A RADIOLOGICAL DOSE ASSESSMENT OF THE

CHURCH ROCK URANIUM MILL TAILINGS DAM FAILURE

CHURCH ROCK, NEW MEXICO

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SUMMARY

This document describes the radiological assessment of the Church Rock uranium mill tailings dam failure. Although the NRC and other federal and state agencies are continuing to evaluate the effects of the dam failure, the NRC staff has performed this radiological assessment based on the available preliminary data.

The NRC staff utilized the MILDOS computer code which is used predominantly to perform the radiological assessments for environmental impact statements. The staff also relied on several NRC Regulatory Guides to provide the required parameters for computer dose modeling.

Under the most conservative assumptions, which are not expected to be exceeded under actual conditions in the affected areas, the maximally exposed individual would receive a total bone dose of less than 18 mrem per year for both the airborne and the meat-water pathways. This may be compared to an estimated gamma radiation background exposure rate of about 16 uR/hr, or an annual natural background dose of 140 mrem per year.

BACKGROUND

On July 16, 1979, a tailings dam at the Church Rock uranium mill of United Nuclear Corporation failed. Estimates of the amount of tailings released from the failure have varied, but it appears that at least about 100 million gallons of acidic tailings solutions and 11 hundred tons of tailings solids escaped from the tailings impoundment area before the break in the dam could be closed. Most of the solids were deposited in an area very near the impoundment in a backup containment area on operator property and in an adjacent stream, the so-called "Pipeline Arroyo." The solutions were carried in the Pipeline Arroyo to the Rio Puerco which flows through Gallup, New Mexico, a town about 20 miles southwest of the mill site, and into Arizona. By evaporation and percolation into the stream bottom, the spilled solutions eventually dissipated at a point estimated by visual observations to be about 20 miles into Arizona.

The Pipeline Arroyo stream and the Rio Puerco run in channels which, except for periods of heavy rain, are very small streams. The release of tailings solutions resulted in a flow which filled the entire channel, contaminating the normally dry bottom portions, or "terraces," as they passed. The result as indicated by early measurements was widespread contamination of the terraces which were wetted by the released solutions. The contamination levels appeared as a result of deposition of fine particles suspended in the tailings solution and of sorption of soluble contaminants from the solution into the terraced soils and stream sediments. There were isolated areas on the terraces where contamination is quite concentrated, being as high as 100 to 500 times background levels. These were, in many cases, areas where solutions became stranded in isolated pools after the spilled solutions passed.

CLEAN UP LIMITS

In a letter dated August 23, 1979, the NRC staff advised the State of New Mexico of acceptable cleanup criteria for this particular case. This letter formalized conversations the staff had with State of New Mexico Environmental Improvement Division prior to the State's letter (signed by T. E. Baca) of August 13, 1979, to the operator concerning monitoring and cleanup requirements. The levels for cleanup specified by the NRC staff as being acceptable for the Church Rock case are: levels which are no greater than 10 pCi/gm Ra-226 and 30 pCi/gm Th-230 (both inclusive of background).

These criteria were selected on the basis of (1) the evaluation of the results of the limited sampling and analysis conducted at the time the criteria were set, (2) the evaluation of potential radiological exposure pathways, and (3) the desirability of reducing exposures to the maximum extent reasonably achievable. The objective of selecting the cleanup levels was to assure that the areas of concentrated radioactivity are cleaned up. However, the cleanup of large portions of arroyos, which are contaminated above background radiation levels, but not at levels which pose a threat to public health, should be minimized. The latter case, in the extreme might result in attempting to clean up the entire 60 mile stretch of contamination, an unreasonable burden to require of the operator.

The 10 pCi/gm activity for radium was specified as consistent with the cleanup objective of reducing contamination to as low as reasonably achievable (ALARA). A few measurements of Ra-226 using the highly accurate radon emanation measurement technique appeared at the time the criteria were set to show that radium levels in areas below the dam breach were on the average of a few pCi/gm. Earlier measurements made by the operator were much higher (as much as 10 pCi/gm and higher). The staff proposed that radium measurement techniques should be checked closely and that, if it was confirmed that the lower Ra-226 measurements were representative of the contaminated area, a limit of 5 pCi/gm Ra-226 (inclusive of background) would be more consistent with the ALARA principle and should be specified. (Recent data from soil sample analyses strongly indicate soil concentrations far below 5 pCi/gm Radium-226, and that the cleanup should be performed to this level.)

The staff chose not to apply in this case, the criteria that it had previously issued for land cleanup ("Staff Technical Position Fuel Processing and Fabrication Branch--Interim Land Cleanup Criteria for Decommissioning Uranium Mill Sites" May, 1978). The land cleanup criteria, as the staff position documented, are based on situations where radon and direct gamma exposure pathways are dominant due to the building of structures on such decommissioned sites. Because the contamination in this case is located in an arroyo where structures will not be constructed, the land cleanup criteria are not appropriate and have not been used. In terms of doses from the realistic pathways existing in each case, the criteria adopted for this cleanup operation are more protective than those for decommissioning mill sites, even though permissible residual concentrations are higher.

Various potential exposure paths which affect human health were evaluated with respect to the levels of radioactive contamination remaining in the arroyo following cleanup. Specifically, the staff looked at four major pathways: inhalation of radon daughters, direct gamma exposure, inhalation of contaminated windblown particulates, and ingestion of beef cattle and sheep which graze near and drink from the Rio Puerco. (From discussions with the State and people residing in the area, it is understood that there is no direct human consumption of water from the affected streams). Using conservative assumptions about such factors as the location and occupancy of structures near the contaminated arroyo, the staff found, that for each of the above pathways, the exposures were below levels which would pose a threat to public health after decontamination of the arroyo, using the above mentioned cleanup criteria. Specifically, calculated exposures which are attributable to contamination of soils at or below the cleanup level for a person living next to the arroyo, are fractions of the limit set by the EPA (40 CFR 190) for exposures to persons in the public from routine releases from fuel cycle facilities. While the EPA limit would not be directly applicable to this accident case, it is a convenient bench mark to use for judging the risks involved.

The most difficult, and perhaps the most limiting, pathway is the meat ingestion pathway where animals drink contaminated stream water. However, it is difficult to relate stream water quality to soil contamination levels; because the rate at which the contaminants are leached or scoured from the soil cannot be quantitatively predicted. To evaluate this pathway, the staff has investigated several cases which are based on available data in order to bound the potential exposures occurring from this pathway. Table 2 presents these concentrations and the associated doses. Total doses from all pathways, including this water-meat ingestion, vary from 6 to 18 mrem/yr (See Table 3).

As was stated in the letter advising the State of the cleanup criteria, it is extremely important to get a comprehensive understanding of the contamination present in the affected arroyo. The NRC, together with the State, and with some assistance from the operator, has undertaken a comprehensive sampling program. This has included setting up a specially equipped mobile laboratory (Battelle Pacific Northwest Laboratory) on-site to rapidly process soil samples. The full nature of the cleanup effort will not be known until the comprehensive sampling program is completed, and cleanup has progressed for a time. The staff set the cleanup limits to be clearly protective of public health and the environment. This report documents the radiological assessments performed by the staff in selecting the cleanup criteria.

RADIOLOGICAL ASSESSMENT

The Uranium Recovery Licensing Branch's computer code, MILDOS, was used to evaluate environmental doses for potential nearby residents. This code is used to perform radiological impacts for licensing casework (Ref. 1).

The MILDOS code permits radiological assessment of doses to man through the following pathways:

1) Inhalation of:

   a) Particulates.
   b) Radon gas and daughters.

2) External exposure from:

   a) Ground.
   b) Cloud immersion.

3) Ingestion of:

   a) Vegetation grown locally.
   b) Meat from local animals.

An additional pathway was considered separately. This was the meat pathway resulting from the ingestion of meat from animals drinking water from the Pipeline Arroyo and the Rio Puerco. Appendix I documents the assumptions and calculations made in estimating the corresponding effect on man.

These pathways were, at first, considered for 30 potential individuals living along the Pipeline Arroyo or Rio Puerco. This assumption was conservative in that no individual dwelling actually exists there. Three locations were finally chosen to be reflective of all possibilities:

1) Living at the edge of the Pipeline Arroyo.

2) Living ten meters removed from the Pipeline Arroyo.

3) Living downstream in the direction of the prevailing wind.

A. Modeling Assumptions

Figure 1 models the flow of the Pipeline Arroyo. The water flows from the northeast. The pictured portion is assumed to represent a portion of the stream such as might occur in Pipeline Arroyo downstream from the dam

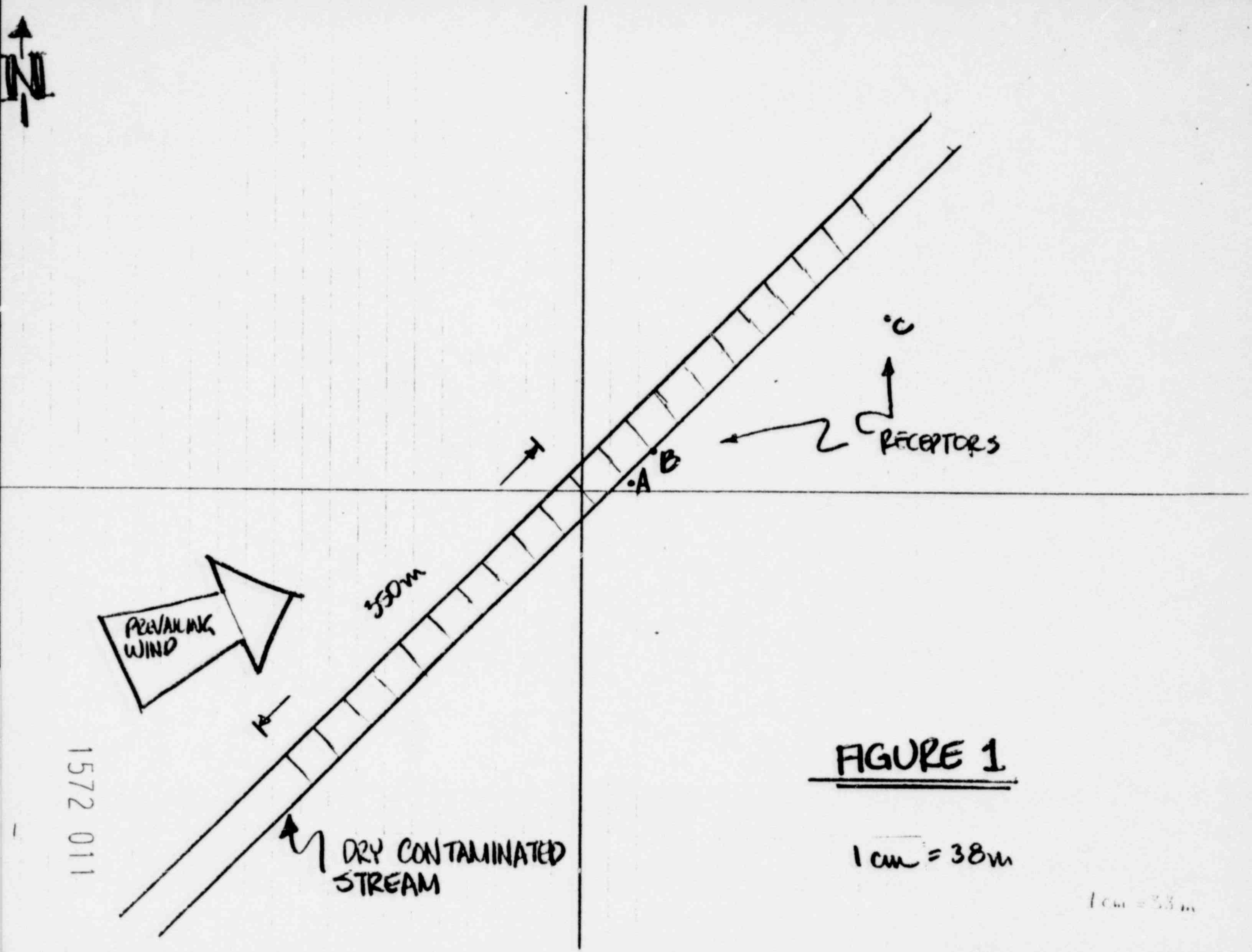

FIGURE 1

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breach and upstream of the intersection with the North Fork of the Rio Puerco. Specifically, this portion was modeled as an elongated area source made up of twenty contiguous squares. The prevailing wind direction is WSW-SW, which explains the choice of the three receptors A, B, and C. Further assumptions are:

1) Each of the twenty segments is assumed to be totally dry and subject to fugitive dust emission. This is presently conservative since there is a portion covered with muddy water, but this case would be representative of conditions in the arroyo upon subsequent termination of mining and milling operations in the affected area.
2) The cleanup criteria specify the following specific activity in the fugitive dust.

Radionuclides	pCi/gm
U-234[a)]	12.0
U-238[a)]	12.0
Th-230	30.0
Ra-226	10.0
Pb-210[b)]	10.0

[a)] Staff estimate of uranium contamination at the time criteria were set. Later sample analysis indicated it may be higher than 12.0 pCi/gm (as much as 20-25 pCi/gm), but the model assessment shows that doses are very insensitive to the amount of uranium present versus the other radionuclides.

[b)] Pb-210 is assumed to be about in equilibrium with Ra-226.

3) The total length of the Pipeline Arroyo under consideration is approximately 700 meters. Considering the proximity of the potential individuals, doses resulting further downstream would have little, if any, effect on the critical individuals, as far as atmospheric transport is concerned.

4) No on site meteorology was available in the form required for the MILDOS code. Lack of information on the reduction of the Gallup Meteorology into atmospheric classes, forced the staff to search for a suitable replacement. Meteorological data for the La Polvadera Valley, New Mexico, proved to be extremely compatible when compared with the Gallup wind rose. The two wind roses are included as Figure 2.

5) Individuals at each of the three locations, A, B, and C, are assumed to:
   a) Breath the air continuously.
   b) Eat vegetables grown at the location.
   c) Eat meat animals raised at location B.[a]

6) More specific data on the models used in the MILDOS code are available in Reference 1.

B. Radiation Exposure Pathways

Inhalation

Airborne radioactive emissions resulting from the contaminated soils are in the form of:

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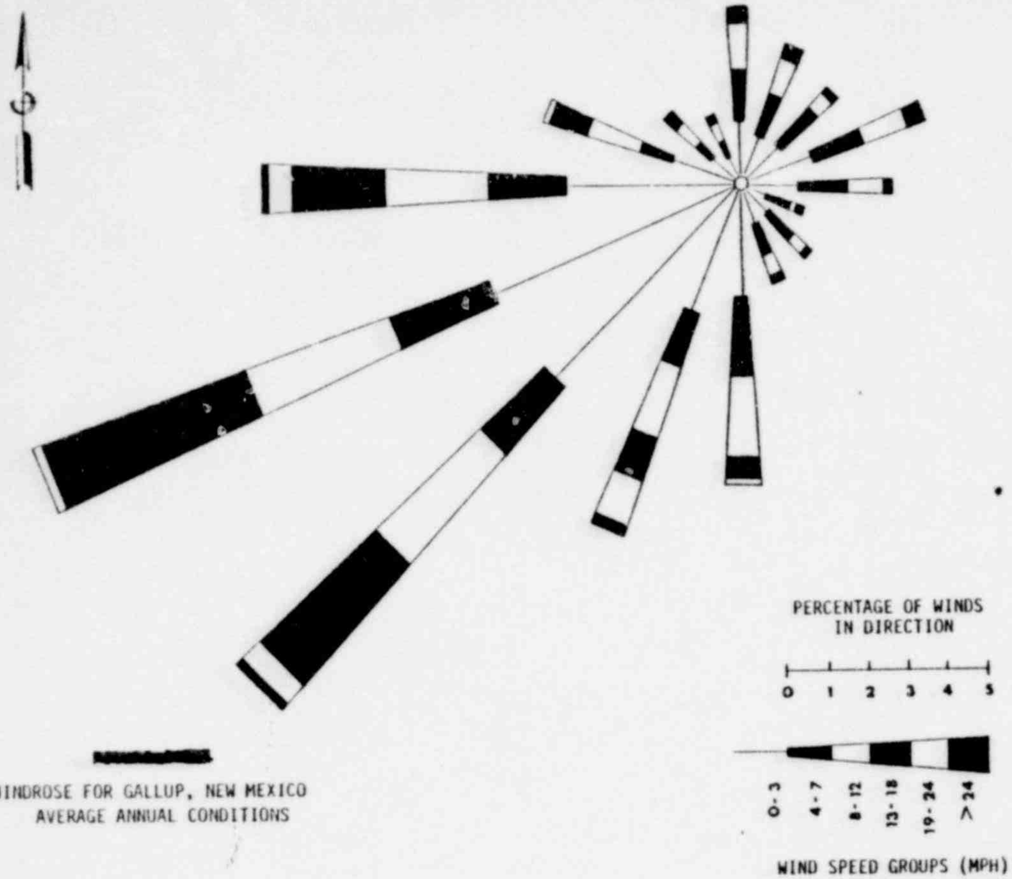
[a] Highest meat ingestion doses result from cattle and sheep foraging at this location.



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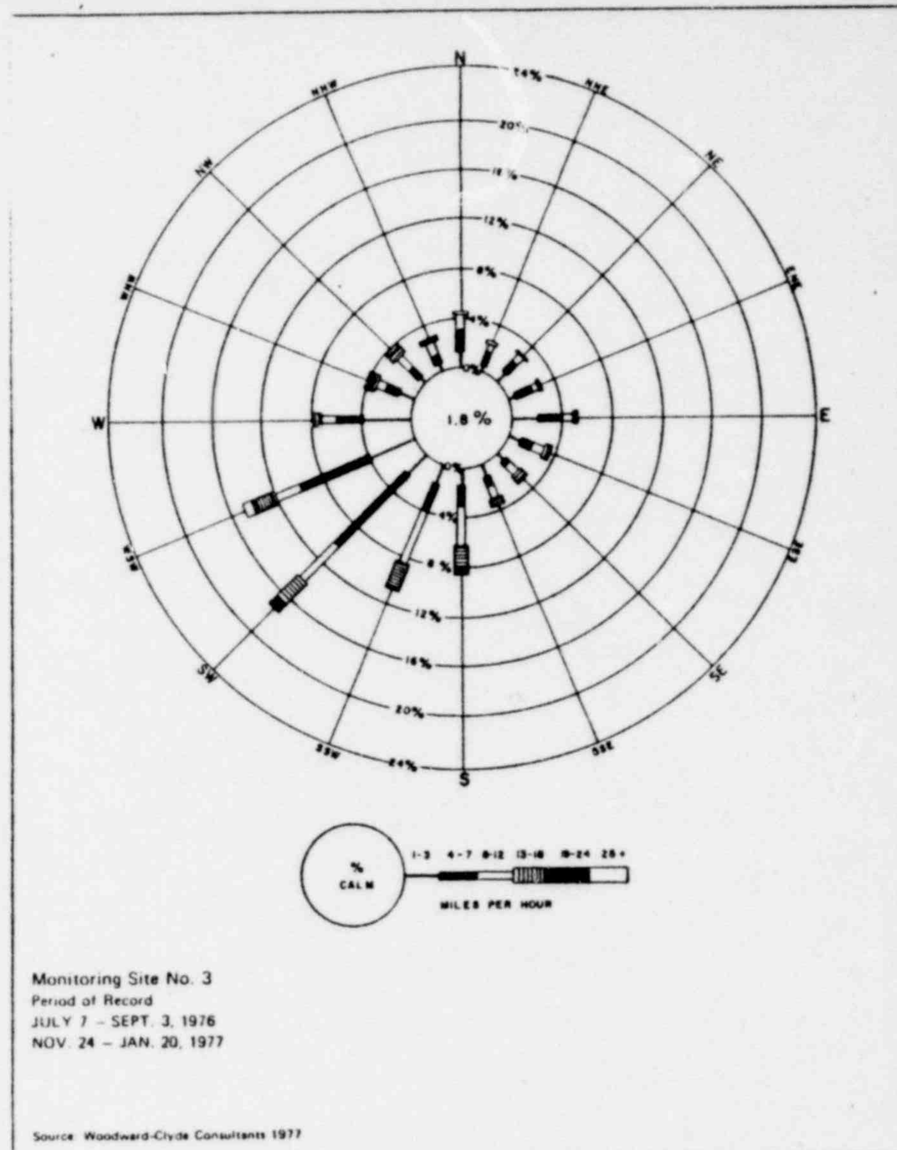
WINDROSE FOR GALLUP, NEW MEXICO
AVERAGE ANNUAL CONDITIONS



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LA POLVADERA VALLEY WIND ROSE

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POOR ORIGINAL

Figure 2

a) Particulates resuspended in the air by the wind blowing mechanism.

b) Radon and daughters.

Individuals in the source vicinity will inhale these radiocative materials and thus will receive internal doses. Table 1 lists the inhalation doses to the potential individuals at locations A, B, and C, previously specified (see Figure 1). Total inhalation doses to the bone are greater than those to any other organ. The adult bone inhalation dose to individuals at locations A, B, and C are 1.50 mrem/yr, 1.65 mrem/yr and 0.94 mrem/yr, respectively.

External Exposure

Individuals in the affected area are exposed to immersion from the following sources:

a) Resuspended particulates in the air from the contaminated soil.

b) Radon and daughters in the air.

c) Radioactive emissions directly from the soil.

Individuals are assumed to be exposed to these materials at the cleanup levels previously mentioned. The resulting maximum doses are negligible. The results show that bone doses fall below 0.1 mrem/yr (see Table 1).

Ingestion

The MILDOS computer code was employed to compute doses from ingestion of vegetables and meat, both of which are assumed to be produced locally. The mechanisms for radioactive uptake by humans are as follows:

1) Ingestion dose from vegetable intake:

   a) Foliar deposition of radioactive particles.

   b) Root uptake of radioactive materials.

2) Ingestion dose from meat animals:

   a) Animals eating vegetation contaminated as in 1 above.

   b) Animals drinking water from the contaminated stream.[a]

Doses from these pathways are listed in Tables 1 - 3. The staff understands that there is no drinking of the water from the Pipeline Arroyo and Rio Puerco by humans; this pathway was, therefore, not considered. The milk pathway was also not considered due to the lack of milk cattle in the nearby area.

Although humans do not drink the water in the Rio Puerco and the Pipeline Arroyo, the sheep and cattle do water themselves in the Rio Puerco. Doses to various organs from water ingestion by animals are listed in Table 2. It should, again, be noted that this pathway cannot be rigorously related to the cleanup criteria, because the leaching and scouring mechanisms, which move the contamination from the soils and sediments into the stream, cannot be quantitatively estimated at this time. Instead, estimates of exposures attributable to contaminated stream waters were based on available stream water data. Such data on radioactivity in water has been, at best, sparse and scattered. Hence, several cases of water contamination levels were considered, in order to bound the situation.[b]

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[a]Not performed by the MILDOS code.

[b]Widely varying data has been reported by the State of New Mexico, the mill operator, and the EPA Las Vegas Facility Laboratory.

The following water concentrations were chosen to place some limits on the effects of the stream contamination caused by the dam breach:

	Concentration pCi/liter		
Radionuclides	Case I[a]	Case II[a]	Case III[b]
U-238	25	25	25
U-234	25	25	25
Th-230	2000	500	10
Ra-226	50	25	2
Pb-210	100	100	10

Appendix I documents the assumptions, parameter values, and calculations used to obtain the doses to humans by way of the water-meat pathway. The doses are included in Table 2 for completeness. Until analysis of the stream contamination is completed, the staff presents a reasonably conservative range of water concentrations in order to give a more complete profile of the potential human dose.

Over time it is likely that the levels of contamination in stream water will decrease on the average. Cleanup of soils will help to assure that this is true. The same leaching and scouring mechanisms, which tend to bring the contamination into the stream, will also be dispersing such contamination over time, thereby reducing the average concentrations. Therefore, while the above mechanisms cannot be quantitatively evaluated in terms of relating exposures through the water-meat pathways to the soil cleanup criteria, the staff considers that use of existing water concentrations places upper bounds on potential future exposures.

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[a] Cases I and II are based on the limited water concentration data available, as reported by the State of New Mexico. Analysis was performed at Eberline.

[b] Case III is based on data reported by the State of New Mexico, the mill operator (UNC) and the EPA/LVF Laboratory.

The staff has learned that there is direct human consumption of groundwater from local wells. This pathway was not included by the staff in the radiological assessment. The primary reasons for this omission is that there is no quantitative, rigorous way to relate water concentrations to those in the soil. The soil cleanup criteria establish no levels for surface water or groundwater. The staff believes that the primary contribution to contamination of the groundwater is attributable to the initial slug of radioactive material released immediately following the dam breach. Although the concentrations in the slug were high, the sorption of radioactivity into the ground and the diffusion of the contamination in the groundwater should reduce the overall contamination over time.

However, the staff realizes that this pathway should not be lightly dismissed. Groundwater monitoring efforts of other agencies, such as the Indian Health Service and the State of New Mexico, should be supplemented by collection and analysis of local well water samples during the arroyo decontamination efforts, and as long as deemed necessary to protect the public health.

It should also be noted that if in the future by whatever soil and water mechanisms, such as saltation or percolation of contaminated or leached water, the soils in and around the arroyo should come to exceed the levels set by the cleanup criteria, the operator would still be subject to return the affected areas to the cleanup levels established.

The evaluation of the effect on the water pathway suffers from additional complications. The primary source of water in the arroyo is from mine dewatering activities upstream of the mill. This water already has elevated levels of

The uranium decay chain series before it passes the mill location. Any assessment must consider what contribution is attributable to the existing flow of mine water down the arroyo. In addition to the contamination attributable to the dam breach and initial slug, and to the mine water, a third source of "technically enhanced" contamination is the appreciable seepage from the tailings impoundment. Presently, the contributions of these three sources to the groundwater contamination have not been determined. In spite of these complications, the staff believes that consumption of potable well water in the affected area would not immediately impose any additional radiological exposure due to the relatively slow migration in the groundwater system. The possible contamination of the groundwater system requires well monitoring for some extended period of time, to fully determine the effects of the dam breach on it.

TABLE 1

ADULT DOSE COMMITMENTS (mrem/yr) TO INDIVIDUALS FROM RESIDUAL CONTAMINATION AFTER CLEANUP

		ORGAN		
Location	Pathway	Whole Body	Bone	Lung
A	Inhalation	0.05	1.50	0.69
	External Exp.	0.08	0.08	0.08
	Ingestion -			
	Veg.[a]	0.24	2.98	0.24
	Meat-Veg.[a]	0.04	0.46	0.04
	TOTAL	0.41	5.02	1.05
B	Inhalation	0.05	1.65	0.75
	External Exp.	0.09	0.09	0.09
	Ingestion -			
	Veg.[a]	0.26	3.27	0.26
	Meat-Veg.[a]	0.04	0.46	0.04
	TOTAL	0.44	5.47	1.14
C	Inhalation	0.03	0.94	0.43
	External Exp.	0.05	0.05	0.05
	Ingestion -			
	Veg.[a]	0.15	1.84	0.15
	Meat-Veg.[a]	0.04	0.46	0.04
	TOTAL	0.27	3.29	0.67

[a] Ingestion doses result from ingestion of vegetation grown at the respective location. Meat ingestion doses result from cattle grazing at location B.

TABLE 2

ADULT DOSES FROM THE MEAT-WATER INGESTION PATHWAY [a)]

	Water Concentrations (pCi/liter)					Doses (mrem/yr)			
						Beef		Mutton	
Case	U-238	U-234	Ra-226	Th-230	Pb-210	Whole Body	Bone	Whole Body	Bone
I	25	25	50	2000	100	0.70	12.1	0.62	7.04
II	25	25	25	500	100	0.41	7.40	0.32	3.78
III	25	25	2	10	10	0.04	0.68	0.03	0.32

[a)] Doses are broken down by organ, nuclide and type of meat in Appendix I.

TABLE 3

SUMMARY OF TOTAL DOSES TO THE MAXIMUM EXPOSED INDIVIDUAL (LOCATION B) FROM RESIDUAL COMTAMINATION AFTER CLEANUP[a)] (mrem/yr)

Case	Beef			Mutton		
	Whole Body	Bone	Lung[b]	Whole Body	Bone	Lung[b]
I	1.14	17.57	1.84	1.06	12.51	1.76
II	0.85	12.87	1.55	0.76	9.25	1.46
III	0.48	6.15	1.18	0.47	5.79	1.17

a) Doses from Table 1 and 2 are added.

b) Ingestion doses to the lung are considered not to exceed whole body doses for all ingestion pathways.

REFERENCES

1. U. S. Nuclear Regulatory Commission Draft Regulatory Guide, "Calculational Models for Estimating Radiation Doses to Man from Airborne Radioactive Materials Resulting from Uranium Milling Operations." Division 3, Task RH-802-4, May 1979.

2. G. G. Eadie and R. S. Kaufmann, "Radiological Evaluation of the Effect of Uranium Mining and Milling Operation on Selected Groundwater Supplies in the Grants Mineral Belt, New Mexico." Health Physics, Pergamon Press, Vol. 32, April 1977.

Appendix I. Water to Meat Pathway an. Ingestion Doses to Humans.

As mentioned in the body of the Radiological Assessment, the water to meat pathway is handled separately. There are two reasons for this decision:

1. The MILDOS code does not include this particular pathway.

2. The cleanup criteria are stipulated in terms of soil contamination.

However, to present a complete profile of doses to humans, this pathway was investigated because of the wide variation in reported water data. These cases are discussed in the Radiological Assessment and the reader is directed to it for further details.

The calculational model for this pathway is taken from References 1 and 2. The computation consists of two steps:

1. The meat concentration is the product of the following:

   - Animal uptake of liquid (liters/day).
   - Environmental transfer coefficients $\left(\frac{pCi/kg}{pCi/day}\right)$
   - Water concentration of the nuclide of interest (pCi/liter).

2. The dose commitment to a given organ is computed as a product of the following:

   - Annual rate of meat consumption (kg/yr).
   - Meat concentration of the nuclide (pCi/kg). This was computed in 1 above.
   - The dose conversion factor for the particular nuclide and organ $\left(\frac{mrem/yr}{pCi\ ingested}\right)$

To permit flexibility, the parameters in Tables 1 and 2 are utilized so as to leave the initial water concentration variable. Table 3 lists factors which convert water concentration directly to dose. Using Table 3 and the concentrations for cases I, II, and III, doses to the various organs are computed and listed in Table 4.

It should be noted that the maximum doses are to the bone; 12.1 mrem/yr from beef and 7.04 mrem/yr from mutton ingestion.

TABLE 1

Pertinent environmental parameters

Description	Value	Reference
Uptake rate of water (liters/day)	50 (cattle) 8 (sheep)	Ref. 1
Transfer coefficients $\left(\frac{\text{pCi/kg meat}}{\text{pCi/day ingested}}\right)$	U 3.4×10^{-4} (cattle)	Ref. 1, 2, 3
	3.4×10^{-4} (sheep)	Ref. 1, 2, 3
	Th 2.0×10^{-4} (cattle)	Ref. 1, 2, 3
	2.0×10^{-4} (sheep)	Ref. 1, 2, 3
	Ra 5.1×10^{-4} (cattle)	Ref. 3
	4.0×10^{-3} (sheep)	Ref. 4
	Pb 7.1×10^{-4} (cattle)	Ref. 3
	8.0×10^{-4} (sheep)	Ref. 4
Adult Meat Ingestion Rate (kg/yr)	78.3 (meat)	Ref. 3

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TABLE 2

ADULT DOSE CONVERSION FACTORS FOR MEAT INGESTION (REF. 3)

mrem/pCi ingested	U-238	U-234	Ra-226	Th-230	Pb-210
Whole Body	4.54×10^{-5}	5.17×10^{-5}	4.60×10^{-3}	5.70×10^{-5}	5.44×10^{-4}
Bone	7.67×10^{-4}	8.36×10^{-4}	4.60×10^{-2}	2.06×10^{-3}	1.53×10^{-2}
Liver	0.0	0.0	5.74×10^{-6}	1.17×10^{-4}	4.37×10^{-3}
Kidney	1.75×10^{-4}	1.99×10^{-4}	1.63×10^{-4}	5.65×10^{-4}	1.23×10^{-2}

TABLE 3

ADULT DOSE FACTOR MULTIPLIERS $\frac{\text{mrem/year}}{\text{pCi/liter}}$

Beef

	U-238	U-234	Ra-226	Th-230	Pb-210
Whole Body	6.04×10^{-5}	6.88×10^{-5}	9.18×10^{-3}	4.46×10^{-5}	1.51×10^{-3}
Bone	1.02×10^{-3}	1.11×10^{-3}	9.18×10^{-2}	1.61×10^{-3}	4.25×10^{-2}
Liver	0.0	0.0	1.15×10^{-5}	9.16×10^{-5}	1.21×10^{-2}
Kidney	2.33×10^{-4}	2.65×10^{-4}	3.25×10^{-4}	4.42×10^{-4}	3.42×10^{-2}

Mutton

	U-238	U-234	Ra-226	Th-230	Pb-210
Whole Body	9.67×10^{-6}	1.10×10^{-5}	1.15×10^{-2}	7.14×10^{-6}	2.73×10^{-4}
Bone	1.63×10^{-4}	1.78×10^{-4}	1.15×10^{-1}	2.58×10^{-4}	7.67×10^{-3}
Liver	0.0	0.0	1.44×10^{-5}	1.47×10^{-5}	2.19×10^{-3}
Kidney	3.73×10^{-5}	4.24×10^{-5}	4.08×10^{-4}	7.08×10^{-5}	6.16×10^{-3}

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TABLE 4

ADULT ORGAN DOSES (mrem/yr) RESULTING FROM THE WATER/MEAT INGESTION PATHWAY [a)]

Case I

Water Concentration pCi/liter	Beef: Whole Body	Beef: Bone	Beef: Liver	Beef: Kidney	Mutton: Whole Body	Mutton: Bone	Mutton: Liver	Mutton: Kidney
U-238 25	0.0+	0.03	0.0	0.01	0.0+	0.0+	0.0	0.0+
U-234 25	0.0+	0.03	0.0	0.01	0.0+	0.0+	0.0	0.0+
Ra-226 50	0.46	4.59	0.0+	0.02	0.58	5.75	0.0+	0.02
Th-230 2000	0.09	3.22	0.18	0.88	0.01	0.52	0.03	0.14
Pb-210 100	0.15	4.25	1.21	3.42	0.03	0.77	0.22	0.62
TOTAL	0.70	12.1	1.39	4.33	0.62	7.04	0.25	0.78

Case II

Water Concentration pCi/liter	Beef: Whole Body	Beef: Bone	Beef: Liver	Beef: Kidney	Mutton: Whole Body	Mutton: Bone	Mutton: Liver	Mutton: Kidney
U-238 25	0.0+	0.03	0.0	0.01	0.0+	0.0+	0.0	0.0+
U-234 25	0.0+	0.03	0.0	0.01	0.0+	0.0+	0.0	0.0+
Ra-226 25	0.23	2.30	0.0+	0.01	0.29	2.88	0.0+	0.01
Th-230 500	0.02	0.81	0.05	0.22	0.0+	0.13	0.01	0.04
Pb-210 100	0.15	4.25	1.21	3.42	0.03	0.77	0.22	0.62
TOTAL	0.41	7.40	1.26	3.66	0.32	3.78	0.23	0.66

TABLE 4 (cont'd.)

Case III

Water Concentration pCi/liter	Beef				Mutton			
	Whole Body	Bone	Liver	Kidney	Whole Body	Bone	Liver	Kidney
U-238 25	0.0+	0.03	0.0	0.01	0.0+	0.0+	0.0	0.0+
U-234 25	0.0+	0.03	0.0	0.01	0.0+	0.0+	0.0	0.0+
Ra-226 2	0.02	0.18	0.0+	0.0+	0.02	0.23	0.0+	0.0+
Th-230 10	0.0+	0.02	0.0+	0.0+	0.0+	0.0+	0.0+	0.0+
Pb-210 10	0.02	0.43	0.12	0.34	0.0+	0.08	0.02	0.06
TOTAL	0.04	0.68	0.12	0.36	0.03	0.32	0.02	0.07

a) The "+" after 0.0 indicates positive numbers which are less than 0.005. Rounding off to two decimal places accounts for any discrepancy in the totals.

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APPENDIX REFERENCES

1. U.S. Nuclear Regulatory Commission Regulatory Guide 1.109, "Calculation of Annual Doses to Man From Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR 50", Appendix I, March, 1976.

2. Reference 1, Revision 1, October 1977.

3. U.S. Nuclear Regulatory Commission Draft Regulatory Guide, "Calculational Models for Estimating Radiation Doses to Man from Airborne Radioactive Materials Resulting from Uranium Milling Operations", Division 3, Task RH-802-4, May 1979.

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