth is expected to diminish and delay radionuclide releases.

Considerably more is known about the free-falling penetrator emplacement option, and this option will be the basis for the Preliminary Concept Feasibility Assessment to be published by the NEA/SWG in 1987. Missile-shaped penetrators containing 1 to 12 high level waste canisters would be loaded onto a ship at a port facility, taken to the repository area and released, at sufficient intervals to prevent collisions, to embed themselves to 50 m deep in the sediments. The penetrators themselves would form part of the multi-barrier system, being constructed of 75 mm low carbon steel, expected to provide containment for 500 to 1000 years. This technologically simple system requires much stricter site criteria than drilled emplacement. While a single ship would only be expected to dispose of about 85 m³ per year, different penetrator designs could be accommodated. Costs in 1984 were estimated to add 0.007 pence per kWhr of generated electricity. The most serious questions about this method at the time of the study concerned 1) control and monitoring of emplacement, and 2) hole closure behind the penetrator. Recent work suggests that 1) wire-guidance technology could be adapted from defense programmes, and 2) holes close rapidly behind penetrators. Penetrator manufacture, assembly, and deployment are considered feasible using present day technology.

Instrumented penetrators launched on the M.S. Marion Dufresne cruise (see ESOPE cruise discussed in section F2 of this chapter) in 1985 achieved emplacement depths consistent with expectations. Objections to penetrator emplacement are either cosmetic (it looks too much like dumping), generic to the subseabed disposal concept (not enough is known about radionuclide transport mechanisms), or generic to all geological emplacement systems (not enough is known about colloid formation and transportation properties).

F. Status of National Research Programmes

All national research programmes were working toward the 1988 Concept Feasibility Assessment of the Seabed Working Group (SWG) until the unilateral U.S. Department of Energy decision of February 6, 1986 to "terminate future funding of its subseabed project effective at the end of fiscal year 1986" (U.S. DoE, 1986). Most were planning national reports along the same lines for 1987 as well. The details and ramifications of that decision are discussed in the socio-political section of this chapter. Because all national programmes are coordinated through the Seabed Working Group (SWG), and joint research programmes are common, research activities are reviewed under the country taking the greatest financial and/or coordinating role.

F.1. Federal Republic of Germany

The F.R.G. does not anticipate using subseabed disposal for its own high level waste, but is sufficiently interested in international discussions and conclusions to maintain its membership in the Seabed Working Group (SWG).

F.1.a. Research Activities

Germany participates in research to evaluate disposal safety. About one million DM will be spent between 1985 and 1987 on radiological safety modelling to assess the effects on man. The F.R.G. deadline, set before U.S. withdrawal caused the Seabed Working Group (SWG) to shorten its programme, now coincides with the Seabed Working Group (SWG) deadline. Major modelling programmes undertaken in the F.R.G. include a computer code on the biological effects of subseabed disposal, and modelling of Atlantic Oceanic Circulation. There have been 2 cruises a year that focused on measuring the deep sea mass, and the vertical movement of fish, and their potential for transporting radionuclides. Research will almost terminate with the publication of the Dornier assessment in 1987. (Closs, 1986).

F.1.b. Future Work

It is the expectation in the F.R.G. that the London Dumping Convention (LDC) will hamper subseabed disposal of high level waste and will likely continue its moratorium on sea-dumping. Because of the commitment to land disposal of high-level waste, no programme for investigating subseabed disposal is planned in the Federal Republic of Germany. (Closs, 1986).

F.2. France

France has no specific national subseabed disposal deadlines. Nonetheless, interest in the subseabed disposal programme of the Seabed Working Group has remained high since its inception. Subseabed and

sea-dumping are viewed as only being possible as multi-national programmes. That is, a unilateral decision to engage in either is considered impossible, although suggestions have been made to dispose of uranium mill tailings in France's territorial waters. (Farges et al, 1986).

The French attitude toward subseabed disposal is that it is very similar to a mined geological repository. Some people think that subseabed disposal could be the best solution for high level waste disposal, would be less expensive than land-based geological disposal and could be a good alternative in case land-based sites that meet standards are not found, either in modelling or due to political opposition. Signatories of the LDC, some parties in France are in favour of sea-dumping of iodine- and tritium-contaminated wastes. They are against the British option of an engineered structure for high level waste being placed on the seabed. Subseabed disposal is considered a geological programme in France.

The Institute of Protection and Safety has sole responsibility for French subseabed disposal research. Presently, France is concentrating on systems analysis and a safety assessment, which will be issued in 1987. Modelling for the programme is being done mainly at the Ecole des Mines.

F.2.a. Research

In 1985 the French Atomic Energy Commission (C.E.A.) organized the ESOPE (Etude des Sediments Oceaniques par Penetration) cruise in the North Atlantic, the purpose of which was to obtain large-diameter

undisturbed sediment cores to the proposed emplacement depth of penetrometers (30m) and the launching of instrumented penetrometers for correlation with the cores and for verification of models (ESOPE, 1986). Five other countries and the CEC Joint Research Centre at Ispra gave financial support to the project and provided scientific staff and equipment. As the French have no subseabed disposal deadlines, they asked the Seabed Working Group (SWG) task groups to select the scientific programme and the areas in which to carry it out. The result was the most ambitious scientific cruise undertaken under the auspices of the Seabed Working Group (SWG) (Barbreau, 1986).

Priority during the 40-day cruise was given to long coring operations and the onboard geochemical analysis of the collected samples in order to prevent alteration of sediment properties. The heavy, new STACOR corer, an invention of the French Petroleum Institute, was successful in obtaining cores up to 35m (the U.S.-supplied APC corer did not work). The STACOR took 13 cores; 5 in the 5400 m deep waters of GME (lengths: 19m; 34.3m; 33.8m; 30m; 30m) and 8 in 5700 m deep waters at SNAP (22m; 17.36m; 23.40m; 19.62m; 23m; 24.90m; 26.20m; 25.68m). It should be noted that, while no core reached 30 m on SNAP, the longest core taken before the ESOPE cruise was 13m. In addition, 15 penetrator launchings (4 French, 11 U.K. and JRC-Ispra) demonstrated that reference depths could be achieved. In GME 40m was reached; in SNAP, 32.4m.

Three point five (3.5) kHz profiling and bathymetric surveys were conducted while underway, as in past cruises. Other in-situ experiments were carried out, including watergun, multi-channel seismic profiling, pore-water sampling, and box core sampling (for the microbiologists).

Additional work on the cores is being carried out in various national labs and the JRC-Ispra.

The M.S. Marion Dufresne carried, in addition to its more than 40 regular crew, 23 extra deck hands, more than 70 scientists (including 21 geochemists), and a French film crew. The single microbiologist found bacteria present in cores at all depths. A final cruise report has been published.

Since the ESOPE cruise, the French have launched 2 penetrometers in 400m deep water using technology from wire-guided missile systems. Also on that cruise the U.S. and the United Kingdom launched penetrometers, and hole closure behind the penetrometers, was directly observed (via television) for the first time.

While the French are interested in continuing research on the subseabed disposal programme, cancellation of U.S. involvement may erode support for French research.

F.3. Sweden

Sweden is the latest member of the Seabed Working Group (SWG). Sweden held observer status at the Seabed Working Group (SWG) annual meetings in 1985 and 1986, represented by the National Institute of Radiation Protection (SSI). The SSI reports to the Government on all international disposal options, and it is in this context that they attend Seabed Working Group (SWG) meetings. There is no Swedish scientific research conducted on subseabed disposal. However, the SSI would be in favor of continued research on the subseabed option, particularly in the area of an overall radiological safety assessment comparing the

effects of land-based repositories with subseabed disposal. Very long lived radionuclides disposed of in a 500 m deep geological formation on land will eventually migrate through the geosphere, pass through the biosphere into the ocean and eventually settle into the ocean sediments. Why not look at the possibility of putting them there in the first place, thereby avoiding passing the radionuclides through the biosphere in the earlier, more radioactive stages?

All of Sweden's reactors are located along the coast, and fuel (fresh and spent) presently is delivered and picked up by ship. Some critics of the Swedish nuclear waste policy claim that the SFR (Swedish Final Repository for Low- and Intermediate-Level Wastes) presently under construction constitutes subseabed disposal. That facility consists of mined caverns, 50 m below 6 m deep water, in some of the hardest rock in Sweden. It is reached through horizontal access tunnels from the mainland.

F.4. Switzerland

As might be expected of a land-locked country, Switzerland does not actively pursue research on subseabed disposal. It is nonetheless an observer at annual Seabed Working Group (SWG) meetings due to its strong interest in an international solution to high level waste disposal. Unlike the F.R.G., French and U.S. viewpoints, subseabed disposal is seen as a possible first choice for the national nuclear waste disposal programme within an international context. The current view is that subseabed disposal is a good solution on its scientific and technical merits, but may not be politically feasible (Flury and Alder, 1986).

Worries center on the possible short-circuit through living organisms acting as a radionuclide transport mechanism; the strong stand of the Australians against exploration of the concept; the cuts in French and British research programmes; and the cancellation of the U.S. programme.

F.5. United Kingdom

The United Kingdom proposes to bring its knowledge of the subseabed disposal route to the same level as that for mined geological repositories. The U.K. programme differs from other programmes in that respect and in that it considers alternative emplacement techniques. (Hemming, 1986)

Since postponing site selection for a mined geological repository in 1981, the U.K. Department of the Environment (DoE) has concentrated on bringing an equivalent level of understanding to the subseabed disposal repository concept. Five years of research will conclude with a radiological safety assessment in December 1986, and a draft feasibility report in February 1987 (Hemming, 1986).

Some U.K. research has been co-sponsored by the CEC, notably feasibility studies on emplacement by free-falling penetrators and by drilled emplacement (which are discussed in greater detail in the Engineering Studies section, Appendix I). Reliability studies are in progress to yield probability information for a comprehensive risk analysis allowing direct comparison between free-fall penetrator and drilled emplacement. A third option presently going through reliability analysis is engineered placement on the seabed, based on a U.K. study done in 1979.

For the last two years, the United Kingdom has concentrated its research on the Great Meteor East (GME) study area on the Madeira Abyssal Plain (one of the (SWG) North Atlantic Study Areas), as has the Seabed Working Group and has concentrated characterization efforts on a 10 km square box centred at $31^{\circ}17'N$, $25^{\circ}24'W$. A year's detailed examination of the site has yielded two cores nearly 35 meters deep in the sediments. Five penetrometers were launched at the GME site; the two which had functioning transponders are known to be within 6 percent of their predicted depth (ESOPE, 1986). A biology cruise last year (1985) concentrated on life in the water column and benthic animals. Only the water column samples have been worked up and reported to date. Work is continuing on the benthic samples and a report on these is expected towards the end of 1986. A 1986 cruise will study benthic animals.

Primary research is carried out by the Natural Environment Research Council's (NERC) Institute of Oceanographic Sciences (IOS), under contracts with the Department of the Environment (DoE). The stated objective of the detailed characterization of the selected 100 km^2 site is to show that suitable techniques are available for characterization of a seabed repository. A risk-based safety assessment of individual and collective dose exposures for the specific site will be carried out comparing the three emplacement options. The radiological assessment (within the overall safety assessment) will cover sediment chemistry, corrosion rates of container materials, biology, ocean circulation, benthic boundary layer and particulates in the water column.

The April 1987 final report will consist of three sections plus a summary: Site Selection Assessment; Engineering Feasibility; and Safety

Assessment. That report will determine the technical feasibility of the subseabed disposal option and highlight the major unanswered questions.

SSBD research is currently funded at about 1.8 million pounds sterling per year, which is considerably higher than the one million pounds considered necessary to pursue active research (cruises, tests and laboratory work) and maintain international cooperative research. With the publication of the final report, U.K. funding is going to drop considerably, (100,000 to about 200,000 pounds sterling per year) enough to keep track of indirect research (oceanographic studies, etc.) and to maintain an involvement in international research efforts, if any (Johnston, 1986).

F.6. United States

The U.S. has studied the feasibility of subseabed disposal since 1974. Research on the Subseabed Disposal Project (SDP), funded by the Department of Energy (DoE) and managed by Sandia National Laboratories, is carried out by Sandia, in conjunction with universities and other research organizations. The SDP, which intended to produce a comprehensive Concept Feasibility Assessment Report in 1990, has had its funding slashed from about US\$8 million in 1986 to zero in 1987. By transferring funds from the equipment budget to the operations budget, the programme expects to be able to participate in the Seabed Working Group (SWG) Final Report and to produce a Preliminary Concept Feasibility Assessment Report of its own. With research incomplete and models unvalidated, this report will not really serve as a reliable basis for

deciding whether to resume research (The 1990 report was intended to assess whether the SDP should continue).

The action to terminate funding was taken as a direct result of funding limitations for research and development programmes in the civilian radioactive waste management programme. The U.S. authorities stated: "The termination of the project should not be construed in any way as an early judgement that seabed disposal is not a feasible concept: No judgements have been made regarding the technical potential of the work nor has an adverse finding been made regarding the high quality of the scientific work. Judgements have been made purely on the basis of near term budget priorities." (U.S. DOE, 1986) Despite this statement, there is skepticism that the facts are as stated.

The U.S. Seabed Disposal Project was divided into four overlapping phases. Phase 1, scientific research, was a preliminary assessment based on existing data (completed in 1976) and the determination of concept feasibility based on newly acquired oceanographic and other data. This latter phase was scheduled for completion in 1990. An incomplete version of it will be summarized in a final report in 1987, and will be contributed to the Seabed Working Group (SWG) final report.

If the SDP were deemed as an acceptable route for radiation waste disposal on its scientific and environmental merits, Phase 2 called for engineering development to be completed by the year 2000. Had all gone well, Phase 3 called for a demonstration disposal facility to be completed by 2010. Following successful demonstration, the facility would have been made operational. The U.S. has made a simplistic economic

study shown in Table 1 (J.K. Associates, 1985) indicating the economic advantages of subseabed disposal.

The ISHTE test, described earlier, would have field tested the predictive models of heat transfer. This type of field validation is essential to determining concept feasibility. More elaborate models of the movement of the waste material through the oceans to humans were being developed, with emphasis on the field verification of the physical transport models using short-lived radioactive tracers. Direct biological transport of radioactive materials to humans is estimated to be 1000 to 10,000 times less significant to man than physical transport.

G. Institutional and Regulatory Issues

Because a subseabed repository would be located under international waters, the feasibility of the concept depends in part on an adequate international regulatory structure. The legitimate rights and concerns of both nuclear and non-nuclear states must be addressed. This was recognized early in the U.S. programme and in a number of papers commissioned on the topic (Deese et al. 1981, Deese 1978).

Existing international laws relevant to a subseabed repository include The 1958 Geneva Convention on the High Seas, 1982 Jamaica Convention on the Law of the Sea, and most importantly, provisions of the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matters (London Convention-LDC) (IMO, 1972) and the United Nations Conference on the Law of the Sea (UNCLOS III) (1982).

TABLE 1

COST COMPARISON SUBSEABED DISPOSAL
VERSUS MINED REPOSITORY

Activity	Subseabed Disposal		Mined Repository
Transportation	Ground Transport	=	Ground Transport
	Port Facility	<	Surface Facility
Repository Construction and Maintenance	Ship Construction	<	Mine Shaft Sinking and Lateral Excavation
	Operation	≤	Operation, Backfilling, and Sealing
	Monitoring and Surveillance	≤	Monitoring and Surveillance
	Retrieval	≤	Retrieval (after back- filling and sealing)

Source: J. K. Associates, 1985.

G.1. London Convention

The London Convention, adhered to by 56 states including most major maritime nations (membership shown in Appendix 2), forbids the disposal of high level waste into the sea and controls low level radioactive waste dumping by a permit system. The International Atomic Energy Agency (IAEA) is assigned responsibility for defining high level waste and for recommendations on allowable sites for dumping other than high level waste. The current activity threshold is 37 kBq g^{-1} for alpha emitters and 3.7 MBq g^{-1} for beta and gamma emitters with half-lives greater than six months. Further recommendations of the IAEA stipulate disposal sites at least 4000 m deep and waste packages with sufficient integrity to reach the sea floor undamaged. The detailed recommendations of the IAEA are shown in Appendix 3.

Clearly, in 1972 no one foresaw subseabed disposal of high level waste as a possibility, and the Convention is silent on that point. Consequently a debate has raged over whether it is legally permissible to practice subseabed disposal. Some proponents of subseabed disposal maintain that the London Convention does not apply to the current repository concept.

The debate is about the meaning of the definition of dumping which is defined in Art. III, Sec. 1 (a) (i) as "any deliberate disposal at sea of wastes or other matter from vessels, platforms or other man-made structures at sea". Certainly under Article I whereby the parties agree to "promote the effective control of all sources of pollution of the marine environment" subseabed disposal would be prohibited unless it

could be shown that such disposal did not present a hazard to man or his environment. Legal quibbling over the meaning of the wording has resulted in an examination of all four official texts, French, Spanish, Russian and English and invocation of the 1969 Vienna Convention on the Law of Treaties on how to interpret the text (Moore, 1986).

Moore argues that the Convention is not the appropriate vehicle for resolving the dispute since it forces a yes or no solution with no compromise possible and that the issues involved: environment, non-proliferation, alternative energy sources etc. are too important to be decided upon over the definition of dumping.

The debate began officially in the February 1983 meeting (Seventh Consultative Meeting of Contracting Parties to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter) when the governments of Kiribati and Nauru proposed an amendment to ban the dumping of nuclear waste, which was supported by a document "Evaluation of Oceanic Radioactive Dumping Programmes" (Davis 1982). The author, W. Jackson Davis, has been the most influential scientific critic of sea dumping and subseabed disposal. In these matters he is the Scientific Advisor to the Association of Chief Executives of the Pacific Basin. Jackson's main contentions are:

- "1) Scientific studies of oceanic radioactive dumpsites have furnished evidence of radioactive leakage into the marine environment;
- 2) the environmental and health effects of existing and proposed oceanic radioactive dumping operations have been estimated on the basis of incorrect models, limited models for which authoritative data are not

yet available, and untested safety factors; 3) scientific studies of oceanic radioactive dumpsites have furnished evidence that radioactivity from the dumpsites has entered into the oceanic food chain and is present in edible fish; 4) current international standards for radiation risk factors have not been revised since the 1950's but are once again under review in light of recent scientific data suggesting that the risk of cancer and other adverse health effects is greater than previously reported; 5) the importance of dumpsite monitoring has been acknowledged but empirical data needed to fully assess the environmental and health impacts of ocean dumping programs are still not available; 6) the importance of compiling a full register of radionuclides deposited into the oceans by human activity is acknowledged but no such complete register has been compiled; 7) land based storage of radioactive wastes does not suffer the disadvantages of irretrievability in the event of miscalculation; 8) the legal status of dumping radioactive wastes into international water is unclear".

From this he concludes that ocean dumping is the least attractive of the various waste management options on 5 grounds:

" First, the oceans are a living, interconnected environment that can return radioactive wastes to humans via the ocean food chain. Second, the ocean is a formidable environment, destructive of human structures such as radioactive waste containers. Third, despite recent rapid strides in the oceanographic sciences, the ocean is still largely an unknown environment. Fourth, the oceans represent a global resource, the birthright of all people and all generations. Fifth, damage of this global commons by a minority of people is contrary to principles of

international law." There has been vigorous scientific rebuttal to Davis's claims. (Yayanos, 1982; Hinga & Gomez, 1982). The response to each of the eight conditions are that though there have been releases of radioactaive material into the ocean, there has been "little or no detrimental effect on man, the environment or its resources"; models are always in need of improvement; though more needs to be known, no detrimental effects have been found and in any case these will be less than land burial; ICRP standards do not relate to sea disposal alone. In any case, they have not been exceeded; they agree with items 5 and 6 that more monitoring should be done and that a register of disposals should be compiled; they argue that sea disposal is safer than land disposal because it poses no threat to ground water supplies; and that if sea disposal is technically the best solution, then it would be made legal.

Another critic of subseabed disposal has recently published a critique on the methodology (Glasby, 1985). His main points are:

1. The scale of the operations is large and their logistics have not been seriously addressed.
2. Retrievability on a massive scale will be extremely difficult and particularly so after the canisters have corroded.
3. Emplacement is likely to be extremely slow (2 canisters/day) if backfilling is required, and self closure and adequate depth emplacement (>30 m) of free falling penetrometers has not yet been demonstrated.
4. The canisters may not have an appreciable life because the sediments around them would be hot, acidic and oxidizing. In addition convective cells would likely be initiated and combined with bioturbation could lead to early release (hundreds of days) of the radionuclides to the oceanic waters.

5. Knowledge of deep-sea biology is inadequate to credibly describe the consequences of such massive disposals.

6. It is absurd to believe that subseabed disposal does not contravene the spirit and intent of the London Convention.

7. There is a viable alternative to subseabed disposal--mined geological repositories--and it is not necessary for the nuclear powers to export and internationalize their waste disposal problems.

In addition to Moore, Curtis of the Oceanic Society (Curtis 1985) contends that "the only harmonious and reasonable interpretation is that which defines 'disposal at sea' to mean the place where the dumping activities occur" which would then clearly forbid subseabed disposal under the London Convention. He further points out that in contrast to land masses, oceanic waters are continuous and the interrelationships between its boundaries, land, air and subseabed are more marked and cannot be treated separately.

Norway, at the Seventh Consultative Meeting (1983) questioned whether subseabed disposal was dumping and should be prohibited. As a result, an Ad-Hoc Group of Legal Experts on Dumping met in London in December, 1983 to study the question. There, the Nordic Countries offered a resolution that subseabed disposal of high level radioactive waste was incompatible with the Convention but if at a later date a safer method were possible, the contracting parties "shall evaluate the necessity of adopting appropriate amendments to the Convention". France, the U.K. and the Netherlands held that subseabed disposal was not covered by the Convention.

Spain introduced a resolution to suspend ocean dumping of low level waste which eventually led to a compromise, non-binding resolution to suspend dumping until experts in ecology, oceanography, radiological protection, marine chemistry and mathematical modelling had examined the problem and reported back to the February 1984 consultative meeting. Some nations viewed the resolution as morally binding while others intended to continue dumping. However, boycotts in several countries have led to a cessation of sea dumping of low level waste since that time. The legal experts were not able to reach consensus nor was the consultative meeting able to reach consensus on the legality of subseabed disposal. The meeting did reaffirm the suspension of dumping at sea until the final scientific and technical report was presented at the Eighth Consultative Meeting in September 1984 (NACOA, 1984). The meeting did agree that the consultative meeting is the appropriate international forum to address the compatibility of subseabed disposal with the provisions of the London Convention, and that no such dumping shall take place until subseabed disposal is "technically feasible and environmentally acceptable". (The full text is shown in Appendix 4).

At the Ninth Consultative Meeting (held in September 1985) it was indicated that even "experimental emplacement of high-level radioactive material in the seabed" might be challenged, even though the convention is not supposed to apply to scientific research. This possibly could have prevented the ISHTE tests. The delegates then passed a resolution continuing the suspension of sea dumping until an assessment of the wider political, legal, economic and social aspects, a comparative analyses of the land based options and their respective risks and costs,

an assessment of whether it can be proven that dumping will not harm human life and/or cause significant damage to the marine environment, and a report from the IAEA on a redefinition of wastes not suitable for dumping at sea, upper source and dose bounds for dumping, and definition of exempt quantities are prepared (The full text is given in Appendix 5). The debate and the resolution engendered strong feelings (Olivier, 1985). Canada, though favouring a renewal of the moratorium, felt strongly enough to make a statement protesting the indefinite postponement of a decision on prohibiting the disposal of radioactive waste at sea (full text of Canada's statement is in Appendix 6). Ignored in all of this discussion is the fact that under international law a multilateral convention cannot be altered by resolution unless all parties agree, and that forcing an interpretation may cause major nuclear waste producing states to withdraw from the Convention, as permitted by law. (Moore, 1986).

G.2. Convention on the Law of the Sea (UNCLOS III)

UNCLOS III was adopted on April 30, 1982 and opened for signature on the 10th of December and remained open for two years. It entered into force 12 months after the date of deposit of the sixtieth instrument of accession or ratification. (NEA 1984). UNCLOS III has been signed by 132 nations and ratified by 11. It was an outgrowth of the first U.N. Conference on the Law of the Sea (UNCLOS I) held in Geneva in 1958, which adopted the Convention on the High Seas. That Convention in Article 25 called on every state to "take measures to prevent pollution of the seas by dumping of radioactive wastes." UNCLOS III

spends an entire part (XII) calling on all nations "to protect and preserve the marine environment" and "to minimize to the fullest extent possible" the release of persistent, toxic, harmful or noxious substances (Curtis, 1985). It could be added that adoption of UNCLOS III would help protect the exclusive economic zones over which each nation has jurisdiction because ratifying states must endeavor to establish regional rules controlling pollution, acting through competent international organizations or diplomatic conference. These obviously include the International Atomic Energy Agency (IAEA) and the London Convention (LDC) as the jurisdiction of the LDC extends through the exclusive economic zones and territorial sea. (NACOA, 1984).

G.3. Status of Seabed Working Group (SWG)

A special meeting of the Executive Committee was held in Paris on April 21-22, 1986 to consider how to minimize the adverse consequences of the U.S.A.'s decision to terminate funding for the Seabed Programme after September 1986. There was agreement among the members (U.K., Belgium, Canada, CEC, France, Italy, Japan and Switzerland) that the project should be continued even at a reduced level because without an international project, national programmes might not be feasible.

The committee agreed to dissociate its interim report from the future of the programme, to coordinate its report with that of the U.K. and to finish all but editorial work by April 1987.

It was also agreed that without prejudice to final site selection the Great Meteor East (GME) and Southern Hares Abyssal Plain (SHAP) sites would be considered as the reference sites.

G.4. Perspective

To understand both the legal and technical complexities some background information may be helpful. Table 2 shows anthropogenic radionuclides added to the sea (NACOA, 1984). In addition ocean waters contain, on the average, 330 pCi/l and marine sediments, 25-500 pCi/gm dry weight of naturally occurring radioactive material. The concentration of major nuclides in ocean waters and sediments are shown in Figures 6 and 7 (NACOA, 1984). Potassium-40 accounts for more than 90 percent of the radioactivity in sea water and, while still the largest contributor to the radioactivity in marine sediments, is not so dominating. Consequently, the ocean waters contain about 4.5×10^{11} curies of naturally occurring radioactive material (Hinga, 1982). For comparative purposes, the Swiss expect to disposal of approximately 4400 MCi from a 240 Gwa nuclear energy scenario in the high level waste repository (NAGRA 1985) and that a 100,000 ton repository would contain within an order of magnitude the same curie amount as the oceans. However, the naturally occurring nuclides are not the same as those in spent fuel and the hazards cannot be compared on the basis of the curie content alone. Only a safety assessment, as would have been carried out the original seabed working group program, could have detailed the dosage caused by subseabed disposal and compared it to the dose caused by the naturally occurring radionuclides in the oceans.

TABLE 2

ANTHROPOGENIC RADIONUCLIDES FROM
FISSION AND NEUTRON ACTIVATION PRODUCTS

<i>Radionuclide</i>	<i>Half-life</i>	<i>Type of Decay</i>
Fission Products		
⁹⁰ Sr (strontium)	51 days	Beta
⁹⁰ Sr (strontium)	28 years	Beta
⁹¹ Y (yttrium)	58.1 days	Beta
⁹² Zr (zirconium)	65 days	Beta
¹⁰³ Ru (ruthenium)	40 days	Beta
¹⁰⁶ Ku (ruthenium)	368 days	Beta
¹²⁵ Sb (antimony)	2.7 years	Beta
¹³⁷ Cs (cesium)	30 years	Beta
¹⁴¹ Ce (cerium)	33 days	Beta
¹⁴⁴ Ce (cerium)	282 days	Beta
¹⁴⁷ Pr (praseodymium)	2.6 years	Beta
¹⁵³ Eu (europium)	4.9 years	Beta
Neutron Activation Products		
³ H (hydrogen; tritium)	12.3 years	Beta
¹⁴ C (carbon)	5,730 years	Beta
³² P (phosphorus)	14.3 days	Beta
³⁵ S (sulfur)	87 days	Beta
⁴⁶ Sc (scandium)	84 days	Beta
⁵¹ Cr (chromium)	28 days	EC ¹
⁵⁴ Mn (manganese)	300 days	EC
⁵⁹ Fe (iron)	2.6 years	EC
⁵⁹ Fe (iron)	45 days	Beta
⁶⁰ Co (cobalt)	270 days	EC
⁶⁰ Co (cobalt)	72 days	EC
⁶⁰ Co (cobalt)	5.26 years	Beta
⁶³ Ni (nickel)	92 years	Beta
⁶⁵ Zn (zinc)	246 days	EC

¹ EC—Electron capture mode of decay.

Adapted from: Burton J.D. 1975. Radioactive Nuclides in the Marine Environment. *In* J.P. Riley and G. Skirrow (editors), *Chemical Oceanography*, Volume 3, Academic Press Inc., London, p. 91-191.

Friedlander, G., J.W. Kennedy, and J.M. Miller. 1964. *Nuclear and Radiochemistry*. John Wiley & Sons, New York, 585 p.

Source: National Advisory Committee on
Oceans Atmosphere, Nuclear Waste
Management and the Use of the Sea, April 1984.

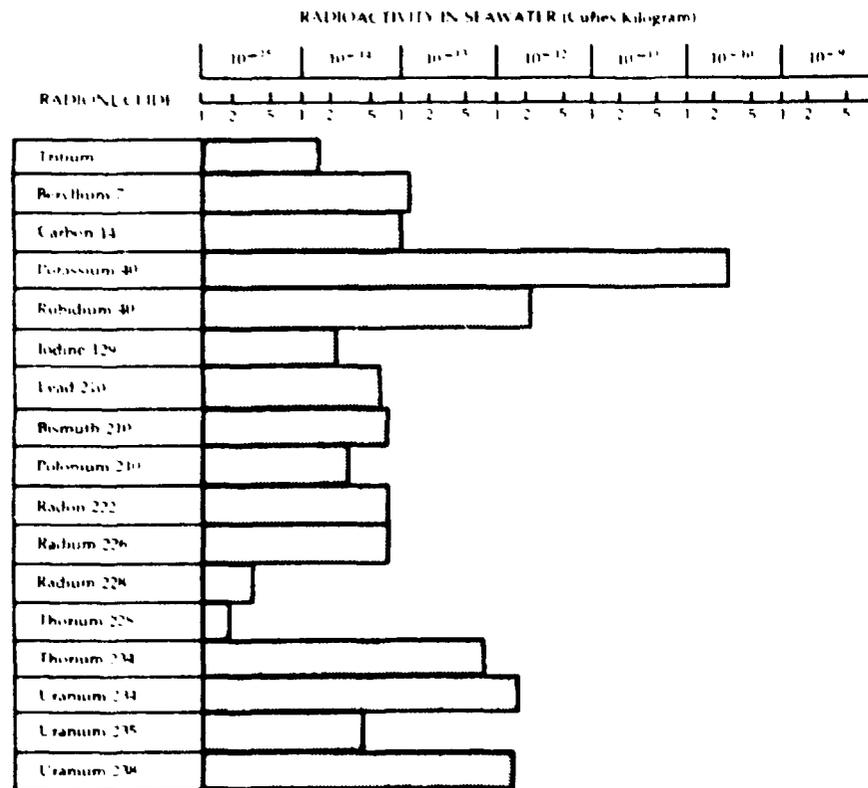


Figure 6. Concentrations of Major Radionuclides in Seawater.

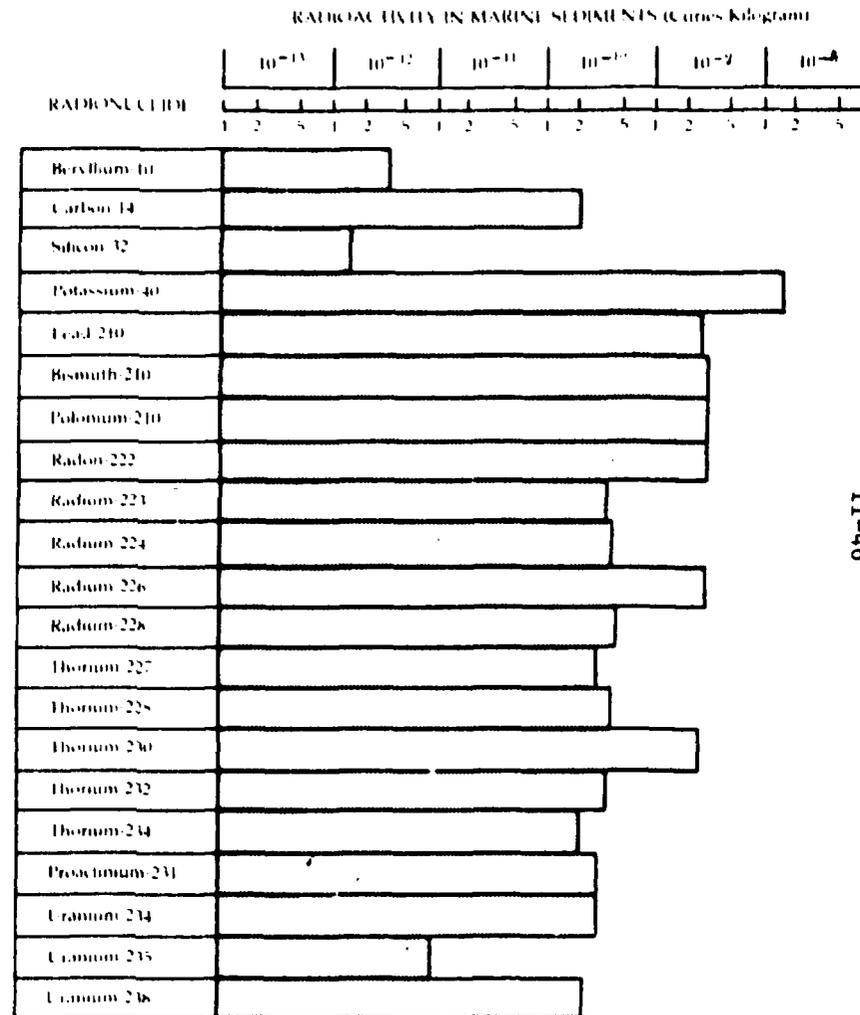


Figure 7. Concentrations of Major Radionuclides in Marine Sediment.

Both interim storage and final disposal of spent fuel on land creates a stockpile of material capable of being made into nuclear weapons. If one is concerned about the non-proliferation of nuclear weapons then the subseabed disposal program provides greater assurance against the unauthorized spread of fissile material than the storage or disposal of spent fuel on land.

H. Conclusions

Subseabed disposal of high level radioactive waste and spent fuel, in contrast to land based mined geologic repositories, has not yet been judged by any nation or international bodies to be technologically acceptable.

The work under the scientific program for subseabed disposal the most truly international of all the radioactive waste program, was proceeding along a well defined route to proof or rejection of concept. This date will certainly be delayed because of the withdrawal of the USA from the program. The work under the aegis of the NEA will result in a report in 1987 that will be a status report. To date no scientific information has emerged that would negate the advantages of the subseabed disposal method. Validation of some of the models has not been completed.

The option, if possible, would be very attractive for many reasons including no easy direct exposure to man, no contamination of potential drinking water supplies, no near neighbors, an international solution rather than a parochial solution, and location in a formation with highly desirable attributes (stability, exchange capacity, etc.) that

may not be available in every nation with a nuclear energy program. Even if the scientific feasibility were proven, then there still remain enormous institutional obstacles to be overcome including the determined opposition of many countries on ecological and philosophical grounds, the existence of international treaties that appear to prohibit such disposal and the fact that it is not the first choice for disposal of spent nuclear fuel or high level radioactive waste.

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APPENDIX I

DETAILED ASSESSMENT OF DRILLED AND
FREE FALL PENETRATOR EMPLACEMENT

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DETAILED ASSESSMENT OF DRILLED AND
FREE FALL PENETRATOR EMLACEMENT

1-1. Drilled Emplacement (Bury, 1985)

The report is divided into 12 chapters, plus a summary report, references and appendix. These chapters are

1. Reference Criteria,
2. Drilling operation,
3. Transfer of Radioactive Waste, Personnel, and Other Supplies,
4. Handling of Radioactive Waste on Board,
5. Lowering Strings of Canisters,
6. Emplacement and Backfilling of Canisters,
7. Preliminary Design of Marine Platform,
8. Retrieval of Flasks or Canisters Lost or Misplaced,
9. Variations to the Features of the Lowering System,
10. Logistics of the Operation,
11. Construction Cost Estimates, and
12. Operational Costs.

The proposed method, drilled emplacement, (summarized below) was chosen because it appears to be feasible using techniques and equipment already developed, or reasonable extensions of them. "It is not necessarily the most cost effective or even most reliable, and it is to be expected that further improvements in both aspects will be achievable."

1-1.a. Drilling

Global Marine Development Inc. (GMDI) was asked to assist in this part of the feasibility study, due to their experience in drilling in water depths greater than 4000 m, most recently

greater than 5500 m for the U.S. National Science Foundation's Deep Sea Drilling Program (DSDP). The 475 m long steel-lined borehole "vault" would be prepared prior to disposal operations, and would provide (with backfilled grout) a sealed enclosure for 300 or more reference high level waste (HLW) canisters that would remain structurally intact for hundreds, perhaps thousands of years. The bottom of the vault would be at least 200 m above bedrock, the top some 275 m below the seafloor. The casing above the vault would be removed and backfilled after disposal operations, with the re-entry cone (used in initial drilling operations) left in place in the event retrieval of the wastes becomes desirable. The whole operation (vault emplacement and closure) is expected to take 25 to 30 days to accomplish, using present equipment and techniques.

1-1.b. Transport and Offloading

Dedicated supply vessels will transport waste canisters in shielded casks weighing up to 150 tonnes. Eight possible systems for transfer of the casks to the platform were considered, six of which were eliminated for either not being able to handle such heavy loads, being impractical, unrealistic, and/or heavily weather dependent. Considered were a motion-compensated crane and a load transfer bridge. The crane would require a motion compensating shock absorbing table on the supply vessel as well. For the capacity required

considerable development would be required. The lattice-built load transfer bridge would be provided with either a rail and rack system to allow braking in case the hauling cable were to snap, or smooth-surfaced plate structure for transfer by water skates. The bridge system is preferred, as additional gangways could be used for transfer of personnel and non-radioactive cargo. While the transfer bridge can be built using present day technology, further work is called for in engineering the end connections in their degrees of rotational and linear freedom.

1-1-c. Handling of Radioactive Waste on Board

Conventional "dry-cell" handling used in land-based radioactive waste handling, though already developed and easily adapted to platform conditions, was determined to be less desirable than "wet cell" handling, for which machines that could operate under water would need to be developed. Major advantages of the wet-cell are: water provides all shielding and cooling of canisters, rather than requiring an air-tight cell and considerable air cooling and filtering equipment and maintenance, and operations can be viewed directly, whereas dry-cell operations must be viewed remotely via TV monitors.

Flasks would be maneuvered and waste canisters removed from them and placed in stringer pipes using hydraulically powered cranes and manipulators, which are available for the

required capacity. Some development would be required, however, for their reliable operation in sea water.

Stringer pipes of 15 m length, wall thickness 25 mm and outer diameter less than 600 mm (for reference 430 mm diameter canisters), will be joined using well-developed offshore drilling technology. Canister-filled pipes will be pumped full of grout and washed down. Clean pipes will be assembled into stringer loads. The first length will be a "dummy pipe", smaller in diameter and considerably more flexible than the stringer pipes, whose function is to guide the string into the pre-drilled hole. It will carry transponders and a video camera to facilitate the emplacement operations. The "dummy" will be connected to the first stringer pipe by a stab-in joint, as are other stringer pipes to each other until a load for a lowering trip has been completed. Procedures and machinery for assembling stringer sections are well established.

1-1-d. Lowering Strings of Canisters

The proposal calls for lowering the canister strings by means of drill pipes, using drill strings attached to one another using conventional drilling rig elevators, slips, and other equipment. The whole load, however, is considerably heavier, as conventional deep-sea oil drilling operations rarely exceed 2000 m in depth. As the proposed emplacement depth is some 750 m beneath the seabed, which itself is around

5500 m below the surface, the total drill string length will exceed 6000 m. The weight of the lowering strings will require greater strength and buoyancy of materials than conventional operations. Larger diameters, however, offer a larger surface subject to stresses from internal waves, currents, etc. Lowering pipes may be made of steel, titanium, or composite fiber materials with steel fittings. The choice of pipe size and material is dependent on the weight of the load in the lowering operation. Recommended loads range from 10 canisters (which would call for 30 trips per well) in order to limit consequences of accidents, to 150 or 300 canisters, allowing each disposal hole to be filled in just one or two trips, which would allow filling the pre-drilled hole with delayed setting grout prior to the disposal operation. A loss of a drill string during the lowering operation is the most severe problem envisioned in normal operations. Several techniques for attaching high-tensile strength cables to the waste-bearing portion of the drill string are discussed as possible back-up systems in the event the lowering pipe string breaks. Some of these cable systems incorporate guidance systems that would be retrievable, as opposed to the sonar guidance transponder and TV camera in the prepared "dummy pipe" at the lower end of the drill string. Dynamic positioning of the platform is used to guide the drill string onto the well head, which is equipped with sonar transponders and the re-entry cone. Additional lengths of drill string are

used to lower the load to its proper destination within the well. When sufficient canisters have been lowered to fill the well to its intended level it is backfilled and completed.

1-1-e. Backfilling and Completion

As pointed out above, holes filled with canisters in one or two trips can benefit from pre-filling the drilled hole with delayed-setting grout, which also helps keep the number of underwater operations required to a minimum. Otherwise pre-grouting operations must be alternated with drill string emplacement; or if granular filling is acceptable, the same operation may be used or it may be injected afterwards in a single operation.

Above the vault area, the casing is removed by reaming in order to avoid providing a path along the lining wall for radionuclide migration. The reamed area is backfilled with grout to plug the repository. The guide cone and casing conductor will be left in place in the event re-entry is desired. Radiation monitoring devices could be installed in the plugged wellhead, if desired.

1-1-f. Design of Structure

A number of designs and materials were considered, but the necessity for a large shielded moon pool and a maintenance free hull dictated the choice of a concrete structure, comprised of a 48 m diameter cylindrical tower surrounded below

the water line by 8 smaller cylinders of 25 m diameter. Several similar designs have been engineered through the preliminary design stage, but no floating concrete platforms have been built. The proposed concrete structure has a displacement of 490,000 tonnes, and carries a deck of approximately 30,000 tonnes, which includes accommodations, generators, all handling equipment, storage areas, and so forth. The outer cylinders could be used for storage of fuel oil and grouting materials. Dynamic positioning of the platform would be accomplished through the use of 18 thrusters of 6,800 horsepower (2250 kw) each, mounted atop the smaller cylinders.

The design of the platform takes into account the environmental conditions for a location in the Great Meteor East (GME) study area. In order to maintain a minimum air gap of 3 m between water and the operations deck, total static freeboard of 24 m to the top of the concrete structure is provided. The concrete hull and the integrated steel deck will be constructed separately, probably at different locations. No new construction techniques would be required. However, the deck mating would have to take place in waters at least 135 m deep. Such locations are known and have been used for similar operations on the west coast of Scotland.

1-2. Penetrator Emplacement (Arup, 1985)

The report is divided into 10 chapters, plus references and appendices. These chapters are:

1.0 Introduction

Part I General Assessment of Options

2.0 Penetrator Designs

3.0 Disposal Operations

4.0 Selected Options

Part 2 Further Study of Selected Options

5.0 Penetrator Specification

6.0 Penetrator Manufacture

7.0 Ship Design and Penetrator Release

8.0 Disposal Site Usage

9.0 Cost Assessment

10.0 Feasibility Assessment and Recommendations

The report includes 51 figures.

Four proposed penetrator designs have been developed that satisfy the preliminary design conditions. Those conditions are broken down into fundamental and secondary requirements.

1-2-a. Fundamental Requirements

1. Compatibility with waste form
2. Provisions of engineered barriers
3. Achievement of adequate embedment performance

Requirements 1 and 3 are readily achievable. The requirement to provide an engineered barrier has the greatest impact on penetrator design. It is intended to shield the waste from sea water for 500 years after embedment, allowing the waste to cool to nearly ambient temperatures. Initially titanium alloy

and mild steel were considered. Thin-skinned corrosion-resistant materials would require structural filling of voids to resist collapsing under hydrostatic pressure and are sensitive to mechanical damage. Importantly, there is considerable uncertainty about their corrosion rates. Therefore they are not considered further in the study. Mild steel would require close to 300 mm to provide a safety margin above the thickness required for pressure and corrosion. Although it would provide nearly adequate safety shielding as well, the consequent weight and cost were shown to be not worthy of further consideration.

The reference design considered in Part Two of the report has a steel shell 75 mm thick.

1-2-b. Secondary Requirements

Manufacturing, transport, assembly and cost considerations suggested that the barrier be provided by a single penetrator body shell containing several canisters. Penetrators containing up to five waste canisters could be handled and transported over existing rail and road networks. Assembly operations could be carried out at the vitrification works site. Shipboard assembly was found to be inefficient and posed unnecessary risks.

1-2-c. Reference Option

In order to assess manufacturing and operating systems, a reference penetrator design was chosen that took the most

desirable features outlined above. However, this does not make it an optimized design.

The reference penetrator contains five HLW canisters. The 75 mm thick mild steel body shell could be manufactured in conventional workshops and transported to the assembly area. In assembly the voids would be filled so as to make the waste and penetrator body resistant to hydrostatic pressure. Dedicated ships would store and transport the penetrators to the disposal site, where they would be released.

A high-purity 0.15% carbon mild steel with routine mechanical properties was selected. The decision was driven by ease of welding, and based on current general engineering low-carbon steel grades, with the additional requirements for high purity. The proposed manufacturing technique calls for separate fabrication of nose, tube, tail and fins, to be assembled by welding. While welding could be minimized by manufacturing tubes with integral noses or tails, some high quality manufacturing processes applicable only to plain tubes would have to be ruled out.

1-2-d. Ship Design and Penetrator Release

Operations once the penetrators are assembled are: transfer to ship, voyage, and release. By and large the length of the penetrator will be the most influential factor in designing the ship and handling facilities.

1-2-e. Shore to Ship Transfer

While no exceptional handling equipment is expected to be necessary, prudent security would suggest dedicating a dock for nuclear waste penetrator loading. If the penetrators are shipped in by truck or rail, it is likely that some type of temporary storage might be necessary. Maintaining a secured area would make it possible to limit the "rolling stock" for bringing penetrators to the dock.

Proposed transfer methods range from the simple roll on, roll off vehicular loading ramp, to a sophisticated underwater handling system, involving a dock with a tunnel that extends under the moonpool of the ship. The former method is already a world-wide standard loading method, while the latter would involve high overhead and maintenance costs as well as unnecessary risks in the event of systems failure. Transfer in shielded flasks or through shielded tunnels would reduce radiation to an acceptable level.

1-2-f. Ship Design

The purpose-built transfer ship would likely incorporate safety features found on Japanese (and Swedish) spent fuel transport ships. Hulls with wide wing tanks would surround the cargo bay, double bottoms would protect against grounding damage, and a number of transverse and longitudinal bulkheads could be provided to guarantee buoyancy even in the event of a severe collision. As the reference penetrator body does not provide sufficient radiation shielding, such shielding would

be built into the ship (unless shielded flasks are provided for each penetrator).

Twin engines would drive twin propellers, with the engine room preferably in the stern. If the engines must be located forward, they could drive electric generators, the power cables running to electric engines in the stern, thus avoiding long prop shafts through the shielded hold. Back-up fire-fighting, navigation, and generating equipment would naturally be carried aboard.

Much development is required for equipment to handle and release penetrators. Generally, cargoes are rarely moved about while at sea; when they are, the process tends to be contact handling. Remote handling equipment, probably hydraulically powered, would usually be used for loading as well as unloading operations.

Five ship design options are explored, in which penetrators are stored vertically, longitudinally, or transversely. It is assumed that a penetrator will be retrieved from shipboard storage and taken to the release station as the ship approaches the launch site. There it will be inspected, and any instruments aboard it will be activated. Launching method is specific to the ship's design.

Option A. Penetrators are loaded via underwater conveyor, and picked up by a rail-mounted ship gantry crane through a stern moonpool. A carriage on the same rails carries the penetrator to the lateral storage racks. In release, the

carriage takes the penetrator from the storage rack to the moonpool, where it is tipped off.

The transfer mechanism has already been criticized. It also involves storing wet penetrators, which will drip contaminated water, necessitating washing systems that will add complication, expense, and a secondary waste stream.

Option B. This design calls for vertical loading of penetrators, leaving them nose-down in individual water filled compartments. Each compartment has doors above and below it. When the ship reaches release position the doors in the hull below the penetrator open and the penetrator is released.

Due to the depth of water in the hold, penetrator length is restricted to 4.5 m (2 canister capacity), with ship draft about 7.5 m. Maintaining reasonable proportions with such a deep hull requires building a bigger ship than is considered in the other options. The many doors in the bottom of the hull weaken it, and their remote release mechanisms are least accessible for maintenance while being most susceptible to grounding damage.

Option C. Penetrators are loaded and stored longitudinally in a dry hold, and released through a moonpool in the center of the ship. Loading and onboard transfer are carried out via 2 rail-mounted, self-propelled transfer flasks. Penetrators of up to 18 m length, carrying 12 canisters, can be accommodated. Transfer flasks would carry the penetrator to a dedicated elevator at shipside. While the load is slowly

transferred to the ship, the weight is compensated by pumping ballast water to the opposite wing tank. On board the flask would roll on the rail network to the storage rack areas, where flask and deck doors would open, allowing the penetrator to be lowered into position and hydraulically clamped in place. Reversing the process, and rolling to the moonpool would provide launch positioning.

Option D. Electro-hydraulic locomotives would pull a train of penetrators on board through a shielded tunnel mating with the ship's stern. On board, remotely controlled locomotives would use elevators and transversers to distribute the penetrators. All penetrator designs studied (1 to 12 canisters) could be accommodated. At the release site the penetrator carriage is clamped onto the rear ramp, the rear end of which is lowered below sea level, and the combination released. The carriage, retained on a safety line for recovery, releases the penetrator under water.

Though present day technology can accomplish all operations in this option, the absence of bulkheads in the holds would allow local damage that could lead to uncontrolled flooding and possibly capsize the ship.

Option E. Penetrators are carried in individual transport flasks and stored in conventional holds. At the launch site a travelling portal crane brings the flask to a launching frame, which upends it, and releases the penetrator through the moonpool. The empty flask is returned to the hold.

A reference penetrator and flask would weigh 100-120 tonnes, and could be transported to the dock by train. More than one penetrator design could be handled if such flexibility is designed into the system. Since each penetrator has a shielding transport flask, no special shielding would be needed for the transfer equipment or the ship.

1-2-g. Conclusions

Only Option B limits penetrator length, but there are more compelling reasons for not favouring that option. Option E, or a cross between Options A and C seem to be most worthy of further consideration. Penetrators longer than the reference cannot be stored athwart, however, and limit the number of feasible designs. Loading and launching are considered feasible.

1-2-h. Site Usage

Waste emplacement should be spaced at least 7.5 m apart. Nominal launch spacing has been set at 125 m, allowing plenty of room for error in positional accuracy of the ship, penetrator trajectory, and ocean current allowance. Wire guidance systems were not considered. Reference penetrators carry 0.75 m^3 of HLW. At the proposed disposal rate of 85 m^3 per year, 115 penetrators would take up 1.9 km^2 . At this rate it would take 51 years to fill the 100 km^2 U.K. study site in the Great Meteor East.

Emplacement and transport accidents are not considered very likely due to the simplicity of the methods considered. In emplacement, loss of a tail fin might cause an unstable trajectory, but the penetrator is calculated to bury itself 1 m deep in the sediments. Detection of such a misburial should be rather straight forward if it is instrumented. While it is considered unrealistic to attempt recovery with present technology, radiological consequences are considered to be very small. Wire guided penetrators have been successfully recovered in recent trials. Shallow water retrieval in the event of a transportation accident should be possible, either through attaching recovery cables using submersibles or by lifting or re-floating the entire ship.

APPENDIX 2

SIGNATORY COUNTRIES TO THE LONDON
DUMPING CONVENTION

Signatory Countries to the London Dumping Convention

Contracting Parties to the *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter* (December 29, 1972 London: IMO, 1972), as of January 1, 1983:

Afghanistan	Monaco
Argentina	Morocco
Belize	Nauru
Brazil	Netherlands
Byelorussian Soviet Socialist Republic	New Zealand
Canada	Nigeria
Cape Verde	Norway
Chile	Onam
Cuba	Panama
Denmark	Papu: New Guinea
Dominican Republic	Philippines
Federal Republic of Germany	Poland
Finland	Portugal
France	Seychelles
Gabon	Solomon Islands
German Democratic Republic	South Africa
Greece	Spain
Guatemala	Suriname
Haiti	Sweden
Honduras	Switzerland
Hungary	Tunisia
Iceland	Tuvalu
Ireland	Ukrainian Soviet Socialist Republic
Japan	Union of Soviet Socialist Republics
Jordan	United Arab Emirates
Kenya	United Kingdom
Kiribati	United States
Libya	Yugoslavia
Mexico	Zaire

Source: U.S. Department of State. 1983. *Treaties in Force. A List of Treaties and Other International Agreements of the United States in Force on January 1, 1983*. Publication 9351, Office of the Legal Advisor, Washington, D.C., p. 253.

APPENDIX 3

IAEA DEFINITIONS AND RECOMMENDATIONS

.— Definition of High-Level
Radioactive Wastes or Other High-Level
Radioactive Matter Unsuitable for
Dumping at Sea.

For the purpose of Annex I to the Convention, high-level radioactive wastes or other high-level radioactive matter unsuitable for dumping at sea means any waste or other matter with an activity per unit gross mass (in tonnes) exceeding:

- (a) 1 curie/ton (Ci/t) for alpha-emitters, but limited to 10^4 Ci/t for radium-226 and supported polonium-210 ("supported" means plutonium that is present in equilibrium concentrations because its relatively long-lived parent, lead-210, is present);
- (b) 100 Ci/t for beta/gamma-emitters with half-lives of at least half a year (excluding tritium), and beta/gamma-emitters of unknown half-lives; and
- (c) one million Ci/t for tritium and beta/gamma-emitters with half-lives of less than half a year.

The above activity concentrations shall be average over a gross mass not exceeding 1000 tonnes.

The definition must not be taken to imply that material falling outside the definition is deemed suitable for dumping.

[1.] The Definition is based on:

- (1) An assumed upper limit to the mass dumping rate of 100,000 tonnes per year at a *single dumping site*; and
- (2) Calculated upper limits to activity release rates from *all sources* (other than natural sources) of:
 - (a) 100,000 curie/year (Ci/yr) alpha-emitters (but limited to 10,000 Ci/yr for radium-266 and supported polonium-210);
 - (b) 10 million Ci/yr for beta/gamma-emitters with half-lives of at least half a year (excluding tritium), and beta/gamma emitters of unknown half-lives; and
 - (c) 10^{11} Ci/yr for tritium and beta/gamma-emitters with half-lives of at least half a year (excluding tritium), and beta/gamma emitters of unknown half-lives; and also in the case of alpha-emitters when released to an ocean basin of not less than 10^{11} cubic meters.

Source: International Atomic Energy Agency, 1978 *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter*. The Definition Required by Annex I, paragraph 6 to the Convention, and the Recommendations Required by Annex II, section D (NE/CIRC/205, Add. 1/Rev. 1, Vienna, Austria, p. 3)

-International Atomic Energy
Agency Recommendations for Ocean Dumping
of Low-Level Nuclear Waste.

1. Sites should exist between 50°S and 50°N latitudes to avoid sources of bottom water (characterized by strong vertical mixing) and areas of high biological productivity (polar regions);
2. Depth should be 4,000 meters or more (biological, chemical, physical and topographical gradients are generally low, bottom water circulation is slower, and organic carbon in the sediments tends to be low);
3. Sites should be remote from continental margins to avoid regions of high biological productivity, active resource exploration and exploitation, and geologic unpredictability and instability (continental slope, rise and associated fans and canyons);
4. Sites should be away from areas of potential seabed resources, transoceanic cables in use, and areas where geologic hazards (such as submarine slides, volcanoes and earthquakes) decrease a site's environmental predictability;
5. The area of a site should be defined by precise coordinates, with an area as small as practicable, and if possible, covered by precise navigational aids to assist in relocating the site.
6. Sites should be away from features such as submarine canyons which may unpredictably affect rates of exchange between deep and surface waters near the continental shelf.
7. Sites should be chosen for convenience of disposal operations and to avoid so far as possible, the risk of collision with other traffic and undue navigational difficulties; and
8. Bottom current shear stress should not exceed critical erosional shear stress to prevent high rates of resuspension and eroding of the sediments.

Source: International Atomic Energy Agency, 1978, *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter*. The Definition Required by Annex I, paragraph 6 to the Convention and the Recommendations Required by Annex II, section D. INF/CIRC/205/ Add. 1/Rev. 1. Vienna, Austria.

APPENDIX 4

RESOLUTION PASSED AT THE EIGHTH CONSULTATIVE MEETING,
SEPTEMBER 1984

"Without prejudice to the question of the applicability of the London Dumping Convention to disposal of high-level radioactive wastes or other high-level radioactive matter into the sea-bed, the Consultative Meeting arrived at a consensus on the following:

1. The Consultative Meeting of the Contracting Parties to the London Dumping Convention is the appropriate international forum to address the question of the disposal of high-level radioactive wastes and matter into the sea-bed, including the question of compatibility of this type of disposal with the provisions of the London Dumping Convention.
2. No such disposal should take place unless and until it is proved to be technically feasible and environmentally acceptable, including a determination that such wastes and matter can be effectively isolated from the marine environment, and a regulatory mechanism is elaborated under the London Dumping Convention to govern the disposal into the sea-bed of such radioactive wastes and matter."

APPENDIX 5

RESOLUTION PASSED AT THE NINTH CONSULTATIVE MEETING,
SEPTEMBER 1985



NINTH CONSULTATIVE MEETING OF
CONTRACTING PARTIES TO THE
CONVENTION ON THE PREVENTION
OF MARINE POLLUTION BY DUMPING
OF WASTES AND OTHER MATTER
23-27 September 1985
Agenda item 4

IMO

REPORT OF INTERSESSIONAL ACTIVITIES RELATING TO
THE DISPOSAL OF RADIOACTIVE WASTES AT SEA,
INCLUDING THE FINAL REPORT OF THE SCIENTIFIC REVIEW

Draft resolution

Submitted by Spain, Australia, Brazil, Chile, Cuba, Denmark,
Dominican Republic, Finland, Haiti, Iceland, Mexico, New Zealand,
Norway, Panama, Saint Lucia and Sweden

THE NINTH CONSULTATIVE MEETING,

RECOGNIZING that the marine environment and the living resources of the sea are of vital importance to all nations and that the objective of the London Dumping Convention is to prevent the pollution of the seas by dumping,

CONSIDERING that the Convention should continue to provide an effective global forum for the Contracting Parties in which to pool the advances of science and technology in their effort to combat marine pollution,

TAKING NOTE of the increasing concern of a growing body of public opinion, and in particular among the populations living near present or potential dumping sites, with regard to the dumping of radioactive wastes at sea,

RECOGNIZING that dumping of radioactive wastes at sea may adversely affect the environment of other nations and of regions located beyond the limits of national jurisdiction in contravention with Principle 21 of the UN Declaration on the Human Environment adopted in Stockholm in June 1972,

RECOGNIZING that, under Article 1 of the Convention, Contracting Parties have pledged themselves specially to take all practicable steps to prevent the pollution of the seas by the dumping of wastes and other matter that is liable to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea,

For reasons of economy, this document is printed in a limited number. Delegates are kindly asked to bring their copies to meetings and not to request additional copies.

RECALLING that the Seventh Consultative Meeting in February 1983 adopted Resolution 14(7) which called for the suspension of all dumping at sea of radioactive materials pending the presentation to the Contracting Parties of the final report of an expert meeting on radioactive matters related to the London Dumping Convention,

RECOGNIZING that the practice of dumping radioactive wastes at sea has been limited to a few States which have halted such dumping since the adoption of resolution LDC.14(7) of February 1983,

NOTING the findings of the Expert Panel on the Disposal at Sea of Radioactive Wastes contained in document LDC 9/4, Annex 2, and expressing its appreciation to the experts involved in the preparation of this report,

NOTING that the Expanded Panel of Experts recognizes deficiencies in scientific information that need to be resolved for a rigorous and precise assessment of the consequences of sea dumping of radioactive wastes,

ACCEPTING that, as noted by the Expert Panel, in the comparison between options, social, economic, scientific and technological factors are difficult to quantify on a common basis, especially where the social factors have international dimensions; and that, as also noted by the Expert Panel, in the final analysis social and related factors may outweigh those of a purely scientific and technical nature.

NOTING also the absence of comparison between land-based and sea dumping options,

1. Agrees to a suspension of all dumping at sea of radioactive wastes and other radioactive matter to permit time for the further consideration of issues which would provide a broader basis for an informed judgement on proposals for the amendment of the Annexes of the Convention. This suspension will continue pending the completion of the studies and assessments referred to in paragraphs 2 to 5 hereunder.
2. Requests that additional studies and assessments of the wider political, legal, economic and social aspects of radioactive waste dumping at sea be undertaken by a panel of experts to complement the existing Expanded Panel Report.

3. Requests that further assessments examine the issue of comparative land-based options and the costs and risks associated with these options.
4. Requests that studies and assessments examine the question of whether it can be proven that any dumping of radioactive wastes and other radioactive matter at sea will not harm human life and/or cause significant damage to the marine environment.
5. Requests the IAEA to advise Contracting Parties with respect to certain outstanding scientific and technical issues relating to the sea dumping of radioactive wastes; specifically to:
 - 1) Determine whether additional risks to those considered in the revised IAEA Definition and Recommendations justify re-examination of the definition of radioactive wastes and other radioactive matter unsuitable for dumping at sea for certain individual radionuclides;
 - 2) Establish source (dose) upper bounds appropriate to the practice of radioactive waste dumping under the Convention,
 - 3) Define quantitatively the exempt levels of radionuclides for the purposes of the Convention,
6. Requests the Organization to approach appropriate international agencies to establish and maintain an inventory of radioactive wastes from all sources entering the marine environment.
7. Calls upon Contracting Parties to develop as envisaged in Article X procedures for the assessment of liability in accordance with the principles of international law regarding State responsibility for damage to the environment of other States or to any other area of the environment resulting from dumping.

APPENDIX 6

STATEMENT BY CANADA

Statement by Canada

Mr. Chairman,

This delegation voted against resolution LDC.22(9) for both process-related and substantive reasons.

Canada cannot, on the basis of current information, endorse a resumption of radioactive waste dumping at sea and consequently came to this meeting seeking renewal of the 1983 moratorium. Throughout intensive negotiations outside of the plenary, the Canadian delegation worked long and hard towards reaching a consensus agreement on a resolution to that end. We believe substantial progress had been made in these negotiations and were thus deeply disappointed that delegations, not convinced as we were of the necessity of a renewed moratorium, did not give a concrete indication of their willingness to work towards a compromise earlier in the meeting. We were similarly disappointed, however, when other delegations refused to allow time for further negotiations and in our view prematurely brought resolution LDC.22(9) to a vote.

As to the substance of that resolution, Mr. Chairman, we explained yesterday the elements that remained unacceptable to us and proposed amendments to remove them, in order that the Consultative Meeting of Contracting Parties be able to make an informed decision on proposals to prohibit radioactive waste dumping at sea within a reasonable time frame. When these amendments failed to gain general acceptance, we voted in favour of the amendment proposed by the distinguished representative of the Federal Republic of Germany, thus indicating our willingness to accept the full text of resolution LDC.22(9) providing the moratorium was not an open-ended one. When this too failed to gain general acceptance, although fully supporting the principle of a renewed moratorium, we were reluctantly compelled to vote against resolution LDC.22(9), since as phrased it will indefinitely prevent a decision from being made on the prohibition of radioactive waste at sea.

REPORTS PUBLISHED BY THE NATIONAL BOARD FOR SPENT
NUCLEAR FUEL, SKN.

NAK Report 1

SAMMANSTÄLLNING AV NUKLEÄRA
KÄLLDATA FÖR ANVÄNT KÄRNBRÄNSLE

(Compilation of Nuclear Source Data
for Spent Nuclear Fuel)

Göran Olsson
Studsvik Energiteknik AB
April 1983

(19 pages of tables and diagrams,
Swedish text)

NAK Report 2

MATERIAL OCH PROCESSUTVECKLING FÖR
DIREKT SLUTFÖRVARING AV ANVÄNT
KÄRNBRÄNSLE

(Material - and Process Development
of Ceramic Encapsulation of Spent
Nuclear Fuel for Disposal)

Caj Airola
Studsvik Energiteknik AB
November 1983

(119 pages mainly on engineering
aspects of ceramic encapsulation,
in Swedish)

NAK Report 3

ENCAPSULATION OF SPENT NUCLEAR FUEL
IN CERAMIC MATERIALS AN
INTRODUCTORY STUDY

S Forsberg
T Westermark
Department of Nuclear Chemistry
The Royal Institute of Technology
Stockholm, Sweden
March 1983

(37 pages mainly on material
properties, in English)

NAK Report 4

INTERNATIONELL UTVECKLING FÖR
KOMMERSIELL UPPARBETNING AV KÄRN-
BRÄNSLE, BEHANDLING AV
UPPARBETNINGSAVFALL OCH
ÅTERANVÄNDNING AV PLUTONIUM

(International Development of
Commercial Reprocessing of Spent
Nuclear Fuel, Treatment of
Reprocessing Wastes and Recycling
of Plutonium)

Göran Carleson
Åke Hultgren
Studsvik Energiteknik AB
Mars 1983

NAK Report 5

(44 pages in Swedish)
SAMMANSTÄLLNING OCH VÄRDERING AV
UTLÄNDSKA SÄKERHETSSTUDIER ÖVER
SLUTFÖRVARING AV KÄRNBRÄNSLEAVFALL

(Review of Foreign Safety Studies
on Disposal of Spent Nuclear Fuel
Waste)

Ragnar Gelin
Studsvik Energiteknik AB
April 1983

(109 pages in Swedish)

NAK Report 6

NÅGRA HUVUDRIKTNINGAR INOM MODERN
RISKTEORI

(Som Main Trends in Recent
Development of Risk Theory)

Nils-Eric Sahlin
AB Episteme
Lund
Juli 1983

(23 pages in Swedish)

NAK Report 7

RISK PÅ LÅNG SIKT OCH DISKONTERING
AV RISK

(Risk in the Long Term and
Discounting of Risk)

Bengt Hansson
AB Episteme
Juli 1983

(17 pages in Swedish)

NAK Report 8

RISK PÅ LÅNG SIKT OCH DISKONTERING
AV RISK I SAMBAND MED FÖRVARING AV
RADIOAKTIVT MATERIAL

(Long Term Risk and Discounting of
Risk in Relation to Disposal of
Radioactive Materials)

Ola Svensson
Gunnar Karlsson
Department of Psychology,
University of Stockholm
September 1983

NAK Report 9

(43 pages in Swedish)
UPPFÖLJNING AV UTLÄNDSKA SÄKERHETS-
STUDIER ÖVER SLUTFÖRVARING AV
KÄRNBRÄNSLEAVFALL

(Review of Foreign Safety Studies
on Disposal of Spent Nuclear Fuel
Waste)

Ragnar Gelin
Studsvik Energiteknik AB
June 1984

(40 pages in Swedish)

NAK Report 10

INTERNATIONELL UTVECKLING AV
MELLANLAGRING OCH UPPARBETNING AV
ANVÄNT KÄRNBRÄNSLE SAMT
PLUTONIUMÅTERFÖRING

(International Development of
Intermediate Storage and
Reprocessing of Spent Nuclear Fuel
and on Recycling of Plutonium)

G Carleson
Å Hultgren
Studsvik Energiteknik AB
August 1984

(56 pages in Swedish)

NAK Report 11

THE DISPOSAL OF HIGH-LEVEL
RADIOACTIVE WASTE 1984
Volume I and II

Frank L Parker
Robert E Broshears
Janos Pasztor
The Beijer Institute of the Royal
Swedish Academy of Sciences
October 1984

(Vol I 116 pages, Vol II 209 pages,
in English)

NAK Report 12

KÄRNBRÄNSLENÄMNDENS FORSKNINGSSIN-
VENTERING 1983-1984

DEL I SLUTRAPPORT

DEL II FORSKARUTLÅTANDEN

(An inventory of research needs

Vol I Summary and Conclusions
30 pagesVol II Research proposals
196 pages)Clas-Otto Wene et al
December 1984

The report identifies knowledge gaps and presents proposals on items which ought to be addressed in the on-going Swedish research programme on disposal of spent nuclear fuel (in Swedish).

NAK Report 13

RISKFORSKNING OCH BESLUT OM RISKER

(Risk Research and Decisions about Risks)

Sven Ove Hansson
Februari 1985

(14 pages in Swedish)

NAK Report 14

UPPFÖLJNING AV UTLÄNDSKA SÄKERHETS-
STUDIER ÖVER SLUTFÖRVARING AV
KÄRNBRÄNSLEAVFALL

(Review of Foreign Safety Studies on Disposal of Spent Nuclear Fuel Waste)

Ragnar Gelin
Studsvik Energiteknik AB
April 1985

(37 pages in Swedish)

NAK Report 15

UPPFÖLJNING AV DEN INTERNATIONELLA
UTVECKLINGEN AV MELLANLAGRING OCH
UPPARBETNING AV ANVÄNT KÄRNBRÄNSLE

(International Development of Intermediate Storage and Reprocessing of Spent Nuclear Fuel and on Recycling of Plutonium)

Göran Carlsson
Studsvik Energiteknik AB
June 1985

(39 pages in Swedish)

SKN Report 16

NAK WP-CAVE PROJECT - REPORT ON THE
RESEARCH AND DEVELOPMENT STAGE, MAY
1984 TO OCTOBER 1985

Boliden WP-Contech AB
November 1985

(129 pages in English)

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DISPOSAL 1986

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Storage (184 pages)

Vol IA Appendices (197 pages)

Vol II Subseabed Disposal
(95 pages)

Frank L Parker
Roger E Kaspersen
Tor Leif Andersson
Stephan A Parker
The Beijer Institute of the Royal
Swedish Academy of Sciences

November 1987

SKN Report 18

INTERNATIONELL UTVECKLING INOM
KÄRNBRÄNSLECYKELN MED TYNGDPUNKT PÅ
TRANSPORTER OCH SAFEGUARDS

(International Development within
the Spent Nuclear Fuel Cycle with
Emphasis on Transports and
Safeguards)

Karin Brodén
Göran Carleson
Åke Hultgren
Studsvik Energiteknik AB
November 1987

(52 pages in Swedish)

SKN Report 19

RISK DECISIONS AND NUCLEAR WASTE

Sven Ove Hansson
The National Board for Spent
Nuclear Fuel
November 1987

(38 pages in English)

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