

NUCLEAR REGULATORY COMMISSION
ABNORMAL OCCURRENCE
MILL TAILINGS IMPOUNDMENT DAM FAILURE

Section 208 of the Energy Reorganization Act of 1974, as amended, requires the NRC to disseminate information on abnormal occurrences (i.e., unscheduled incidents or events which the Commission determines are significant from the standpoint of public health and safety). The following incident was determined to be an abnormal occurrence using the criteria published in the Federal Register on February 24, 1977 (42 FR 10950). Appendix A (Example III.B.1) of the Policy Statement notes that an event which seriously compromised the ability of a confinement system to perform its designated function can be considered an abnormal occurrence. The following description of the event also contains the remedial action taken.

Date and Place - On July 16, 1979 a uranium mill tailings impoundment dam failed at the United Nuclear Church Rock Uranium Mill, located near Gallup, New Mexico. This United Nuclear Corporation facility is licensed by the State of New Mexico under the provisions of the NRC State Agreements Program. At the time of the incident, the uranium mill tailings at the Church Rock Uranium Mill were also under general license from the NRC pursuant to the Uranium Mill Tailings Radiation Control Act of 1978.

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Nature and Probable Consequences - As a result of the dam failure, mill tailings solution and solids poured through the break into a catchment area below the dam. The catchment embankment was subsequently breached and tailings solution flowed into an arroyo (water-carved gully) and on into the Rio Puerco River which flows past Gallup, New Mexico.

The break in the dam allowed approximately 100 million gallons of tailings solution and 1100 tons of tailings solids (sand) to flow out of the impoundment before it could be closed. Most of the solids were deposited in an area very near the impoundment in a backup containment area on United Nuclear Corporation property and in an adjacent stream, the "Pipeline Arroyo." The tailings solutions travelled 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. The spilled solutions eventually dissipated at a point estimated to be about 30 miles into Arizona. (See Figure 1.)

The radioactive isotopes in the mill tailings and tailings solutions are those which naturally occur in the soil of the area but which have been concentrated by the milling process. These isotopes, primarily thorium-230 and radium-226, did not present any immediate health hazard when released by the dam failure. The concentrated contamination of normally dry areas of the Pipeline Arroyo and the tailings solids in the Arroyo would contribute a relatively small increment^{1/} to the estimated

^{1/} Calculated values are: 1.3 mrem/year to the whole body, 22.0 mrem/year to the bone from all exposure pathways.

normal background dose rate of 140 mrem/year for persons living near the Arroyo. However, cleanup of these sources has been undertaken in accordance with maintaining doses as low as reasonably achievable and lowering the potential for radiological contamination of groundwater.

The immediate health hazard arose from the acidic nature of the tailings solution which could cause chemical burns if ingested or brought in contact with skin. The potential for acute chemical effects persisted for approximately 2 days, until water from the upstream mining operations and the natural alkalinity of the stream bed neutralized the tailings solution. Chemical contamination (e.g., elevated trace metal concentrations) of groundwater presents a long-term problem.

Cause or Causes - The tailings impoundment dam failed as a result of differential settlement and direct exposure of the dam to tailings solutions. The first factor was the result of the manner in which the dam was constructed; the second factor was the result of failure of the operator to maintain a buffer of mill tailings between the dam and the tailings solutions.

The dam is located on a site containing alluvial soils overlying bedrock having an irregular surface. Depths of this relatively loose soil ranged from less than 20 feet up to a maximum of 100 feet. During design and construction of the dam, tests were conducted to determine how much the alluvial soil would compress under a load. These tests indicated that settlement of about 5 percent would result from the loading of the embankment under dry conditions. With water in the

impoundment, additional settlement ranging from 1-1/2 percent to 13 percent was experienced due to collapse of the soil structure. As a result of this high compressibility of the alluvial soil and the irregular bedrock surface, large differential settlement of the dam occurred. As a result of differential settlement, cracks developed in the embankment. These cracks coupled with the lack of a buffer of solid tailings between water and the dam allowed tailings water to penetrate and weaken the embankment.

Actions Taken to Prevent Recurrence -

Licensee - The United Nuclear Corporation (UNC) performed an evaluation of the dam failure and examined the serviceability of the remaining portions of the dam. UNC is also performing a study of alternate sites for the tailings impoundment. UNC is conducting cleanup operations to standards established by the State of New Mexico and the NRC. Cleanup of contamination has been completed in the most heavily affected areas near the mill. Cleanup in the remaining sections of the Arroyo will probably take several more months to complete.

State of New Mexico - Soon after the spill State officials arrived at the site to begin an investigation. The State requested aerial surveillance of the site and began an extensive sampling program along the route of the spill.

On July 16, 1979 the Environmental Improvement Division (EID) issued an order requiring termination of operations. EID issued a second order on July 18 requiring the licensee to take steps to minimize dispersion of materials. The State engineer also issued an order on July 18 requiring an investigation of the cause of the dam

failure prior to any repair and resumption of tailings discharge to the impoundment. New Mexico officials subsequently met on July 20 with representatives of the NRC, the Army Corp of Engineers and UNC to discuss the dam failure.

New Mexico amended its July 16 order on October 23, 1979 to allow operation of the facility subject to provisions for monitoring tailings solution levels and impoundment dam integrity. The October 23 amendment also required a study of alternative sites for long-term disposal of tailings solution and solids.

On November 8, 1979 a State engineer again ordered the facility to stop the generation of tailings because the licensee was not maintaining the required beach of tailings solids between the tailings solution and the dam. Operations were allowed to resume on November 13, 1979.

NPC - The NRC has worked in conjunction with numerous other State and Federal organizations in responding to the accident and formulating longer-term corrective action, including cleanup of contamination and continued monitoring of groundwater quality.

The NRC issued an order on October 12, 1979 banning generation of additional tailings until a review provided adequate assurance that all causes of the dam failure had been identified and that the remaining portions of the embankment were free of deficiencies. The NRC reviewed the licensee's evaluation of the dam failure, concurred in the findings with regard to the major causes, and determined that limited generation

and storage of uranium tailings could be conducted with reasonable assurance of protection for the public and the environment. The staff issued an order to this effect on October 24, 1979. The order allowed operation for a limited time subject to continued demonstration of dam integrity by documented inspection, prohibited planned expansion of the current tailings area until NRC staff approval was given, and required that UNC submit a proposal for development of a new tailings site for ultimate disposal. Direct NRC regulatory authority over tailings in Agreement States was subsequently removed by an act of Congress amending the Uranium Mill Tailings Radiation Control Act of 1978 (Public Law 96-106, November 2, 1979) and the NRC order can no longer be enforced. However, a State of New Mexico order which imposes essentially the same terms and conditions remains in effect. NRC is continuing to provide technical assistance to New Mexico.


The staff reviewed docket files on the tailings dams at operating mills in non-Agreement States and in all but one case found that differential settlement was satisfactorily addressed. The exception was a dam authorized in 1971 and documentation does not indicate that differential settlement was addressed. However, no evidence of excessive differential settlement leading to cracking has shown up in routine inspection of the dam.

An NRC summary report on the dam failure at Church Rock will be completed in the near future. The report will address the cause of the failure, what aspects the States should look at for tailing impoundments

in their States and an offer of technical assistance by the NRC. The report will be provided to all Agreement States so that they can take appropriate action.

The NRC had also proposed prior to the accident regulations which specify requirements for mill tailings disposal. These regulations identify certain siting and design features which must be incorporated into tailings disposal programs to assure long-term isolation and containment of tailings without continuing active maintenance. The regulations identify burial of tailings below the surrounding grade as the preferred mode of tailings disposal. In this way, dams such as the one which failed at the Church Rock mill would be avoided.

For the Nuclear Regulatory Commission


Samuel J. Chinn
Secretary of the Commission

Dated at Washington, D. C. this 4th day of January, 1980

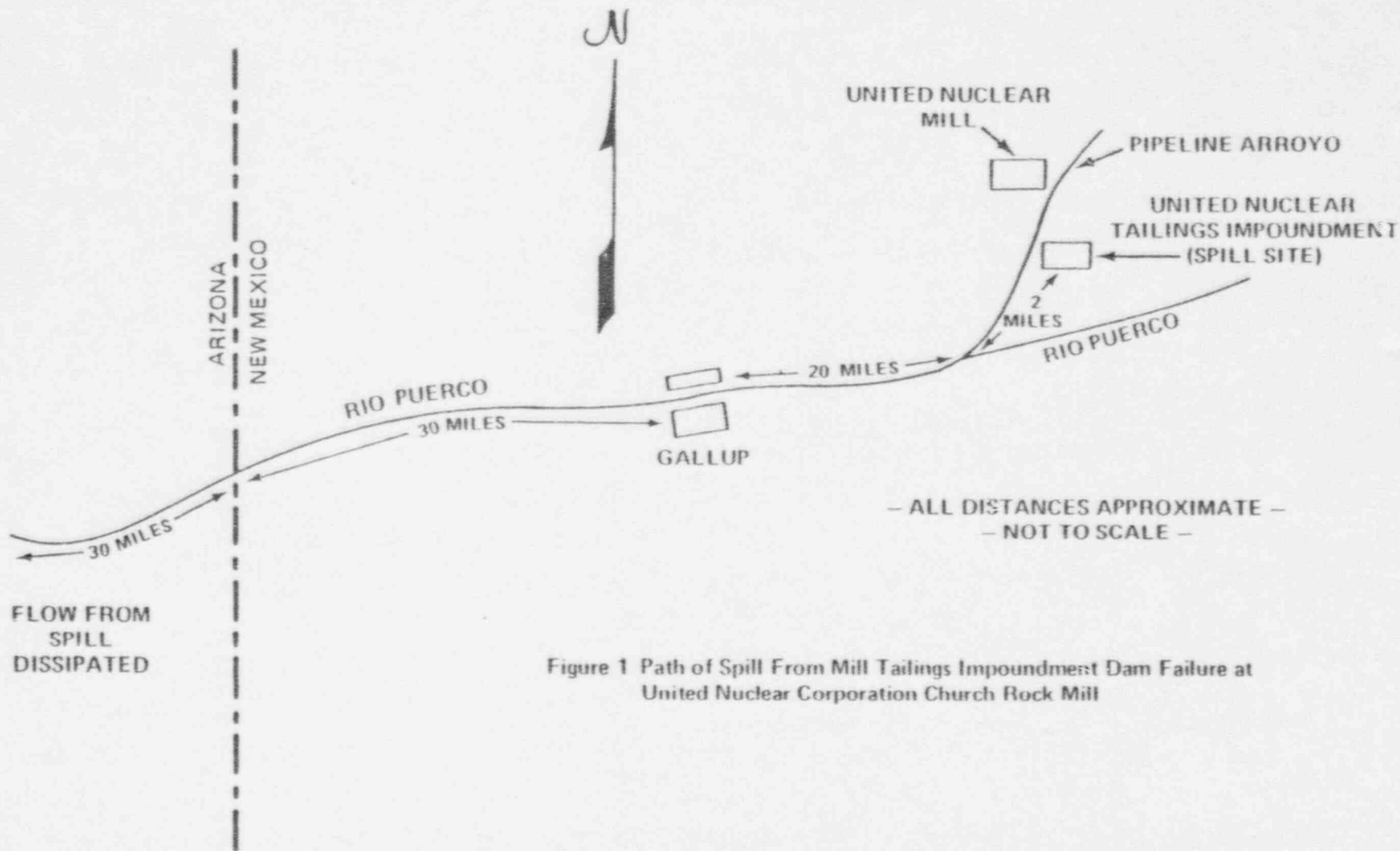
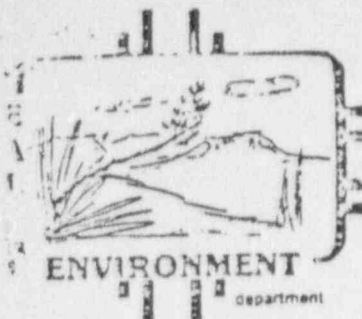


Figure 1 Path of Spill From Mill Tailings Impoundment Dam Failure at United Nuclear Corporation Church Rock Mill



STATE OF NEW MEXICO
ENVIRONMENTAL IMPROVEMENT DIVISION
P.O. Box 968, Santa Fe, New Mexico 87503
(505) 827-5271

Thomas E. Baca, M.P.H., Director

Bruce King
GOVERNOR

George S. Goldstein, Ph.D.
SECRETARY

Larry J. Gordon, M.S., M.P.H.
DEPUTY SECRETARY

RADIATION PROTECTION BUREAU

April 23, 1980

Mr. Hubert Miller
Uranium Recovery Licensing Board
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Hub:

As we discussed on the phone, there is a possibility that the criteria for cleanup of the Rio Puerco, developed as a result of the Churchrock tailings breach, may need to be modified. This is a consequence of the inability of United Nuclear Corporation (UNC) to clean up the arroyo to the specified limit for thorium-230, as given by our interim criteria.

UNC has been cleaning the arroyo for some nine months. In spite of this effort, a close analysis of the post clean-up data, a copy of which you have, shows very little, if any, reduction of thorium-230 concentrations in the soil.

Enclosed is a copy of the proposed modifications. It keeps both radium-226 and lead-210 at the same levels as before while increasing the thorium-230 limit from 30 pCi/gram to 60 pCi/gram. It also allows for averaging over an area of up to 1000' x 100', requiring that the limits be specified at the 67% confidence level, i.e., the mean plus one-half of the standard error ($\bar{x} + s_m/2$) must be less than the limits. From past experience, the standard error for a set of 5 measurements averaging around 50-60 pCi/gram is some 20-30 pCi/gram. Thus, this $\bar{x} + s_m/2$ criteria requires that the mean be less than 45-50 pCi/gram.

Since theoretically averaging over an area allows for the hypothetical situation of low thorium-230 everywhere but in a small area, where the thorium-230 could be very high, criteria 7B ii was included to limit the maximum thorium-230 concentration allowed by the clean-up limits. This would then avoid these high values.

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C. Gordon

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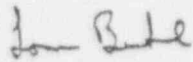
Mr. Hubert Miller
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April 23, 1980

In deriving these new criteria, several UDAD runs were made with soil concentrations at the proposed limits. Individual doses remained small; roughly 1.5 mrem/year to the bone for inhalation. Since thorium-230 has a small dose conversion factor for ingestion, it should be noted that the proposed change would mainly affect inhalation doses.

Your reviewing these proposed criteria would be appreciated.

Thank you in advance for your help.

Sincerely yours,



Thomas E. Buhl
Program Manager
Surveillance and Field Unit

Enclosure

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The New Mexico Environmental Improvement Division (NM EID) on August 13, 1979 issued an Order to United Nuclear Corporation (UNC) which required UNC to comply with recommendations for a clean-up program as described in a letter from Mr. Thomas E. Baca, NM EID, to Mr. D. D. Turberville, UNC, of the same date. This letter refers to condition seven of that August 13 letter.

In accordance with Section 4-1003 of the New Mexico Regulations for Governing the Health and Environmental Aspects of Radiation, every reasonable effort should be made to maintain radiation exposure as far below the limits specified in part four as practicable. Pursuant to this section, the staff of the Environmental Improvement Division has evaluated clean-up reports submitted by the United Nuclear Corporation, and performed an assessment of the radiation exposures resulting from the increased radionuclide soil concentrations in the areas affected by the spill. Based on the results of these evaluations, the interim clean-up criteria given in condition number seven of the August 13, 1979 letter will be replaced by the following:

- 7A. All contaminated areas shall be cleaned up to background levels of all radionuclides. This criteria shall be considered satisfied if the mean concentrations of thorium-230, radium-226 and lead-210, averaged over nine square feet, are less than or equal to -

thorium-230	3 pCi/gram
radium-226	3 pCi/gram
lead-210	3 pCi/gram

at the 50% confidence level.

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7B. Those areas for which it has not been possible to meet the criteria given in part 7A, upon approval by the Division, shall comply with the following criteria:

- i: Mean concentrations of thorium-230, radium-226, and lead-210 shall not exceed the following limits:

thorium-230	60 pCi/gram
radium-226	10 pCi/gram
lead-210	10 pCi/gram

For the purpose of compliance with this criteria radionuclide concentrations may be averaged over areas with length of no more than 1000 feet parallel to the arroyo, and width defined by the bases of the cut banks of the arroyo. This width shall not exceed 100 feet. Those arroyo areas whose widths exceed 100 feet must be separated into 1000 foot by 100 foot segments, and the radionuclide concentrations averaged over each segment. All samples to be included in these averages must be taken from the area between the bases of the cut banks.

- ii: Mean concentrations of thorium-230, radium-226, and lead-210 when averaged over nine square feet, shall not exceed the following limits:

thorium-230	150 pCi/gram
radium-226	10 pCi/gram
lead-210	20 pCi/gram

- iii: The limits given in parts 7B. i. and B. ii. above will apply at the 67% upper confidence level. Soil samples shall be taken in accordance with the standardized soil sampling technique described in the September 25, 1979 letter from Dr. Ted Wolff, NM EID, to Mr. John Abbiss, UNC.



DEC 31 1979

Distribution:

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Mill file DCS

MEMORANDUM FOR: G. Wayne Kerr, Assistant Director
for State Agreement Program
Office of State Programs

FROM: Ross A. Scarano, Chief
Uranium Recovery Licensing Branch
Division of Waste Management

SUBJECT: INFORMATION NOTICE TO AGREEMENT STATES REGARDING
CHURCH ROCK FAILURE

Enclosed is a summary of the probable cause of failure of the Church Rock uranium mill tailings impoundment and the Uranium Recovery Licensing Branch's recommendations regarding embankment inspections and evaluations to be performed by Agreement States. We recommend that this enclosure be forwarded to all appropriate Agreement States in the form of a State Programs Information Notice.

Original Signed by:

R. A. Scarano

Ross A. Scarano, Chief
Uranium Recovery Licensing Branch
Division of Waste Management

Enclosure:
As stated

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EVALUATION OF URANIUM MILL TAILINGS RETENTION
SYSTEMS FOLLOWING THE EMBANKMENT
FAILURE AT CHURCH ROCK

The Church Rock Embankment Failure:

The United Nuclear Corporation dam impounding tailings and raffinate from the Church Rock mill was observed to have been breached early on July 16, 1979.

We have reviewed the company's evaluations of the probable cause of the accident and generally concur with the reported findings. The dam was located on a site containing alluvial soils overlying bedrock having an irregular surface. Depths of alluvium ranged from less than 20 feet up to a maximum of about 100 feet.

Consolidation tests were conducted on samples of the alluvial soils during the preconstruction design phase and after construction of the starter embankment. These tests indicated that settlement of about 5 percent would result from the loading of the embankment under unsaturated conditions. After saturation, additional settlement ranging from 1-1/2 percent to 13 percent was experienced due to collapse of the soil structure. As a result of the potential for large compression of the alluvium and because of the irregular bedrock surface, large differential settlement of the dam occurred. Settlement in excess of 3 feet was measured in January 1979 by a consultant to United Nuclear Corporation. As a result of differential settlement, cracks developed in the embankment. Longitudinal cracking along 1250 feet of the embankment has been well documented by observations made by the operator's consultant in December 1977 and photographs of the cracks in July 1978. Transverse cracks, perpendicular

to the dam axis and extending nearly to the downstream shell, have been observed in the breach area after the failure. For some time period immediately prior to the failure, tailings water was maintained in direct contact with the embankment near the breach area. The high pore water pressure in the embankment resulted in a decrease in the strength of the embankment and caused instability to develop. After the instability was created, the large flow of water through the cracks resulted in internal erosion which accelerated the breach. One factor which may have helped to accelerate the internal erosion is the fact that the high acidity of the tailings water causes the embankment soil to be highly dispersive.

Recommended Evaluation Procedures:

It is the recommendation of the Uranium Recovery Licensing Branch of the NRC that the appropriate Agreement States perform inspections and evaluations of all uranium mill tailings dams under their respective jurisdictions to insure that an incident similar to the Church Rock failure will not occur. To accomplish this goal it is recommended that in addition to regular state inspection procedures, the following specific evaluations should be performed by a licensed professional engineer:

- a. Embankments should be visually inspected for signs of slumping, cracking, movement or concentration of seepage. Records should be viewed to determine whether slumping, cracking, movement or concentration of seepage has been evident in the past and if so, what remedial measures have been performed.

- b. If the embankment inspection performed under item "a" reveals evidence of slumping, cracking, movement or concentration of seepage, the following detailed analyses should be performed.
 - 1. The embankment and foundation soils should be checked for their susceptibility to collapse when saturated.
 - 2. The embankment and foundation soils should be checked for their dispersive characteristics when exposed to the impounded tailings solution.
 - 3. The foundation profile should be examined to determine the existence of any factors which could lead to significant differential settlement.
- c. Regardless of the results of items "a" and "b", the operators should be required by license condition to initiate a continuing program that meets the criteria presented in NRC Regulatory Guide 3.11.1, "Operational Inspection and Surveillance of Embankment Retention Systems for Uranium Mill Tailings."

If additional information regarding this matter is desired, contact Mr. Ross A. Scarano, Chief, Uranium Recovery Licensing Branch, U. S. Nuclear Regulatory Commission at 301-427-4103.