XI. COST-RISK-BENEFIT CONSIDERATIONS

A. METHODOLOGY

1. Monetary Valuation of Risks

Radiation Exposures

The Office of Management and Budget and the Nuclear Regulatory Commission (NRC) have requested that a value of $1000/man-rem be used to convert changes in radiation risks to dollars for use in cost-benefit analyses of reactor safety systems. The same value is suggested in NRC Regulatory Guide 1.110 for cost-benefit analyses for reactor radwaste systems (March 1976).[1] Even though the NRC value is recommended for changes in radiation risk, it is applied in this document to total radiation risk to illustrate a method of comparing budgetary cost of an alternative with one credible method of dollar-valued total risk of that alternative. An analysis has also been made of the incremental cost of risk reduction, using the least expensive alternative as a base. In each case, the analysis applies to implementation of a complete alternative, because implementation of only part of an alternative to achieve a partial risk reduction is not feasible.

The suggested value of $1000/man-rem is used in this assessment for analyzing the alternative plans on a total dollar cost basis. However, there are other methods of evaluating radiation risk that some decision makers may wish to use; for example, the risks to individuals are important to consider along with the overall population risks. Thus, it may be desired to use a lower value than $1000/man-rem for individual exposures about equal to or below those received from natural background and a higher value for exposures posing an immediate threat to the individual.

The validity of interpreting man-rem exposure to a population as actual risk is in doubt and may result in gross overestimates when exposure to the involved individuals is very low. The following excerpts on this subject are taken from Report No. 43 of the National Council on Radiation Protection (NCRP), January 15, 1975:

> "The indications of a significant dose rate influence on radiation effects would make completely inappropriate the summing of doses at all levels of dose and dose rate in the form of total person-rem for purposes of calculating risks to the population on the basis of extrapolation of risk estimates derived from data at high doses and dose rates."

"The NCRP wishes to caution governmental policy-making agencies of the unreasonableness of interpreting or assuming 'upper limit' estimates of carcinogenic risks at low radiation levels as actual risks, and of basing unduly restrictive policies on such an interpretation or assumption."

Land Contamination

Levels of radionuclide deposition that would require evacuation of people and restrictions on farming and milk production are given in Table XI-1. The deposition limits were determined by using methods described in Reference 2 and pathways parameters from References 3 and 4. The dose criteria in Table XI-2 were derived from those used in Reference 2 and from Protective Action Guides issued by the Federal Radiation Council, which sets guidelines for actions to be taken in the event of widespread contamination resulting from an unplanned occurrence.

The dollar valuation placed on deposition of radioactivity offsite depends on whether or not crop restrictions apply, on the fraction of land used for crops, and on whether people must be evacuated. These considerations are discussed in detail in Reference 2. Offsite land contamination occurs only to a limited extent and only for a few events considered in this document. Therefore, average values for the decontamination costs of the different types of land use (farm land and developed land) from Reference 2 were used, rather than specific values constructed for each event. These values and those from Reference 2 used for relocation and loss of income for affected people are the following:

1. All land within a radial sector above the milk and crop restriction limit was assumed to carry a cost of $230 per acre. This cost is a weighted average cost of deep plowing or scraping with replanting, a procedure that gives an overall decontamination factor of about 20.

2. A cost of $1700 per acre was used for the weighted average cost of decontaminating commercial and residential areas.

3. A cost of $2,900 per capita was used for moving expenses and loss of income.

Tables XI-3 and XI-4 give the number of people affected, the acreage, and the dollar valuation for the alternative plans and events for which a deposition limit is exceeded. The same atmospheric conditions were assumed for the radionuclide deposition calculations as for the dose estimates, i.e., 95th percentile pessimistic dispersion conditions with 1-cm/sec particle settling velocity and wind in the Jackson-Augusta direction. The site boundary is 15 km from the waste management area.

TABLE XI-1

Radionuclide Deposition Limits for Evacuation and Restrictions on Farming, Ci/m^2

	Evacuation		Restrictions on Farming	
Isotope	*Direct Radiation*	*Inhalation*	*First Year*	*Longer*
^{90}Sr	-	2×10^{-4}	4×10^{-5}	2×10^{-4}
^{137}Cs	3×10^{-5}	1×10^{-3}	2×10^{-6}	8×10^{-5}
$^{238,239}Pu$	-	1×10^{-7}	-	-

TABLE XI-2

Radiation Dose Criteria

Evacuation Limits	
External Irradiation	10 rem to whole body in 30 years
Inhalation	75 rem to critical organ in 50 years
Farming Restrictions (Short Term)	
^{90}Sr	5 rem to bone marrow in first year[a]
^{137}Cs	5 rem to whole body in first year[a]
Farming Restrictions (>1 year)	
^{90}Sr	(5 rem to bone marrow in 50 years)/year
^{137}Cs	(1 rem to whole body in 50 years)/year

a. The 50-year dose commitments due to these exposures in the first year are about 25 rem to the bone marrow from ^{90}Sr and 5 rem to the whole body from ^{137}Cs. (Almost all the dose from ^{137}Cs is received in the year in which it is ingested.)

TABLE XI-3

Contamination Effects from Sabotage During Removal of Waste from Tanks

Distance from Release, km	*Acres Decontaminated*	*People Moved*
15-20	8.5×10^3	2.2×10^3
20-25	1.1×10^4	3.2×10^2
25-30	1.3×10^4	0
30-35	1.6×10^4	0
35-40	1.8×10^4	0
40-45	2.1×10^4	0
45-50	2.3×10^4	0
50-55	2.5×10^4	0
55-60	0	0
Total Offsite	1.3×10^5	2.5×10^3
Cost	$\$3.0 \times 10^7$	$\$1.2 \times 10^7$

TABLE XI-4

Contamination Effects from Sabotage During Waste Processing

Distance from Release, km	*Acres Decontaminated*	*People Moved*
15-20	8.5×10^3	0
20-25	0	0
Total Offsite	8.5×10^3	0
Cost	$\$2.0 \times 10^6$	

2. Ranking According to Total Effective Cost

Tables XI-5 through XI-9 give the sum of capital and operating costs in 1980 dollars for each of the 3 alternative plans. They also show consequences of each important event for each of the four functional operations of removal from tanks, processing, transportation, and storage. The consequences are given as radiation dose commitment to the offsite population in the year of maximum consequence. A conversion factor of 1/6 was used to convert bone doses to equivalent whole body doses. The factor of 1/6 is the ratio of occupational limits for whole body and bone dose. Use of this factor is an attempt to account for the fact that health effects in bones would occur only at doses considerably higher than health effects induced by whole body doses.

The annual probability assumed for each event is shown, and the maximum annual risk in man-rem/year is given as probability times consequence. The time-integrated risks are shown for a 300-year period and a 10,000-year period, and are based on an assumed population growth in the local area of a factor of five between now and year 2140, then a level population. The integrated risks are evaluated at $1000 per man-rem and are added to the budgetary cost to obtain total dollar cost of the alternative.

The disposal risks from several candidate Federal geologic repository sites are now being studied by other groups as part of the waste management program for wastes from commercial reactors. As the studies are completed, their results will be factored into the analysis given in this document. It is presently assumed that an offsite Federal repository would be in bedded salt or other formations with no likely pathway to a water supply. The disposal risks are assumed to be the same as those for SRP bedrock with canned, high-integrity waste.

3. Incremental Cost-Risk

Another method of evaluating the trade-off between cost and risk was used to generate the incremental cost-risk results in Tables XI-5 through XI-9. Those results show the cost per man-rem for reducing risk by spending money beyond that required to implement the least expensive alternative (Alternative 1, continued tank farm operation). The integrated risk for Alternative 1 reflects the assumption that the tanks would be abandoned after 100 years with a probability of 1.0. This assumption is in compliance with a request by the U.S. Environmental Protection Agency during the comment period that their proposed criterion of reliance on administrative control for no longer than 100 years be recognized.

The calculations for each of the more-expensive alternatives were made by dividing the difference in budgetary costs between that alternative and Alternative 1 by the difference in risk between the two alternatives. The result, expressed as dollars per man-rem, is the cost for reducing risk below the risk attainable with the least expensive alternative. The negative result for Alternative 3 indicates that it has higher cost and higher risk than Alternative 1.

B. RESULTS

1. Total Effective Cost and Incremental Cost Risk

Results of the evaluation discussed in Section A are given in Tables XI-5 through XI-9 , along with maximum year consequences and probabilities that form part of the total risk. More detail on the basis of both the risks and costs is given in Reference 6.

2. Comparison of Risks with Natural Background and Standards

Radiation from naturally occurring radioisotopes and extra terrestrial sources (e.g., cosmic rays) is estimated to result in an average exposure of about 120 mrem/year to each individual living in the vicinity of the SRP site. Within 150 km (93 miles) of SRP, the background radiation level ranges from 60 to 450 mrem/year. In addition, about 100 mrem/year is received by the average individual in the general population from medical x-rays. For comparison, the present Federal standard that limits exposure to the average member of the population to acceptable levels is an additional 170 mrem/year from nuclear plant operations.

The population within 150 km of the center of the plantsite is about 1.7 million. In one year, the total exposure of this population to natural radiation is about 200,000 man-rem, and the total exposure from medical x-rays is about 180,000 man-rem. The total yearly exposure of this population, from natural radiation and medical x-rays, is thus about 380,000 man-rem/yr. Exposure risks to the surrounding population have been integrated over a 300-year period and a 10,000-year period, and in the latter case are compared with the average natural exposure to the same population. The risks over 10,000 years are not markedly different from those over 300 years, because most of the risk arises from short-lived isotopes. It has been hypothesized that health effects such as cancer might be caused in individuals exposed to low levels of radiation, and an average value of about 200 health effects per million man-rem has been calculated by extrapolating observations at high dose rates to low dose rates. This value has been used to calculate the possible health effects from waste management activities over 10,000 years, as well as those to be expected from natural background.

As detailed in other sections of this report, estimated exposures to the general population for the various alternative plans for long-term waste management are far below exposures from naturally occurring radioisotopes and from medical x-rays. The estimated exposures are very small in comparison with standards set by the Federal Government.

During the period in which the waste would be processed (if the waste is converted to a solid form), the radiation dose commitment* risk from processing operations is estimated to be about 3 man-rem/yr to the population within 150 km of the center of the plantsite, or 0.001 percent of the dose received from naturally occurring radioisotopes and medical x-rays. If solidified waste is shipped offsite, the dose commitment risk during this period due to transportation of the waste would be 60 to 160 man-rem/yr to the (much larger) general population along the transportation routes. Again, this is a very small fraction of the exposure to naturally occurring radioisotopes and medical x-rays.

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* Radiation dose commitment is the amount of radiation dose received from major pathways of exposure, internal and external, throughout the 70-year lifetime of an individual from direct first-pass exposure, assuming the exposure is received at age 20. Population dose commitment is the sum of radiation dose commitment of all individuals (total population in a given area) and is expressed in units of man-rem.

TABLE XI-5

Summary of Costs and Exposure Risks for Alternative 1:
Storage of Waste as Sludge and Damp Salt Cake in Onsite Waste Tanks
(Present SRP Waste Management Technique)

Event	*Population Dose for Maximum Year, man-rem*	*Probability, events/year*	*Maximum Risk, man-rem/year*
Removal From Tanks	Not applicable	Not applicable	Not applicable
Processing	Not applicable	Not applicable	Not applicable
Transportation	Not applicable	Not applicable	Not applicable
Storage			
Routine Releases	1.4	1.0	1.4
Spill During Transfer	5.3×10^{2}	5.0×10^{-3}	2.6
Explosion	3.0×10^{4}	1.0×10^{-4}	3.0
Sabotage by Dispersal	2.3×10^{4}	1.0×10^{-5}	2.3×10^{-1}
Sabotage by Explosion	9.8×10^{3}	1.0×10^{-5}	9.8×10^{-2}
Airplane Crash	1.1×10^{4}	1.0×10^{-5}	1.1×10^{-1}
Abandonment	2.7×10^{4}	1.0×10^{-5}	2.7×10^{-1}

Time-Integrated Risk, man-rem (300 years) (with abandonment)	2.4×10^{4}
Risk Value at $1000/man-rem, millions	$24
Budgetary Cost, millions	$510
Total Cost, millions	$534
Incremental Cost-Risk, dollars/man-rem	(Base Case)
Time-Integrated Risk, man-rem (10,000 years)	2.3×10^{3}
Natural Background Exposure, man-rem (10,000 years)	1.0×10^{10}
Possible Waste Management Health Effects	0.5
Health Effects from Natural Background	2,000,000

TABLE XI-6

Summary of Costs and Exposure Risks for Alternative 2-Subcase 1: Glass Stored in Offsite Geologic Storage and Decontaminated Salt Cake Stored in Onsite Underground Waste Tanks

Event	*Population Dose for Maximum Year, man-rem*	*Probability, events/year*	*Maximum Risk, man-rem/year*
Removal From Tanks			
Routine Releases	1.4	1.0	1.4
Sludge Spill	1.5×10^{1}	5.0×10^{-2}	7.5×10^{-1}
Spill at Inlet	3.7×10^{1}	5.0×10^{-2}	1.9
Tornado	5.4×10^{1}	6.0×10^{-4}	3.2×10^{-2}
Spill	1.1×10^{3}	5.0×10^{-3}	5.4
Explosion	3.0×10^{4}	1.0×10^{-4}	3.0
Sabotage	3.5×10^{5}	1.0×10^{-5}	3.5
Below-Ground Leaks	1.7×10^{5}	1.0×10^{-5}	1.7
Processing			
Routine Releases	3.0	1.0	3.0
Process Incidents	4.2×10^{-1}	1.0	4.2×10^{-1}
Sabotage	8.9×10^{4}	1.0×10^{-5}	8.9×10^{-1}
Airplane Crash	3.1×10^{2}	7.0×10^{-8}	2.2×10^{-5}
Transportation			
Routine Exposures	6.3×10^{1}	1.3×10^{-4}	6.3×10^{1}
Accidents	1.2×10^{4}	2.1×10^{-5}	1.6×10^{-2}
Storage			
Expected Releases	1.3×10^{2}	1.0	1.3×10^{2}

Time-Integrated Risk, man-rem (300 yr)	6.5×10^{2}
Risk Value at $1000/man-rem, millions	0.65
Budgetary Cost, millions	$3600
Total Cost, millions	$3600.7
Incremental Cost-Risk, dollars/man-rem	$132,000
Time-Integrated Risk, man-rem (10,000 yr)	6.5×10^{2}
Natural Background Exposure, man-rem (10,000 yr)	1.0×10^{10}
Possible Waste Management Health Effects	0.1
Health Effects from Natural Background	*2,000,000*

TABLE XI-7

Summary of Costs and Exposure Risks for Alternative 2-Subcase 2: Glass Stored in Onsite Surface Storage Facility and Decontaminated Salt Cake Returned to Onsite Waste Tanks

Event	*Population Dose for Maximum Year, man-rem*	*Probability, events/year*	*Maximum Risk, man-rem/year*
Removal From Tanks			
Routine Releases	1.4	1.0	1.4
Sludge Spill	1.5×10^{1}	5.0×10^{-2}	7.5×10^{-1}
Spill at Inlet	3.7×10^{1}	5.0×10^{-2}	1.9
Tornado	5.4×10^{1}	6.0×10^{-4}	3.2×10^{-2}
Spill	1.1×10^{3}	5.0×10^{-3}	5.4
Explosion	3.0×10^{4}	1.0×10^{-4}	3.0
Sabotage	3.5×10^{5}	1.0×10^{-5}	3.5
Below-Ground Leaks	1.7×10^{5}	1.0×10^{-5}	1.7
Processing			
Routine Releases	3.0	1.0	3.0
Process Incidents	4.2×10^{-1}	1.0	4.2×10^{-1}
Sabotage	8.9×10^{4}	1.0×10^{-5}	8.9×10^{-1}
Airplane Crash	3.1×10^{2}	7.0×10^{-8}	2.2×10^{-5}
Transportation	Not Applicable		
Storage			
Sabotage	3.8×10^{3}	1.0×10^{-5}	3.8×10^{-2}
Airplane Crash	3.1×10^{2}	7.0×10^{-8}	2.2×10^{-5}
Abandonment	0	-	0

Time-Integrated Risk, man-rem (300 yr)	2.2×10^{2}
Risk Value at $1000/man-rem, millions	$0.22
Budgetary Cost, millions	$3750
Total Cost, millions	$3750.2
Incremental Cost-Risk, dollars/man-rem	$135,000
Time-Integrated Risk, man-rem (10,000 yr)	3.4×10^{2}
Natural Background Exposure, man-rem (10,000 yr)	1.0×10^{10}
Possible Waste Management Health Effects	0.07
Health Effects from Natural Background	2,000,000

TABLE XI-8

Summary of Costs and Exposure Risks for Alternative 2-Subcase 3: Glass Disposed of in SRP Bedrock and Decontaminated Salt Cake Stored in Onsite Underground Waste Tanks

Event	*Population Dose for Maximum Year, man-rem*	*Probability, events/year*	*Maximum Risk, man-rem/year*
Removal From Tanks			
Routine Releases	1.4	1.0	1.4
Sludge Spill	1.5×10^{1}	5.0×10^{-2}	7.5×10^{-1}
Spill at Inlet	3.7×10^{1}	5.0×10^{-2}	1.9
Tornado	5.4×10^{1}	6.0×10^{-4}	3.2×10^{-2}
Spill	1.1×10^{3}	5.0×10^{-3}	5.4
Explosion	3.0×10^{4}	1.0×10^{-4}	3.0
Sabotage	3.5×10^{5}	1.0×10^{-5}	3.5
Below-Ground Leaks	1.7×10^{5}	1.0 x 10-5	1.7
Processing			
Routine Releases	3.0	1.0	3.0
Process Incidents	4.2×10^{-1}	1.0	4.2×10^{-1}
Sabotage	8.9×10^{4}	1.0×10^{-5}	8.9×10^{-1}
Airplane Crash	3.1×10^{2}	7.0×10^{-8}	2.2×10^{-5}
Transportation		Not Applicable	
Storage			
Expected Releases	1.3×10^{2}	1.0	1.3×10^{2}

Time-Integrated Risk, man-rem (300 yr)	3.4×10^{2}
Risk Value of $1000/man-rem, millions	$0.34
Budgetary Cost, millions	$3610
Total Cost, millions	$3610.3
Incremental Cost-Risk, dollars/man-rem	$129,000
Time-Integrated Risk, man-rem (10,000 yr)	3.4×10^{2}
Natural Background Exposure, man-rem (10,000 yr)	1.0×10^{10}
Possible Waste Management Health Effects	0.07
Health Effects from Natural Background	2,000,000

TABLE XI-9

Summary of Costs and Exposure Risks for Alternative 3: Unprocessed Waste Slurry Disposed of in SRP Bedrock

Event	*Population Dose for Maximum Year, man-rem*	*Probability, events/year*	*Maximum Risk, man-rem/year*
Removal From Tanks			
Routine Releases	1.4	1.0	1.4
Sludge Spill	1.5×10^{1}	5.0×10^{-2}	7.5×10^{-1}
Spill at Inlet	3.7×10^{1}	5.0×10^{-2}	1.9
Tornado	5.4×10^{1}	6.0×10^{-4}	3.2×10^{-2}
Spill	1.1×10^{3}	5.0×10^{-3}	5.4
Explosion	3.0×10^{4}	1.0×10^{-4}	3.0
Sabotage	3.5×10^{5}	1.0×10^{-5}	3.5
Below-Ground Leaks	1.7×10^{5}	1.0×10^{-5}	1.7
Processing	Not Applicable		
Transportation	Not Applicable		
Storage			
Expected Releases	1.3×10^{2}	1.0	1.3×10^{2}
Earthquake With Shaft Open	3.8×10^{8}	3.3×10^{-5}	1.3×10^{4}
Earthquake After Sealing	8.3×10^{6}	3.3×10^{-6}	2.8×10^{1}
Sabotage Before Sealing	1.5×10^{9}	1.0×10^{-5}	1.5×10^{4}
Sabotage After Sealing	1.4×10^{7}	3.3×10^{-10}	4.6×10^{-3}

Time-Integrated Risk, man-rem (300 yr)	6.2×10^{4}
Risk Value at $1000/man-rem, millions	$62
Budgetary Cost, millions	$755
Total Cost, millions	$817
Incremental Cost-Risk	-$6500[a]
Time-Integrated Risk, man-rem (10,000 yr)	1.4×10^{5}
Natural Background Exposure, man-rem (10,000 yr)	1.0×10^{10}
Possible Waste Management Health Effects	28
Health Effects from Natural Background	2,000,000

a. The negative value indicates this alternative is more expensive and has higher risk than Alternative 1.

The estimated radiation dose commitment risk to the general public during storage of the waste is less than 10 man-rem/yr for most of the cases. This dose commitment is also very small compared to those from naturally occurring radioisotopes and x-rays.

If liquid is stored in a cavern, a severe earthquake or major sabotage during the one-year filling period could contaminate the Tuscaloosa aquifer. Large (probably lethal) individual radiation doses would result if people drank this contaminated water. Because of the possibility of these occurrences, the average radiation dose risk over a 300-year period for liquid waste storage in a bedrock cavern is about 180 man-rem/yr. These comparisons are summarized in Table XI-10.

C. SENSITIVITY ANALYSIS

This section is limited to highlighting the important elements of risk for the alternative plans. The cost estimates particularly those for geologic storage could change in magnitude for many different reasons, but the relative cost differences among the alternatives are expected to remain as given in this document.

TABLE XI-10

Comparison of Radiation Risks from Waste Management Operations with Other Sources

Source of Radiation	*Estimated Average Radiation Dose Risk, man-rem/year*[a]	*Time Factor, years*
Natural Sources	200,000	-
Medical x-rays	180,000	-
Liquid Waste in Bedrock Cavern	180	300
Canned Waste in Bedrock Cavern	30	300
Monitored Storage in Vaults	<10	300
Waste Processing Operations	22	5
Offsite Shipment of Canned Waste	60 to 160	5

a. Whole body equivalent.

The time-integrated risks arise almost completely from the storage operation. This is primarily because a time period of 300 or 10,000 years is considered for storage, but removal from tanks, processing, and transportation are all accomplished within about five years. Events with some of the largest consequences are also involved with storage.

Another aspect of the importance of the storage options is that removal from tanks is common to all the alternative plans except one, and processing is common to many. These two operations therefore cancel out of the comparison of many of the alternatives.

The events that have large consequences that strongly influence the relative risks of the alternatives are the following:

1. Sabotage for all the operations in each alternative has been assessed to be among the events with the largest consequences. Even so, the magnitudes of the consequences, particularly as measured by offsite individual doses and land contamination, are not very significant and are unlikely to be the kinds of results a terrorist group would find worthwhile. An exception is sabotage of liquid waste in a bedrock cavern at SRP. All the sabotage events were given a probability of success of 10^{-5} per year. If this were increased by two or more orders of magnitude, sabotage could have a dominating influence on the relative risks of the alternative plans.

2. Possible contamination of the Tuscaloosa aquifer if liquid waste is disposed of in an SRP bedrock cavern has the largest risk considered. This risk arises from possible earthquakes before or after shaft sealing and from sabotage before sealing. The consequences of these events are quite high, and although their probabilities are estimated to be low, the current state of knowledge does not allow them to be reduced enough further to result in a low risk. This alternative does, however, have promising possibilities for corrective action to almost eliminate the consequences if the events did occur. Consideration of using corrective action and of obtaining confidence in lower probabilities of contaminating the aquifer is important, because this alternative is relatively inexpensive.

3. Abandonment of a continued tank farm operation during the next century has a relatively large consequence that is reduced to a relatively small risk by using a probability of 10^{-5} per year. Raising this probability by an order of magnitude would make risk from abandonment comparable to the other tank farm risks. Even if the probability were assumed to be 100% that abandonment would occur early in the next century, the integrated population dose of 6.1×10^5 man-rem

valued at $\$6.1 \times 10^8$ would leave this alternative with the second lowest total cost (with liquid in SRP bedrock being slightly cheaper). Another consideration regarding abandonment is that the resulting individual doses would be low, and the event is amenable to corrective action.

An exception to the rule of low individual doses could occur from concentration of ^{137}Cs in fish in the Savannah River. If a societal situation could exist that could support a commercial fishing operation on the present scale and at the same time tolerate abandonment of the tanks, then about 200 people could get individual doses as great as 11 rem/yr if they continued to eat downstream fish.

In addition to the difficulty in estimating a probability for abandonment, there is also an uncertainty about the proper valuation of the consequences. In a society that had degenerated to the point that the tanks were abandoned, any adverse effects from the small amount of radiation exposure would be inconsequential compared with other hazards to life. The figure of $1000 per man-rem would probably overestimate the value the populace would place on possible radiation insults.

4. Consideration was given to the possible radiation doses that could occur over time periods of thousands of years. Time integrated doses given in previous sections of this document were evaluated for 300 years, and risks from ^{90}Sr and ^{137}Cs have ended by that time and risks from ^{238}Pu have almost ended. After about 1000 years, ^{239}Pu and ^{99}Tc are the main radioactive constituents of the waste. Because whole body and bone dose conversion factors for ^{99}Tc are factors of 500 and 6000, respectively, below those for ^{239}Pu, any radiological hazard would arise primarily from ^{239}Pu.

   Perspective on what such hazards might be can be obtained by considering the contribution to individual dose commitments from ^{239}Pu for the previously discussed abandonment of tanks. For that event, it was postulated that all waste would escape in about 135 years and that 10% would reach the Savannah River and influence the drinking water downstream. Such a rate of human consumption of ^{239}Pu would be much faster than the remaining 90% could leave the immediate tank area, move through the groundwater and surface streams, and ultimately undergo human consumption. Present indications from ion exchange mechanisms are that such movement, if it occurred at all, would take tens of thousands of years. However, for the tank abandonment case, individual bone dose commitments for the year of maximum uptake of ^{239}Pu were shown in the DWD[5] to be only 4.4×10^{-4} rem/person. Even if an individual added to that commitment by drinking such water for his lifetime, the result would still only be comparable to the lifetime dose commitment from ^{40}K (about 10^{-2} rem) that has always been a natural part of the bones of humans.

Thus, as shown in Tables V-12 through V-16 and Tables XI-5 through XI-9, individual doses that could be incurred from the risk scenarios covered in this document by extending the time scale beyond 300 years are so low that such a time extension is irrelevant to the process of choosing among waste management alternatives. Individual doses over time periods of a thousand years and longer would arise almost exclusively from ^{239}Pu, and, with the exception of a few maximum individuals near the scene of a hypothetical sabotage, would be tens to thousands of times lower than doses occurring naturally (which themselves vary by factors of three or four). This conclusion is supported by:

1. the low individual doses that would result from even a relatively rapid introduction of ^{239}Pu to the drinking water pathway (tank abandonment, over 135 years); and,

2. the much longer time span and greater dilution that would prevail for other pathways because of ion exchange holdup, slow movement of groundwater, dilution and holdup in the oceans, and radioactive decay.

D. CORRECTIVE ACTIONS

Radiation doses have been reported in this document with an emphasis on establishing a sound physical basis for upper limits on the amount of activity that could be released and on the most pessimistic pathways to man. Humans were assumed to receive the resulting radiation doses in a passive manner with no attempt at corrective action. However, corrective action could be taken if some responsible, organized society exists in the future. Because these corrective actions are relatively inexpensive and technically straightforward, the possibility of their implementation should be considered in weighing the pros and cons of each alternative. Likewise, the existence of these possibilities should further decrease the attractiveness of the waste storage facilities to saboteurs.

Table XI-11 gives examples of the corrective actions that could be applied to typical events, with an estimate of the cost. The corrective actions are described below.

1. Corrective Action A — Reduction of Atmospheric Exposure

Assume a rapid warning system has been set up for the area in which significant individual doses could be obtained from an airborne waste release. Analyses show that the required coverage would not have to be as great as even the SRP-to-Augusta distance. Given a wind velocity of 6 to 8 mph under the assumed 95th percentile bad weather conditions, at least an hour would be available to spread the alarm after an SRP release. The warning network might be any combination of in-place sirens, roving automobiles with loudspeakers, commercial radio and television announcements, C.B. radio, operators ringing telephones, and the civil defense warning system. The Savannah River Plant already has in operation a meteorological instrumentation and computer system to predict and monitor the path of any airborne release, so only people within the affected direction and distance would need to be contacted.

The appropriate action would require no special equipment or prior training. It would merely be for people to stay inside buildings or cars with the windows closed and any forced ventilation systems turned off. In addition, they might take simple air filtering action. The reason these actions are effective is that the hazard is from inhalation of the small radioactive particles, not from the negligible external dose from the radioactive plume passing over.

If the assumption is made that only 95% of the people in the affected area get the alarm and follow the procedure, then the population dose would be reduced by a factor of 14.

The risk of these airborne events is probably too low to justify any prior action, but for purposes of this study the cost is assumed to be $1 million for 100 sirens at $10,000 each, plus $1 million for an educational campaign, plus $1 million for operational expenses during an incident.

TABLE XI-11

Corrective Actions for Typical Events

	Type of Corrective Action	*Cost of Corrective Action, $*
Air-Cooled Vault with Glass		
Sabotage with conventional explosives	A	3×10^6
Airplane crash	A	3×10^6
Tank Farm		
Abandonment	B	2×10^6
Sabotage by spraying	A & B	5×10^6
Sabotage with conventional explosives	A &.B	5×10^6
Airplane crash	A & B	5×10^6
Triassic Cavern		
Expected releases	None required	---
Explosion in cavern	None required	---
Earthquake with open shaft	D	2.0×10^7
Earthquake after sealing	C	2.5×10^7
Sabotage with conventional explosives	D	2.0×10^7
Sabotage by drilling	None applicable	---

2. Corrective Action B — Reduction of River Water Exposure

A few days would pass before a liquid waste spill on the surface of the SRP site could flow through the creeks and swamp and to the river and then down the river to the drinking water users in the Savannah area. During this time a monitoring system would be set up downriver, and water system intake pumps would be shut down as the pulse of activity passed. This action should not cause an intolerable inconvenience because the pulses from the events studied would last at most a day or two. The available lead time could also be used to fill reservoir capacity before the arrival of activity. Another factor that mitigates the inconvenience is that industrial and household use of contaminated water could continue if adequate reservoir capacity were not available for storage during the entire length of the pulse. Drinking water accounts for less than 0.1% of a typical city's consumption, and adequate supplies could be stored in each household, etc., before arrival of the contaminated water.

With the above considerations, it is reasonable to expect the population dose would be reduced by a factor of at least 100. The maximum individual dose will be assumed to remain unchanged.

The cost is assumed to be $1 million for the monitoring system and flushout and $1 million for the spread of information and operations during an incident. Because SRP already has the required monitoring instrumentation and personnel, none of this money has to be spent in advance.

3. Corrective Action C — Reduction of Tuscaloosa Aquifer Exposure

The population doses given from use of contaminated Tuscaloosa aquifer water are based upon the assumption that the 50,000 users taking a certain fraction of the flow also take that same fraction of the activity released to the aquifer. This means the activity is assumed to be mixed uniformly, but in reality it will enter in a small area and then will diffuse outward. It will also be transported as a diffused plume in the direction of flow.

The corrective action would be to drill test wells to determine the boundaries of acceptable dilution created by the combination of diffusion and plume formation. The assumed 10% of the aquifer flow to be used by the 50,000 people is then taken from regions with negligible activity. Since the Sr and Cs is expected to remain within the aquifer under the plantsite for thousands of years, it will decay before reaching the river. The population doses are therefore assumed to be zero, except for the dose that might arise over very long periods from the long-lived isotopes such as ^{129}I, ^{135}Cs, and ^{239}Pu (if Pu migrates). The latter doses have been included in the consequence calculations, even though the resulting individual doses would be spread over thousands of years and would be a very small fraction of natural background.

All the water needed for ordinary use by people and probably all the industrial uses could be obtained from the McBean-Congaree aquifer, which lies above the Tuscaloosa aquifer and is unconnected to it. The projected use of the water under the plantsite by 50,000 people was based on 200 gal/day per person and use of 10% of the Tuscaloosa flow,[6] to give 10 million gal/day withdrawal. This is equivalent to 6900 gal/min. Wells in the McBean-Congaree aquifer now routinely supply 300 gal/min, so 23 such wells over the area of the plantsite could meet the requirement. Jackson and New Ellenton now each have a well capable of over 1 million gal/day withdrawal from that source.

Another approach is to consider that, of the 200 gal/day per capita consumption, only perhaps 50 gal/day need be distributed through an ordinary city system. This water and that used by small rural wells could be taken from the McBean-Congaree, as it is now. The remaining 150 gal/day allocation to industrial users could be taken from the Tuscaloosa. Any small amount of activity in the reject water flowing to the river would be sufficiently diluted in the river that negligible downstream dose would result.

The cost of this action is assumed to be $20 million for the mapping wells and monitoring plus $5 million for user wells not required otherwise. An initial system of monitoring wells would be part of any bedrock storage project, so that again none of this expense would have to be incurred in advance of an actual contamination incident.

4. Corrective Action D — Repair of Shaft Breakage to Re-isolate SRP Bedrock Storage from the Tuscaloosa Aquifer

One of the largest consequence accidents considered in the risk section is from a breaching in the open shaft of an SRP bedrock cavern; this breach could admit the waste from the cavern to the overlaying Tuscaloosa aquifer. However, such an accident can occur only when the shaft is actively manned because, once the waste is emplaced, the shaft will be sealed. During this active period, it is highly probable any shaft breach could be cleared out and resealed before significant activity were transferred to the Tuscaloosa aquifer.

The assumption is made that the shaft could be cleared and resealed for double the $10 million cost of construction the shaft initially. It is further assumed that this action prevents any activity from reaching the aquifer.

E. REFERENCES FOR SECTION XI

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