EEG-12

Potential Release Scenario and Radiological Consequence Evaluation of Mineral Resources at WIPP

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CONTENTS

FOREWORD

The purpose of the Environmental Evaluation Group (EEG) is to conduct an independent technical evaluation of the potential radiation exposure to people from the proposed Federal radioactive Waste Isolation Pilot Plant (WIPP) near Carlsbad, in order to protect the public health and safety and ensure that there is minimal environmental degradation. The EEG is part of the Environmental Improvement Division, a component of the New Mexico Health and Environment Department -- the agency charged with the primary responsibility for protecting the health of the citizens of New Mexico.

The Group is neither a proponent nor an opponent of WIPP.

Analyses are conducted of available data concerning the proposed site, the design of the repository, its planned operation, and its long-term stability. These analyses include assessments of reports issued by the U.S. Department of Energy (DOE) and its contractors, other Federal agencies and organizations, as they relate to the potential health, safety and environmental impacts from WIPP.

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INTRODUCTION

In providing a technical evaluation of the potential radiation doses and health effects resulting from the nuclear waste repository (Waste Isolation Pilot Plant) being considered for southeastern New Mexico, the Environmental Evaluation Group attempts to consider all credible pathways of exposure of the population to the waste, including those events which might occur long after the repository is sealed, controls over the site are abandoned and records are lost. Some of these potential long-term breach events were considered by the U.S. Department of Energy in its Final Environmental Impact Statement and in other reports (Refs. 1, 2, and 3), and it was pointed out that these events might be associated with exploration or mining of the important resources located at the site. EEG evaluates the radiological health consequences of these and other scenarios which may reasonably be expected to lead to release of the waste to the biosphere. The DOE has considered the following long-term breach scenarios, all of which might arise as a result of exploration or mining of the resources at the site, or from certain natural geologic events:

Scenario 1: A hydraulic communication connects the Rustler aquifers above the repository, the Bell Canyon aquifer of the Delaware Mountain Group below the repository, and the repository.

Scenario 2: A hydraulic communication allows water to flow from the Rustler, through the repository, and back to the Rustler.

Scenario 3: A stagnant pool connects the Rustler aquifers with the repository. In contrast to scenarios 2 and 3, which involve flowing water, this communication permits radionuclide migration to the Rustler only by molecular diffusion.

Scenario 4: A hydraulic communication connects the Rustler aquifers with the repository; all the Rustler water normally moving above the repository flows through the repository and back to the Rustler. In contrast, scenarios 1 and 2 establish only a limited hydraulic connection.

Scenario 5: A drill shaft penetrates the repository and intercepts a radioactive waste container; the radioactive material is brought directly to the surface.

This report discusses the implications of the above scenarios which might arise as a result of exploration or mining of resources. The first four of the foregoing scenarios involve a liquid breach of the repository and transport of the dissolved waste through the Rustler aquifer, above the repository, to the Pecos River at Malaga Bend. Only Scenario 5 brings a fraction of the waste to the surface at the WIPP site. The DOE has concluded that scenario 5 provides a worst-case consideration of transport of the waste to the surface, and does not consider a breach of the repository from the mining of halite as credible.

EEG agrees that (1) the shortage of water and processing facilities for salt in the area, (2) impurities present in the salt of the Salado, and (3) vast amounts of salt available in other areas of the U. S. lead one to conclude that the salt at the WIPP site could not be economically extracted in the foreseeable future. However, EEG believes that significant climatic and social changes could make such mining more plausible. Therefore this report analyzes the potential radiological consequences of solution mining of halite 250 years after decommissioning. The report also discusses the reasons why solution mining of potash or drilling for natural gas are believed to be bounded by other scenarios considered by DOE in the Final Environmental Impact Statement (Ref. 2).

SUMMARY

This report has reviewed certain of the natural resources which may be found at the site of the nuclear waste repository being considered for southeastern New Mexico, and discussed the scenarios which have been used to estimate the radiological consequences from the mining of these resources several hundred years after the radioactive waste has been emplaced.

It has been concluded that the radiological consequences of the mining of potash or hydrocarbons (mostly natural gas) are probably bounded by the consequences of hydrologic breach scenarios already considered by the U. S. Department of Energy, (Ref. 2), and by reports of EEG (Refs. 4, 5). These studies conclude that the resultant doses would not constitute a significant threat to public health.

This report also evaluates the radiological consequences of solution mining of halite at the WIPP site. Although such mining in the Delaware Basin and particularly at the WIPP site, is not likely at the present time, significant economic, social or climatic changes a few hundred years after emplacement may make these resources more attractive. The DOE did not consider such mining at the site credible (Ref. 2, p. 9-145).

The fifty-year individual dose commitment from the ingestion of the average adult consumption of salt (contaminated with the radioactive waste from the repository) was 72 millirems for one year. This might be compared to an average lifetime dose from natural background radiation of 7500 millirem. Assuming that 0.2% of the radioactive inventory was mined and contaminated the salt during the solution mining event, and that about 2.5% of the total salt was consumed in food products, the total whole body dose to a population at risk of 300 million would be 0.9 million person-rems. This represents about 0.06% of the 50 year dose commitment from natural background. Although this population dose may not be considered insignificant, the small probability of such an event, and the very conservative assumptions used would lead one to conclude that the risk of such an event is small.

It is unlikely that the small doses resulting from this solution mining breach event would produce any detectable biological effects. It is possible that the long term consequences would be an increase in the normal incidence of cancer in the population, but such an increase would be within the range of statistical variation. Based on the recent conclusions of the National Academy of Sciences BIER Committee (Ref. 6, Table V-3) the total risk of such cancers would be about 0.32 fatal cancers per million population over the 50 years. This can be compared with the current incidence of 167,000 cancers per year per million population, or 8.35 million cancers over 50 years.

NATURE OF RESOURCES AT WIPP SITE

Mineral resources at the site include potash in the form of the potassium salts, sylvite and langbeinite; hydrocarbon resources, which, if present, may include crude oil, but mostly natural gas and distillate (liquid associated with natural gas). The potassium salts are found in strata 400 to 700 feet above the repository which is 1400 to 1700 feet below the surface; the hydrocarbons most likely would be found 8,000 to 12,000 feet below the repository which is 10,000 to 15,000 feet below the surface. Although other minerals such as salt, caliche, and gypsum are also in this area in quantity, there are enormous quantities in many other areas. Of these only halite is in close enough proximity to the repository to warrant considertion of a breach scenario. The size and economic value of potash, halite and hydrocarbons which may exist at the WIPP site are summarized below:

(a) Potash

Potash resources were estimated by the U.S. Geological Survey (USGS), the U.S. Bureau of Mines (USBM), and Agricultural and Industrial Minerals, Inc. (AIM) (Refs. 7, 8, and 9). In reference to potash, the terms "resources," and "reserves" as used here are defined as follows:

> Resources are considered minerals that are currently or potentially of economic value; this includes seams that are thicker than 4 feet and contain sylvite or langbeinite with a potassium oxide richness greater than 8% or 4% respectively.
>
> Reserves are the portion of the resources that are economically recoverable at today's market prices and removable with existing technology; this includes seams that are thicker than 4 feet and contain sylvite or langbeinite with potassium oxide richness greater than 13% or 9% respectively. The current estimates of resources and reserves under the four zones of the WIPP site are shown in Table 1.

TABLE 1

POTASH WITHIN WIPP SITE*

Deposit	Resources (million tons)	Reserves (million tons)	% of Resources recoverable in Zone IV	% of Reserves recoverable in Zone IV
Sylvite	133	27.4	71	100
Langbeinite	351	48.5	65	73

Since the surface value of mined potash ore at the present time is about $15/ton, the total surface value of the reserves is about $1.14 billion. The in-place value of the ore is much less, but more difficult to estimate. The U.S. Department of Energy has estimated in-place value of the potash ore as 14 cents per ton for sylvite and 5 cents per ton for langbeinite (Ref. 2, Table 9-16). The DOE has stated that mining in Zone IV of the WIPP site is possible without adverse impact on the proposed repository (Ref. 2, p. 9-118), and such recovery may be allowed before decommissioning. If this is the case, then 83% of the potash reserves (100% of 27.4 million tons of sylvite and 73% of 48.5 million tons of langbeinite) would be authorized for removal.

The Department of Energy has considered the impact of several mechanisms of liquid breach of the repository and transport of the radionuclides to the Pecos River at Malaga Bend (Refs. 1, 2, 3 and 10), or to a well in the Rustler, located about three miles downstream from the repository (Ref. 10). The EEG has independently calculated doses resulting from the transport of the radionuclides to Malaga Bend or to a well following a liquid breach and agrees that the doses would represent only a small fraction of the natural radiation background, even if very conservative (designed to increase severity) hydrologic parameters are assumed (Refs. 4, 5). Therefore, if the mining of potash leads to a liquid breach with transport of radionuclides to the Rustler at the WIPP site, the results would be bounded by the long-term scenarios

*This table is adapted from Table 9-19 of the FEIS (Ref. 2).

already considered. Because the potash ore is located at least 400 feet above the repository horizon, it is likely that the ore could be removed by conventional techniques without disturbing the repository; however EEG has requested that DOE provide a detailed plan and consequence evaluation if the decision is made to allow such removal.

Solution mining of the potash is not economical in the area because of the limitation of suitable water, absence of processing facilities and thinness of the ore beds. However, if water and facilities did become available, and solution mining were attempted, it is likely that the potash could be successfully solution-mined without breach of the repository during the operation. Nonetheless, such techniques near a nuclear repository might constitute a risk because the liquid-filled caverns may weaken the formations leading to breach after thousands of years, possibly resulting in transport of the radionuclides to one of the underground aquifers (Ref. 11).

To remove the potash ore by solutioning or brining techniques involves drilling two or more large diameter wells to the ore zone, establishing a circulation between the wells through hydrofracturing or hydrocarbon padding and recovering the dissolved brine. Because these ores are found in quantity considerably above the repository horizon, it is not plausible to believe that the hydrofracturing and brining would accidently extend 400 feet down into the repository horizon, unless some pathway already existed. The presence of horizontal clay seams in the salt would tend to move the hydrofractures up or horizontally along the clay seams, and current techniques permit shaping of the cavern to follow closely the ore horizon (Refs. 12, 13, 14, 15). If abandoned drill holes were present in the area and extended down into the repository, the effect of such a communication would be readily detected because of the retarding effect of such undesirable hydraulic communication on the solutioning of the potash ore. (The returning solution generally is monitored for potassium content.) For these reasons, a breach associated with potash mining resulting in transport of the radioactive material to the surface is not considered credible.

(b) Solution Mining of Halite and Consequence Analysis

Dickinson estimates that halite (sodium chloride) production in the U.S. for a variety of applications is over 40 million tons per year, valued at $300 million. Another 20% or more of salt is being imported from Canada, Mexico, and to a lesser extent, from other countries (Ref. 16).

There are extensive deposits of bedded halite in many areas of the Delaware Basin. The thickest and purest salt beds at the site are found in the Castile, although the Salado contains from 80 to 90% halite. The New Mexico Bureau of Mines and Mineral Resources has estimated that there are 118 billion tons of salt in the Salado within the WIPP boundary (Ref. 17). The Castile formation would add approximately 80 billion tons of additional salt resource. Along with gypsum and caliche, the halite deposit was not considered by the DOE to have any economic significance, because of the prevalence of salt deposits throughout the Permian Basin and other areas within the United States (Ref. 18). Because of the purity, domed salt usually is preferred to bedded salt. Approximately 56% of the halite produced in the United States is derived from the salt domes of Louisiana and Texas (Ref. 14). Within the Permian Basin, salt is being recovered by mechanical or solution-mining techniques at locations in Kansas, Texas and southwestern Oklahoma. No mining of halite has occurred in the Delaware Basin, and commercial mining is not considered economical in the WIPP area in the near future, because of the shortage of water, the remote location of the site from processing facilities and the presence of anhydrite and polyhalite beds intermingled with the bedded halite formations. It is conceivable, however, that in the long-term, climatic and social changes may render these deposits more attractive. For example, in the United States during the Pleistocene epoch, 1 to 2 million years ago, several lakes were formed or expanded during periods of increased precipitation, especially in the western United States in areas that are now deserts (Ref. 10, Sec. 2.3.4.1).The climate of New Mexico during such periods was characterized by more precipitation (about 60% more than at present), less evaporation (only about 70% of present) and a mean June - September temperature about 18°F lower than at present. Flooding was probably more frequent. Given greater access to water, there would be increased probability that industry supportive of solutioning techniques would be available to the area. Therefore, although mining of halite at the WIPP site is considered highly unlikely, it is sufficiently plausible to warrant evaluation of the potential radiological consequences of a breach resulting from this activity.

This is considered in the following way. It is assumed that a commercial brining operation is initiated 250 years after decommissioning, directly over the 100 acres which house the abandoned repository. Initial exploratory and drilling operations fail to detect the repository, and two or more wells are drilled to produce hydraulic fracturing and to establish solutioning of salt. A cavern in the Salado is produced of approximately one million cubic feet, and the dissolved brine is routed to a nearby chemical processing plant for removal of the salt and recycling of the reconstituted unsaturated water. It is assumed that the radionuclides dissolve at the same rate as the salt, and that 0.2% of the 100 acre column of the Salado salt is removed by brining. Any more than this fraction might lead to some collapse of the overlying formations. It also would be reasonable to assume that detection of radioactive impurities occurred after 1 year. The scenario is illustrated by a typical cavern as shown in Figure 1. The radionuclide inventory at 250 years after storage is shown in Table 3.* Table 4 provides the resultant whole body dose from ingestion of the contaminated salt for a period of 1 year (1800 gms).

The 50-year individual dose commitment provided in Table 4 is considered conservative for at least two reasons: (1) It assumes the ingestion of 1800 gms of the unrefined salt extracted entirely from the solution mining breach event described. In other words, the salt is undiluted with other salt obtained from uncontaminated sites. (2) It neglects the potential reduction of plutonium contamination which is likely to occur as a result of adsorption to the clay constituents of the Salado, as follows:

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*This inventory is calculated from the initial inventories of TRU waste provided in Tables 3.1-2, and 3.1-4 of the SAR (Ref. 10).

To a rough approximation, the distribution of radioactivity between brine and suspended solids is given by

$$C_s = K_d\ C_\ell \qquad (1)$$

C_s = concentration per unit mass of a given nuclide sorbed on solids, Ci/gm

C_ℓ = concentration per unit volume in the liquid phase, Ci/mℓ

K_d = distribution coefficient, mℓ/gm

As the water dissolves the repository, conservation of activity also is maintained. This is expressed by the following equation

$$m_s\ C_s + C_\ell = A \qquad (2)$$

m_s = mass of solid in volume of repository suspended by a unit volume of H_2O (gm/ml)

A = activity in volume of repository dissolved or suspended by a unit volume of H_2O. C_s and C_ℓ are as previously defined. Combining equations (1) and (2) one obtains

$$C_\ell = \frac{A}{m_s\ K_d + 1} \qquad (3)$$

$$C_s = \frac{A\ K_d}{m_s\ K_d + 1}$$

Equation (3) can be interpreted as follows:

Of the activity, A, leached by a unit volume of water (assuming the saturated brine contains total dissolved solids of 0.4 gm/ml), a fraction

$$\frac{1}{m_s\ K_d + 1}$$

remains in the water and a fraction

$$\frac{m_s\ K_d}{(m_s\ K_d + 1)}$$

is resorbed on the suspended clay freed by the brining of the water. If 5% of the Salado is material other than salt, and 1% of this material is clay for which K_d for Plutonium can range from 40,000 to 180,000 mℓ/gm (Ref. 10, Table 2.5-12); then m_s is 2×10^{-4} gm/mℓ and between 90 to 97 percent of the Plutonium is resorbed on the clay. The clay in the Salado is thus an effective barrier against bringing plutonium to the biosphere.

An important question that must be resolved is what fraction of the insoluble material is brought to the surface as suspended particulates and what fraction remains in the subsurface cavity.

In summary, therefore, the 72 millirem individual fifty-year dose commitment might be compared with normal background radiation of about 100 millirem each year, or a lifetime dose of about 7,500 millirem. The total population dose may be conservatively estimated by assuming that each member of a population of 300 million consumes 1800 gms of salt per year. It also is assumed that 1/24 of this salt for food is derived from this solution mining event. (If the annual production in the nation is 48 million tons, only about 1/50 of a year's production is consumed as food.)

Based on one year's production of the contaminated salt, the total population 50-year dose commitment would be 0.9 million person-rems. This might be compared to a background 50-year dose commitment of about 1.5 billion person-rems. Therefore, there would result from this breach event a 0.06% increase over background.

It might be of interest to compare these results to those obtained from a halite solution mining scenario involving a salt dome (Ref. 19). That scenario assumed a breach 1000 years after emplacement and a total of 2.6 million tons mined from nine wells over a period of one year. It was assumed that three percent of this salt was consumed as food (1800 gms/individual). The resulting 70-year whole-body dose commitment, for spent fuel nuclear waste, was 390 millirems, and for reprocessed high-level waste the dose was 100 millirems. This was converted into a 70-year total population dose commitment of 16 million person-rems from spent fuel, or four million person-rems from reprocessed waste.

It is unrealistic to assume a production rate at the WIPP site in excess of one million tons/year, because of the water limitations in the area - even if much more favorable climatic conditions occurred. Assuming an average flow of the Pecos of 2000 liters/second, the fresh water required for mining of one million tons/year is about equal to four percent of the total annual Pecos flow.

If solution mining of halite should occur in the WIPP site area at some time after termination of controls, it is likely that the scenario considered in this report provides the upper limit of dose consequences from solution mining at WIPP for the following reasons:

1. Most of the transuranic nuclides would probably be bound to the clay impurities in the salt formation and would not be contained in the processed and purified salt.
2. The limitation of fresh water in the area, even under conditions of favorable climatic change, is likely to discourage solution mining of salt because of the large reserves in other areas more accessible to water.
3. Because the salt is located at considerable depth, solution mining would require high technology to achieve economic return, and such technology would be expected to include the ability to recognize and remove radioactive impurities, if present.

Health Effects of Radiation Consequences

It is unlikely that any adverse health effects would occur from small doses resulting from the present scenario. If the 900,000 person-rems are assumed to be uniformly spread over the population of 300 million. The average 50 year dose would be only 3 millirems. Such doses are far too low to produce detectable effects. Using the data provided in the most recent report of the National Academy of Sciences BIER Committee (Ref. 6, Table V-3) and using a linear extrapolation from dose-effect curves provided by high doses, there would be about 96 fatal cancers resulting from this population dose over the 50 years, or 0.32 per million population. These values should be compared to the current cancer risk of 167,000 per million population per year, or 8.35 million cancers over 50 years.

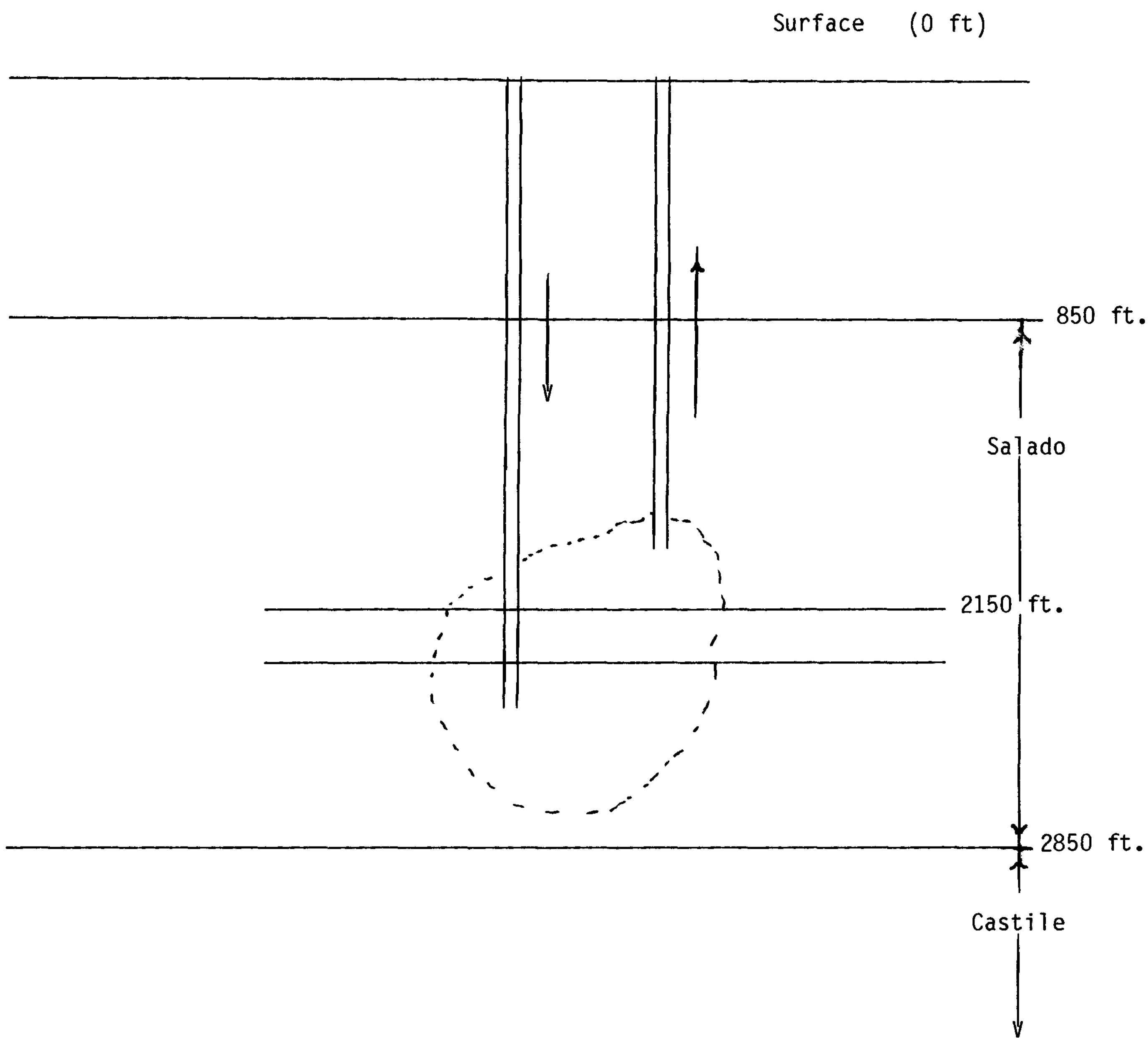

Figure 1. Breach of repository from solution mining of halite.

TABLE 2

PARAMETERS FOR SOLUTION MINING (BRINING) OF HALITE SCENARIO

1. Area of Repository Site: 100 acres
2. Thickness of Salado Salt at Site: 2000 ft. (600 m)
3. Volume of Salt ore under 100 acres of the Salado at site: 8.7×10^9 ft^3 (2.5×10^{11} ℓ)
4. Volume of CH waste: 1.7×10^8 liters
5. Volume of RH waste: 7.1×10^6 liters
6. Volume of repository: 5.2×10^7 ft^3 (1.5×10^9 ℓ)
7. Fraction of salt which is repository: 6×10^{-3}
8. Fraction of repository which is CH waste: .113
9. Fraction of repository which is RH waste: .0047
10. Production rate: or 1×10^6 metric tons of solid salt/year (1.6×10^7 ft^3)
11. Fraction of total Salado at WIPP site removed by brining in 1 year: 0.002
12. Volume of salt in the Salado under entire area of WIPP site (Zones 1, 2, 3, 4): 4.6×10^{13}ℓ (1.6×10^{12} ft^3)
13. Density of recovered and dried salt: 2.2 gm/ml
14. Annual Adult Consumption of salt: 1800 gms
15. Total population at risk: 300 million

TABLE 3

NUCLIDE INVENTORIES OF TRU WASTE AT 250 YEARS

Nuclide A	CH TRU (Ci/ℓ) B*	CH TRU Total (Ci) C*	RH TRU Ci/ℓ D*	RH TRU Total (Ci) E*	Final Total (Ci) F*
Pu-238	2.9 - 5**	4.9 + 3	1.2 - 5	8.5 + 1	5.0 + 3
Pu-239	2.2 - 3	3.7 + 5	1.1 - 3	7.8 + 3	3.8 + 5
Pu-240	5.2 - 4	8.8 + 4	2.4 - 4	1.7 + 3	9.0 + 4
Am-241	3.3 - 4	5.6 + 4	2.0 - 4	1.4 + 3	5.7 + 4
Sr^{90} + d			1.4 - 3	1.0 + 4	1.0 + 4
Cs^{137} + d			1.1 - 5	80.	80.
				Total	5.4 + 5

*Explanation of columns:

B = Average inventories from SAR at 250 years

C = (B) (1.7×10^8 liters)

D = Average inventories from SAR at 250 years

E = (D) (7.1×10^6 liters)

F = C + E

**2.9 - 5 = 2.9×10^{-5}

TABLE 4

FIFTY-YEAR DOSE COMMITMENT FROM ONE YEAR'S INGESTION OF SALT

Nuclide G	Concentration PCi/gm of salt H*	Dose (50 yr.) Commitment (mrem per Pci) I*	Whole Body Dose/ (mrem) J*
Pu-238	8.9	1.7 - 5	.27
Pu-239	7.0 + 2	1.9 - 5	24.0
Pu-240	1.7 + 2	1.9 - 5	5.8
Am-241	1.0 + 2	5.4 - 5	10
Sr^{90} + d***	1.9 + 1	9.3 - 4	32.
C_s^{137} + d	1.4 - 1	3.6 - 5	.009
		Total:	72

*Explanation of columns:

$$H = \frac{(F)\ (10^{12})\text{pCi/Ci liter}}{2.5 \times 10^{11}\ \text{liters} \times 2200\ \text{gm}}$$

I = NUREG 0172 dose conversion factors (Ref. 20)

J = (H) (I) (1800)

**7.0 + 2 = 7.0 x 10^2

***d = including daughters

(c) Hydrocarbons

The New Mexico Bureau of Mines and Mineral Resources (BMMR) evaluated the hydrocarbon resources at the earlier WIPP site, about five miles northeast of the current site (Ref. 17). This evaluation was based upon known reserves of crude oil and natural gas, and on the probability of discovering new reservoirs. The estimate of natural gas was 16.5 billion cubic feet per 640 acres, which amounts to a total of 490 billion cubic feet for the present site. Since the hydrocarbon estimate relies on statistical probabilities, this value would not be as accurate as the potash values. This volume also assumes that the quantity of hydrocarbon resources at the current WIPP site are about the same as at the old site, five miles away. A later evaluation of hydrocarbon resources of the present site was made by Sipes, Williamson and Aycock, Inc. (Ref. 21), in which they relied on information gained from nearby exploration. To protect the site no hydrocarbon drilling has occurred in Zones I, II, and III of WIPP. The area evaluated was 400 square miles centered on the present site. They concluded that a single zone, between 14,000 and 15,000 feet below the surface is worthy of exploratory risk, based on current economic considerations. Only natural gas is estimated to be present in quantities that are economical. The potential resources and reserves of natural gas are summarized in Table 5.

TABLE 5

POTENTIAL NATURAL GAS WITHIN WIPP SITE

	Total BCF*	In Zones I, II III BCF*	In Zone IV BCF*
Resources 100%	490 (100%)	211 (43%)	279 (57%)
Reserves	44.6	21 (47%)	23.6 (53%)

*BCF = billion cubic feet

At a value of $4.40/1000 cubic feet, the total surface value of the natural gas reserves is about $200 million.

Sipes, Williamson, and Aycock, Inc. have also evaluated the extra cost of extracting the natural gas through directional drilling. If drilling is allowed in Zone IV, 23 directional boreholes from the boundary of Zone III would be necessary to extract the natural gas from Zone I, II, and III (Ref. 22).

The DOE has considered the radiological consequences of drilling for hydrocarbons and drilling directly through a canister containing either contact-handled or remote-handled TRU waste (Ref. 2, p.9-143). Since the hydrocarbons, if present, are located 8,000 to 12,000 feet below the repository, a breach of the repository as a result of extraction of these resources would be bounded by either the liquid breach or direct drilling scenarios already considered in the FEIS.

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