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SEISMIC DESIGN OF LOW-LEVEL NUCLEAR WASTE REPOSITORIES AND TOXIC WASTE MANAGEMENT FACILITIES

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SEISMIC DESIGN OF LOW-LEVEL NUCLEAR WASTE REPOSITORIES AND TOXIC WASTE MANAGEMENT FACILITIES

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Earthquakes can affect nuclear waste management facilities through ground shaking, faulting, earthquake-induced ground failures, and possibly tsunamis. Seismic safety is one of many factors that must be considered in the permanent management of radioactive wastes (high- and low-level wastes as well as uranium mill tailings) in geologic media.

The interest in surface and subsurface repository seismic effects spans two time periods: The operational phase where the primary interest is in the safety of men and equipment, and the decommissioned phase where the primary interest is in permeability enhancement. Seismic effects on surface facilities, shafts, etc., are of particular significance during the operational phase, i.e., access to the repository must be maintained.

Over a long term (say 10,000 years), one of the main mechanisms for breaching the seal around the repositories and allowing water to enter and leave is through seismic activity. The permeability issue is difficult to assess because current model studies give void volume increase, i.e., changes in rock porosity, yet the permeability depends on the size and connectivity of

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the individual elements of this new open space. Small earthquakes could induce microfractures and extend other fractures. Large earthquakes could cause local faulting and open up direct pathways or damage important equipment. It is assumed that for various reasons (not all necessarily technical) that it will be necessary to consider very remote events, i.e., the risk of damage to the facility from an earthquake must be very small. This requires a very careful and detailed analysis.

The state of the science and engineering of determining and predicting damage to underground facilities, from earthquakes, with particular emphasis on the ultimate goal of developing criteria for the site characterization and design evaluation of mined geologic high-level waste repositories, is poor. It is presumed that seismic criteria for the surface and/or shallow subsurface facilities of a low-level waste management repository will be similar to seismic criteria for other comparable surface nuclear facilities. However, there is a growing body of evidence that subsurface deep underground facilities respond to earthquake motions in a manner that is substantially different from that of surface facilities. Thus, the criteria for both site characterization and design evaluation may be different.

The Nuclear Regulatory Commission (NRC) has not yet established the design response criteria for a radioactive waste storage facility. While separate hazard/risk analyses (both deterministic and probabilistic) will have to be done for a repository, the procedures specified by the NRC for reactors could be used as a basis for a repository even though the applied criteria may be different. The Environmental Protection Agency (EPA) seismic design criteria are also very rudimentary and consist primarily of a requirement that hazardous waste facilities not be built on active faults.

We have performed an analysis of hazardous waste facilities (HWFs) to determine what the most significant contributors to the risk to the public from HWF due to seismic activity. Using the results of the study and examining other regulations, codes, etc., to see what impact costing rules, regulations, and design codes had on the risk, we concluded that they had little to none. Rules and regulations were nonexistent, or like the EPA's, too rudimentary, and did not cover the factors that most contribute to the risk to the public from seismic activity.

Because regulations and effective design standards are virtually nonexistant in the remainder of our discussion, we focus in on the identification of the elements of typical HWF that are the major contributors to the risk as the elements which require additional considerations in the design and construction of low-level nuclear waste management repositories and HWFs.

As far as hazardous waste (non-nuclear) management facilities are concerned, we have determined from our recent study of six typical HWFs that the factors that contribute most to the human and environmental risk fall into four basic categories as follows:

- o Geologic and seismological conditions at each HWF; e.g., location of the nearest fault, soil conditions, probability of having earthquakes, etc.

- o Engineered structures at each HWF; e.g., tanks, ponds, pipes, buildings, etc., whose failure would release the hazardous materials to the environment.

- Environmental conditions at each HWF; e.g., nearby rivers, population centers, location of nearest aquifer, etc., i.e., pathways to the public.

- Nature of the material being released; e.g., its toxicity, liquid, powder, gas, etc.

In selecting and carrying out the six case studies, we have examined three groups of hazardous waste facilities: generator industries which treat or temporarily store their own wastes; generator facilities which dispose of their own hazardous wastes on site; and industries in the waste treatment and disposal business.

The case studies have a diversity of geologic setting, nearby settlement patterns and environments. Two sites are above a regional aquifer, two are near a bay important to regional fishing, one is in rural hills, and one is in a desert, although not isolated from nearby towns and a groundwater/surface-water system.

From the results developed in our study, we concluded that the effect of seismic activity on hazardous facilities poses a significant risk to the population because:

- Given that a damaging earthquake has occurred, there would be a high probability of release and environmental damage.

- The mean annual probability of a damaging earthquake is on the order of 0.02 to 0.05. Because it has been a number of years since a major earthquake occurred near any of the case study sites, the likelihood of a major earthquake is higher than the mean probability of 0.02 to 0.05 per year.

- Ground shaking is much more important than fault rupture, since the ground shaking affects a large number of facilities in the region where the earthquake occurs.

- Soil instability (liquefaction, soil failure, large settlements) plays a very important role, significantly increasing the risk of release and environmental damage.

- Of the waste technologies examined, tanks and poorly designed impoundments are major contributors to the risk of release of hazardous wastes. Containers (55-gal drums) appear to pose the lowest risk.

- Explosions and fire as a result of seismic activity are a major cause of release and environmental damage.

- Air and groundwater are the major environmental pathways, or at some sites air and surface water.

- The soil/groundwater/surface water pathway is put at risk from waste containment units without backup, e.g., single-walled underground tanks, and in larger earthquakes from all waste technology units, due to the probability of damage to both the waste unit and its spill containment system.

- The surface water pathway is put at risk from tank or impoundment failure combined with failure of dikes.

- The air pathway is put at risk from spills of volatiles and from fires.

- At the sites studied, most of the public health risk comes from short-term airborne exposure.

- At three of the six sites studied, a slow long-term contamination of groundwater or surface water arising from an earthquake could put the public health at risk.

- At two sites over an important aquifer, withdrawal of the resource from use rather than public health damage will be the result, since contamination will certainly be monitored for after an earthquake.

- Site location factors (e.g., proximity to population centers, siting near a major river or a major aquifer) play an important role in the probability and degree of environmental and public health damage.

- o Hazardous waste facility damage and a large earthquake would be much more critical together than either one alone. Evacuation routes would be damaged, and emergency response services and long-term resources for restoration would be overtaxed.

The probability of a significant release of hazardous materials per waste technology unit per site from seismic activity is approximately 0.01 per year. Over the, say, 40-year lifetime of a facility, the probability of a significant release of hazardous materials is approximately 0.33 per waste-containment unit (tank, pond, etc.). The importance of this result is clearer when one considers that each facility has a number of different structures holding hazardous waste, all of which will be stressed at the same time. Moreover, in a large earthquake, a large number of facilities will experience potentially damaging ground motion at the same time. Thus, the likelihood of a release at a number of facilities is very high.

One important factor represented in the probability estimates is the fact that our hazard model is Poissonian in time. This means that in any period of time we have the same probability that a large earthquake will occur. On the contrary, it is generally agreed that an earthquake is more likely the longer the time elapsed since the last major earthquake. for all the sites studied it has been a long time since the last major earthquake. Thus, the risk is most likely higher at these sites than that indicated by computations based on a simple Poissonian model.

We found that ground shaking and liquefaction are more important than faulting as major contributors to the risk of release of hazardous materials and environmental damage. This is so for several reasons. First, many more sites are involved, both those "near" faults and those "far" from faults. Second, for any given earthquake the only sites which can have surface rupture are those sites located on the surface trace. The probability that a given site is on the surface trace is low--even if the site is within 3,000 ft of the fault. Furthermore, usually less than one third of the fault will rupture, even in a major earthquake. Thus, the probability that a site will experience surface rupture is smaller than the probability that it will experience damaging ground motion. Finally, both liquefaction and faulting provide a cause of similar facility damage and pathways for environmental damage. Thus, faulting contributes less to the risk than ground shaking and liquefaction. That is not to say that faulting can be neglected, but only that other hazards contribute more to the risk of release and environmental damage. For example, in the eastern United States, faulting poses no hazard, while liquefaction poses a very major hazard.

Large tanks pose a significant hazard. The typical failure of a large tank is a buckling failure. Hence, a tank has less reserve strength than other typical structures. This lack of reserve is reflected in the "high" risk numbers at all sites. This is a major problem if there is no secondary containment, such as dikes. In very large earthquakes liquefaction and land spreading will tend to breach even secondary containment.

Wastes stored in 55-gallon storage containers pose some hazard. At most sites this hazard comes from the common-mode failure introduced by an earthquake. By this we mean that the strong ground shaking causes failure in other structures, affecting the 55-gallon drums, which in themselves are reasonably low risk. The two modes of potential interaction projected to occur are by explosive missiles and/or fire reaching the drums. No doubt at other sites a similar result would arise from different means, such as collapse of certain structures.

There is considerable uncertainty in our results. However, even taking the least conservative set of our results reduces the risk (from the median case) by a factor of only 2 to 6, depending upon the median failure PGA. This result still indicates that large amounts of hazardous wastes will be released during a major earthquake in a large-population area such as the San Francisco Bay Area, because a major earthquake will shake a large number of facilities with sufficient intensity to cause failure at several of them.

The environmental media immediately next to the sites were found to have high conditional probabilities of contamination, given a damaging earthquake. At some case-study sites this was due to units without backups, and at others due to the probability of a severe earthquake with liquefaction. But given this high conditional probability, it then becomes very important that thenearby environmental units be relatively unimportant in themselves and that they retard the wider spread of wastes and provide separation from more critical environmental units. Most of the case study sites, located for industrial rather than safety reasons, were near one or more critical environmental resources and were in populated areas. Two sites were in locations fair-to-good in terms of isolation or limited environmental units at risk.

The absolute probabilities of damage to a facility, of environmental contamination with hazardous waste, and of health and environmental damages (probability per year do not differ greatly among the six case studies, despite their diverse seismic hazards and environmental settings. Case study facilities with higher perceived risk generally have better design and better procedures to limit the risk. This shows the potential benefits from good design of waste technology units and backups, and from good procedures. Examples of good procedures are limiting the quantities of waste and refraining from conducting the more hazardous commercial activities at high-risk sites (e.g., sites with high seismic hazards, poor soil foundation conditions, or sensitive environments exposed nearby).