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WATER QUALITY IMPACTS OF URANIUM MINING AND MILLING ACTIVITIES IN THE GRANTS MINERAL BELT, NEW MEXICO

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

U. S. ENVIRONMENTAL PROTECTION AGENCY
REGION VI, DALLAS, TEXAS 75201

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IMPACT OF URANIUM MINING AND MILLING ON WATER QUALITY IN THE GRANTS MINERAL BELT, NEW MEXICO

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Purpose and Scope

In September 1974, Mr. John Wright of the New Mexico Environmental Improvement Agency requested that the staff of EPA Region VI assist in implementing a survey of the uranium mining and milling activities of the Grants Mineral Belt to determine the impact of these activities on surface and ground water in the area.

The objectives outlined for the survey were:

1. Assess the impacts of waste discharges from uranium mining and milling on surface and ground waters of the Grants Mineral Belt.

2. Determine if discharges comply with all applicable regulations, standards, permits and licenses.

3. Evaluate the adequacy of company water quality monitoring networks, self-monitoring data, analytical procedures and reporting requirements.

4. Determine the composition of potable waters at uranium mines and mills.

5. Develop priorities for subsequent monitoring and other follow-up studies.

In response to the request by the New Mexico Environmental Improvement Agency, plans were developed to conduct a joint, cooperative study involving Region VI, EPA; the Office of Radiation Programs - Las Vegas Facility (ORP-LV); the National Enforcement Investigation Center, Denver (NEIC-Denver), and the New Mexico Environmental Improvement Agency (NMEIA).

A reconnaissance was conducted in January 1975 to view the study areas, meet with mining/milling company officials, and plan the data collection effort. Sample collection began in late February 1975, and was completed in early March 1975. Laboratory analyses for trace metals, gross alpha, radium-226 analysis and other radiological analyses were completed in July 1975.

Study Results

The details of the study are presented in two reports which are appended to this summary report: Surface Water Quality Impacts of Uranium Mining and Milling in the Grants Mineral Belt, New Mexico, and Ground-Water Quality Impacts of Uranium Mining and Milling in the Grants Mineral Belt, New Mexico.

Based on the data collected and analyzed, the following conclusions and recommendations were developed.

SUMMARY AND CONCLUSIONS

I. TASK: Assess the Impacts of Waste Discharges from Uranium Mining and Milling on Surface and Ground Waters of the Grants Mineral Belt.

1. Ground water is the principal source of water supply in the study area. Extensive development of ground water from the San Andres Limestone aquifer occurs in the Grants-Bluewater area where the water is used for agriculture, public water supply, and uranium mill feed water. Development of shallow, unconfined aquifers in the alluvium also occurs in this area. Principal ground-water development in the mining areas at Ambrosia Lake, Jackpile-Paguate, and Churchrock is from the Morrison Formation and, to a lesser extent, from the Dakota Sandstone or the Tres Hermanos Member of the Mancos Shale. The Gallup water supply is derived primarily from deep wells completed in the Gallup Sandstone using well fields located east and west of the urban area and 11 kilometers north of the city.

2. In proximity to the mines and mills and adjacent to the principal surface drainage courses, shallow ground-water contamination results from the infiltration of (1) effluents from mill tailings ponds; (2) mine drainage water that is first introduced to settling lagoons and thence to watercourses, and (3) discharge (tailings) from ion exchange plants. In the case of the Anaconda mill, seepage from the tailings ponds and migration of wastes injected into deep bedrock formations is observed in the San Andres Limestone and in the alluvium, both of which are potable aquifers. With the exception of seepage from the Kerr-McGee Section 36 mine in Ambrosia Lake, significant amounts of wastewater from the remaining mines and mills probably does not return to known bedrock aquifers. Deterioration of water quality results from conventional underground mining as a result of penetration or disruption of the ore body. The most dramatic changes are greatly increased dissolved radium and uranium. Induced movement of naturally saline ground water into potable aquifers is also likely but undocumented. Similarly, the ground-water quality impacts of solution (in situ) mining are unknown.

3. The Grants, Milan, Laguna, and Bluewater municipal water supplies have not been adversely affected by uranium mining and milling operations to date. For the Grants and Milan areas, chemical data from 1962 to the present indicate that near the Anaconda mill some observation wells have increased slightly in total dissolved solids, sulfate, chloride and gross alpha but domestic wells have generally remained unchanged. Projections made in 1957 of gross nitrate deterioration of ground water have not been substantiated by subsequent data. Of the municipal supply wells in the study area, the Bluewater well bears additional monitoring because of its location relative to the Anaconda tailings ponds.

4. Contamination of the Gallup municipal ground-water supply by surface flows, consisting mostly of mine drainage, has not occurred and is extremely unlikely because of geologic conditions in the well field and the depth to productive aquifers. Another well field north of the City will, in no way, be affected by the drainage.

5. With the exception of the area south and southwest from the United Nuclear-Homestake Partners mill, widespread ground-water contamination from mining and milling was not observed in the study area. Throughout the study area widespread contamination of ground water with radium was not observed despite concentrations of as much as 178 pCi/l in mine and mill effluents. Radium removal is pronounced, probably due to sorptive capacity of soils in the area. In the vicinity of the Anaconda mill, radium and nitrate concentrations in the alluvial aquifer decline with distance from the tailings ponds, but neither parameter exceeds drinking water standards.

6. Ground water in at least part of the shallow aquifer developed for domestic water supply downgradient from the United Nuclear-Homestake Partners mill is contaminated with selenium. Alternative water supplies can be developed using deep wells completed in the Chinle Formation or in the San Andres Limestone. Potential well sites are located in the developments affected or in the adjacent area. A third alternative includes connecting to the Milan municipal system. Further evaluations are necessary to determine the best course of action.

7. Mining practices, per se, have an adverse effect on natural water quality. Initial penetration and disruption of the ore body in the Churchrock mining area increased the concentration of dissolved radium in water pumped from the mines from 0.05 - 0.62 pCi/l to over 8 pCi/l. According to company data, the concentration rose to over 75 pCi/l, or at least 75 times the natural concentration in the two-year period during which the mine was being developed. The pattern of increasing radium with time, also seen in Ambrosia Lake, is being repeated. Ground-water inflow via long holes in the Kerr-McGee Section 36 mine contain a relatively low concentration of dissolved radium-226. Therefore, much of the radium loading of mine effluent is apparently a result of leaching of ore solids remaining from mucking and transport within the mine. In some cases, this could be reduced by improved mining practices such as provision of drainage channels along haulage drifts.

8. Radium concentrations in Arroyo del Puerto, a perennial stream, exceed New Mexico Water Quality Criteria as a result of discharges from the Kerr-McGee ion exchange plant and Section 30W and 35 mines, and from the United Nuclear-Homestake Partners ion exchange plant. Selenium and vanadium concentrations exceed EPA 1972 Water Quality

8. (Continued)

Criteria for use of the water for irrigation and livestock watering, and render the stream unfit for use as a domestic water source.

9. Company data show that seepage from the Anaconda tailings pond at Bluewater averages 183 million liters/year (48.3 million gallons) for 1973 and 1974. The average volume injected for the same time period was 348 million liters/year (91.9 million gallons). Therefore, approximately one-third of the total effluent volume remaining after evaporation (531 million liters/year) enters the shallow aquifer, which is a source of potable and irrigation water in Bluewater Valley. From 1960 through 1974, seepage alone introduced 0.41 curies of radium to the shallow potable aquifer. Adequate monitoring of the movement of the seepage and the injected wastes is not underway.

10. There are indications that waste injected into the Yeso Formation by the Anaconda Company are not confined to that unit as originally intended in 1960. Three nearby monitoring wells, completed in the shallower San Andres Limestone and/or the Glorieta Sandstone, show a trend of increasing chloride and uranium with time. Positive correlations of water quality fluctuations with the volumes of waste injected are a further indication of upward movement. The absence of monitoring wells in the injection zone is a major deficiency in the data collection program.

11. Rainfall and runoff at the Anaconda Jackpile Mine erode uranium- and selenium-rich minerals into Rio Paguate. This erosion can be mitigated by waste stabilization and runoff control.

12. The maximum concentration of radium observed in shallow ground water adjacent to the Kerr-McGee mill at Ambrosia Lake was 6.6 pCi/l. According to company data, seepage from the tailings ponds occurs at the rate of 491 million liters/year (130 million gallons/year). This is 29 percent of the influent to the "evaporation ponds" and attests to their poor performance in this regard. Radium and gross alpha in the seepage are 56 pCi/l and 112,000-144,000 pCi/l, respectively. Total radium introduced to the ground water to date is estimated at 0.7 curies. Wells completed in bedrock and in alluvium, and located near watercourses containing mine drainage and seepage from tailings ponds, contain elevated levels of TDS, ammonia, and nitrate. One well, which contained 1.0 pCi/l in 1962 now is contaminated with 3.7 pCi/l of radium. Sorption or bio-uptake of radium is pronounced, hence concentrations now in ground water are not representative of ultimate concentrations.

13. Water-quality data from 11 wells over a 200-square kilometer area in the Puerco River and South Fork Puerco River drainage basins reveal

13. (Continued)

essentially no noticeable increase in concentrations of radionuclides or common inorganic and trace constituents in ground water as a result of mine drainage. Natural variations in the uranium content of sediments probably account for differences in radium content in shallow wells. Dissolved radium in shallow ground water underlying stream courses affected by waste water is essentially unchanged from areas unaffected by mine drainage. None of the samples contained more than recommended maximum concentrations for radium-226, natural uranium, thorium-230, thorium-232, or polonium-210 in drinking water. However, the paucity of sampling points and the absence of historical data make the foregoing conclusion a conditional one, particularly in the reaches of the Puerco River within approximately 10 kilometers downstream of the mines.

14. Four wells sampled in the vicinity of the Jackpile mine near Paguate contained 0.31 to 3.7 pCi/l radium-226. With the exception of the latter value from the new shop well in the mine area, remaining supplies contain 1.7 pCi/l or less radium. The Paguate municipal supply contains 0.18 pCi/l. None of the wells were above maximum permissible concentrations (MPC) for the other common isotopes of uranium, thorium, and polonium. Ground water from the Jackpile Sandstone may contain elevated levels of radium as a result of mining activities. Mine drainage water ponded within the pit contained 190 pCi/l radium and 170 pCi/l of uranium in 1970. The impacts of mining on ground-water quality downgradient from the mining area are unknown due to the lack of properly located monitoring wells. No adverse impacts from mining on the present water supply source for Paguate are expected.

15. Of the 71 ground-water samples collected for this study, a total of 6 had radium-226 in excess of 3 pCi/l PHS Drinking Water Standard. Two of the 6 involved potable water supplies. One containing 3.6 pCi/l serves a single family and is located adjacent to Arroyo del Puerto and downgradient from the mines and mills in Ambrosia Lake. The second contains 3.7 pCi/l and is used as a potable supply for the labor force in the new shop at the Jackpile Mine.

16. The highest isotopic uranium and thorium, and polonium-210 contents for any potable ground-water supplies sampled in the study area are less than 1.72% of the total radionuclide population guide - MPC as established in NMEIA regulations.

17. The lowest observed concentration (background levels) in ground water are summarized as follows:

17. (Continued)

Radionuclides	Range (pCi/l)	Average (pCi/l)
Radium-226	0.06 - 0.31	0.16
Polonium-210	0.27 - 0.57	0.36
Thorium-230	0.013 - 0.051	0.028
Thorium-232	0.010 - 0.024	0.015
U-Natural	14 - 68	35

18. The uranium isotopes (uranium 234, 235 and 238) are the main contributors to the gross alpha result; however, in several determinations, gross alpha underestimated the activity present from natural uranium.

19. No correlation was found between gross alpha content of 15 pCi/l (including uranium isotopes) and a radium-226 content of 5 pCi/l.

20. It is doubtful that the gross alpha determination can even be used as an indicator of the presence of other alpha emitters (e.g. U-natural and polonium-210); and since the gross alpha results have such large error terms, no meaningful determination of percentage of radionuclides to gross alpha can be implied.

21. Gross alpha determinations also failed to indicate the possible presence of lead-210 (primarily a beta emitter) which, because of the lower MPC of 33 pCi/l, may be a significant contributor to the radiological health hazard evaluation of any potable water supply.

22. Radium-226 in ground water is a good radiochemical indicator of waste-water contamination from mines and mills. Due to the low maximum permissible concentration, it also provides a good means for evaluating health effects. Selenium and nitrate also indicated the presence of mill effluents in ground water. Polonium-210, thorium-230 and thorium-232 concentrations in ground water fluctuate about background levels and are poor indicators of ground-water contamination from uranium mining and milling activities.

23. For routine radiological monitoring of potable ground-water supplies, isotopic uranium and thorium and polonium-210 analyses do not appear to be necessary due to their high maximum permissible concentrations (chemical toxicity of uranium may be a significant limiting factor, however).

II. Task: Determine if Discharges Comply with all Applicable Regulations, Standards, Permits, and Licenses.

1. At the time of sampling, the effluent from the Kerr-McGee ion exchange plant contained dissolved radium-226 at concentrations in excess of the applicable NPDES permit and New Mexico uranium-milling license conditions. This radium discharge was partly responsible for violations of New Mexico Water Quality Standards for Arroyo del Puerto, a perennial stream. The discharge also contained uranium at concentrations in excess of NPDES permit criteria. No treatment other than settling is currently in operation.

2. The Kerr-McGee Section 30W mine discharge contained dissolved radium-226 at concentrations in excess of the applicable NPDES permit condition. No treatment other than settling is currently in operation. This radium discharge also was partly responsible for violation of New Mexico Water Quality Standards in Arroyo del Puerto.

3. Kerr-McGee Nuclear Corporation has not applied for a discharge permit for their Section 35 mine, although the effluent reaches Arroyo del Puerto, a perennial stream. The discharge contains an average of 51 pCi/l of dissolved radium-226. No radium-removal treatment is currently in operation.

4. Sampling at the United Nuclear Corporation Churchrock mine was conducted when the operation was inactive due to a power failure and subsequent mine flooding. Indications are that the present treatment facility is inadequate to meet existing NPDES permit conditions.

5. Approximately 15 percent of the total flow through the United Nuclear-Homestake Partners ion exchange plant is discharged to Arroyo del Puerto, with the balance of the flow returning to the mines for *in situ* leaching. The discharge to Arroyo del Puerto is not regulated by an NPDES permit, and contributes to the violation of New Mexico Water Quality Standards for radium-226 in this perennial stream. Uranium is lost from the ion exchange facility. The facility is currently violating conditions of the applicable State license.

III. Task: Evaluate the Adequacy of Company Water Quality Monitoring Networks, Self-Monitoring Data, Analytical Procedures, and Reporting Requirements.

1. Company sponsored ground-water monitoring programs range from inadequate to nonexistent. Actual monitoring networks are deficient in that sampling points are usually poorly located or of inadequate depth/location relative to the hydrogeologic system and the introduction of contaminants thereto. Compared to the multi-million dollar uranium industry, producing multi-billion liters of toxic effluents, the ground-water sampling and monitoring programs represent minimal efforts in terms of network design, implementation, and level of investment.

2. Company radiochemical analytical methods are inadequate for measuring environmental levels of radionuclides and have high minimum detectable activities and large error terms. Incomplete analysis of radionuclide contents prevails. Few data are reported on other naturally occurring radionuclides such as isotopic thorium, polonium-210, and radium-228. In some cases, monitoring has been restricted to analysis of radium-226 and natural uranium, without consideration of these other radionuclides or toxic metals.

3. Monitoring of hydraulic and water-quality impacts associated with conventional mining and with solution (in situ) mining is not reported to regulatory agencies. It is likely that such monitoring is limited to meeting short-term economic and engineering needs of the companies rather than addressing long-term, general environmental concerns. As a result, overall impacts on ground water are not routinely determined and reported.

4. Off-site ground-water sampling networks do not utilize wells specifically located and constructed for monitoring purposes. Reliance on wells already in existence and utilized for domestic or livestock use falls short of the overall monitoring objectives (i.e., to determine impacts on ground water and to adjust company operations to acceptable levels). Deficiencies of this type can allow contamination to proceed unnoticed. On-site wells constructed specifically for monitoring are generally not completed to provide representative hydraulic and water quality data for the aquifer most likely to be affected.

5. Proven geophysical and geohydrologic techniques to formulate environmental monitoring networks are apparently not used. Such techniques can assist in specifying sampling frequencies, and provide the basis for adjustment of monitoring and operational practices to mitigate adverse impacts on ground water.

6. Monitoring the effects of the Jackpile and Paguate open pit mines on ground-water quality is nonexistent, despite the magnitude of these operations. Drainage water within the pits has contained as much as 190 pCi/l. Two wells, used for potable supply and completed in the ore body contain elevated levels of radium, further indicating a need for data to determine what the future impacts might be when mining ceases and before additional programs for heap leaching and in situ mining are implemented.

7. Careful analysis of material and water balances to determine seepage input to ground water for the various tailings disposal operations is not evident. For the Anaconda Company, the method utilized has not been altered in 14 years. For Kerr-McGee, overland flow presents a potential threat to the structural integrity of the retention dams. At the United Nuclear-Homestake Partners Mill, no quantitative estimates of seepage are available.

8. Records of U. S. Atomic Energy Commission (USAEC) inspection reports, mill license applications, seepage reports, etc., on file with the State appear to be incomplete and disorganized. No interpretive summary or review-type reports utilizing the monitoring data reported by industry are available from either the State or the U. S. Atomic Energy Commission files now held by the State. Liberal mill licensing conditions with respect to ground-water monitoring and water-quality impacts were initially established by the USAEC. Subsequently, there has been essentially no review, in any critical sense, of company operations with respect to ground-water contamination. The uranium mining and milling industry has not been pressed to monitor and protect ground-water resources. The limited efforts put forth by industry to date have largely not been reviewed by regulatory agencies at the State and Federal levels.

IV. Task: Determine the Composition of Potable Waters at Uranium Mines and Mills.

1. Four industry potable water supply systems, obtained from mine waters, exceeded 1962 U. S. Public Health Service Drinking Water Standards for selenium. Three such potable systems exceeded both the existing USPHS and proposed EPA Interim Primary Drinking Water Standards for radium. Such mine water is supplied as potable to families of miners at the United Nuclear Corporation Churchrock mine. These conditions are considered intolerable as they bear on the long-term health of those using the supplies. Non-potable systems at the Kerr-McGee mill and Churchrock mine have high radium and selenium concentrations, and are not adequately marked as non-potable.

V. Task: Develop Priorities for Subsequent Monitoring and Other Follow-up Studies.

See RECOMMENDATIONS

RECOMMENDATIONS

Action Required

1. Procedures be initiated to require United Nuclear Corporation to immediately provide potable water which meets Federal Drinking Water Standards for their Ambrosia Lake and Churchrock operations.

2. Procedures be initiated to require Kerr-McGee Nuclear Corporation to immediately provide potable water supplies which meet Federal Drinking Water Standards at their mill and Section 35 and 36 mines; the mill and Churchrock mine non-potable water supplies be clearly marked.

3. NMEIA initiate appropriate action to insure safe industrial potable water supplies at the United Nuclear Corporation's Ambrosia Lake and Churchrock operations and at the Kerr-McGee Nuclear Corporation's mill and Section 35 and 36 mines.

4. NMEIA should conduct periodic sampling of potable water supplies at operating uranium mines and mills throughout the State.

5. Improved industry-sponsored monitoring programs should be implemented and the data made available to State and Federal Regulatory Agencies. Programs should be designed to detect likely hydraulic and water quality impacts from uranium milling and mining (open pit, underground, in situ). Revamped programs, specifically developed by joint concurrence of industry and regulatory agencies, should be incorporated in licenses, where possible. Licenses should specify minimal radiochemical analytical methods for detecting specific radionuclides as well as requirements for participation in quality assurance programs. Specific reporting procedures should include raw data, summary reports, and interpretations of data. Conclusions concerning impacts of operations on ground-water quality and remedial steps taken to abate or eliminate adverse impacts should be prepared. It is essential that the programs developed, as well as the data and interpretive reports prepared therefrom, be critically reviewed by the State to meet continuing regulatory responsibilities.

6. Because seepage from the Anaconda and Kerr-McGee tailings ponds constitutes a significant portion of the inflow to the ponds, it is recommended that seepage control measures be adopted. According to company records, such seepage presently totals some 674 million liters per year. Water budget analyses of the United Nuclear-Homestake Partners tailings pond should be made to determine how much seepage is occurring and thereby contributing to contamination of the shallow aquifer locally developed for domestic water supplies in two adjacent privately owned housing developments.

7. Improved mining practices should be adopted to reduce the amount of radium leached from ore solids by ground water present in operating mines.

8. Procedures should be initiated to require Anaconda Company to improve its present efforts at stabilizing waste and ore piles at the Jackpile Mine in order to prevent water erosion from transporting uranium and selenium into Rio Paguate.

9. Procedures be initiated to require Kerr-McGee Nuclear Corporation to immediately install necessary treatment systems to reduce the dissolved radium-226 concentration in the Section 30W mine discharge to applicable NPDES permit conditions.

10. Procedures be initiated to require Kerr-McGee Nuclear Corporation to file an application for discharge from their Section 35 mine. The permit should provide limits on total suspended solids, radium-226 and uranium, consistent with the permit conditions for the Section 30W mine.

11. Procedures be initiated to require Kerr-McGee Nuclear Corporation to immediately install necessary treatment systems to ensure that effluent from their ion exchange plant meets applicable NPDES permit and State uranium-milling license conditions. The Company should develop operating schedules to guard against undetected uranium breakthrough and subsequent discharge of uranium to Arroyo del Puerto.

12. United Nuclear-Homestake Partners should install necessary pumps and pipe lines necessary to achieve complete recycle of ion exchange discharge. If unable to accomplish this, it will be necessary to apply for an NPDES permit, and immediately install necessary treatment facilities to come into compliance with the applicable State uranium-milling license.

ADDITIONAL STUDIES REQUIRED

1. Studies should be immediately initiated to verify whether the source of ground-water contamination in the Broadview Acres and Murray Acres subdivision is from the nearby uranium mill. A sound monitoring program should be developed to predict contaminant migration and to provide the basis for subsequent enforcement action. Necessary action should be taken to provide potable water for the affected area. Studies should be undertaken to determine the means to prevent continuing contamination.

2. With regard to the Anaconda waste injection program, all available chemical and water level data for pre-injection and post-injection periods should be evaluated to ascertain if waste is migrating out of the Yeso Formation and into overlying aquifers containing potable water. Of particular concern are radium-226 and thorium-230 because of their abundance in the injected fluid. Limited chemical data indicating migration of waste beyond the injection interval necessitate that a thorough re-evaluation be made of the long term adequacy of this method of waste disposal. Construction of additional monitoring wells in the Yeso Formation and the Glorieta-San Andres is in order. Because of low MPC values, this is particularly true if increasing concentrations of radium-226 and possibly lead-210 are appearing in the aquifers above the injection zone. The Anaconda Company should also evaluate the current loss of uranium resources to the subsurface through their current disposal technique.

3. Available chemical data for ground-water samples collected by Kerr-McGee from wells located adjacent to Arroyo del Puerto and San Mateo Creek should be evaluated for long-term trends in water quality. Data for the Wilcoxson (P. Harris), Bingham, Marquez, and County Line Stock Tanks wells are of principal concern.

4. Water-quality data from the newly completed monitoring wells peripheral to the Kerr-McGee mill should be cross-checked using non-industry laboratories to determine the extent of contamination in the Dakota Sandstone.

5. The breadth of mining and milling activities in the Grants Mineral Belt clearly requires additional study if ground-water impacts are to be understood in any detailed or quantitative sense. The present study provides a preliminary assessment of but a small facet of the overall activity in the district. Further study is recommended to determine impacts of past operations or expected impacts from mines and mills now in the planning or construction stage. Site specific investigations are necessary to determine the hydraulic and water quality responses to dewatering and solution mining.

6. Additional ground-water samples should be collected from wells adjacent to the Rio Puerco and east of Gallup to determine if radium concentrations are acceptably low and to establish baseline conditions for future reference. It is recommended that concentrations of trace metals should also be measured.

7. Resampling should be scheduled at the United Nuclear Corporation Churchrock mine during normal operations.

Action Taken

The study was designed so that immediate action could be taken when data obtained indicated such was needed. Therefore, in June 1975, the participants in the study met to review the results available at that time and take any action that was deemed necessary to protect the public health.

The following conclusions were drawn and action taken:

1. A review of the gross alpha and radium-226 analytical results indicated a possible problem involving drinking water at the United Nuclear Churchrock Mine and Kerr-McGee 35 and 36 Mines.

   ACTION: NMEIA contacted the company officials, indicated the data at hand, and requested that action be taken to remedy the situation.

2. The preliminary data suggested the possibility of high selenium concentrations in water used for drinking at the United Nuclear Churchrock Mine and trailer park; United Nuclear Churchrock office; Kerr-McGee Mill; and Kerr-McGee Section 35 and 36 Mines.

   ACTION: NMEIA notified the companies of the preliminary data and suggested using alternate sources of drinking water.

3. Possible problems with selenium concentrations were noted in samples from shallow ground water downgradient from the United Nuclear-Homestake Partners complex.

   ACTION: NMEIA notified the company and individual well owners of the data and suggested using an alternate source of drinking water. A meeting was held by NMEIA in the Grants area to discuss the problem with persons living in the area.

   Forty additional wells were sampled to better define the problem.

4. An analysis of the data indicated a possible violation of radium discharge limits by Kerr-McGee and United Nuclear-Homestake Partners Mills.

   ACTION: NMEIA is in the process of reviewing each license to determine compliance with license requirements.

5. Three NPDES permits have been issued in the Grants Mineral Belt: Kerr-McGee Churchrock; Kerr-McGee Ambrosia Lake and United Nuclear Churchrock. Kerr-McGee has asked for adjudicatory hearings on their two permits.

   ACTION: Region VI, EPA has issued notice of the hearings and will be holding the hearings as soon as possible. Violations of permit requirements at the United Nuclear Churchrock facility have been reported and appropriate enforcement action is underway.

Various follow-up actions will be taken by EPA and NMEIA to ensure that the recommendations as listed are carried out. The close working relationship that has been developed between the State and EPA will be continued to ensure that the surface and ground-water resources in the Grants Mineral Belt are fully protected.

Applicable Laws and Regulations

There are a number of Federal and State authorities which call for the regulation and control of water quality. Specifically the discharge of wastes to surface or ground waters from uranium mining and milling operations are subject to a number of regulations as follows:

New Mexico Water Quality Standards

The New Mexico Environmental Improvement Agency maintains that the State's general water quality standards that govern radioactive discharges applies to uranium milling and mining activity. This regulation sets a maximum concentration of 30 pCi/l of dissolved radium-226 in water.

National Pollutant Discharge Elimination System (NPDES) Permits

The Federal Water Pollution Control Act, as amended, provides that discharge of any pollutant by any person into navigable waters shall be unlawful except in compliance with various sections of the Act. EPA has consistently interpreted its authority over pollutants under this Act to include authority over radioactive materials not covered by the Atomic Energy Act of 1954, as amended, e.g., radium and accelerator produced isotopes. However, the Agency had determined that it did not have authority over radioactive materials within the NRC's jurisdiction; i.e., source materials - uranium, thorium, and other material designated as essential to the production of special nuclear material and their ores; special nuclear material - plutonium, enriched uranium, and other designated material capable of releasing substantial quantities of atomic energy; and by-product material - material yielded or made radioactive in the production or utilization of special nuclear material. This determination of limited EPA authority was overruled on December 9, 1974, by the U. S. Court of Appeals for the Tenth Circuit in the case of Colorado Public Interest Research Group v. Train. The Court found that all radioactive materials are pollutants under the Federal Water Pollution Control Act and subject to EPA's authorities under that Act. The U. S. Supreme Court has agreed to review this decision.

Uranium Milling Licenses

Title 10 C.F.R. Part 20 provides that all persons "who receive, process, use, or transfer.......source material" shall be controlled by general or specific licenses issued by the U. S. Atomic Energy Commission (succeeded by NRC), or any State conducting a licensing program. Under this regulation, all ion exchange plants and uranium mills are licensed by NMEIA.

Uranium Milling Licenses (Continued)

Mining activities, however, do not appear to be licensed by NMEIA but probably would be covered by the NPDES program.

Potable Water Requirements

Under the Safe Drinking Water Act, EPA has the authority to:

a. Propose and promulgate national primary and secondary drinking water regulations, including maximum contaminant levels covering radioactive materials.

b. Propose and promulgate regulations for State or Federal underground injection control programs, including requirements concerning underground injection of radioactive materials.

The State is primarily responsible for enforcement of the regulations.

The Act extended Federal control over many potable water supply systems. Previously only those systems used in interstate commerce were required to meet U. S. Public Health Service Drinking Water Standards. The latest issue of the USPHS standard sets a limit of 3 pCi/l for radium-226 and 0.01 mg/l for selenium.

The Safe Drinking Water Act applies to all public systems supplying water to fifteen service connections or at least 25 individuals unless the system is exempt under four specific criteria. The industrial potable water supply systems in the Grants Mineral Belt are covered by this Act. Proposed standards will call for 5 pCi/l for radium, 15 pCi/l gross alpha, and 0.01 mg/l selenium.

Section 1431 of the Act also provides that the Administrator, "upon receipt of information that a contaminant which is present in or is likely to enter a public water system may present an imminent and substantial endangerment to the health of persons, and that appropriate State and local authorities have not acted to protect the health of such persons, may take such actions as he may deem necessary in order to protect the health of such persons."

ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF ENFORCEMENT

IMPACTS OF URANIUM MINING AND MILLING ON SURFACE AND POTABLE WATERS IN THE GRANTS MINERAL BELT, NEW MEXICO

September 1975

NATIONAL ENFORCEMENT INVESTIGATIONS CENTER - Denver, Colorado
and
REGION VI - Dallas, Texas

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ABBREVIATIONS

AEC	Atomic Energy Commission
gpm	gallons per minute
kg	kilograms
km	kilometers
l/min	liters per minute
m^3/day	cubic meters per day
mg/l	milligrams per liter
NEIC	National Enforcement Investigations Center
NMEIA	New Mexico Environmental Improvement Agency
NRC	Nuclear Regulatory Commission
ORP-LVF	Office of Radiation Programs-Las Vegas Facility
pCi/l	picocuries per liter
RIP	resin in pulp (ion-exchange process)
USPHS	United States Public Health Service

I. INTRODUCTION

BACKGROUND

The United States experienced its first uranium "boom" in the early 1950's as a result of cold-war activities and the fabrication of large numbers of nuclear weapons. During that time, most of the currently-known uranium deposits were discovered by massive exploration by the U.S. government and private citizens. Many uranium mills were built at various sites throughout the west to treat the uranium ores to produce a uranium oxide called *yellow cake.*

This uranium milling was not without environmental damage. Among the first recognized water-pollution problems was in the Animas River Basin of Colorado and New Mexico. A mill at Durango, Colorado was contributing abnormally high concentrations of radium to the water supply of Aztec, New Mexico. To control radiochemical pollution resulting from uranium milling in this area, the Colorado River Basin Enforcement Conference was convened in 1960 by the states composing the Colorado River Basin. Federal, State, and industry cooperative efforts resulted in pollution control by which streams in the Colorado River Basin contained near background levels of pollutants resulting from uranium milling. Other uranium milling areas, most notably the Grants Mineral Belt, were not situated on interstate streams and thus not subject to Federal pollution control before the Federal Water Pollution Control Act Amendments were passed in 1972. Little pollution control effort was expended toward mine and mill discharges within this area.

The Grants Mineral Belt [Fig. 1], stretching west from just northwest of Albuquerque, New Mexico to the New Mexico-Arizona state line, contains almost half of the United States uranium reserves. A second uranium "boom" now underway promises to make the Grants Mineral Belt the

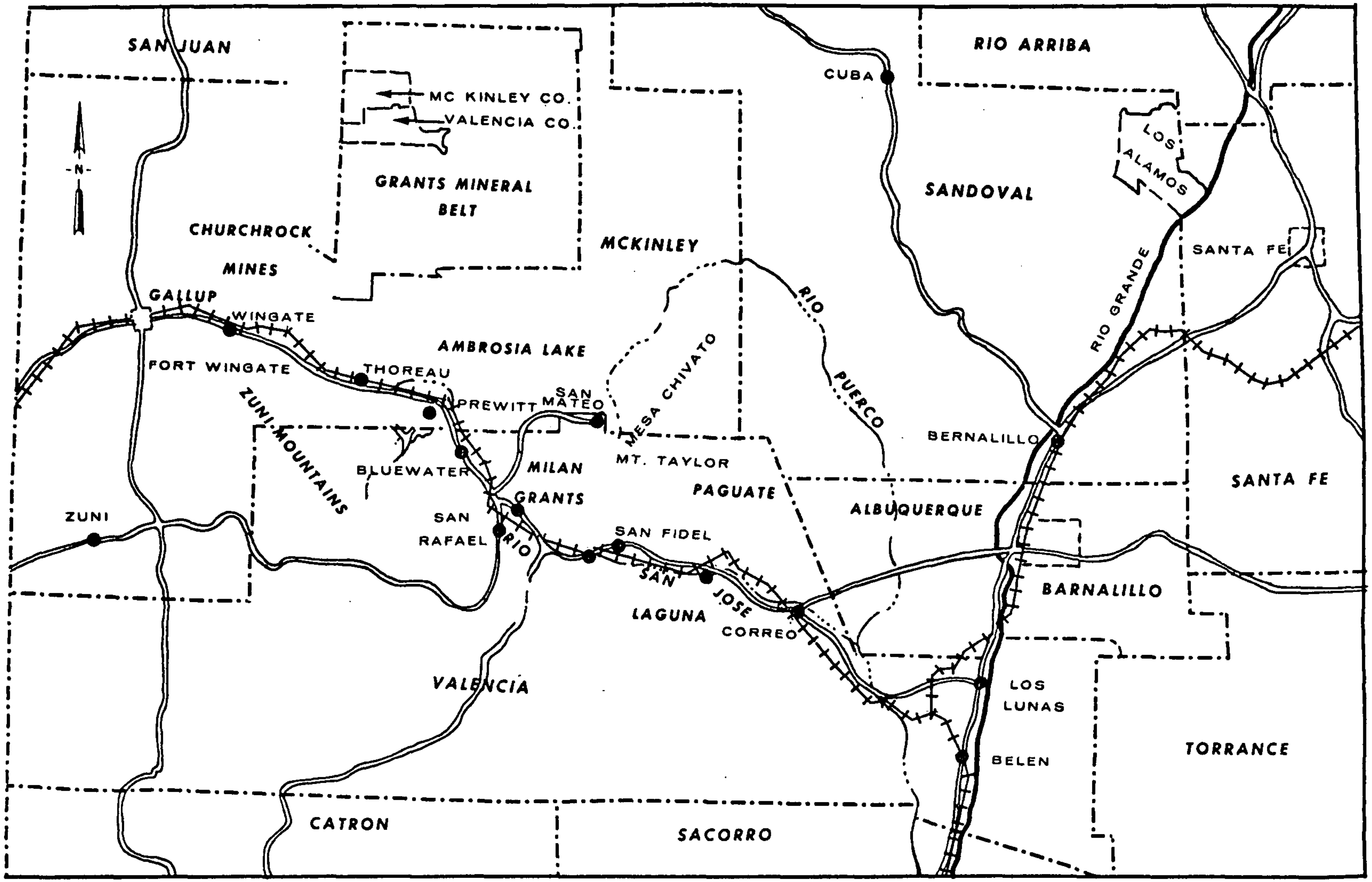

FIGURE 1. Location and General Features of the Grants Mineral Belt in Northwestern New MEXICO

foremost uranium mining and milling site in the United States. This "boom" results from the demand for nuclear fuel elements in nuclear power plants (Guccione, Aug. 1974).

1975 WATER QUALITY INVESTIGATION

The New Mexico Environmental Improvement Agency (NMEIA) realized that little information was available on the water discharges from mining and milling in the Grants Mineral Belt, and the subsequent effect on ground and surface water resources of the area. On September 25, 1974 NMEIA requested EPA Region VI to conduct a survey of water-pollution sources and surface and ground-water quality in the Grants Mineral Belt. The National Enforcement Investigations Center (NEIC) and the Office of Radiation Programs-Las Vegas Facility (ORP-LVF) were subsequently asked by Region VI to conduct a survey in cooperation with the NMEIA.

Studies conducted from February 24 to March 6, 1975 included industrial waste source evaluation, potable water sampling, and limited stream surveys by NEIC, and ground-water evaluations by ORP-LVF. NMEIA provided assistance to both NEIC and ORP-LVF during the survey. The three mining areas evaluated in the Grants Mineral Belt were [Fig. 1]:

Area	Approximate Location
Ambrosia Lake	32 km (20 mi) N of Milan, N. Mex.
Churchrock	32 km (20 mi) NE of Gallup, N. Mex.
Paguate	16 km (10 mi) N of Laguna, N. Mex.

The mill sites are:

Kerr-McGee	near Ambrosia Lake
United Nuclear-Homestake Partners	8 km (5 mi) N of Milan
Anaconda	11 km (7 mi) W of Milan

United Nuclear Corporation operates an ion-exchange plant in the old "Phillips" mill near Ambrosia Lake. No conventional milling is currently done at this site.

As stated in a February 14, 1975 letter from the Director of NMEIA, the primary tasks of the study were to:

1. Assess the impacts of waste discharges from uranium mining and milling on surface and ground waters of the Grants Mineral Belt.
2. Determine if discharges comply with all applicable regulations, standards, permits and licenses.
3. Evaluate the adequacy of company water quality monitoring networks, self-monitoring data, analytical procedures and reporting requirements.
4. Determine the composition of potable waters at uranium mines and mills.
5. Develop priorities for subsequent monitoring and other follow-up studies.

During the survey, samples were collected from wells, industrial discharges, drinking water supplies, and surface streams. The samples were appropriately preserved to determine the radiochemical, nutrient, and metals content and shipped to the NEIC and ORP-LVF laboratories for analyses (Appendix A). NEIC custody procedures were maintained during the collection and analyses of the samples (Appendix B).

This report presents the findings of analyses of surface water streams, potable water supplies, and industrial discharges. Appendix C contains raw data for all samples collected during the survey and analyzed by NEIC. The NEIC analysis, when combined with the ORP-LVF report, will present an overall study of water quality in the Grants Mineral Belt.

II. SUMMARY AND CONCLUSIONS

Task: *Assess the impacts of waste discharges from uranium mining and milling on surface and ground waters of the Grants Mineral Belt.*

1. Radium concentrations in Arroyo del Puerto, a perennial stream, exceed New Mexico Water Quality Criteria as a result of discharges from the Kerr-McGee ion-exchange plant and Sections 30W and 35 mines and from the United Nuclear-Homestake Partners ion-exchange plant. Selenium and vanadium concentrations exceed EPA 1972 Water Quality Criteria for use of the water for irrigation and livestock watering, and render the stream unfit for use as a domestic water source.

2. Rainfall and runoff at the Anaconda Jackpile Mine erode uranium- and selenium-rich minerals into Rio Paguate. This erosion can be mitigated by waste stabilization and runoff control.

Task: *Determine if discharges comply with all applicable regulations, standards, permits, and licenses.*

1. At the time of sampling, the effluent from the Kerr-McGee ion-exchange plant contained dissolved-radium 226 at concentrations in excess of the applicable NPDES permit and New Mexico uranium-milling license conditions. This radium discharge was partly responsible for violations of New Mexico Water Quality Standards for Arroyo del Puerto, a perennial stream. The discharge also contained uranium at concentrations in excess of NPDES permit criteria. No treatment other than settling is currently in operation.

2. The Kerr-McGee Section 30W mine discharge contained dissolved radium-226 at concentrations in excess of the applicable NPDES permit condition. No treatment other than settling is currently in operation. This radium discharge also was partly responsible for violation of New Mexico Water Quality Standards in Arroyo del Puerto.

3. Kerr-McGee Nuclear Corporation has not applied for a discharge permit for their Section 35 mine, although the effluent reaches Arroyo del Puerto, a perennial stream. The discharge contains an average of 51 pCi/l of dissolved radium-226. No radium-removal treatment is currently in operation.

4. Sampling at the United Nuclear Corportion Churchrock mine was conducted when the operation was inactive due to a power failure and subsequent mine flooding. Indications are that the present treatment facility is inadequate to meet existing NPDES permit conditions.

5. Approximatley 15 percent of the total flow through the United Nuclear-Homestake Partners ion-exchange plant is discharged to Arroyo del Puerto, with the balance of the flow returning to the mines for in situ leaching. The discharge to Arroyo del Puerto is not regulated by an NPDES permit, and it contributes to the violation of New Mexico Water Quality Standards for radium-226 in this perennial stream. Uranium is lost from the ion-exchange facility. The facility is currently violating conditions of the applicable State license.

Task: Determine the composition of potable waters at uranium mines and mills.

1. Four industry potable water supply systems, obtained from mine waters, exceeded 1962 U. S. Public Health Service Drinking

Water Standards for selenium. Three such potable systems exceeded both the existing USPHS and proposed EPA Interim Primary Drinking Water Standards for radium. Such mine water is supplied as potable to families of miners at the United Nuclear Corporation Churchrock mine. These conditions are considered intolerable as they bear on the long-term health of those using the supplies. Non-potable systems at the Kerr-McGee mill and Churchrock mine have high radium and selenium concentrations, and are not adequately marked as non-potable.

III. RECOMMENDATIONS

ACTION REQUIRED

1. Procedures be initiated to require United Nuclear Corporation to immediately provide potable water which meets Federal Drinking Water Standards for their Ambrosia Lake and Churchrock operations.

2. Procedures be initiated to require Kerr-McGee Nuclear Corporation to immediately provide potable water supplies which meet Federal Drinking Water Standards at their mill and Sections 35 and 36 mines; the mill and Churchrock mine non-potable water supplies be clearly marked.

3. NMEIA initiate appropriate action to insure safe industrial potable water supplies at the United Nuclear Corporation's Ambrosia Lake and Churchrock operations and at the Kerr-McGee Nuclear Corporation's mill and Section 35 and 36 mines.

4. NMEIA should conduct periodic sampling of potable water supplies at operating uranium mines and mills throughout the State.

5. Improved mining practices should be adopted to reduce the amount of radium leached from ore solids by ground water present in operating mines.

6. Procedures should be initiated to require Anaconda Company to improve its present efforts at stabilizing waste and ore piles at the Jackpile Mine in order to prevent water erosion from transporting uranium and selenium into Rio Paguate.

7. Procedures be initiated to require Kerr-McGee Nuclear Corporation to immediately install necessary treatment systems to reduce the dissolved radium-226 concentration in the Section 30W mine discharge to applicable NPDES permit conditions.

8. Procedures be initiated to require Kerr-McGee Nuclear Corporation to file an application for discharge from their Section 35 mine. The permit should provide limits on total suspended solids, radium-226 and uranium, consistent with the permit conditions for the Section 30W mine.

9. Procedures be initiated to require Kerr-McGee Nuclear Corporation to immediately install necessary treatment systems to ensure that effluent from their ion-exchange plant meet applicable NPDES permit and State uranium milling license conditions. The Company should develop operating schedules to guard against undetected uranium breakthrough and subsequent discharge of uranium to Arroyo del Puerto.

10. United Nuclear-Homestake Partners should install pumps and pipelines necessary to achieve complete recycle of ion-exchange discharge. If unable to achieve complete recycle, it will be necessary to issue an NPDES permit. The Company should immediately install necessary treatment facilities to comply with the applicable State uranium milling license.

ADDITIONAL STUDIES REQUIRED

Resampling should be scheduled at the United Nuclear Corporation Churchrock mine during periods of normal operation.

IV. DESCRIPTION OF STUDY AREA

LOCATION

The Grants Mineral Belt extends west from a point slightly northwest of Albuquerque, New Mexico, north of the towns of Grants and Gallup, almost to the New Mexico-Arizona state line [Fig. 1]. The Belt extends about 48 km (30 mi) north from the routes of U.S. 66 and the Atchison, Topeka and Santa Fe railroad. Some mining is conducted in Valencia County, but the bulk of the Grants Mineral Belt is in southern McKinley County.

The principal centers of population in the area are the towns of Grants and Gallup, and the villages of Churchrock, Wingate, Milan, and Laguna. Population in the area has increased rapidly since 1950, with the development of extensive uranium mining and milling operations.

With the exception of the volcanically formed Mt. Taylor area, most of the area is plateau topography underlain by sedimentary rocks. Streams have incised steep-walled valleys in the area, with broad valleys in those areas underlain by easily erodable sediments.

The eastern half of the Grants Mineral Belt, including the Ambrosia Lake district, is tributary to Rio San Jose. The western portion is in the valley of the Rio Puerco, a tributary to the Little Colorado River.

CLIMATE

The Grants Mineral Belt area is semi-arid to arid, with an average annual temperature of about 10°C (50°F). Maximum summer temperatures rarely exceed 38°C (100°F) with minimum temperatures occasionally below -18°C (0°F). The humidity in the area is usually low, and moderate to strong winds are common during the spring. Precipitation is largely influenced by elevation, with a positive correlation between increasing elevation and increasing precipitation. Annual average precipitation at the Grants Airport is 21 cm (8.3 in), approximately 70% of which occurs May through September.

INDUSTRY

Industry in the Grants Mineral Belt used to be largely centered around farming and ranching, with limited tourism. Since 1950, the economic base of the Grants Mineral Belt area has completely shifted to industry, based on the mining and milling of uranium ore to produce yellow cake.

Underground mining operations in the Grants Mineral Belt are by the room and pillar method, which consists of driving a number of parallel development drifts in the ore horizon. A series of parallel sluicer drifts are driven at right angles, leaving a grid of ore pillars to support the overlying rock, or "roof." As the pillars are mined (robbed), the roof is rock-bolted and supported by timbers as necessary to prevent subsidence. The mined area (stope) is then abandoned.

The ore horizon in underground mines in the Grants Mineral Belt is composed of the Westwater Canyon member of the Jurassic Morrison formation, which is the main aquifer of the Grants Mineral Belt area. Therefore, large quantities of ground water must be pumped from each mine to prevent mine flooding. Ore bodies are dewatered by drilling "long holes" from the development drifts into the ore horizon, and permitting ground water to flow from the long holes into the drifts and then be pumped to the surface for discharge. Water flow is by gravity to sumps near the mine shaft, with positive pumpage to the surface. This water passes through settling basins at each mine to remove solids and then is either pumped to an ion-exchange plant for removal of contained uranium, or is discharged directly to surface water courses. Some of the ion-exchange water is recycled to the mines for use in solution mining or is used as a potable water supply for workers in the mines and mills.

Where the physical and economic situations permit, most mining companies now collect underground mine water in a single location for ion-exchange treatment to recover uranium which is dissolved in the mine water. Recovery is accomplished by using specific resins which are extremely selective in the removal of dissolved uranium. The mine water is passed through the resin column where the resin becomes *loaded* until it reaches its capacity for uranium (*breakthrough*). Flow is then diverted to another barren resin column and the loaded resin is *stripped* or eluted with a sodium chloride brine. The pregnant sodium chloride brine is then treated in one of the uranium mills to precipitate yellow cake. The barren solution is returned and reused for subsequent elution steps.

Experience has shown that a carefully operated ion-exchange plant will yield an effluent containing less than 1 mg/l uranium in solution (USEPA, April 1975). The greatest operating difficulty has been in monitoring for breakthrough of the uranium, or the loading of ion-exchange resins. Both United Nuclear Corporation and United Nuclear-Homestake Partners return a portion of the ion-exchange effluent, or *tailings*, to abandoned mines in the Ambrosia Lake area. This barren water is used to leach the ore which remained behind in ore pillars and rock which was not of ore grade. By this practice, uranium resources are recovered which would otherwise be lost.

The Anaconda Company operates its Jackpile-Paguate mine mostly as an open-pit operation. From 1953 to the present, the operation has yielded approximately 10 million tons of uranium ore with an average grade of 0.25% uranium oxide (Graves, Aug. 1974). Mining is accomplished with power shovels loading off-highway trucks. Ore is transported from the mine to Anaconda's mill by rail.

No surface discharge of water is reported from the Jackpile mine. Rainfall collects in pits and seeps or evaporates. However, intense summer thunderstorms erode piles of waste and ore.

Three uranium mills are currently operating in the Grants Mineral Belt, and several other mills are in the design or construction phase. The three operating mills practice different techniques for uranium recovery. All three operate on the basis of zero discharge of waste to surface waters by utilizing evaporation, seepage and, in one case, subsurface injection. To solubilize the uranium, two of the mills acid leach the ore while the third uses an alkaline leach circuit. Uranium is concentrated by solvent extraction at two of the mills. In all three mills, uranium is precipitated as yellow cake, a complex uranium oxide. Ammonia is used in precipitating or purifying the yellow cake at all three mills. Details on milling techniques at the three facilities are provided in the August 1974 issue of *Mining Engineering* (Vol. 26, no. 8).

V. REGULATIONS

The discharge of wastes to surface or ground waters from uranium mining and milling operations are subject to a number of regulations. Applicable portions of each regulation are discussed below.

NEW MEXICO WATER QUALITY STANDARDS

Water Quality Standards were adopted by the New Mexico Water Quality Control Commission under the authority of Paragraph C, Section 75-39-4 of the New Mexico Water Quality Act (Chapter 326, Laws of 1973, as amended). The NMEIA has held that general standards do apply to receiving waters in the Grants Mineral Belt. The general standard that governs these radioactive discharges follows:

> Radioactivity - The radioactivity of surface waters shall be maintained at the lowest practical level and shall in no case exceed the standards set forth in Part 4 of New Mexico Environmental Inprovement Board Radiation Protection Regulations, adopted June 16, 1973.

These regulations set a maximum concentration of 30 pCi/1 of dissolved radium-226.

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES) PERMITS

Congress, with the passage of the *Federal Water Pollution Control Act Amendments of 1972* (PL92-500, Oct. 18, 1972) established the requirement for NPDES permits for discharge of pollutants to waters of the United States. Discharge of pollutants without a valid NPDES permit is illegal.

To date, three permits have been written covering four sources in the area studied.

Permit No.	Outfall No.	Source
NM0020532	001	Kerr-McGee Nuclear Corp. Sec. 30W Mine
NM0020532	002	Kerr-McGee Nuclear Corp. Ion Exchange Facility
NM0020524	001	Kerr-McGee Nuclear Corp. Churchrock Mine
NM0020401	001	United Nuclear Corp. Churchrock Mine

The first three sources are currently pending adjudication with respect to the need for an NPDES permit to discharge to Puertecito Creek or Rio Puerco.

Specific numerical limits are set for the concentration of total suspended solids (TSS), total uranium, and dissolved radium-226 [Table 1]. In addition, each permit contains the following statement: ,

> Provision shall be made to assure the elimination of all seepage, overflow or other sources which may result in any direct or indirect discharge to surface waters other than that authorized by this permit.

URANIUM-MILLING LICENSES

U.S. Regulation 10CFR20 provides that all persons "who receive, possess, use or transfer ... source material" shall be controlled by general or specific license issued by the U.S. Atomic Energy Commission (now called the Nuclear Regulatory Commission) or any state conducting a licensing program. Source materials are defined as ores which contain more than 0.05% of combined uranium and thorium. Under the regulation, all ion-exchange plants and uranium mills are licensed by the New Mexico Environmental Improvement Agency.

The regulations set forth the maximum concentration of various radionuclides which are permitted in effluents to "unrestricted areas." An unrestricted area is defined as any area to which access is not

Table 1

SUMMARY OF NPDES PERMIT CRITERIA

Company/Discharge	Period of Limitation	Parameter[†] TSS (mg/l) Daily Avg.	TSS (mg/l) Daily Max.	Total Uranium (mg/l) Daily Avg.	Total Uranium (mg/l) Daily Max.	Dissolved Radium-226 (pCi/l) Daily Avg.	Dissolved Radium-226 (pCi/l) Daily Max.	pH Range
Kerr-McGee Corporation								
Churchrock Mine	1/28/75-6/30/77	20	30	-	2	-	30	6.0-9.5
	7/1/77-1/27/80	20	30	-	2	-	3.3	6.0-9.0
Section 30W Mine (Ambrosia Lake)	1/28/75-12/31/75	20	30	-	2	-	150	6.0-9.0
	1/1/76-6/30/77	20	30	-	2	-	30	6.0-9.0
	7/1/77-1/27/80	20	30	-	2	-	3.3	6.0-9.0
Ion-Exchange Plant (Ambrosia Lake)	1/28/75-12/31/75	20	30	-	1	-	100	6.0-9.0
	1/1/76-6/30/77	20	30	-	1	-	30	6.0-9.0
	7/1/77-1/27/80	20	30	-	1	-	3.3	6.0-9.0
United Nuclear Corporation								
Churchrock Mine	1/28/75-12/31/75	100	200	-	2	-	30	6.0-9.5
	1/1/76-6/30/77	20	30	-	2	-	30	6.0-9.5
	7/1/77-1/27/80	20	30	-	2	-	3.3	6.0-9.0

† *In addition to these parameters, the companies are required to monitor flow, temperature, total molybdenum, total selenium and total vanadium.*

controlled by the licensee to protect individuals from exposure to radiation and radioactive materials. Personnel badge monitoring is not required in unrestricted areas. The maximum allowable concentration of radium-226 in a water effluent to an unrestricted area is 30 pCi/l. All uranium mills and ion-exchange plants are controlled by this regulation from the initial start-up of the facility.

POTABLE WATER REQUIREMENTS

Congress, with the passage of the *Safe Drinking Water Act* (PL93-523, Dec. 16, 1974) extended Federal control over many potable water supply systems. Previously, only those systems used in interstate commerce were required to meet USPHS Drinking Water Standards. The latest issue of the USPHS Standards set a limit of 3 pCi/l for radium-226, and 0.01 mg/l for selenium.

The Safe Drinking Water Act applies to all public systems supplying water to fifteen service connections or at least 25 individuals unless the system is exempted by four specific criteria. The industrial potable water supply systems in the Grants Mineral Belt are thus covered by the Safe Drinking Water Act.

As required by Sections 1412, 1414, 1415, and 1450 of the Safe Drinking Water Act, the EPA Administrator, on March 14, 1975, proposed *Interim Primary Drinking Water Standards*. These proposed regulations include a limit of 0.01 mg/l selenium. The Interim Primary Drinking Water Standards are to be promulgated within 180 days of the enactment of the Act, and they become effective 18 months after their promulgation, or Dec. 1977. The EPA has proposed standards of 5 pCi/l radium (226 and 228) and 15 pCi/l gross alpha (exclusive of uranium) under the Act (Appendix D quotes the *EPA Water Quality Criteria, 1972* on selenium).

The New Mexico Environmental Improvement Agency (Sections 4 and 12, Chapter 277, New Mexico Laws of 1971) is vested with authority to maintain, administer, and enforce the "Regulations Governing Water Supplies and Sewage Disposal" adopted in 1937 by the former New Mexico State Board of Public Health.

Section 1 of the aforementioned 1937 Water Supply Regulations states:

> No person, firm, corporation, public utility, city, town, village or other public body or institution shall furnish or supply or continue to furnish or supply water used or intended to be used for human consumption or for domestic uses or purposes, which is impure, unwholesome, unpotable, polluted or dangerous to health, to any person in any county, city, village, district, community, hotel, temporary or permanent resort, institution or industrial camp.

It is from this and other sections of the 1937 regulations that the NMEIA has authority to regulate public water supply systems. However, individual residential sources used for private consumption are not covered by the 1937 regulations. Therefore, the NMEIA can only advise as to the quality of the water in the case of such residential sources.

NUISANCE SUITS

New Mexico is given specific authority to take enforcement action against a polluter under the Nuisance statute (40A-8-1 through 40A-8-10, 1953 Compilation). A section titled Polluting Water (40A-8-2) allows the New Mexico Environmental Improvement Agency to seek remedial action against any wastewater discharger that pollutes any water of the state whether it is public or private, surface or subsurface water. In 1973 the NMEIA successfully prosecuted the City of Hobbs for polluting ground water by land disposal of the city's sewage effluent. The court order required the City to remove the polluted water and supply potable water to affected parties.

VI. WASTE SOURCE EVALUATION

Five companies are currently engaged in mining and/or milling operations in the Grants Mineral Belt, and several other companies are presently in design or construction phases. The results of waste-source evaluations at each of the operating companies are presented below.

KERR-MCGEE NUCLEAR CORPORATION

Kerr-McGee operates mines in both the Ambrosia Lake and Churchrock Mining Districts of the Grants Mineral Belt. Water from five of the Ambrosia Lake mines (Sections 17, 22, 24, 30 and 33)* is pumped to an ion-exchange plant at the Kerr-McGee mill [Fig. 2]. The majority of ion-exchange discharge (also referred to in the mining industry as tailings) is used in the mill as process water and non-potable water. A small remainder receives additional ion-exchange treatment for potable water use within the mill. Excess ion-exchange tailings are discharged into Arroyo del Puerto. The NPDES permit** and State uranium milling license for this discharge requires that the radium 226 concentration not exceed 100 pCi/l and 30 pCi/l, respectively. The data [Table 2] shows that this discharge contained an average of 151 pCi/l radium-226 during the survey. This exceeds both the NPDES permit immediate limitations and the State license. This latter license has been in effect since the time of the construction of the ion-exchange plant. The

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* *The names of mines are based on the section in which they are located; all of these are in T14N, R9W, McKinley County, New Mexico.*

** *Kerr-McGee has requested an adjudicatory hearing on its permits for the ion-exchange plant and Section 30W mine. The company contends that an NPDES permit is not required to discharge to Arroyo del Puerto. The Kerr-McGee State license is effective for the Kerr-McGee ion-exchange plant.*

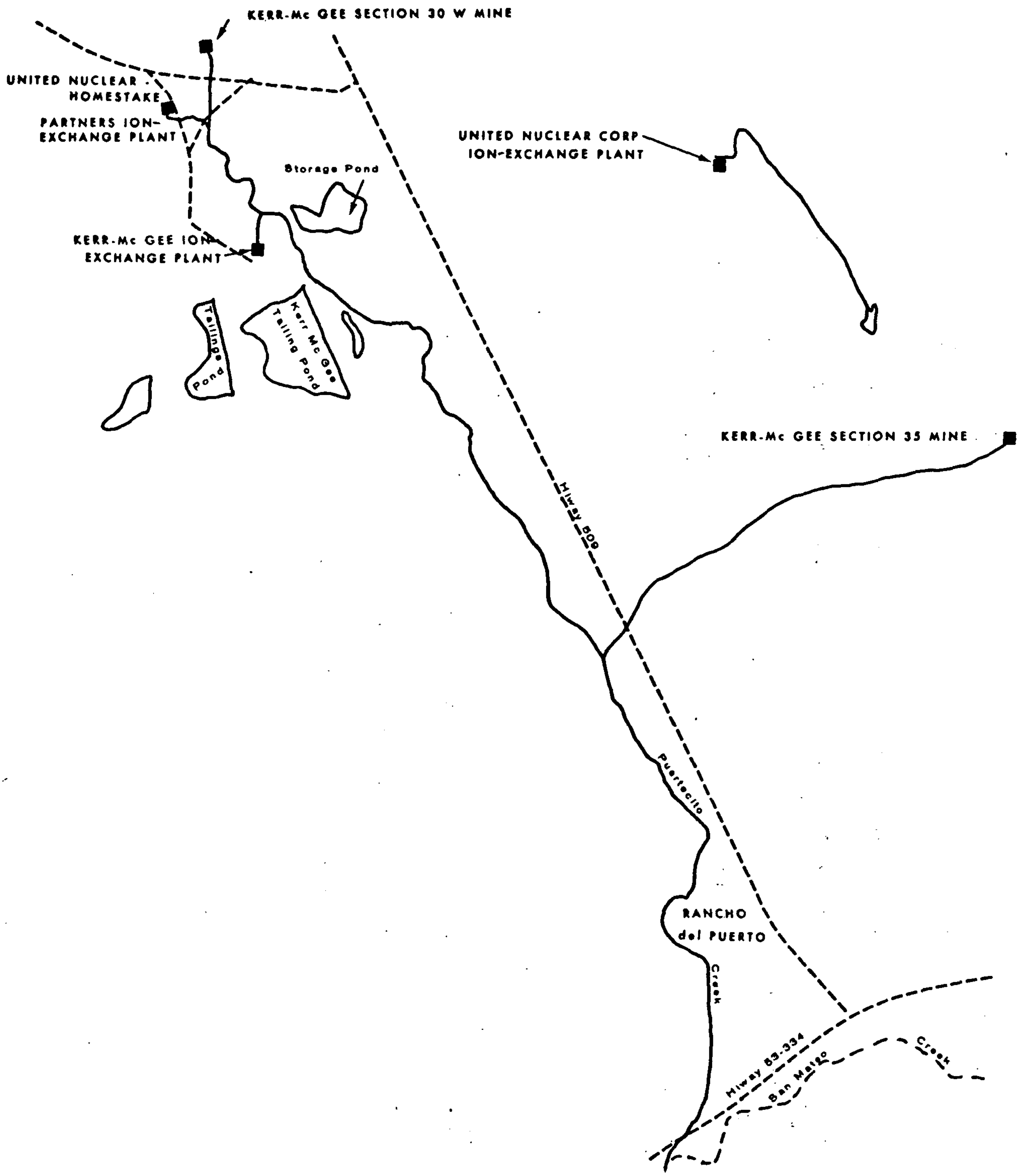

Figure 2. Ambrosia Lake Mining District Surface Water Discharges

Table 2

SUMMARY OF ANALYTICAL DATA FOR INDUSTRIAL DISCHARGES
GRANTS MINERAL BELT SURVEY
February 26-March 6, 1975

Station Description	Average Flow (mgd)	Number Composite Samples	Gross Alpha (pCi/l)			Radium 226 (pCi/l)			Uranium (mg/l)			Total Suspended Solids (mg/l)			Selenium (mg/l)			Vanadium (mg/l)		
			Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
Kerr-McGee I-X Tailings Bypass	0.64	3	600	430	510	157	148	151	4.2	1.3	2.5	31	16	25	0.07	0.03	0.05	1.0	0.7	0.9
Kerr-McGee Sec 30W Mine Dischg	1.36	3	1,400	1,300	1,400	174	154	163	6.7	5.9	6.2	26	17	22	0.04	0.03	0.03	0.8	0.7	0.7
Kerr-McGee Sec 19 Mine Discharge	0.15	1	--	--	72	-	-	9.3	-	-	0.23	-	-	16	-	-	<0.01	-	-	0.6
Kerr-McGee Sec 35 Mine Discharge	3.77	3	3,000	2,400	2,700	68	32	51	26	14	19	120	86	100	0.08	0.04	0.07	1.0	0.6	0.8
Kerr-McGee Sec 36 Mine West Discharge	2.07	3	850	570	680	178	101	131	3.4	2.6	3.0	44	33	38	0.01	<0.01	<0.01	1.0	0.8	0.9
Kerr-McGee Sec 36 Mine East Discharge	0.14	3	580	510	560	72	59	65	2.5	2.3	2.4	32	27	29	0.03	<0.01	0.01	0.8	0.4	0.6
Kerr-McGee Seepage below Tailings Pond	-	1	-	-	144,000	-	-	65	-	-	160	-	-	38	-	-	0.70	-	-	5.6
Ranchers Exploration-Johnny M Mine Discharge	0.46	1	-	-	20	-	-	1.6	-	-	0.12	-	-	7	-	-	<0.01	-	-	<0.3
United Nuclear Corp. Ion-Exchange Discharge	0.08	3	2,300	1,400	1,800	39	14.3	31	11	5.9	7.8	7	3	5	0.12	0.02	0.08	0.5	<0.3	0.3
United Nuclear-Homestake Partners Ion Exchange Discharge	0.60	3	970	760	830	111	101	108	5.8	2.3	3.7	16	7	10	0.33	0.30	0.32	0.5	<0.3	0.3
United Nuclear-Homestake Partners Tailings Pile Decant		1	-	-	29,000	-	-	52	-	-	150	-	-	5	-	-	0.92	-	-	6.8
Anaconda Co. Injection Well Feed	0.16	1	-	-	62,500	-	-	53	-	-	130	-	-	3	-	-	0.03	-	-	6.3
United Nuclear Corp. Churchrock Mine Discharge	2.06	3	870	730	810	27.3	19.8	23.3	7.6	6.5	7.2	71	33	50	0.06	<0.01	0.04	0.5	0.4	0.4
Kerr-McGee Churchrock Mine Discharge	2.18	3	240	210	230	8.7	6.8	7.9	0.97	0.72	0.81	58	38	47	0.01	0.01	0.01	0.9	0.7	0.8

concentration of radium in the ion-exchange discharge could be reduced to meet permit conditions with the relatively simple addition of barium chloride. The New Mexico Water Quality Standards for Arroyo del Puerto, a perennial stream, limits radium concentrations to a maximum of 30 pCi/l. The Kerr-McGee ion-exchange discharge to Arroyo del Puerto contributes to violations of these standards (see Section VII. *STREAM SURVEYS*).

The NPDES permit for the Kerr-McGee ion-exchange discharge limits uranium to a daily maximum concentration of 1 mg/l. During the three days of composite sampling, the uranium concentration in the discharge ranged from 1.3 to 4.2 mg/l for an average of 2.5 mg/l, or 2.5 times the permitted maximum concentration. This violation of the permitted level probably resulted from overloading of the resin and failure to switch resin columns. The Company should adopt a regeneration cycle that will prevent resin saturation by uranium (breakthrough) which results in permit violation.

Selenium is an extremely toxic substance which behaves very similarly to arsenic. It is present in the ore of the Grants Mineral Belt, and thus it could reasonably be expected to be present in water from processing plants. The Kerr-McGee ion-exchange tailings contained from 0.03 to 0.07 mg/l, an average of 0.05 mg/l. These tailings also contained almost 1 mg/l vanadium, which has been shown to be toxic to plants when present in irrigation water. The high selenium and vanadium concentration precludes the use of Arroyo del Puerto for irrigation (discussed in Section VII).

Mine water from other Kerr-McGee Ambrosia Lake mines (Sections 19, 30W, 35, and 36) does not receive ion-exchange treatment. Section 19 Mine, currently under development, discharges approximately 378 l/min (100 gpm) of wastewater which contains 9.3 pCi/l of radium on the land surface. Since this discharge does not reach a surface water course, the Company has not applied for an NPDES permit.

The NPDES permit for the Kerr-McGee Section 30W mine imposes immediate limits on the radium-226 content of this discharge. The initial maximum limit is 150 pCi/l, with a final limit of 3.3 pCi/l [Table 1]. During the survey, this discharge contained an average concentration of 163 pCi/l of radium-226 [Table 2] which exceeds permit conditions. The discharge enters Arroyo del Puerto upstream of the Kerr-McGee ion-exchange discharge and contributes to the water quality standards violation in Arroyo del Puerto (see Section VII). The 30W discharge also contained selenium and vanadium [Table 2] and contributes to the high concentration of these elements in Arroyo del Puerto.

The uranium concentration of Section 30W mine discharge is limited to 2 mg/l daily maximum by the NPDES permit. During the survey, the uranium concentration of this discharge ranged from 5.9 to 6.7 mg/l, for an average of 6.2 mg/l, a violation of the NPDES permit conditions. The company reportedly plans to pipe this discharge to their ion-exchange plant.

During the Grants Mineral Belt survey, 14,300 m^3/day (3.77 mgd) of water was discharged from Kerr-McGee Section 35 mine settling ponds into a marshy area south of the mine. Company officials claim this discharge does not reach any surface water and therefore an NPDES discharge permit is not required. Visual observations by NEIC personnel showed that this discharge, estimated at several hundred gallons per minute, does enter Arroyo del Puerto. The flow rate was highly variable, depending on climatic conditions. The radium concentration in this wastewater ranged from 32 to 69 (average 51) pCi/l which exceeds limitations currently specified in permits for similar discharges. The radium concentrations can be reduced to less than 30 pCi/l with the addition of a barium chloride treatment system. Gross alpha concentrations were high, ranging from 2,400 to 3,000 pCi/l. ORP-LVF conducted analyses for the alpha emitters other than radium contained in this discharge. The analyses indicated that lead-210 may be significant in this and other discharges; however, the data are not available at this time. Uranium, selenium, and vanadium are also present in this discharge [Table 2] and contribute to high values in Arroyo del Puerto. Suspended solids in the Section 35 mine discharge were high, ranging from 86 to 120 mg/l with an average of 100 mg/l. Analysis of incoming mine water from long holes within the area indicates that the radium concentrations in natural ground water are less than 10 pCi/l. However, water moves over the entire floor of the drift, and it is subject to agitation by passage of haulage trains and during mucking. Accordingly, the suspended solids concentration in the mine water is high, producing a high dissolved radium concentration. The suspended solids and radium concentrations in the effluent could be greatly lowered by improved housekeeping in the mining operations, such as providing drainage channels along the sides of the mine workings.

Section 36 mine has two discharges, identified as the east and west discharges in relation to the mine shaft. Samples from each discharge were collected and analyzed. Except for a minor amount of water used by drilling rigs in the area, the entire mine pumpage receives treatment in sedimentation basins before discharge into a large closed basin over the San Mateo fault. During the survey, all the water was sinking into the subsurface and moving as ground water. Survey results [Table 2] show the west discharge contained an average of 131 pCi/l radium-226 compared to 65 pCi/l in the east discharge. These concentrations exceed license criteria (10 CFR20) for discharge to an unrestricted environment. The discharge also contained from 0.4 to 1.0 mg/l vanadium, which precludes use of this water for crop irrigation on acid soils, or long-term use on any soil (Committee on Water Quality Criteria, 1972).

Company officials stated that the Section 35 and 36 mine discharges will be diverted to a new set of treatment ponds for biological removal of radium 226, utilizing algal growth and radium incorporation. If necessary, radium-226 concentrations can be further reduced by barium chloride treatment. These new ponds, to be constructed sometime during 1975, will discharge into the closed basin currently receiving the Section 36 mine discharge. The increased flow into this closed basin may result in a surface discharge to San Mateo Creek. In this case, an NPDES permit will be required which should specify an immediate radium-226 limit of 30 pCi/l.

Kerr-McGee Nuclear Corporation is developing a new mine in the Churchrock mining district. The mine water receives treatment in two sedimentation ponds. Some of the effluent from the pond is used in the mine change-house for non-potable uses such as showers and commodes, and the remainder is discharged into Rio Puerco. The immediate NPDES permit limitations for this discharge include 100 mg/l daily average and 200 mg/l daily maximum total suspended solids concentration, 2 mg/l daily maximum uranium concentration and 30 pCi/l dissolved radium-226. The lack of ongoing mining activities in the mine is reflected in the relatively low radiochemical concentration in the water from this mine [Table 2], with an average radium-226 concentration of 7.9 pCi/l.

The Kerr-McGee Nuclear Corporation mill near Ambrosia Lake removes uranium from the ore by an acid leach technique, followed by solvent extraction to concentrate the uranium, and by ammonia precipitation of yellow cake. A molybdenum byproduct recovery is also practiced at the Kerr-McGee mill. Approximately 75% of the mill water is recycled, while the other 25% is lost through seepage and evaporation. Because of dissolved solids buildup, it is thought to be impossible to practice 100% recycle without dissolved solids removal techniques. Process water for the Kerr-McGee mill is obtained from the Kerr-McGee ion-exchange treatment plant. Tailings are discharged to a single large tailings pond on the company property. Seepage from the pond is collected in a catchment basin and is then pumped to a pond upgradient from the tailings pond. Overflow from this pond is pumped upstream to another pond.

In this way, all seepage from the evaporating ponds should be captured by the catchment basin. However, physical inspection of the area indicated that a quantity of seepage is lost to the subsurface, with a portion of the seepage possibly appearing in the flow in Arroyo del Puerto. This will require control under proposed NMEIA ground-water regulations, or regulations to be proposed under the U.S. Safe Drinking Water Act.

An 8-hr composite was collected from the catchment basin and analyzed to determine the quality of waste which might enter the ground water. The sample contained 144,000 pCi/l and 65 pCi/l, respectively, of gross alpha and radium-226. The radium concentration exceeds the AEC license criteria (30 pCi/l) for discharge to a nonrestricted environment. The gross imbalance which exists between gross alpha and radium indicates high concentrations of other alpha emitters. Identification and quantification of these emitters, and the effect on ground water, is discussed in the report by ORP-LVF. This water is extremely high in sulfate (15,000 mg/l) due to the use of sulphuric acid for leaching the Kerr-McGee ore. Suspended solids concentration in the seepage was approximately 38 mg/l. Selenium was present in 0.70 mg/l concentration, or 70 times the drinking water standard. Vanadium was present in the seepage at a concentration of 5.6 mg/l.

RANCHERS EXPLORATION AND DEVELOPMENT CORPORATION

Ranchers Exploration is currently developing the Johnny M. mine. Mine water is treated in two settling ponds before being discharged into San Mateo Creek. An NPDES permit application was filed by Ranchers Exploration, however the permit had not been issued at the time of the survey. The data [Table 2] show that the gross alpha and radium-226 concentrations were 20 and 1.6 pCi/l, respectively. This reflects the lack of ongoing mining activities in the operation. Uranium concentration in the water was 0.12 mg/l, while the suspended solids concentration was 7 mg/l.

UNITED NUCLEAR CORPORATION

United Nuclear Corporaton has three mines (two active and one on standby) in the Ambrosia Lake area. All mine water is pumped to an ion-exchange plant for uranium recovery. Over 99% of the ion-exchange effluent is used for solution mining. The remainder is either used as potable water or is discharged into a holding pond for use in sand backfill operations. There was no discharge from the pond at the time of the survey. Although an application has been filed, company officials stated that wastewater does not reach Arroyo del Puerto; therefore an NPDES permit is not required.

Samples were collected from the ion-exchange effluent at a point ahead of its return to the underground mines. The ion-exchange effluent contained an average of 31 pCi/l radium-226 and 1,800 pCi/l of gross alpha. Suspended solids concentration in the ion-exchange discharge were from 3 to 7 mg/l. As shown in Table 2, selenium concentration ranged from 0.02 to 0.12 mg/l, for an average of 0.08 mg/l.

United Nuclear Corporation also operates an underground mine in the Churchrock mining district. The NPDES permit limits the radium-226 concentration to a maximum of 30 pCi/l. Other NPDES permit criteria include 100 mg/l of suspended solids daily average, 200 mg/l suspended solids daily maximum, and 2 mg/l uranium daily maximum. A power failure at the mine during the last week in February resulted in flooding of work areas. During the survey, company personnel were pumping out the mine and repairing underground equipment. Composite samples collected during the clean-up operations contained an average radium-226 concentration of 23.3 pCi/l. After the survey, NMEIA personnel collected a grab sample on 14 March 1975 following the resumption of mining activities. This sample contained 57 pCi/l of radium-226 which exceeds the permit limitation. The composite samples contained from 33 to 71 mg/l suspended solids concentration, while the later grab sample contained 320 mg/l suspended solids. Uranium was present in the discharge at an average concentration of 7.2 mg/l. Additional sampling is suggested to check for NPDES compliance, once the mine returns to typical operation.

UNITED NUCLEAR-HOMESTAKE PARTNERS

The United Nuclear-Homestake Partners joint venture operates four underground mines (Sections 15, 23, 25 and 32) in the Ambrosia Lake mining district. Uranium in the mine water is removed in an ion-exchange plant. About 85% of the effluent is recycled through the mines and used for in situ leaching (solution mining). The remaining 15% (0.08 mgd) of the ion-exchange effluent is discharged into Arroyo del Puerto upstream of the Kerr-McGee mill. An NPDES application has recently been filed for this discharge. During this survey, the radium-226 concentration in this discharge exceeded 100 pCi/l. The radium-226 concentration in this discharge can be reduced to 30 pCi/l or less with the addition of a barium chloride treatment system. These high concentrations exceed the NPDES permit issued for similar discharges and the State uranium milling license currently in effect for this facility. This discharge contributes to the violation of the New Mexico Water Quality Standards for Arroyo del Puerto (see Section VII).

Suspended solids concentration in the United Nuclear-Homestake Partners ion-exchange discharge are low, ranging from 7 to 10 mg/l. Selenium concentrations range from 0.30 to 0.33 mg/l, more than 30 times the drinking water standard for selenium. These concentrations would pose a health hazard if the water were used for a potable supply.

The presence of a large supply of clear water suggests an attractive alternative to plant personnel bringing their own drinking water to the plant. Uranium concentrations averaged 3.7 mg/l, indicating a need for closer monitoring of resin loading, or more frequent resin regeneration.

The United Nuclear-Homestake Partners Uranium mill recovers uranium by alkaline leaching of the ore, followed by ammonia precipitation of yellow cake. No ion-exchange or solvent extraction is practiced. Tailings-pile decant water is recycled through the mill. Seepage from the pile also enters ground water as determined by visual observation and ORP-LVF sampling. A sample of the decant, which is indicative of the quality of the seepage, contained 29,000 pCi/l and 52 pCi/l, respectively, of gross alpha and radium-226. The radium concentrations exceed the 10CFR20 criteria for discharge to a nonrestricted environment. The seepage also was found to contain 0.92 mg/l of selenium, or 92 times the drinking water standard. This is indicative of the geochemistry of selenium, which is found to be highly mobile in alkaline solutions. Results of the seepage on ground water are discussed in the ORP-LVF report.

Additional samples have been collected from a number of wells in the area downgradient from the United Nuclear-Homestake Partners tailings pond and are currently undergoing analyses. Problems of interlaboratory agreement are being resolved by appropriate Analytical Quality Control (AQC) programs. AQC data for the NEIC determinations are included in Appendix A. Results to date indicate that alkaline leaching of uranium milling tailings or uranium ore produces water high in a mobile form of selenium, and it presents definite problems of groundwater pollution. Seepage control measures should be required at this facility. Additional laboratory analysis of existing samples, and additional sampling to define the extent of the problem are planned for the near future.

ANACONDA COMPANY

The Anaconda Company operates the world's largest open pit uranium mine, the Jackpile Mine on the Laguna Indian Reservation. There is no discharge of mine water to Rio Paguate or Rio Maquino. Precipitation runoff from the disturbed land surface, however, adds radiochemical-bearing solids to these streams. Stream samples [Table 3] show a definite increase in radium-226 and selenium concentrations downstream from the mining operation. The data show the need for stabilization of waste material and improved handling of storm runoff.

The Anaconda Company uranium mill at Bluewater uses a Resin In Pulp (RIP) ion-exchange process on an acid leach operation (Anon, Aug. 1974). In this circuit, baskets of ion-exchange beads are agitated in a crushed slurry ore. The beads, when loaded, are eluted with a dilute solution of sulfuric acid and sodium chloride. Uranium is precipitated in two steps, with the addition of calcium hydroxide during the first step and magnesium hydroxide during the second step. This precipitate is then washed with ammonium sulfate to remove sodium and produce a saleable yellow cake.

Process wastes from the Anaconda mill are discharged into a 70-acre tailings pond constructed on a highly permeable basalt flow. The water which does not seep from this pond is decanted, filtered to remove suspended solids, and fed at a rate of 1,100 l/min (300 gpm) to an injection well. A sample of the well feed, which is indicative of the seepage to the ground water, contained 62,500 pCi/l and 53 pCi/l, respectively, of gross alpha and radium-226 [Table 2]. Vanadium was present in a concentration of 6.3 mg/l. The well feed contained 150 mg/l uranium, which corresponds to a uranium loss of 245 kg (540 lb)/day. At present values of yellow cake, this would have a market value of $8,100 to $10,800/day. This uranium could be recovered by the installation of an ion-exchange plant between the present filter and injection well.

VII. STREAM SURVEYS

When the mines and mills were evaluated, selected stream stations were sampled to determine the effect of mine and mill discharges on water quality. The New Mexico Water Quality Standards limit the radium concentration in surface streams to a maximum of 30 pCi/l. Data on the samples collected from surface streams are provided in Table 3.

ARROYO DEL PUERTO

Arroyo del Puerto receives waste from the United Nuclear-Homestake Partners and Kerr-McGee ion-exchange plants and from Kerr-McGee Section 30W and 35 mines. There is no flow in the creek upstream of these discharges.

Radium-226 concentrations of samples collected downstream from the Kerr-McGee mill were from 45 to 50 pCi/l. These concentrations not only violate the New Mexico Water Quality Standards, but exceed the AEC criteria (30 pCi/l) for radium in water discharged to an unrestricted environment. Radium concentrations in Arroyo del Puerto decreased near the mouth to levels ranging from 6.1 to 7.2 pCi/l. This decrease is due to the adsorption of radium on sediment and/or vegetation. During periods of heavy run-off, the radium concentration can be expected to increase due to scouring of the stream bed.

The selenium concentration of Arroyo del Puerto downstream from the Kerr-McGee mill was 0.15 mg/l, decreasing to 0.04 mg/l near the mouth. Vanadium concentrations in Arroyo del Puerto near the Kerr-McGee mill averaged 0.8 mg/l, increasing to 1.1 mg/l near the mouth. Selenium and

Table 3

SUMMARY OF ANALYTICAL DATA
FOR
SURFACE WATER SAMPLING

Station Description	Number of Samples	Gross Alpha (pCi/l)			Radium-226 (pCi/l)			Uranium (mg/l)			Selenium (mg/l)			Vanadium (mg/l)		
		Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
Arroyo del Puerto downstream of Kerr-McGee Mill	3	1,700	1,400	1,500	50	45	47	12	5.0	7.7	0.16	0.13	0.15	1.0	0.6	0.8
Arroyo del Puerto near the mouth	3	1,500	750	1,100	7.2	6.1	6.5	6.6	4.7	5.8	0.07	0.01	0.04	1.9	0.5	1.1
San Mateo Creek at Highway 53 Bridge	1	-	-	1,000	-	-	1.09	-	-	4.7	-	-	0.02	-	-	<0.3
Rio Puerco downstream of Churchrock Mines	3	500	470	490	2.60	0.97	2.04	5.0	3.8	4.2	0.07	0.03	0.04	0.6	0.5	0.6
Rio Puerco upstream of Wingate Plant	3	510	720	440	1.63	0.36	0.81	4.8	3.7	4.2	0.01	0.01	0.01	0.9	0.3	0.6
Rio Puerco at Highway 666 Bridge	3	350	210	260	0.42	0.09	0.22	2.5	1.7	2.0	<0.01	<0.01	<0.01	0.6	0.3	0.5
Rio Paguate at Paguate	1	-	-	2.8	-	-	0.11	-	-	<0.02	-	-	<0.01	-	-	0.6
Rio Moquino upstream of Jackpile Mine	1	-	-	11.2	-	-	0.17	-	-	<0.02	-	-	<0.01	-	-	1.8
Rio Paguate at Jackpile Ford	1	-	-	270	-	-	4.8	-	-	1.2	-	-	<0.05	-	-	0.5
Rio Paguate at Paguate Reservoir Discharge	1	-	-	230	-	-	1.94	-	-	1.1	-	-	<0.01	-	-	0.6
Rio San Jose at Interstate Bridge	1	-	-	38	-	-	0.37	-	-	0.10	-	-	<0.01	-	-	0.3

vanadium have harmful effects when present in high concentrations in water used for irrigation or livestock watering. The 1972 EPA Water Quality Criteria (Committee on Water Quality Criteria, 1972) suggests that irrigation waters not exceed 0.02 mg/l selenium and 0.1 mg/l vanadium, while livestock waters should not exceed 0.05 mg/l selenium and 0.1 mg/l vanadium. On this basis, Arroyo del Puerto is rendered unfit for irrigation and livestock watering by the uranium mining discharges throughout its entire length. This is contrary to New Mexico Water Quality Standards which require that discharges not render a water unfit for a beneficial use.

The flow of Arroyo del Puerto enters San Mateo Creek where the entire flow enters the aquifer within three miles of the confluence. This recharge adds a large loading of radium and selenium to the ground water. Ground-water evaluations by ORP-LVF will address this question.

RIO PUERCO

The Rio Puerco receives drainage from Kerr-McGee and United Nuclear Corporation Churchrock mines. Samples collected downstream from these discharges contained a maximum radium-226 concentration of 2.6 pCi/l [Table 3]. The concentration decreased to 0.4 pCi/l at the town of Gallup. These concentrations meet the New Mexico Water Quality Criteria of 30 pCi/l, as well as the PHS Drinking Water Standard of 3 pCi/l for radium-226. Selenium concentrations downstream from the mine discharges ranged from 0.03 to 0.07 mg/l for an average of 0.04 mg/l, or four times PHS Drinking Water Standards. The selenium concentration decreased downstream to 0.01 mg/l at the Wingate plant and to less than detection limits at Gallup.

RIO PAGUATE, RIO MOQUINO, RIO SAN JOSE

The Rio Paquate and Rio Moquino flow through the Anaconda open pit mines on the Laguna Indian Reservation. The combined flow enters Rio San Jose near Laguna, New Mexico. Samples collected from these three streams had radium concentrations of less than 5 pCi/l, which is less than the Water Quality Standard of 30 pCi/l set by the State of New Mexico. An increase in the selenium concentration of Rio Paguate was noted downstream from the Jackpile Mine. However, the concentration of selenium at Paguate reservoir and in Rio San Jose were less than detection limits.

VIII. INDUSTRIAL WATER SUPPLIES

The majority of the mines and mills in the Grants Mineral Belt use mine water as a potable supply. The present PHS Drinking Water Standards specify that the radium concentrations not exceed 3 pCi/l, and the selenium not exceed 0.01 mg/l. The *Safe Drinking Water Act* (Public Law 92-523, Dec. 16, 1974) requires establishment of national drinking water standards. The proposed standards limit selenium to 0.01 mg/l. Also, EPA has proposed standards of 5 pCi/l for radium-226 and -228 and 15 pCi/l for gross alpha (40 CFR 141).

Data from potable water supplies in the Grants Mineral Belt are summarized in Table 4. All but one of the water-supply systems contain radium-226 in concentrations greater than the PHS Drinking Water Standard of 3.0 pCi/l. Severe violations of the 0.01 mg/l selenium standard are also present. Kerr-McGee Nuclear Corporation supplies water to mill workers and to several mobile homes within the area; the source is ion-exchange water from the mines, subsequently treated for radium removal. As shown in Table 4, the radium concentration in this water was at an acceptable level of 0.5 pCi/. The selenium in the water supply was 0.05 mg/l, or 5 times the drinking water standard. Treatment or an alternate source of supply will be required to meet the selenium standards.

Kerr-McGee operates a dual water supply system within the mill and the office facility -- a potable system described above, and a non-potable system used for washing and sanitary facilities. The latter uses ion-exchange tailings without further treatment. Radium concentrations in this water are extremely high, averaging over 150 pCi/l. Company personnel are largely uninformed about the existence of the dual water supply system and have admitted to drinking from the non-potable

Table 4

SUMMARY OF DATA FOR
INDUSTRY POTABLE WATER SUPPLIES

Description	Gross Alpha (pCi/l)	Radium 226 (pCi/l)	Selenium (mg/l)
Kerr-McGee - Mill Water Supply	510	0.5	0.05
Kerr-McGee - Sec. 35 and 36 Mines	3,000	43	0.05
Kerr-McGee - Churchrock Mine†	120	6.5	0.01
United Nuclear Corporation - Ambrosia Lake Area	1,500	23.5	0.11
United Nuclear Corporation - Churchrock	620	12.6	0.06
United Nuclear Corporation - Mobile Home Supply at the Churchrock Mine	1,110	39.7	0.06

† *Reportedly used only for showers, stools, etc. and not for drinking water.*

source. Warning signs should be posted on the non-potable water system to prevent subsequent potable use of this radioactive water.

Water from the Kerr-McGee Section 35 mine is treated by ion-exchange and used for a potable system for workers in Section 35 and 36 mines. This water contained a radium concentration of 43 pCi/l and a gross alpha concentration of 3,000 pCi/l. This exceeds existing and proposed standards for radiochemistry in the potable supply. The selenium in this supply was 0.02 mg/l, twice the level which constitutes grounds for rejection as a water supply under Drinking Water Standards.

Clarified water from the settling ponds at the Kerr-McGee Churchrock mine are pumped into the Kerr-McGee change house for use in sanitary facilities. The water contained concentrations of radium-226 approximately twice the Drinking Water Standards. It also contained selenium at a concentration of 0.01 mg/l, or the concentration which constitutes grounds for rejection as a potable water supply. The supply is not intended as potable, but it is not adequately marked as non-potable.

United Nuclear Corporation maintains a potable water supply system for its Churchrock mine as well as for mobile homes within the area. Water from the mine is pumped into a holding pond on Sunday, when mining activities are not under way. Water from this holding pond is then passed through a filter for removal of suspended solids. No further treatment is given. A sample collected from a water fountain within the United Nuclear Corporation change-house contained 12.6 pCi/l radium-226 and 0.06 mg/l selenium. These levels exceed PHS Drinking Water Standards and proposed standards under the Safe Drinking Water Act. The system is supplied to a number of private trailers in the area, and it clearly will come under the provision of the Safe Drinking Water Act.

A sample was collected on March 5, 1975 from one of the mobile homes supplied by the United Nuclear Corporation Churchrock mine water-supply system. The sample contained 39.7 pCi/l radium-226 and 0.06 mg/l selenium. The trailer was occupied by the wife and three children of one of the uranium miners. These concentrations grossly exceed the proposed and present drinking water standards and pose a health hazard to the employees and their families. The United Nuclear Corporation should take immediate action to improve the quality of this domestic supply or locate an alternate source of water.

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Appendix A

ANALYTICAL QUALITY CONTROL
FIELD AND LABORATORY PROCEDURES

ANALYTICAL QUALITY CONTROL
FIELD AND LABORATORY PROCEDURES

WASTE SOURCE EVALUATIONS

Mining and milling operations operated by five companies were investigated during the Grants Mineral Belt survey. Information was obtained through in-plant surveys, review of NPDES permit applications, and interviews with industry personnel, on water pollution control practices at each site.

Sampling was conducted in accord with a previously prepared Study Plan (attached). Sampling proceeded as planned, except that conditions at United Nuclear Corporation's Churchrock mine were atypical due to power failure and subsequent mine flooding. Daily composite samples were collected manually into large cleaned containers on an equal volume basis. The composite sample was then returned to a central sample preparation site where individual samples were prepared in accord with Table 4 of the Study Plan. Company sample splits were prepared where requested. Filtering was done through a 0.45 μ filter, using stainless steel pressure filtering equipment.

Where available, industry flow-measurement equipment was used. In other cases, various standard flow measurement techniques such as "V" notch weirs and stage recorders were used.

The samples were maintained under custody procedures and transported to the NEIC laboratory in NEIC vehicles.

STREAM SURVEYS

Limited stream surveys were conducted to determine the effects of mining and milling discharges on surface waters of the Grants Mineral Belt. Sampling was generally in accord with the Study Plan, except where there was no flow. Sampling in the Paguate area was restricted to one-time grab sampling. Sample preparation was in accord with the discussion in the previous section.

INDUSTRY WATER SUPPLIES

Grab samples were collected from industry potable and non-potable (sanitary) water supplies, in accord with the Study Plan. Sampling sites were at water fountains, faucets, or showers. The source was permitted to run for a time before sample collection. Samples were subsequently split and preserved, as discussed in the section on waste source evaluation.

ANALYTICAL PROCEDURES AND QUALITY CONTROL

Samples collected during this survey were, for the most part, analyzed according to procedures outlined in the EPA Manual, *Methods for Chemical Analysis of Water and Wastes, 1971.* Gross alpha and radium-226 levels were measured according to procedures described in *Standard Methods for Water and Wastewater Analysis, 13th Ed.* Uranium was measured by the fusion/fluorescence procedure described as Method #D2907-701 in the *ASTM Manual, Part 31, 1975.* Selenium was analyzed by a fluorometric procedure developed by Crenshaw and Lakin (Journal Research U.S. Geological Survey, 2 (4), 483 (1974)); the fusion step was omitted, however, since the samples were non-geological in origin. These analytical procedures are summarized below.

Parameter	Method	Reference
Co, Cu, Fe	Atomic Absorption[1]	EPA Methods for Chemical Analysis, 1971
V, Mo		
Na	Atomic Emission[1]	EPA Methods for Chemical Analysis, 1971
As	Colorimetric	EPA Methods for Chemical Analysis, 1971
TSS, TDS	Gravimetric	EPA Methods for Chemical Analysis, 1971
SO_4	Turbidimetric	EPA Methods for Chemical Analysis, 1971
Cl	Titrimetric	EPA Methods for Chemical Analysis, 1971
NH_3	Automated Colorimetric	EPA Methods for Chemical Analysis, 1971
$NO_2 + NO_3$	Automated Cadmium Reduction	EPA Methods for Chemical Analysis, 1971
Gross	Internal Proportional Counting	Standard Methods, Section 302.4.a.
Radium-226	Radon emanation[2]	Standard Methods, Section 305
Uranium	Fusion/Fluorescence[1]	ASTM, D290F
Se	Fluorometric	Crenshaw and Lakin, J. Res. U.S. Geol. Survey, Vol. 2, No. 4, July-August, 1974, p. 483-487

[1] *Digestion of samples per Sec. 4.1.4. EPA Methods*

[2] *$RaSo_4/BaSO_4$ precipitate collected by centrifugation, dissolved in diethylenetriamine pentaacetic acid, and placed directly in bubbler.*

Reliability of the analytical results was documented through an active Analytical Quality Control (AQC) Program. As part of this program, replicate analyses were normally performed with every tenth sample to ascertain the reproducibility of the results. In addition, every tenth sample was spiked with a known amount of the constituents to be measured and reanalyzed to determine the percent recovery. These results were evaluated in regard to past AQC data on the precision, accuracy, and detection limits of each test. As an example, AQC results for Ra-226 and Se are tabulated on the following page.

Parameter	Radium-226	Selenium
Detection Limit	0.05 pCi/l	0.005 mg/l
Percent Difference in Duplicate Measurements	0-1 pCi/l: 0-52% 22% Avg.†	0-0.1; 0-30%, 21% Avg.
	1-200 pCi/l: 0-8%, 5% Avg.	0.1-1.0: 9-32%, 15% Avg.
Percent Recovery from Spiked Samples	1-200 pCi/l: 79-104%, 93% Avg.	0-0.1 mg/l: 60-134%, 109% Avg.

† *0-1 pCi/l represents the concentration range being considered, 0-52% represents the range of the percent difference between duplicates, and 22% represents the average of these variations.*

On the basis of these findings, all analytical results reported for the survey were found to be acceptable with respect to the precision and accuracy control of this laboratory.

STUDY PLAN

NEW MEXICO URANIUM MINING AND MILLING WATER QUALITY INVESTIGATIONS

OBJECTIVES

1. Determine the impact of previous and existing discharges to ground and surface waters of the Grants-Mineral Belt and establish a data base for future National Pollutant Discharge Elimination System (NPDES) permits and uranium mining and milling license guidelines due to expanded mining and milling activities.

2. Determine whether the discharges from uranium mines and mills comply with existing and proposed NPDES permits and uranium-milling licenses.

3. Determine the composition of potable waters at uranium mines and mills.

4. Determine if NPDES non-filers exist in the study area.

5. Evaluate the adequacy of company monitoring networks, self-monitoring data, analytical procedures and reporting requirements.

BACKGROUND

Uranium ore was discovered in the Grants Mineral Belt in 1950 resulting in the construction of four processing mills, three of which are still operating. The early mining started in the shallow deposits of the Bluewater area and has progressed into the Ambrosia Lake area where shaft mines of greater than 1000 ft have been developed. Ground water from the overlying Dakoata aquifer and Westwater Canyon member of the Morrison Formation is pumped from these mines and discharged to surface waters. The industry is currently experiencing a major expansion with design and/or construction of three new mills and numerous mines.

Since the discovery of ore and the construction of uranium mills, only a limited amount of company data has been developed on the chemical and radiochemical characteristics of the mining and milling wastes. The surface discharges from the mines receives only minimal treatment and companies have not made a concerted effort to prevent seepage from mill tailings ponds from entering subsurface water.

The NMEIA requested EPA, Region VI (letter dated September 25, 1974) to conduct a "definitive survey of the Grants Mineral Belt". Through meetings and subsequent correspondence, it was decided that the study will be conducted jointly by New Mexico Environmental Improvement Agency (NMEIA), National Field Investigations Center (NFIC) and Office of Radiation Programs-Las Vegas Facility (ORP).

The three uranium mills (Kerr-McGee, United Nuclear-Homestake Partners and Anaconda) and three mine (Kerr-McGee, United Nuclear and United Nuclear-Homestake Partners) water treatment facilities (ion exchange units or IX) operate under AEC licenses. These licenses have been transferred to NMEIA. The licenses require meeting conditions set forth in 10 CFR 20 of which the most significant is that liquid waste discharged to areas with controlled access have radium 226 levels equal to or less than 30 picocuries per liter (pCi/l).

NPDES permits have been issued for the Kerr-McGee mine discharges at Ambrosia Lake (ion exchange unit and Section 30W mine) and Churchrock, and the United Nuclear Corporation mine at Churchrock. The permit limitations are summarized in Table 1. Kerr-McGee has requested adjudicatory hearings on their permits.

General New Mexico Water Quality Standards for perennial reaches of streams, including those formed by wastewater discharges, apply to the streams in the study area. The most significant provision of these standards is that radium 226 concentrations must be less than 30 pCi/l.

REQUIRED STUDIES

A. Reconnaissance Survey

A reconnaissance survey was conducted by personnel of NMEIA, ORP and NFIC during the period January 27-31, 1975. Company officials were contacted to obtain existing data and facility inspections were conducted at each of the mills and mines. A number of mine discharges, which are not covered by an NPDES permit, are believed to be reaching San Mateo Creek and its tributaries. Seepage from the Anaconda, Kerr-McGee and United Nuclear-Homestake Partners mill tailings piles has an extremely high potential of degrading water in the study area. Potable water supplies at the mines and mills is, for the most part, obtained from mine water treated by sedimentation followed in a few cases by selective ion exchange units which may not remove radium and most heavy metals, if present, from the mine water.

B. Industrial Waste Survey

Effluent monitoring of mine wastewaters will be conducted. Samples will also be collected of the mill tailings pond water to ascertain the type of pollutants which can enter the ground water.

Operating (active) mine discharges will be sampled for three consecutive days with 24-hour composite samples being collected. Mines currently under development and mill tailing piles will be monitored for 8 hours one day [Table 2 lists the stations and parameters which will be measured during the survey].

C. Stream Surveys

In conjunction with the industrial survey, selected stream stations will be sampled to determine possible water quality violations [Table 3]. These stations are located in San Mateo Creek upstream and downstream from the Johnny M Mine discharge and downstream from the confluence of Puertecito Creek; Puertecite Creek upstream of all discharges (upstream of United Nuclear-Homestake Partners IX discharge), downstream from Kerr-McGee Mill, and near the mouth at Rancho del Puerto; Rio Puerco downstream of United Nuclear and Kerr-McGee mines, upstream of Wingate plant, and in Gallup at Highway 666 Bridge; Rio Moquino upstream of Jackpile Mine; Rio Paguate at Paguate, at the Jackpile Mine Ford and at the Paguate Reservoir discharge; and the Rio San Jose at I-40 bridge east of Laguna.

The Rio Moquino, Rio Paguote and Rio San Jose are influenced by storm run-off of tailings and ore piles. These streams will be sampled during run-off.

D. Ground-Water Survey

Ground-water related activities will emphasize definition of the hydrogeologic environment and sampling of selected wells and springs to characterize existing water quality and relate it to uranium mining and milling waste discharge.

A separate study plan for this portion of the study has been prepared by ORP.

LOGISTICS

All industrial, stream and well samples will be sent to the NFIC laboratory for analysis. Industrial samples will be split with the appropriate company. All samples will be field split for radiochemical analysis with ORP. Alpha and radium 226 screening tests at NFIC will be considered for further analyses by ORP for Th-230, Pb-210, Po-210, Th-228, and possibly Ra-228. All samples will be collected and analyzed following established NFIC Chain-of-Custody procedures. The size of sample and preservative required are summarized in Table 4.

TIME SCHEDULE*

January 27-31, 1975	Reconnaissance Survey
February 3-21, 1975	Develop sampling schedule and notify industries
February 24-25, 1975	Start setting up flow monitoring equipment
February 26-March 8, 1975	Sample industries and streams
February 24-March 14, 1975	Sample ground water

PERSONNEL

A. Field Survey

NFIC	1 Supervisory Engineer (coordinator) 1 Geologist 3 Technicians
NMEIA	3 Technicians

*Report on the study findings will be completed within 2-3 weeks following receipt of final analytical data.

ORP	1 Hydro-Geologist 1 Health Physicist 1 Technician
Region VII (Kerr Water Lab)	1 Technician (part-time)

B. Report Preparation

NFIC	1 Engineer 1 Geologist 1 Technician (limited time)
NMEIA	1 Hydro-Geologist 1 Health Physicist
ORP	1 Hydro-Geologist 1 Health Physicist 1 Nuclear Chemist

EQUIPMENT

Gaging equipment

Peristaltic pump

Sampling and metering equipment

Pressure filtering units

Vehicles

4 Four-Wheel drive - 2 Denver and 2 Albuquerque (NFIC)

1 Sedan - Albuquerque (NFIC)

1 Van - Las Vegas (ORP)

1 Panel Truck - Kerr Center, Ada (ORP)

TABLE 1

SUMMARY OF NPDES PERMIT CRITERIA

Company/Discharge	Period of Limitation	Parameters[1/] TSS-mg/l Daily Avg.	TSS-mg/l Daily Max.	Total Uranium-mg/l Daily Avg.	Total Uranium-mg/l Daily Max.	Dissolved Radium 226-pCi/l Daily Avg.	Dissolved Radium 226-pCi/l Daily Max.	pH Range
Kerr-McGee Corp.	1/28/75-6/30/77	20	30	-	2	-	30	6.0-9.5
-Churchrock Mine Discharge	7/1/77-1/27/80	20	30	-	2	-	3.3	6.0-9.0
-Section 30W Mine	1/28/75-12/31/75	20	30	-	2	-	150	6.0-9.0
Discharge	1/1/76-6/30/77	20	30	-	2	-	30	6.0-9.0
(Ambrosia Lake)	7/1/77-1/27/80	20	30	-	2	-	3.3	6.0-9.0
-Ion Exchange	1/28/75-12/31/75	20	30	-	1	-	100	6.0-9.0
Discharge	1/1/76-6/30/77	20	30	-	1	-	30	6.0-9.0
(Ambrosia Lake)	7/1/77-1/27/80	20	30	-	1	-	3.3	6.0-9.0
United Nuclear	1/28/75-12/31/75	100	200	-	2	-	30	6.0-9.5
Corporation	1/1/76-6/30/77	20	30	-	2	-	30	6.0-9.5
-Churchrock Mine Discharge	7/1/77-1/27/80	20	30	-	2	-	3.3	6.0-9.0

1/ In addition to these parameters, the companies are required to monitor flow, temperature, total molybdenum, total selenium and total vanadium.

TABLE 2, Page 2

Station Number	Station Description	Number Days Sampled	Type Sample	Flow By	Analysis Required 2/ TSS	SO_4	Cl	Cu	Fe	Mo	Na	NH_3 & NO_3	Se	V	As	Mn	Co	U-Nat	Gross Alpha	Ra_{226}
9016	United Nuclear Corp. IX Discharge	4/	24-Hr. Comp. 8-Hr. Comp.	Weir or Gage	X		X			X	X	X	X	X		X		X	X	X
9017	United Nuclear Corp. Potable Water Supply	1	Grab	None						X		X	X		X				X	X
9018	United Nuclear-Homestake Partners IX Discharge	3	24-Hr. Comp.	Calculate from company meters	X		X			X	X	X	X	X		X		X	X	X
9019	United Nuclear-Homestake Partners Tailings Pile Decant	1	8-Hr. Comp.	None	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
9021	Anaconda Co. Injection Well Feed	1	24-Hr. Comp.	Company Meter	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
9023	United Nuclear Churchrock Mine	3	24-Hr. Comp.	Parshall	X		X			X	X	X	X	X		X		X	X	X
9024	United Nuclear Churchrock Potable Water Supply	1	Grab	None						X		X	X		X				X	X
9025	Kerr-McGee Churchrock Mine	3	24-Hr. Comp.	Weir & Recorder	X		X			X	X	X	X	X		X		X	X	X
9026	Kerr-McGee Churchrock Mine Potable Water Supply	1	Grab	None						X		X	X		X				X	X

1/ pH, conductivity and temperature will be measured periodically at all stations.
2/ Additional radiochemical (Th-230, pb-210, Po210, Th 228, Ra 228) will be required if gross alpha and radium 226 analysis indicate these compounds are present.
3/ Two separate discharges, sample will be flow composited from both sources.
4/ Three 24-hour composite samples will be collected if discharging; if however, all water is being used for solutions mining (i.e., recycled to the mines) then one 8-hr. composite will be collected.

TABLE 2
INDUSTRIAL SAMPLING 1/

Station Number	Station Description	Number Days Sampled	Type Sample	Flow By	Analysis Required 2/ TSS	SO_4	Cl	Cu	Fe	Mo	Na	NH_3 & NO_3	Se	V	As	Mn	Co	U-Nat	Gross Alpha	Ra_{226}
9001	Kerr-McGee Ion Exchange Tailings By-Pass	3	24-Hr. Comp.	Parshall	X		X			X	X	X	X	X		X		X	X	X
9003	Kerr-McGee Sec. 30 W Mine Water	3	24-Hr. Comp.	Gage in Control Str.	X		X			X	X	X	X	X		X		X	X	X
9005	Kerr-McGee Sec. 19 Mine Water	1	8-Hr. Comp.	Bucket and Stopwatch	X		X			X	X	X	X	X		X		X	X	X
9007	Kerr-McGee Sec. 35 Mine Water	3	24-Hr. Comp.	Rectangular Weir	X		X			X	X	X	X	X		X		X	X	X
9009	Kerr-McGee Sec. 3/ 36 Mine Water	3	24-Hr. Comp.	Gage or Bucket & Stopwatch	X		X			X	X	X	X	X		X		X	X	X
9011	Kerr-McGee Seepage below tailings pond	1	8-Hr. Comp.	None	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
9012	Kerr-McGee Mill Potable Water Supply	1	Grab	None						X		X	X		X				X	X
9013	Kerr-McGee Sec. 35 Mine Potable Water Supply	1	Grab	None						X		X	X		X				X	X
9014	Ranchers Exploration Johnny M. Mine Water	1	8-Hr. Comp.	Gage	X		X			X	X	X	X	X		X		X	X	X
9015	Ranchers Exploration Johnny M. Mine Potable Water Supply	1	Grab	None						X		X	X		X				X	X

TABLE 3
STREAM STATIONS[1/]

Station Number	Station Description	Number Days Sampled	Type Sample	Analysis Required[2/] Cl	Mo	Na	NO_3 & NH_3	Se	V	Mn	U-Nat	Gross Alpha	Ra_{226}
9030	San Mateo Creek at Highway 53 Bridge West of San Mateo	3	Grab	X	X	X		X	X	X	X	X	X
9032	San Mateo Creek upstream of Puertecito Creek	3	Grab	X	X	X		X	X	X	X	X	X
9034	Puertecito Creek upstream of Partner's IX Plant	3	Grab	X	X	X	X	X	X	X	X	X	X
9036	Puertecito Creek Downstream from Kerr-McGee Mill	3	Grab	X	X	X	X	X	X	X	X	X	X
9038	Puertecito Creek Near the Mouth of Rancho del Puerto	3	Grab	X	X	X	X	X	X	X	X	X	X
9040	San Mateo Creek at Highway 53 Bridge North of Grants	3	Grab	X	X	X		X	X	X	X	X	X
9050	Rio Puerco at Highway Bridge Downstream from United Nuclear and Kerr-McGee Mines	3	Grab	X	X	X		X	X	X	X	X	X
9052	Rio Puerco Upstream of Wingate Plant	3	Grab	X	X	X		X	X	X	X	X	X

TABLE 3, Page 2

Station Number	Station Description	Number Days Sampled	Type Sample	Analysis Required 2/ Cl	Mo	Na	NO_3 & NH_3	Se	V	Mn	U-Nat	Gross Alpha	Ra_{226}
9054	Rio Puerco at Highway 666 Bridge, Gallup, N. Mex.	3	Grab	X	X	X		X	X	X	X	X	X
9060	Rio Paguate at Paguate	3/	Grab	X	X	X		X	X	X	X	X	X
9062	Rio Moquino Upstream of Jackpile Mine	3/	Grab	X	X	X		X	X	X	X	X	X
9064	Rio Paguate at Jackpile Ford	3/	Grab	X	X	X		X	X	X	X	X	X
9066	Rio Paguate at Paguate Reservoir Discharge	3/	Grab	X	X	X		X	X	X	X	X	X
9068	Rio San Jose at I-40 Bridge East of Laguna	3/	Grab	X	X	X		X	X	X	X	X	X

1/ pH, conductivity and temperature will be measured periodically at all stations.
2/ Additional radiochemical (Th-230, Pb-210, Po 210, Th-228, Ra-228) will be required if gross alpha and radium 226 analysis indicate these compounds are present.
3/ This station will be sampled for 1 to 3 days if surface run-off occurs.

TABLE 4
PRESERVATIVES AND SAMPLE SIZE REQUIRED

Size of Sample	Preservative	Parameter
1 liter (unfiltered)	Iced	TDS, TSS, Sulfate, Chloride
1 liter (unfiltered)	5 ml HNO_3/l	Copper, iron, Moly, Sodium, Silenum, Vanadium, Arsenic, Manganese, Cobalt, Total Uranium
125 ml (unfiltered)	40 mg $HgCl_2$/l - Iced	Nitrate + Nitrite, Ammonia
2 l (filtered)	5 ml HNO_3/l	Gross alpha
8 l (filtered)*	5 ml Hcl/l	Dissolved Radium 226 Th-230, Pb-210, Po-210, Th-228, Ra-228

*4 liters each to NFIC and ORP.

Appendix B

CHAIN OF CUSTODY PROCEDURES

CHAIN OF CUSTODY PROCEDURES

General:

The evidence gathering portion of a survey should be characterized by the minimum number of samples required to give a fair representation of the effluent or water body from which taken. To the extent possible, the quantity of samples and sample locations will be determined prior to the survey.

Chain of Custody procedures must be followed to maintain the documentation necessary to trace sample possession from the time taken until the evidence is introduced into court. A sample is in your "custody" if:

1. It is in your actual physical possession, or
2. It is in your view, after being in your physical possession, or
3. It was in your physical possession and then you locked it up in a manner so that no one could tamper with it.

All survey participants will receive a copy of the survey study plan and will be knowledgeable of its contents prior to the survey. A pre-survey briefing will be held to re-appraise all participants of the survey objectives, sample locations and Chain of Custody procedures. After all Chain of Custody samples are collected, a de-briefing will be held in the field to determine adherence to Chain of Custody procedures and whether additional evidence type samples are required.

Sample Collection:

1. To the maximum extent achievable, as few people as possible should handle the sample.
2. Stream and effluent samples shall be obtained, using standard field sampling techniques.
3. Sample tags (Exhibit I) shall be securely attached to the sample container at the time the complete sample is collected and shall contain, at a minimum, the following information: station number, station location, date taken, time taken, type of sample, sequence number (first sample of the day - sequence No. 1, second sample - sequence No. 2, etc.), analyses required and samplers. The tags must be legibly filled out in ballpoint (waterproof ink).

Sample Collection (Continued)

4. Blank samples shall also be taken with preservatives which will be analyzed by the laboratory to exclude the possibility of container or preservative contamination.

5. A pre-printed, bound Field Data Record logbook shall be maintained to record field measurements and other pertinent information necessary to refresh the sampler's memory in the event he later takes the stand to testify regarding his action's during the evidence gathering activity. A separate set of field notebooks shall be maintained for each survey and stored in a safe place where they could be protected and accounted for at all times. Standard formats (Exhibits II and III) have been established to minimize field entries and include the date, time, survey, type of samples taken, volume of each sample, type of analysis, sample numbers, preservatives, sample location and field measurements such as temperature, conductivity, DO, pH, flow and any other pertinent information or observations. The entries shall be signed by the field sampler. The preparation and conservation of the field logbooks during the survey will be the responsibility of the survey coordinator. Once the survey is complete, field logs will be retained by the survey coordinator, or his designated representative, as a part of the permanent record.

6. The field sampler is responsible for the care and custody of the samples collected until properly dispatched to the receiving laboratory or turned over to an assigned custodian. He must assure that each container is in his physical possession or in his view at all times, or locked in such a place and manner that no one can tamper with it.

7. Colored slides or photographs should be taken which would visually show the outfall sample location and any water pollution to substantiate any conclusions of the investigation. Written documentation on the back of the photo should include the signature of the photographer, time, date and site location. Photographs of this nature, which may be used as evidence, shall also be handled recognizing Chain of Custody procedures to prevent alteration.

Transfer of Custody and Shipment:

1. Samples will be accompanied by a Chain of Custody Record which includes the name of the survey, samplers signatures, station number, station location, date, time, type of sample, sequence number, number of containers and analyses required (Fig. IV). When turning over the possession of samples, the transferor and transferee will sign, date and time the sheet. This record sheet

allows transfer of custody of a group of samples in the field, to the mobile laboratory or when samples are dispatched to the NFIC - Denver laboratory. When transferring a portion of the samples identified on the sheet to the field mobile laboratory, the individual samples must be noted in the column with the signature of the person relinquishing the samples. The field laboratory person receiving the samples will acknowledge receipt by signing in the appropriate column.

2. The field custodian or field sampler, if a custodian has not been assigned, will have the responsibility of properly packaging and dispatching samples to the proper laboratory for analysis. The "Dispatch" portion of the Chain of Custody Record shall be properly filled out, dated, and signed.

3. Samples will be properly packed in shipment containers such as ice chests, to avoid breakage. The shipping containers will be padlocked for shipment to the receiving laboratory.

4. All packages will be accompanied by the Chain of Custody Record showing identification of the contents. The original will accompany the shipment, and a copy will be retained by the survey coordinator.

5. If sent by mail, register the package with return receipt requested. If sent by common carrier, a Government Bill of Lading should be obtained. Receipts from post offices and bills of lading will be retained as part of the permanent Chain of Custody documentation.

6. If samples are delivered to the laboratory when appropriate personnel are not there to receive them, the samples must be locked in a designated area within the laboratory in a manner so that no one can tamper with them. The same person must then return to the laboratory and unlock the samples and deliver custody to the appropriate custodian.

<u>Laboratory Custody Procedures</u>:

1. The laboratory shall designate a "sample custodian." An alternate will be designated in his absence. In addition, the laboratory shall set aside a "sample storage security area." This should be a clean, dry, isolated room which can be securely locked from the outside.

2. All samples should be handled by the minimum possible number of persons.

3. All incoming samples shall be received only by the custodian, who will indicate receipt by signing the Chain of Custody Record Sheet

accompanying the samples and retaining the sheet as permanent records. Couriers picking up samples at the airport, post office, etc. shall sign jointly with the laboratory custodian.

4. Immediately upon receipt, the custodian will place the sample in the sample room, which will be locked at all times except when samples are removed or replaced by the custodian. To the maximum extent possible, only the custodian should be permitted in the sample room.

5. The custodian shall ensure that heat-sensitive or light-sensitive samples, or other sample materials having unusual physical characteristics, or requiring special handling, are properly stored and maintained.

6. Only the custodian will distribute samples to personnel who are to perform tests.

7. The analyst will record in his laboratory notebook or analytical worksheet, identifying information describing the sample, the procedures performed and the results of the testing. The notes shall be dated and indicate who performed the tests. The notes shall be retained as a permanent record in the laboratory and should note any abnormalities which occurred during the testing procedure. In the event that the person who performed the tests is not available as a witness at time of trial, the government may be able to introduce the notes in evidence under the Federal Business Records Act.

8. Standard methods of laboratory analyses shall be used as described in the "Guidelines Establishing Test Procedures for Analysis of Pollutants," 38 F.R. 28758, October 16, 1973. If laboratory personnel deviate from standard procedures, they should be prepared to justify their decision during cross-examination.

9. Laboratory personnel are responsible for the care and custody of the sample once it is handed over to them and should be prepared to testify that the sample was in their possession and view or secured in the laboratory at all times from the moment it was received from the custodian until the tests were run.

10. Once the sample testing is completed, the unused portion of the sample together with all identifying tags and laboratory records, should be returned to the custodian. The returned tagged sample will be retained in the sample room until it is required for trial. Strip charts and other documentation of work will also be turned over to the custodian.

Chain of Custody Procedures (Continued)

11. Samples, tags and laboratory records of tests may be destroyed only upon the order of the laboratory director, who will first confer with the Chief, Enforcement Specialist Office, to make certain that the information is no longer required or the samples have deteriorated.

EXHIBIT I

EPA, NATIONAL FIELD INVESTIGATIONS CENTER - DENVER

Station No.	Date	Time	Sequence No.

Station Location	________Grab ________Comp.

		Remarks/Preservative:
________BOD	________Metals	
________Solids	________Oil and Grease	
________COD	________D.O.	
________Nutrients	________Other	

Samplers:

FRONT

ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF ENFORCEMENT

NATIONAL FIELD INVESTIGATIONS CENTER — DENVER

BUILDING 53, BOX 25227, DENVER FEDERAL CENTER

DENVER, COLORADO 80225

BACK

EXHIBIT II

FOR ______________________________ SURVEY, PHASE ______, DATE ______________

TYPE OF SAMPLE ______________________________

STATION NUMBER	STATION DESCRIPTION	TOTAL VOLUME	TYPE CONTAINER	PRESERVATIVE	ANALYSES REQUIRED																					
					NUTRIENTS	BOD	COD	TOC	TOTAL SOLIDS	SUSPENDED SOLIDS	ALKALINITY	DO	pH*	CONDUCTIVITY*	TEMPERATURE*	TOTAL COLIFORM	FECAL COLIFORM	TURBIDITY	OIL AND GREASE	METALS	BACTI	PESTICIDES	HERB	TRACE ORGANICS	PHENOL	CYANIDE

REMARKS

EXHIBIT III

Samplers: ______________________

____

____

____

FIELD DATA RECORD

STATION	NUMBER	DATE	TIME	TEMPERATURE °C	CONDUCTIVITY µmhos/cm	pH S.U.	D.O. mg/1	Gage Ht. or Flow Ft. or CFS

EXHIBIT IV

ENVIRONMENTAL PROTECTION AGENCY

Office Of Enforcement

NATIONAL FIELD INVESTIGATIONS CENTER—DENVER
Building 53, Box 25227, Denver Federal Center
Denver, Colorado 80225

CHAIN OF CUSTODY RECORD

SURVEY	SAMPLERS: *(Signature)*

STATION NUMBER	STATION LOCATION	DATE	TIME	SAMPLE TYPE			SEQ. NO.	NO. OF CONTAINERS	ANALYSIS REQUIRED
				Water		Air			
				Comp.	Grab.				

Relinquished by: *(Signature)*		Received by: *(Signature)*	Date/Time
Relinquished by: *(Signature)*		Received by: *(Signature)*	Date/Time
Relinquished by: *(Signature)*		Received by: *(Signature)*	Date/Time
Relinquished by: *(Signature)*		Received by Mobile Laboratory for field analysis: *(Signature)*	Date/Time
Dispatched by: *(Signature)*	Date/Time	Received for Laboratory by:	Date/Time
Method of Shipment:			

Distribution: Orig.—Accompany Shipment
1 Copy—Survey Coordinator Field Files

GPO 854-809

Appendix C

CHEMICAL ANALYSES DATA
NEW MEXICO SURVEY
Feb. 26-Mar. 14, 1975

CHEMICAL ANALYSES DATA
NEW MEXICO SURVEY
Feb. 26-Mar. 14, 1975

Sample No.†	Station Description	Analyses Performed				
		Dis. Grossα	±95%CL	Dis. Ra-226	±95%Cl	Total U
		(pCi/l)				(mg/l)
9001-30-0227	KM I-X TAILINGS BY-PASS	600	60	149	1	4.2
9001-30-0228	KM I-X TAILINGS BY-PASS	490	60	148	1	2.0
9001-30-0301	KM I-X TAILINGS By-PASS	430	50	157	1	1.3
9003-30-0227	KM SEC 30W MINE WATER	1300	100	174	1	1.3
9003-30-0228	KM SEC 30W MINE WATER	1400	100	161	1	6.1
9003-30-0301	KM SEC 30W MINE WATER	1400	100	154	1	6.7
9005-30-0227	KM SEC 19 MINE WATER	72	19	9.3	0.1	0.23
9007-30-0227	KM SEC 35 MINE WATER	3000	100	32	1	17
9007-30-0828	KM SEC 35 MINE WATER	2400	100	52	1	14
9007-30-0301	KM SEC 35 MINE WATER	2800	100	69	1	26
9009-30-0227	KM SEC 36 MINE WATER	570	60	113	1	2.6
9009-30-0228	KM SEC 36 MINE WATER	630	60	178	1	3.4
9009-30-0301	KM SEC 36 MINE WATER	850	70	101	1	3.0
9010-30-0227	KM SEC 36 MINE WATER	580	70	59	1	2.5
9010-30-0228	KM SEC 36 MINE WATER	510	60	72	1	2.3
9010-30-0301	KM SEC 36 MINE WATER	580	60	65	1	2.3
9011-01-0227	KM SEEPAGE BELOW T POND	144000	3000	65	1	160
9012-01-0226	KM POTABLE WATER SUP	510	60	0.54	0.02	-
9013-01-0226	KM SEC 35 WATER SUP	3000	150	43	1	-
9014-30-0228	RE JOHNNY M MINE WATER	20	10	1.6	0.1	0.12
9016-30-0227	UNC I-X DISCHARGE	1600	100	14.3	0.4	6.6
9016-30-0228	UNC I-X DISCHARGE	2300	100	39	1	11
9016-30-0301	UNC I-X DISCHARGE	1400	100	39	1	5.9
9017-01-0226	UNC POTABLE WATER SUP	1500	100	23.5	0.5	-
9018-30-0227	UN-HP I-X DISCHARGE	760	70	111	2	2.3
9018-30-0228	UN-HP I-X DISCHARGE	770	70	101	2	3.0
9018-30-0301	UN-HP I-X DISCHARGE	970	70	111	1	5.8
9019-30-0228	UN-HP T PILE DECANT	29000	1000	52	1	150
9021-30-0228	ANAC INJ WELL FEED	62500	1300	53	1	130
9023-30-0304	UNC CHURCHROCK MINE D	730	60	19.8	0.5	7.6
9023-30-0305	UNC CHURCHROCK MINE D	840	70	22.9	0.5	6.5

† *Sample numbers are presented by station number-sequence-date.*

Sample No.	Station Description	Date	Analyses Performed				
			Dis. Gross α	±95%CL	Dis. Ra-226	±95%Cl	Total U
			(pCi/l)				(mg/l)
9023-30-0306	UNC CHURCHROCK MINE D		870	70	27.3	0.6	7.6
9023-01-0314	UNC CHURCHROCK MINE D		3100	90	53	1	20
9024-01-0303	UNC CHURCHROCK POTABLE WATER SUP		620	60	12.6	0.1	-
9025-30-0304	KM CHURCHROCK MINE DIS		240	40	8.1	0.3	0.97
9025-30-0305	KM CHURCHROCK MINE DIS		210	30	6.8	0.2	0.74
9025-30-0306	KM CHURCHROCK MINE DIS		230	40	8.7	0.2	0.72
9026-01-0303	KM CHURCHROCK H POTABLE WIS		120	30	6.5	0.1	-
9036-01-0226	PUERTECITO CK DS KM		1700	100	45	1	12
9036-01-0227	PUERTECITO CK DS KM		1400	100	47	1	6.2
9036-01-0228	PUERTECITO CK DS KM		1400	100	1	1	5.0
9038-01-0226	PUERTECITO CK @ RAN D PUERTO		1500	100	6.1	0.1	6.6
9038-01-0224	PUERTECITO CK @ RAN D PUERTO		1100	100	6.2	0.1	6.2
9038-01-0225	PUERTECITO CK @ RAN D PUERTO		750	60	7.2	0.1	4.7
9040-01-0226	SAN MATEO CK AT HWY 53		1000	80	1.09	0.03	4.7
9050-01-0303	RIO PUERCO DS UN & KM		500	50	0.97	0.05	5.0
9050-01-0304	RIO PUERCO DS UN & KM		470	50	2.54	0.05	3.8
9050-01-0305	RIO PUERCO DS UN & KM		490	60	2.60	0.05	3.8
9052-01-0303	RIO PUERCO US WINGATE		480	40	0.36	0.05	4.1
9052-01-0304	RIO PUERCO US WINGATE		510	60	0.43	0.02	4.8
9052-01-0305	RIO PUERCO US WINGATE		320	40	1.63	0.04	3.7
9054-01-0303	RIO PUERCO @ HWY 666		350	50	0.42	0.05	1.7
9054-01-0304	RIO PUERCO @ HWY 666		230	40	0.15	0.01	1.7
9054-01-0305	RIO PUERCO @ HWY 666		210	30	0.09	0.01	2.5
9060-01-0228	RIO PAGUATE @ PAGUATE		2.8	6.8	0.11	0.01	<.02
9062-01-0228	RIO MOQUINO		11.2	9.9	0.19	0.01	<.02
9064-01-0228	RIO PAGUATE @ JACKPILE FORD		270	40	4.8	0.1	1.2
9066-01-0228	RIO PAG @ PAG RES DIS		230	40	1.94	0.04	1.1
9068-01-0228	RIO SAN JOSE		38	18	0.37	0.02	0.10
9080-01-0304	KM SEC 36 3000 DRIFT		51	21	7.5	0.1	0.12
9081-01-0304	KM SEC 36 0900 DRIFT		47	20	8.7	0.1	0.05

Sample No.	Station Description	Date	Analyses Performed: Dis. Grossα (pCi/l)	±95%CL (pCi/l)	Dis. Ra-226 (pCi/l)	±95%Cl (pCi/l)	Total U (mg/l)
9082-01-0305	UNC CHURCHROCK POT WS @ SOWERS TR		1110	80	39.7	0.6	7.6
9101-01-0224			9	11	0.13	0.01	-
9102-01-0224			<3†	13	0.19	0.01	0.07
9103-01-0225			7	10	0.09	0.01	-
9104-01-0225			13	14	0.08	0.01	-
9105-01-0225			140	30	<0.05†	0.01	-
9106-01-0225			12	11	0.05	0.01	-
9107-01-0225			2500	200	0.72	0.02	14
9108-01-0225			47	23	0.34	0.02	-
9109-01-0225			39	17	0.13	0.01	-
9110-01-0225			<1†	6	<0.05†	0.01	-
9111-01-0225			7	9	0.24	0.01	-
9112-01-0225	GRANTS POTABLE		19	13	0.42	0.2	-
9113-01-0226			31	17	0.17	0.02	0.08
9114-01-0226			42	18	0.26	0.01	-
9115-01-0226			7	12	0.18	0.01	-
9116-01-0226			12	10	0.14	0.01	-
9117-01-0227	MONITOR, ANAC.		180	40	2.6	0.1	0.56
9118-01-0227			290	50	0.5	0.02	1.3
9119-01-0227			12	11	0.20	0.01	-
9120-01-0227			21	12	0.27	0.02	-
9121-01-0227			12	14	6.3	0.1	-
9123-01-0227			30	17	0.17	0.01	-
9123-01-0228			20	13	0.26	0.01	-
9124-01-0228			16	12	0.06	0.01	-
9125-01-0228			8	10	0.22	0.01	-
9126-01-0228			5	9	0.11	0.01	-
9127-01-0228			10	10	0.21	0.01	-
9128-01-0228			11	11	0.15	0.01	-
9129-01-0228			<1.6†	7	0.14	0.01	-
9130-01-0301			3	8	0.11	0.01	-
9131-01-0301			18	13	<0.05†	0.01	-
9132-01-0301			<1†	9	0.31	0.02	0.10
9133-01-0302			10	12	0.61	0.03	-

Sample No.	Station Description	Date	Analyses Performed				
			Dis. Grossα	±95%CL	Dis. Ra-226	±95%Cl	Total U
			(pCi/l)				(mg/l)
9134-01-0303			8	11	0.24	0.01	0.04
9135-01-0303			400	70	1.92	0.04	2.6
9136-01-0303			22	16	0.27	0.02	-
9137-01-0303			10	9	0.68	0.03	-
9138-01-0303			6	8	0.64	0.02	-
9139-01-0305			14	11	0.22	0.01	-
9140-01-0305			6	10	0.10	0.01	-
9141-01-0305			3	7	0.12	0.01	0.02
9142-01-0305			9	9	0.16	0.01	-
9143-01-0305			14	9	0.83	0.04	-
9201-01-0226			110	40	3.6	0.1	1.0
9202-01-0226			86	31	0.30	0.02	-
9203-01-0226			33	15	0.07	0.01	-
9204-01-0226			8	13	0.14	0.01	-
9205-01-0226			170	40	0.18	0.01	-
9206-01-0226			56	25	0.60	0.02	-
9207-01-0227			410	120	1.15	0.03	-
9208-01-0227			49	35	4.0	0.1	-
9209-01-0227			<2†	10	1.95	0.04	-
9210-01-0227			45	29	0.26	0.02	-
9211-01-0227			<3†	15	0.20	0.01	-
9212-01-0303			112000	3000	4.9	0.1	-
9213-01-0303			8	32	6.6	0.1	-
9214-01-0303			14	34	1.18	0.03	-
9215-01-0303††			104	37	2.5	0.2	-
9216-01-0303			45	25	0.64	0.02	-
9217-01-0303			70	38	0.94	0.03	-
9218-01-0303			20	24	0.34	0.02	-
9219-01-0303			67	42	0.59	0.02	-
9220-01-0305			12	10	0.12	0.01	-
9221-01-0305			17	10	0.56	0.02	-

Sample No.	Station Description	Date	Analyses Performed: Dis. Grossα	±95%CL	Dis. Ra-226	±95%Cl	Total U
			(pCi/l)				(mg/l)
9222-01-0305			2	9	0.57	0.02	-
9223-01-0305			4	9	0.37	0.02	-
9224-01-0305			24	12	0.13	0.01	-
9225-01-0305			12	15	0.29	0.01	-
9230-01-0228			<2†	6	0.31	0.02	-
9231-01-0228			10	10	1.7	0.05	-
9232-01-0228			18	13	3.7	0.08	0.02
9233-01-0228			2	4	0.18	0.02	0.04

† *Minimum detectable concentration*

†† *Gross alpha sample used for radium determination*

Sample No.	Station Description	Date	Analyses Performed			
			Cu	Fe	As	Co
			mg/l			
9011-30-0227			1.9	1,500	1.1	0.94
9012-01-0226			-	-	<0.05	-
9013-01-0226			-	-	<0.05	-
9017-01-0226			-	-	<0.05	-
9019-38-0228			0.1	0.22	3.0	0.10
9021-30-0228			0.5	200	0.15	0.62
9024-01-0303			-	-	<0.05	-
9026-01-0303			-	-	<0.05	-

Sample No.	Station Description	Date	Analyses Performed				
			Mo	Na	Se	V	Mn
			mg/l				
9001-30-0227	KM I-X TAILINGS BYPASS		2.5	180	0.06	0.7	0.03
9001-30-0228	KM I-X TAILINGS BYPASS		2.3	180	0.03	1.0	0.03
9001-30-0301	KM I-X TAILINGS BYPASS		2.4	180	0.07	1.0	0.03
9003-30-0227	KM Sec 30W MINE WATER		2.8	160	0.03	0.8	0.15
9003-30-0228	KM Sec 30W MINE WATER		2.6	160	0.04	0.7	0.18
9003-30-0301	KM Sec 30W MINE WATER		2.6	160	0.03	0.7	0.17
9005-30-0227	KM Sec 19 MINE WATER		0.6	120	<0.01	0.6	0.03
9007-30-0227	KM Sec 35 MINE WATER		5.2	190	0.08	0.6	0.09
9007-30-0228	KM Sec 35 MINE WATER		5.0	200	0.08	0.7	0.04
9007-30-0301	KM Sec 35 MINE WATER		4.7	210	0.04	1.0	0.06
9009-30-0227	KM Sec 36 MINE WATER		0.3	190	0.01	1.0	0.12
9009-30-0228	KM Sec 36 MINE WATER		0.3	190	<0.01	0.8	0.10
9009-30-0301	KM Sec 36 MINE WATER		0.3	180	0.01	0.8	0.12
9010-30-0227	KM Sec 36E MINE WATER		0.2	170	<0.01	0.8	0.10
9010-30-0228	KM Sec 36E MINE WATER		0.5	170	0.03	0.6	0.08
9010-30-0301	KM Sec 36E MINE WATER		0.3	170	0.01	0.4	0.08
9011-30-0227	KM SEEPAGE BELOW T POND		11	1,500	0.70	5.6	120
9012-01-0226	KM POTABLE WATER SUP		3.3	-	0.05	-	-
9013-01-0226	KM Sec 35 WATER SUP		8.2	-	0.02	-	-
9014-30-0228	RE JOHNNY M MINE WATER		0.3	60	<0.01	<0.3	0.01
9016-30-0227	UNC I-X DISCHARGE		4.4	310	0.11	<0.3	0.22
9016-30-0228	UNC I-X DISCHARGE		4.4	360	0.12	0.4	0.18
9016-30-0301	UNC I-X DISCHARGE		4.4	360	0.02	0.5	0.28
9017-01-0226	UNC POTABLE WATER SUP		6.0	-	0.11	-	-
9018-30-0227	UN-HP I-X DISCHARGE		1.3	140	0.33	0.4	0.05
9018-30-0228	UN-HP I-X DISCHARGE		1.5	140	0.33	<0.3	0.05
9018-30-0301	UN-HP I-X DISCHARGE		1.3	140	0.30	0.5	0.04
9019-30-0228	UN-HP T PILE DECANT		70	4,300	0.92	6.8	<0.01
9021-30-0228	ANAC INJ WELL FEED		0.2	1,200	0.03	6.3	340
9023-30-0304	UNC CHURCHROCK MINE D		0.2	100	0.06	0.5	0.05
9023-30-0305	UNC CHURCHROCK MINE D		0.2	100	0.06	0.4	0.06
9023-30-0306	UNC CHURCHROCK MINE D		0.1	90	<0.01	0.4	0.07
9023-01-0314	UNC CHURCHROCK MINE D		0.2	90	0.05	0.7	0.18
9024-01-0303	UNC CHURCHROCK POTABLE WATER SUP		1.9	-	0.06	-	-

Sample No.	Station Description	Date	Analysis Performed				
			Mo	Na	Se	V	Mn
			mg/l				
9025-30-0304	KM CHURCHROCK MINE DIS		0.2	90	0.01	0.7	0.07
9025-30-0305	KM CHURCHROCK MINE DIS		0.2	100	0.01	0.8	0.08
9025-30-0306	KM CHURCHROCK MINE DIS		0.2	100	0.01	0.9	0.10
9026-01-0303	KM CHURCHROCK MINE POTABLE WATER SUP		1.4	-	0.01	-	-
9036-01-0226	PUERTECITO CK DS KM		1.4	180	0.13	1.0	0.25
9036-01-0227	PUERTECITO CK DS KM		1.5	180	0.16	0.8	0.24
9036-01-0228	PUERTECITO CK DS KM		1.5	180	0.16	0.6	0.26
9038-01-0226	PUERTECITO CK @ RAN d PUERTO		2.1	160	0.07	0.5	0.08
9038-01-0227	PUERTECITO CK @ RAN d PUERTO		0.3	130	0.04	1.9	0.13
9038-01-0028	PUERTECITO CK @ RAN d PUERTO		1.5	130	0.01	0.8	0.11
9040-01-0226	SAN MATEO CK @ HWY 53		1.3	130	0.02	<0.3	1.8
9050-01-0303	RIO PUERCO DS UN & KM		0.5	110	0.07	0.5	1.9
9050-01-0304	RIO PUERCO DS UN & KM		0.3	100	0.03	0.6	0.19
9050-01-0305	RIO PUERCO DS UN & KM		0.3	100	0.03	0.6	0.19
9052-01-0303	RIO PUERCO US WINGATE		0.2	100	0.01	0.9	1.7
9052-01-0304	RIO PUERCO US WINGATE		0.2	90	0.01	0.5	0.61
9052-01-0305	RIO PUERCO US WINGATE		0.2	90	0.01	0.3	1.1
9054-01-0303	RIO PUERCO @ HWY 666		0.1	90	<0.01	0.3	0.12
9054-01-0304	RIO PUERCO @ HWY 666		0.2	90	<0.01	0.6	2.1
9054-01-0305	RIO PUERCO @ HWY 666		0.2	90	<0.01	0.6	2.0
9060-01-0228	RIO PAGUATE @ PAGUATE		<0.1	30	<0.01	0.6	0.11
9062-01-0228	RIO MOQUINO		0.2	70	<0.01	1.8	0.15
9064-01-0228	RIO PAGUATE @ JACKPILE FORD		0.2	120	0.05	0.5	0.28
9066-01-0228	RIO PAG @ PAG RES DIS		0.2	160	<0.01	0.6	0.14
9068-01-0228	RIO SAN JOSE		0.1	230	<0.01	<0.3	0.09
9080-01-0304	KM Sec 36 3000 DRIFT		0.1	220	0.01	<0.3	0.02
9081-01-0304	KM Sec 36 0900 DRIFT		0.4	260	<0.01	<0.3	0.06
9082-01-0305	UNC CHURCHROCK POT WS @ SOWERS TR		<0.1	100	0.06	0.6	0.03
9101-01-0224					-	-	
9102-01-0224	G WILCOX - MURRAY ACRES				1.06	<0.3	
9103-01-0225					-	-	
9104-01-0225					-	-	
9105-01-0225					-	-	
9106-01-0225					-	-	

Sample No.	Station Description	Date	Analysis Performed				
			Mo	Na	Se	V	Mn
			mg/l				
9107-01-0225	C WORTHEN, BROADVIEW ACRES				1.06	0.3	
9108-01-0225					-	-	
9109-01-0225					-	-	
9110-01-0225					-	-	
9111-01-0225					-	-	
9112-01-0225					-	-	
9113-01-0226	C MEADOR - BROADVIEW ACRES				0.20	0.3	
9114-01-0226					-	-	
9115-01-0226					-	-	
9116-01-0226					-	-	
9117-01-0227					0.01	0.3	
9118-01-0227					0.01	0.8	
9119-01-0227					<0.01	0.9	
9120-01-0227					0.01	1.0	
9121-01-0227					0.01	0.8	
9122-01-0227					-	-	
9123-01-0228					0.01	1.1	
9124-01-0228					-	-	
9125-01-0228					-	-	
9126-01-0228					-	-	
9127-01-0228					-	-	
9128-01-0228					-	-	
9129-01-0228					0.02	1.3	
9130-01-0301					-	-	
9131-01-0301					-	-	
9132-01-0301	MARCUS WINDMILL				0.13	<0.3	
9133-01-0302					-	-	
9134-01-0303					<0.01	1.3	
9135-01-0303	UNHP WELL P				1.52	0.4	
9136-01-0303					-	-	
9137-01-0303					-	-	
9138-01-0303					<0.01	<0.3	
9139-01-0305					-	-	
9140-01-0305					<0.01	<0.3	

Sample No.	Station Description	Date	Analysis Performed				
			Mo	Na	Se	V	Mn
			mg/l				
9141-01-0305					<0.01	<0.3	
9142-01-0305					<0.01	<0.3	
9143-01-0305					-	-	
9201-01-0226					<0.01	<0.3	
9202-01-0226					-	-	
9203-01-0226					-	-	
9204-01-0226					-	-	
9205-01-0226					-	-	
9206-01-0226					-	-	
9207-01-0227					<0.01	0.4	
9208-01-0227	06 KM 43 14N, 9W Sec 32				0.29	0.8	
9209-01-0227					0.01	<0.3	
9210-01-0227					-	-	
9211-01-0227					<0.01	0.5	
9212-01-0303					-	-	
9213-01-0303					<0.01	0.6	
9214-01-0303					0.02	<0.3	
9215-01-0303					<0.01	<0.3	
9216-01-0303					-	-	
9217-01-0303					-	-	
9218-01-0303					-	-	
9219-01-0303					0.01	<0.3	
9220-01-0305					-	-	
9221-01-0305					0.01	<0.3	
9222-01-0305					-	-	
9223-01-0305					<0.01	<0.3	
9224-01-0305					-	-	
9225-01-0305					-	-	
9230-01-0228					<0.01	<0.3	
9231-01-0228					-	-	
9232-01-0228					<0.01	<0.3	
9233-01-0228					<0.01	0.3	

Sample No.	Station Description	Date	Analyses Performed				
			TSS	SO_4	Cl	NH_3 †	$NO_2 + NO_3$ †
			mg/l				
9001	KERR-MCGEE I-X TAILINGS BYPASS	Feb. 26	-	-	-	0.06	0.88
		Feb. 27	16	-	45	0.06	0.79
		Feb. 28	31	-	68	0.05	0.90
		Mar. 1	29	-	20	-	-
9003	KERR-MCGEE Sec 30W MINE WATER	Feb. 26	-	-	-	0.19	1.3
		Feb. 27	26	-	52	0.21	1.2
		Feb. 28	23	-	49	0.18	0.94
		Mar. 1	17	-	53	-	-
9005	KERR-MCGEE Sec 19 MINE WATER	Feb. 27	16	-	7.9	0.13	1.4
9007	KERR-MCGEE Sec 35 MINE WATER	Feb. 26	-	-	-	0.11	0.22
		Feb. 27	120	-	9.4	0.15	0.39
		Feb. 28	93	-	7.6	0.06	0.44
		Mar. 1	86	-	8.4	-	-
9009	KERR-MCGEE Sec 36 W MINE WATER	Feb. 26	-	-	-	0.07	0.30
		Feb. 27	36	13	-	0.04	0.21
		Feb. 28	44	13	-	0.04	0.26
		Mar. 1	33	13	-	-	-
9010	KERR-MCGEE Sec 36 E MINE WATER	Feb. 26	-	-	-	0.04	0.34
		Feb. 27	32	14	-	0.03	0.26
		Feb. 28	29	17	-	1.8	0.28
		Mar. 1	27	14	-	-	-
9011	KERR-MCGEE SEEPAGE BELOW	Feb. 27 COMP	38	2,200	15,000	-	-
	TAILINGS POND	Feb. 27 GRAB	48	2,200	16,000	460	16
9012	KERR-MCGEE POTABLE WATER SUPPLY	Feb. 26	-	-	-	0.13	1.0
9013	KERR-MCGEE Sec 35 WATER SUPPLY	Feb. 26	-	-	-	0.18	0.32
9014	RANCHERS EXPL JOHNNY M MINE WATER	Feb. 28	7	6.1	-	-	-
9016	UNITED NUCLEAR CORP I-X DISCHG	Feb. 26	-	-	-	0.07	0.28
		Feb. 27	5	-	190	0.04	0.07
		Feb. 28	7	-	200	0.01	0.06
		Mar. 1	3	-	190	-	-
9017	UNC POTABLE WATER SUPPLY	Feb. 26	-	-	-	0.08	0.06
9018	UNC-HP I-X DISCHARGE	Feb. 26	-	-	-	0.05	2.1
		Feb. 27	7	-	49	0.06	2.1
		Feb. 28	16	-	49	0.10	2.2
		Mar. 1	7	-	49	-	-

† *Grab Samples*

Sample No.	Station Description	Date	Analyses Performed				
			TSS	SO_4	Cl	NH_3†	$NO_2 + NO_3$†
			mg/l				
9019	UNC-HP TAILINGS PILE DECANT	Feb. 28	5	4,300	1.5	4.4	4.4
9021	ANACONDA CO INJECTION WELL FEED	Feb. 27	-	4,900	-	69	7.4
		Feb. 28	3	-	65	-	-
9023	UN CHURCHROCK MINE DISCHARGE	Mar. 3	-		-	0.04	0.23
		Mar. 4	33		5.2	0.03	0.24
		Mar. 5	47		4.5	-	-
		Mar. 6	71		5.0	0.07	0.20
		Mar. 14	320		-	-	-
9024	UNC POTABLE WATER SUPPLY	Mar. 3	-		-	0.05	0.25
9025	KM CHURCHROCK MINE DISCHARGE	Mar. 3	-		-	0.03	0.34
		Mar. 4	38		0	0.06	0.45
		Mar. 5	45		0.5	-	-
		Mar. 6	58		3.2	0.07	0.79
9026	KM CHURCHROCK MINE POTABLE WS	Mar. 3	-		-	0.02	0.42
9036	PUERTECITO CREEK	Feb. 26			72	0.38	2.3
		Feb. 27			83	0.40	1.8
		Feb. 28			71	0.26	2.9
9038	PUERTECITO CREEK	Feb. 26			42	0.10	0.22
		Feb. 27			48	0.13	0.06
		Feb. 28			48	0.11	0.25
9040	SAN MATEO CREEK	Feb. 26			39	-	-
9050	RIO PUERCO @ HWY BRIDGE	Mar. 3			5.9		
		Mar. 4			3.8		
		Mar. 5			3.8		
9052	RIO PUERCO UPSTREAM OF WINGATE PLANK	Mar. 3			6.9		
		Mar. 4			6.8		
		Mar. 5			6.5		
9054	RIO PUERCO @ HWY 666	Mar. 3			23		
		Mar. 4			20		
		Mar. 5			17		
9068	RIO-PAGUATE	Feb. 28			0.6		
9062	RIO MOQUINO	Feb. 28			8.3		
9064	RIO PAGUATE	Feb. 28			2.0		
9066	RIO PAGUATE	Feb. 28			15		
9068	RIO SAN JOSE	Feb. 28			154		

† *Grab Samples*

Sample No.	Station Description	Date	Analyses Performed				
			TDS	SO_4	Cl	NH_3	$NO_2 + NO_3$
			mg/l				
9101	MT TAYLOR MILL WORKS OLD RTE 66	Feb. 24	780		25	0.04	4.2
9102	G WILCOX - MURRAY ACRES	Feb. 24	2,300		180	0.01	5.5
9103	Q CONNERLY - ZUNI TRAILER PARK	Feb. 25	880		33	<0.01	6.2
9104	T SIMPSON - MURRAY ACRES	Feb. 25	1,400		37	<0.01	0.08
9105	SCHWAGERTY - MURRAY ACRES	Feb. 25	1,300		46	<0.01	1.00
9106	J PITMAN - BROADVIEW ACRES	Feb. 25	1,300		39	<0.01	0.33
9107	C WORTHEN - BROADVIEW ACRES	Feb. 25	3,800		260	0.01	14
9108	PITNEY - MURRAY ACRES	Feb. 25	2,200		110	0.01	3.3
9109	T A CHAPMAN - MURRAY ACRES	Feb. 25	1,300		9.5	0.01	2.5
9110	1-X WATER HOLIDAY INN - GRANTS	Feb. 25	430		55	0.01	0.11
9111	C&E CONCRETE - GRANTS	Feb. 26	560		30	0.05	3.4
9112	GRANTS CITY HALL-CITY WATER SUP	Feb. 26	730		32	0.02	0.47
9113	C MEADOR - BROADVIEW ACRES	Feb. 26	1,600		120	0.01	2.9
9114	BELL - TRAILER PARK	Feb. 26	970		34	<0.01	0.08
9115	COWELL - SE OF ANACONDA	Feb. 26	1,100		6.2	0.02	3.9
9116	MILAN WELL #1 CITY WATER	Feb. 26	500		14	0.02	1.6
9117	ANACONDA - MONITOR WELL	Feb. 27	2,300		11	0.03	1.5
9118	ANACONDA - WELL 2	Feb. 29	1,900		270	0.64	9.0
9119	ANACONDA - WELL 4	Feb. 27	880		42	0.13	5.7
9120	ANACONDA - MEXICAN CAMP	Feb. 27	490		10	0.04	0.73
9121	ANACONDA - GERRYHILL Sec 5	Feb. 27	2,000		4.2	0.14	0.05
9122	ANACONDA - NORTH WELL	Feb. 27	1,900		4.2	0.08	1.3
9123	ANACONDA - ENGINEERS' WELL	Feb. 28	960		61	0.09	3.20
9124	ANACONDA - BERRYHILL HOUSE	Feb. 28	940		65	0.05	0.80
9125	ANACONDA - LOS BLUEWATER	Feb. 28	1,000		12	0.05	0.95
9126	ANACONDA - ROUNDY	Feb. 28	1,100		110	0.04	6.5
9127	ANACONDA - FRED FREAS	Feb. 28	540		18	0.03	0.03
9128	ANACONDA - LEROY CHAPMAN	Feb. 28	490		18	0.03	1.4
9129	ANACONDA - JACK FREAS	Feb. 28	780		54	0.04	2.5
9130	N MARQUEZ - HOUSE WELL	Mar. 1	720		4.8	0.04	0.06
9131	C SANDOVAL - WINDMILL	Mar. 1	660		27	0.06	1.2
9132	N MARQUEZ - WINDMILL	Mar. 1	2,200		43	0.22	24
9133	G ENYART - GRANTS	Mar. 2	1,600		50	0.26	0.97

Sample No.	Station Description	Date	Analyses Performed				
			TDS	SO_4	Cl	NH_3	$NO_2 + NO_3$
			mg/l				
9134	UN HP SUPPLY WELL 2	Mar. 3	1,600		0.2	0.03	0.42
9135	UN HP WELL D	Mar. 3	4,500		340	1.0	2.6
9136	UN HP SUPPLY WELL 1	Mar. 3	2,000		<0.2	0.07	0.28
9137	ERWIN WELL - GALLUP	Mar. 5	740		14	0.09	0.02
9138	BOARDMAN TRAILER PARK - GALLUP	Mar. 5	930		<0.2	0.50	1.2
9139	G HASSLER - GALLUP	Mar. 5	880		98	0.02	27
9140	DIXIE WELL - GALLUP	Mar. 5	1,500		<0.2	0.30	0.16
9141	CHURCHROCK VILLAGE	Mar. 5	720		0.5	0.50	0.18
9142	WHITE WELL - GALLUP	Mar. 5	620		630	0.01	0.02
9143	TOGAY WELL - GALLUP	Mar. 5	340		14	0.02	8.0
9201	PHIL HARRIS (WILCOXSON) KM 46	Feb. 26	1,900		23	0.14	0.09
9202	COUNTY LINE STOCK TANK KM 52	Feb. 26	2,100		56	0.06	14
9203	NAVAHO WIND MILL KM 45	Feb. 26	400		6.8	0.02	4.0
9204	INGERSOLL RAND KM 49	Feb. 26	2,200		36	0.05	18
9205	BINGHAM (RAGLAND) KM 47	Feb. 26	2,000		40	0.04	4.7
9206	MARQUEZ (RAGLAND) KM 63	Feb. 26	1,900		34	0.05	44
9207	KM-S-12	Feb. 27	14,000		3,100	0.50	0.04
9208	KM-43	Feb. 27	7,800		38	NS	NS
9209	KM-44	Feb. 27	2,700		17	0.66	11
9210	KM-51	Feb. 27	6,300		44	0.30	79
9211	KM-48	Feb. 27	4,100		31	0.80	1.3
9212	KM SEEPAGE RETURN	Mar. 3	36,000		3,100	590	12
9213	KM B-2	Mar. 3	8,900		3,400	0.12	0.25
9214	KM 36-2	Mar. 3	9,100		1,700	2.9	8.0
9215	KM 46	Mar. 3	3,200		100	10	2.0
9216	KM 47	Mar. 3	2,600		74	0.80	2.6
9217	KM 50	Mar. 3	4,700		470	9.1	16
9218	KM 51	Mar. 3	4,800		61	0.16	0.40
9219	KM 52	Mar. 3	6,700		1,300	0.08	1.3
9220	HARDGROUND FLATS WELL CRKM 2	Mar. 5	850		0.2	0.03	0.28
9221	E PUERCO R WELL CRKM 11	Mar. 5	340		14	0.04	14

Sample No.	Station Description	Date	Analyses Performed				
			TDS	SO_4	Cl	NH_3	$NO_2 + NO_3$
			mg/l				
9222	PUERCO WELL CRKM 16	Mar. 5	1,600		<0.2	34	0.01
9223	PIPELINE ROAD WELL CRK M 5	Mar. 5	880		<0.2	1.4	1.6
9224	NOSEROCK WELL CRKM 3	Mar. 5	980		<0.2	0.07	0.03
9225	NORTHEAST PIPELINE WELL CRK M10	Mar. 5	2,300		8.1	0.12	0.01
9230	ANACONDA JACKPILE WELL 4	Feb. 28	540		<0.2	0.05	0.05
9231	ANACONDA JACKPILE WELL P 10	Feb. 28	1,200		0.5	0.08	0.04
9232	ANACONDA JACKPILE WELL - NEW SHOP	Feb. 28	1,400		0.5	0.14	0.05
9233	PUGUATE MUNICIPAL WELL	Feb. 28	340		6.6	0.08	0.20

Appendix D

SELENIUM

EPA WATER QUALITY CRITERIA 1972

SELENIUM*

The toxicity of selenium resembles that of arsenic and can, if exposure is sufficient, cause death. Acute selenium toxicity is characterized by nervousness, vomiting, cough, dyspnea, convulsions, abdominal pain, diarrhea, hypotension, and respiratory failure. Chronic exposure leads to marked pallor, red staining of fingers, teeth and hair, debility, depression, epistaxis, gastrointestinal disturbances, dermatitis, and irritation of the nose and throat. Both acute and chronic exposure can cause odor on the breath similar to garlic (The Merck Index of Chemicals and Drugs 1968).[236] The only documented case of selenium toxicity from a water source, uncomplicated with selenium in the diet, concerned a three-month exposure to well water containing 9 mg/l (Beath 1962).[231]

Although previous evidence suggested that selenium was carcinogenic (Fitzhugh et al. 1944),[232] these observations have not been borne out by subsequent data (Volganev and Tschenkes 1967).[246] In recent years, selenium has become recognized as a dietary essential in a number of species (Schwarz 1960,[241] Nesheim and Scott 1961,[238] Oldfield et al. 1963[239]).

Elemental selenium is highly insoluble and requires oxidation to selenite or selenate before appreciable quantities appear in water (Lakin and Davidson 1967).[235] There is evidence that this reaction is catalyzed by certain soil bacteria (Olson 1967).[240]

No systematic investigation of the forms of selenium in excessive concentrations in drinking water sources has been carried out. However, from what is known of the solubilities of the various compounds of selenium, the principal inorganic compounds of selenium would be selenite and selenate. The ratio of their individual occurrences would depend primarily on pH. Organic forms of selenium occurred in seleniferous soils and had sufficient mobility in an aqueous environment to be preferentially absorbed over selenate in certain plants (Hamilton and Beath 1964).[234] However, the extent to which these compounds might occur in source waters is essentially unknown. Toxicologic examination of plant sources of selenium revealed that selenium present in seleniferous grains was more toxic than inorganic selenium added to the diet (Franke and Potter 1935).[233]

Intake of selenium from foods in seleniferous areas (Smith 1941),[242] may range from 600 to 6,340 μg/day, which approach estimated levels related to symptoms of selenium toxicity in man based on urine samples (Smith et al. 1936,[243] Smith and Westfall 1937[244]). If data on selenium in foods (Morris and Levander 1970)[237] are applied to the average consumption of foods (U.S. Department of Agriculture, Agriculture Research Service, Consumer and Food Economics Research Division 1967),[245] the normal dietary intake of selenium is about 200 μg/day.

If it is assumed that two liters of water are ingested per day, a 0.01 mg/l concentration of total selenium would increase the normal total dietary intake by 10 per cent (20 μg/day). Considering the range of selenium in food associated with symptoms of toxicity in man, this would provide a safety factor of from 2.7 to 29. A serious weakness in these calculations is that their validity depends on an assumption of equivalent toxicity of selenium in food and water, in spite of the fact that a considerable portion of selenium associated with plants is in an organic form. Adequate toxicological data that specifically examine the organic and the inorganic selenium compounds are not available.

Recommendation

Because the defined treatment process has little or no effect on removing selenium, and because there is a lack of data on its toxic effects on humans when ingested in water, it is recommended that public water supply sources contain no more than 0.01 mg/l selenium.

* *Water Quality Criteria, 1972, Environmental Protection Agency, Washington, D.C.*

Technical Note
ORP/LV-75-4

SUMMARY OF GROUND-WATER QUALITY IMPACTS OF URANIUM MINING AND MILLING IN THE GRANTS MINERAL BELT, NEW MEXICO

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PREFACE

The Office of Radiation Programs of the Environmental Protection Agency carries out a national program designed to evaluate population exposure to ionizing and non-ionizing radiation and to promote development of controls necessary to protect the public health and safety.

Within the Office of Radiation Programs, the Las Vegas Facility (ORP-LVF) conducts in-depth field studies of various radiation sources (e.g., nuclear facilities, uranium mill tailings, and phosphate mills) to provide technical data for environmental impact statement reviews as well as needed information on source characteristics, environmental transport, critical pathways for population exposure, and dose model validation.

This report summarizes the results of the ground-water study conducted by ORP-LVF during February and March 1975 in the Grants Mineral Belt area of New Mexico. The final technical report, "Ground-Water Quality Impacts of Uranium Mining and Milling in the Grants Mineral Belt, New Mexico", will be published at a later date as EPA-520/6-75-013.

Readers of this report are encouraged to inform the Office of Radiation Programs of any omissions or errors. Comments or requests for further information are also invited.

Donald W. Hendricks
Director, Office of
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PURPOSE OF STUDY

In September 1974, the State of New Mexico Environmental Improvement Agency (NMEIA) made a request of Region VI of the U.S. Environmental Protection Agency (USEPA) to conduct a definitive survey of the Grants Mineral Belt area (Wright, 1974). At this time, a summary report evaluating the problem areas in the study area was also prepared by Region VI (Keefer, 1974). Briefly, the water-quality impacts associated with ongoing and projected uranium mining and milling in the Grants Mineral Belt of New Mexico were unknown. Whether a problem existed was questionable but worthy of investigation because of the toxic nature of the effluents and their persistence in the environment. The study areas of most concern were located near Churchrock, Ambrosia Lake-Grants, and Laguna-Paguate.

In late November 1974, the Office of Radiation Programs-Las Vegas Facility (ORP-LVF) and the National Enforcement Investigations Center (NEIC) were requested by Region VI to provide direct assistance to the NMEIA to conduct the study.

Representatives of ORP-LVF, NEIC, and NMEIA completed a field reconnaissance of the study area during the week of January 24, 1975. Industry representatives were contacted, arrangements were made for site access, and sampling locations and collection schedules were finalized after reviewing company monitoring programs. Study plans were prepared by both ORP-LVF and NEIC defining study participants, responsibilities, and specific analyses to be completed per location by each laboratory.

Subsequent meetings between the three participating agencies resulted in a final study plan which defined the following study objectives to the satisfaction of NMEIA (Bond, 1975):

1. Assess the impacts of waste discharges from uranium mining and milling on surface waters and ground waters of the Grants Mineral Belt.

2. Determine if discharges comply with all applicable regulations, standards, permits, and licenses.

3. Evaluate the adequacy of company water quality monitoring networks, self-monitoring data, analytical procedures, and reporting requirements.

4. Determine the composition of potable waters at uranium mines and mills.

5. Develop priorities for subsequent monitoring and other follow-up studies.

Ground-water aspects of objectives 1, 3, and 5 were the responsibility of ORP-LVF, whereas the remaining objectives were pursued by NEIC.

Actual sample collection began in late February 1975 in the Ambrosia Lake-Bluewater area. It proceeded to Paguate-Jackpile and was finally completed in the Gallup-Churchrock area in early March 1975. Laboratory analyses for the trace metals, gross alpha, and radium-226 were completed by NEIC. The other radiological analyses were completed by the Environmental Monitoring and Support Laboratory (EMSL), Las Vegas. Radiometric analyses were assigned the highest priority at each laboratory and were completed in July 1975.

SUMMARY AND CONCLUSIONS

TASK I: Assess the Impacts of Waste Discharges from Uranium Mining and Milling on Ground Waters of the Grants Mineral Belt.

1. Ground water is the principal source of water supply in the study area. Extensive development of ground water from the San Andres Limestone aquifer occurs in the Grants-Bluewater area where the water is used for agriculture, public water supply, and uranium mill feed water. Development of shallow, unconfined aquifers in the alluvium also occurs in this area. Principal ground-water development in the mining areas at Ambrosia Lake, Jackpile-Paguate, and Churchrock is from the Morrison Formation and, to a lesser extent, from the Dakota Sandstone or the Tres Hermanos Member of the Mancos Shale. The Gallup water supply is derived primarily from deep wells completed in the Gallup Sandstone using well fields located east and west of the urban area and 11 kilometers north of the city.

2. In proximity to the mines and mills and adjacent to the principal surface drainage courses, shallow ground-water contamination results from the infiltration of (1) effluents from mill tailings ponds, (2) mine drainage water that is first introduced to settling lagoons and thence to watercourses, and (3) discharge (tailings) from ion exchange plants. In the case of the Anaconda mill, seepage from the tailings ponds and migration of wastes injected into deep bedrock formations are observed in the San Andres Limestone and in the alluvium, both of which are potable aquifers. With the exception of seepage from the Kerr-McGee Section 36 mine in Ambrosia Lake, significant amounts of wastewater from the remaining mines and mills probably does not return to known bedrock aquifers. Deterioration of water quality results from conventional underground mining as a result of penetration or disruption of the ore body. The most dramatic changes are greatly increased dissolved radium and uranium. Induced movement of naturally saline ground water into potable aquifers is also likely but undocumented. Similarly, the ground-water quality impacts of solution (<u>in situ</u>) mining are unknown.

3. The Grants, Milan, Laguna, and Bluewater municipal water supplies have not been adversely affected by uranium mining and milling operations to date. For the Grants and Milan areas, chemical data from 1962 to the present indicate that near the Anaconda mill some observation wells have

increased slightly in total dissolved solids, sulfate, chloride and gross alpha but domestic wells have generally remained unchanged. Projections made in 1957 of gross nitrate deterioration of ground water have not been substantiated by subsequent data. Of the municipal supply wells in the study area, the Bluewater well bears additional monitoring because of its location relative to the Anaconda tailings ponds.

4. Contamination of the Gallup municipal ground-water supply by surface flows, consisting mostly of mine drainage, has not occurred and is extremely unlikely because of geologic conditions in the well field and the depth to productive aquifers. Another well field north of the City will, in no way, be affected by the drainage.

5. With the exception of the areas south and southwest of the United Nuclear-Homestake Partners mill, widespread ground-water contamination from mining and milling was not observed in the study area. Throughout the study area widespread contamination of ground water with radium was not observed despite concentrations of as much as 178 pCi/l in mine and mill effluents. Radium removal is pronounced, probably due to sorptive capacity of soils in the area. In the vicinity of the Anaconda mill, radium and nitrate concentrations in the alluvial aquifer decline with distance from the tailings ponds, but neither parameter exceeds drinking water standards.

6. Ground water in at least part of the shallow aquifer developed for domestic water supply downgradient from the United Nuclear-Homestake Partners mill is contaminated with selenium. Alternative water supplies can be developed using deep wells completed in the Chinle Formation or in the San Andres Limestone. Potential well sites are located in the developments affected and in the adjacent area. A third alternative includes connecting to the Milan municipal system. Further evaluations are necessary to determine the best course of action.

7. Mining practices, per se, have an adverse effect on natural water quality. Initial penetration and disruption of the ore body in the Churchrock mining area increased the concentration of dissolved radium in water pumped from the mines from 0.05 - 0.62 pCi/l to over 8 pCi/l. According to company data, the concentration rose to over 75 pCi/l, or at least 75 times the natural concentration, in the two-year period during which the mine was being developed. The pattern of increasing radium with time, seen in Ambrosia Lake, is being repeated. Ground-water inflow via long holes

in the Kerr-McGee Section 36 mine contains a relatively low concentration of dissolved radium-226. Therefore, much of the radium loading of mine effluent is apparently a result of leaching of ore solids remaining from mucking and transport within the mine. In some cases this could be reduced by improved mining practices, such as provision of drainage channels along haulage drifts.

8. Company data show that seepage from the Anaconda tailings pond at Bluewater averages 183 million liters/year (48.3 million gallons) for 1973 and 1974. The average volume injected for the same time period was 348 million liters/year (91.9 million gallons). Therefore, approximately one-third of the total effluent volume remaining after evaporation (531 million liters/year) enters the shallow aquifer which is a source of potable and irrigation water in Bluewater Valley. From 1960 through 1974, seepage alone introduced 0.41 curies of radium to the shallow potable aquifer. Adequate monitoring of the movement of the seepage and the injected wastes is not underway.

9. There are indications that waste injected into the Yeso Formation by the Anaconda Company are not confined to that unit as originally intended in 1960. Three nearby monitoring wells, completed in the overlying San Andres Limestone and/or the Glorieta Sandstone, show a trend of increasing chloride and uranium with time. Positive correlations of water quality fluctuations with the volumes of waste injected are a further indication of upward movement. The absence of monitoring wells in the injection zone is a major deficiency in the data collection program.

10. The maximum concentration of radium observed in shallow ground water adjacent to the Kerr-McGee mill at Ambrosia Lake was 6.6 pCi/l. According to company data, seepage from the tailings ponds occurs at the rate of 491 million liters/year (130 million gallons/year). This is 29 percent of the influent to the "evaporation ponds" and attests to their poor performance in this regard. Radium and gross alpha in the seepage are 56 pCi/l and 112,000-144,000 pCi/l, respectively. Total radium introduced to the ground water to date is estimated at 0.7 curies. Wells completed in bedrock and in alluvium, and located near watercourses containing mine drainage and seepage from tailings ponds, contain elevated levels of TDS, ammonia, and nitrate. One well, which contained 1.0 pCi/l in 1962, now is contaminated with 3.7 pCi/l of radium. Sorption or bio-uptake of radium is pronounced; hence, concentrations now in ground water are not representative of ultimate concentrations.

11. Water-quality data from 11 wells over a 200-square kilometer area in the Puerco River and South Fork Puerco River drainage basins reveal essentially no noticeable increase in concentrations of radionuclides or common inorganic and trace constituents in ground water as a result of mine drainage. Natural variations in the uranium content of sediments probably account for differences in radium content in shallow wells. Dissolved radium in shallow ground water underlying stream courses affected by waste water is essentially unchanged from that in areas unaffected by mine drainage. None of the samples contained more than recommended maximum concentrations for radium-226, natural uranium, thorium-230, thorium-232, or polonium-210 in drinking water. However, the paucity of sampling points and the absence of historical data make the foregoing conclusion a conditional one, particularly in the reaches of the Puerco River within approximately 10 kilometers downstream of the mines.

12. Four wells sampled in the vicinity of the Jackpile mine near Paguate contained 0.31 to 3.7 pCi/l radium-226. With the exception of the latter value from the new shop well in the mine area, remaining supplies contain 1.7 pCi/l or less radium. The Paguate municipal supply contains 0.18 pCi/l. None of the wells were above maximum permissible concentrations (MPC) for the other common isotopes of uranium, thorium, and polonium. Ground water from the Jackpile Sandstone may contain elevated levels of radium as a result of mining activities. Mine drainage water ponded within the pit contained 190 pCi/l radium and 170 pCi/l of uranium in 1970. The impacts of mining on ground-water quality downgradient from the mining area are unknown due to the lack of properly located monitoring wells. No adverse impacts from mining on the present water supply source for Paguate are expected.

13. Of the 71 ground-water samples collected for this study, a total of 6 had radium-226 in excess of the 3 pCi/l PHS Drinking Water Standard. Two of the 6 involved potable water supplies. One containing 3.6 pCi/l serves a single family and is located adjacent to Arroyo del Puerto and downgradient from the mines and mills in Ambrosia Lake. The second contains 3.7 pCi/l and is used as a potable supply for the labor force in the new shop at the Jackpile Mine.

14. The highest isotopic uranium and thorium, and polonium-210 contents for any potable ground-water supplies sampled in the study area are less than 1.72% of the total radionuclide population guide - MPC as established in NMEIA regulations.

15. The lowest observed concentration (background levels) in ground water are summarized as follows:

Radionuclides	Range (pCi/l)	Average (pCi/l)
Radium-226	0.06 - 0.31	0.16
Polonium-210	0.27 - 0.57	0.36
Thorium-230	0.013- 0.051	0.028
Thorium-232	0.010- 0.024	0.015
U-Natural	14 - 68	35

16. The uranium isotopes (uranium 234, 235 and 238) are the main contributors to the gross alpha result; however, in several determinations, gross alpha underestimated the activity present from natural uranium.

17. No correlation was found between gross alpha content of 15 pCi/l (including uranium isotopes) and a radium-226 content of 5 pCi/l.

18. It is doubtful that the gross alpha determination can even be used as an indicator of the presence of other alpha emitters (e.g., U-natural and polonium-210). Furthermore, since the gross alpha results have such large error terms, no meaningful determination of percentage of radionuclides to gross alpha can be implied.

19. Gross alpha determinations also failed to indicate the possible presence of lead-210 (primarily a beta emitter) which, because of the lower MPC of 33 pCi/l, may be a significant contributor to the radiological health hazard evaluation of any potable water supply.

20. Radium-226 in ground water is a good radiochemical indicator of wastewater contamination from mines and mills. Due to the low maximum permissible concentration, it also provides a good means for evaluating health effects. Selenium and nitrate also indicated the presence of mill effluents in ground water. Polonium-210, thorium-230 and thorium-232 concentrations in ground water fluctuate about background levels and are poor indicators of ground-water contamination from uranium mining and milling activities.

21. For routine radiological monitoring of potable ground-water supplies, isotopic uranium and thorium and polonium-210 analyses do not appear to be necessary due to their high maximum permissible concentrations (chemical toxicity of uranium may be a significant limiting factor, however).

TASK II: Evaluate the Adequacy of Company Water Quality Monitoring Networks, Self-Monitoring Data, Analytical Procedures, and Reporting Requirements.

1. Company sponsored ground-water monitoring programs range from inadequate to nonexistent. Actual monitoring networks are deficient in that sampling points are usually poorly located or of inadequate depth/location relative to the hydrogeologic system and the introduction of contaminants thereto. Compared to the multi-million dollar uranium industry, producing multi-billion liters of toxic effluents, the ground-water sampling and monitoring programs represent minimal efforts in terms of network design, implementation, and level of investment.

2. Company radiochemical analytical methods are inadequate for measuring environmental levels of radionuclides and have high minimum detectable activities and large error terms. Incomplete analysis of radionuclide contents prevails. Few data are reported on other naturally occurring radionuclides such as isotopic thorium, polonium-210, and radium-228. In some cases, monitoring has been restricted to analysis of radium-226 and natural uranium, without consideration of these other radionuclides or toxic metals.

3. Monitoring of hydraulic and water-quality impacts associated with conventional mining and with solution (in situ) mining is not reported to regulatory agencies. It is likely that such monitoring is limited to meeting short-term economic and engineering needs of the companies rather than addressing long-term, general environmental concerns. As a result, overall impacts on ground water are not routinely determined and reported.

4. Off-site ground-water sampling networks do not utilize wells specifically located and constructed for monitoring purposes. Reliance on wells already in existence and utilized for domestic or livestock use falls short of the overall monitoring objectives (i.e., to determine impacts on ground water and to adjust company operations to acceptable levels). Deficiencies of this type can allow contamination to proceed unnoticed. On-site wells constructed specifically for monitoring are generally not completed to provide representative hydraulic and water quality data for the aquifer most likely to be affected.

5. Proven geophysical and geohydrologic techniques to formulate environmental monitoring networks are apparently not used. Such techniques can assist in specifying sampling

frequencies and provide the basis for adjustment of monitoring and operational practices to mitigate adverse impacts on ground water.

6. Monitoring the effects of the Jackpile and Paguate open pit mines on ground-water quality is nonexistent despite the magnitude of these operations. Drainage water within the pits has contained as much as 190 pCi/l of radium. Two wells, used for potable supply and completed in the ore body, contain elevated levels of radium, further indicating a need for data to determine what the future impacts might be when mining ceases and before additional programs for heap leaching and in situ mining are implemented.

7. Careful analysis of material and water balances to determine seepage input to ground water for the various tailings disposal operations is not evident. For the Ananconda Company, the method utilized has not been altered in 14 years. For Kerr-McGee, overland flow presents a potential threat to the structural integrity of the retention dams. At the United Nuclear-Homestake Partners Mill, no quantitative estimates of seepage are available.

8. Records of U. S. Atomic Energy Commission (USAEC) inspection reports, mill license applications, seepage reports, etc., on file with the State appear to be incomplete and disorganized. No interpretive summary or review-type reports utilizing the monitoring data reported by industry are available from either the State or the U.S. Atomic Energy Commission files now held by the State. Liberal mill licensing conditions with respect to ground-water monitoring and water-quality impacts were initially established by the USAEC. Subsequently, there has been essentially no review, in any critical sense, of company operations with respect to ground-water contamination. The uranium mining and milling industry has not been pressed to monitor and protect ground-water resources. The limited efforts put forth by industry to date have largely not been reviewed by regulatory agencies at the State and Federal levels.

RECOMMENDATIONS

Action Required

1. Improved industry-sponsored monitoring programs should be implemented and the data made available to State and Federal regulatory agencies. Programs should be designed to detect likely hydraulic and water quality impacts from uranium milling and mining (open pit, underground, in situ). Revamped programs, specifically developed by joint concurrence of industry and regulatory agencies, should be incorporated in licenses, where possible. Licenses should specify minimal radiochemical analytical methods for detecting specific radionuclides as well as requirements for participation in quality assurance programs. Specific reporting procedures should include raw data, summary reports, and interpretations of data. Conclusions concerning impacts of operations on ground-water quality and remedial steps taken to abate or eliminate adverse impacts should be prepared. It is essential that the programs developed, as well as the data and interpretive reports prepared therefrom, be critically reviewed by the State to meet continuing regulatory responsibilities.

2. Because seepage from the Anaconda and Kerr-McGee tailings ponds constitutes a significant portion of the inflow to the ponds, it is recommended that seepage control measures be adopted. According to company records, such seepage presently totals some 674 million liters per year. Water budget analyses of the United Nuclear-Homestake Partners tailings pond should be made to determine how much seepage is occurring, and thereby contributing to contamination of the shallow aquifer locally developed for domestic water supplies in two adjacent privately owned housing developments.

3. Improved mining practices should be adopted to reduce the amount of radium leached from ore solids by ground water present in operating mines.

ADDITIONAL STUDIES REQUIRED

1. Studies should be immediately initiated to verify whether the source of ground-water contamination in the Broadview Acres and Murray Acres subdivision is from the nearby uranium mill. An improved monitoring program should be developed to predict contaminant migration and to provide the basis for subsequent enforcement action. Necessary action should be taken to provide potable water for the affected area. Studies should be undertaken to determine the means to prevent continuing contamination.

2. With regard to the Anaconda waste injection program, all available chemical and water level data for pre-injection and post-injection periods should be evaluated to ascertain if waste is migrating out of the Yeso Formation and into overlying aquifers containing potable water. Of particular concern are radium-226 and thorium-230 because of their abundance in the injected fluid. Limited chemical data indicating migration of waste beyond the injection interval necessitate that a thorough re-evaluation be made of the long term adequacy of this method of waste disposal. Construction of additional monitoring wells in the Yeso Formation and the Glorieta-San Andres is in order. Because of low MPC values, this is particularly true if increasing concentrations of radium-226 and possibly lead-210 are appearing in the aquifers above the injection zone. The Anaconda Company should also evaluate the current loss of uranium resources to the subsurface through their current disposal technique.

3. Available chemical data for ground-water samples collected by Kerr-McGee from wells located adjacent to Arroyo del Puerto and San Mateo Creek should be evaluated for long-term trends in water quality. Data for the Wilcoxson (P. Harris), Bingham, Marquez, and County Line Stock Tanks wells are of principal concern.

4. Water-quality data from the newly completed monitoring wells peripheral to the Kerr-McGee mill should be cross-checked using non-industry laboratories to determine the extent of contamination in the Dakota Sandstone.

5. The breadth of mining and milling activities in the Grants Mineral Belt clearly requires additional study if ground-water impacts are to be understood in any detailed or quantitative sense. The present study provides a preliminary assessment of but a small facet of the overall

activity in the district. Further study is recommended to determine impacts of past operations or expected impacts from mines and mills now in the planning or construction stages. Site specific investigations are necessary to determine the hydraulic and water quality responses to dewatering and solution mining.

6. Additional ground-water samples should be collected from wells adjacent to the Rio Puerco and east of Gallup to determine if radium concentrations are acceptably low and to establish baseline conditions for future reference. It is recommended that concentrations of trace metals should also be measured.

AREAL DESCRIPTION

Location and Description of Study Area

The Grants Mineral Belt, located in the southeastern part of McKinley County and the north-central portion of Valencia County, is a rectangular shaped area in northwestern New Mexico (John and West, 1963). It is 24 to 32 kilometers wide in the north-south direction and 137 to 177 kilometers long from east to west (see Figure 1) (Kelley, 1963; Kittel, Kelley, and Melancon, 1967).

At present, three mining districts dominate the Mineral Belt. These are Churchrock on the west, Grants-Ambrosia Lake in the center, and Paguate-Jackpile on the east. These contain the Gallup, Churchrock, Smith Lake, Ambrosia Lake, Grants, North Laguna, and South Laguna mining areas. The districts are physiographically separated, Laguna lying to the east and Grants and Gallup to the west (Kelley, 1963; Kittel, Kelley, and Melancon, 1967).

The Continental Divide, extending through approximately the middle of the area, separates the region into two areas of drainage. West of the Divide, streams and rivers drain into the Gulf of California via the Colorado River system, while to the east they eventually join the Rio Grande (Dutton, 1885). Nearly all the streams in the area are intermittent and flow only during periods of intense precipitation (Cooper and John, 1968; Gordon, 1961).

The Grants Mineral Belt of northwestern New Mexico is within the Navajo and Datil sections of the Colorado Plateau physiographic province (Fenneman, 1931). To the east are the Southern Rocky Mountains and to the west and south, the Basin and Range province. To the north lie the Central Rocky Mountains.

Characteristic landforms within the study area include rugged mountains, broad, flat valleys, mesas, cuestas, rock terraces, steep escarpments, canyons, lava flows, volcanic cones, buttes, and arroyos (Kittel, Kelley, and Melancon, 1967; Cooper and John, 1968). Lava flows and volcanic necks are the predominant landmarks of the Datil section (Fenneman, 1931).

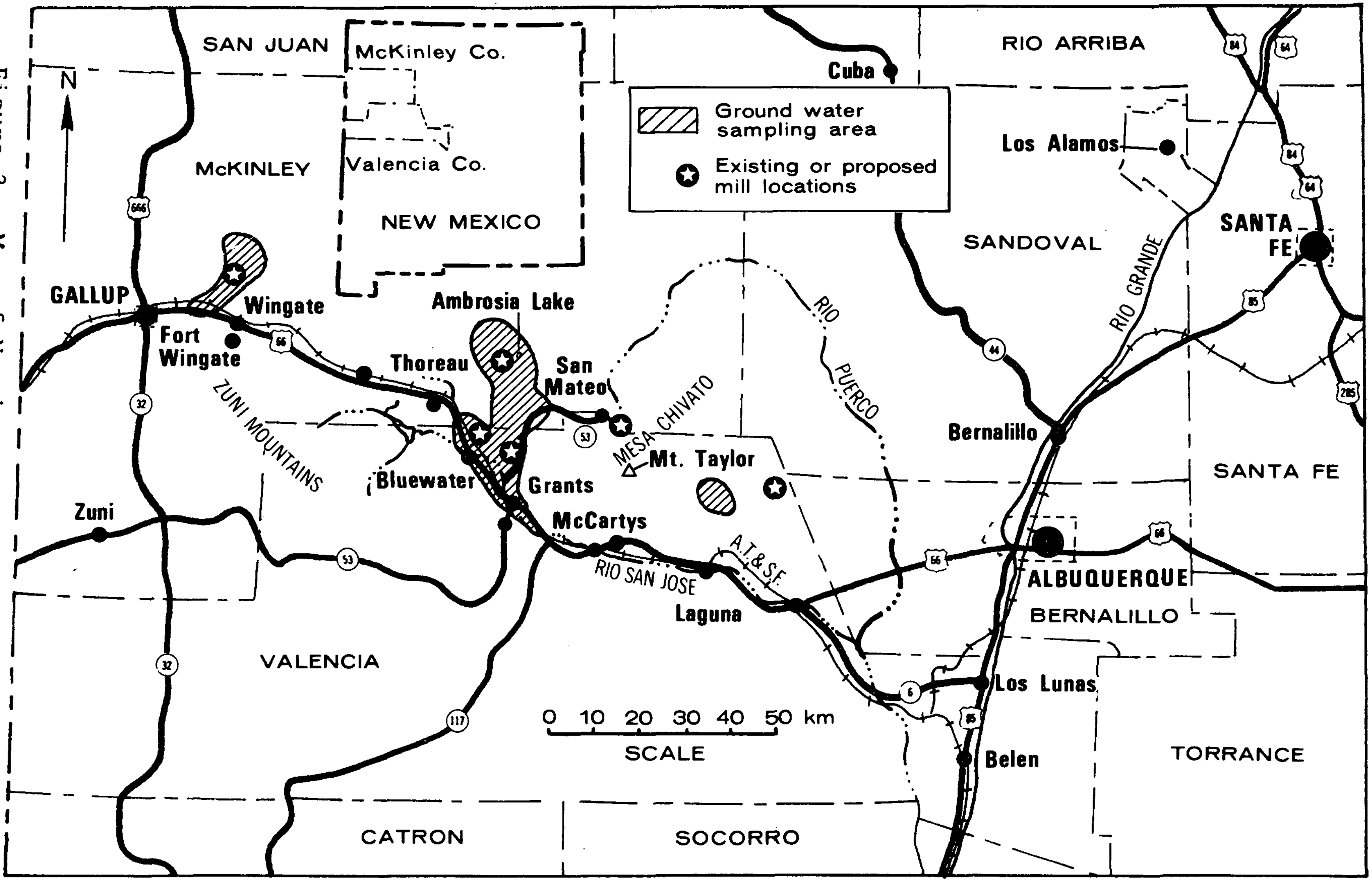

Figure 2. Map of Northwestern New Mexico Showing General Location of Sampling Areas in the Grants Mineral Belt

Prior to uranium mining and the discharge of mine and mill effluents, there were no perennial streams in southeastern McKinley County. In this period, the arroyos and wash channels and other natural depressions such as Ambrosia Lake, Casamero Lake and Smith Lake contained water only after heavy rains. There are intermittent ponds and lakes in the volcanic craters of the Cebolleta Mountains. The only perennial source of water is part of Bluewater Lake at the junction of Azul and Bluewater Creeks (Cooper and John, 1968).

Principal Industries

Until relatively recently, the principal industries in McKinley and Valencia Counties of northwestern New Mexico were farming and ranching. Tourism and small-scale logging were secondary. The land is mostly used for livestock grazing, while some irrigated farming is done in the valleys of Bluewater Creek and the Rio San Jose. The main crops are vegetables, and plants exist in the area for processing and packaging them.

Now that uranium ore has been found to be widespread throughout the Grants Mineral Belt, the uranium mining and milling industry predominates. What was a rural agricultural economy has partly become an industrial one. The figures on Table 1 indicate the importance of the uranium industry in the economy of New Mexico, especially the northwest part. The growth of the uranium industry has created a need for associated industries and services, especially the chemical industry. Caustic soda and soda ash are the main alkalies used in uranium milling. The construction and housing industries have flourished, and mining supply firms and concrete companies have been established (Gordon, 1961).

Gallup and Grants have grown rapidly, as have some of the smaller villages and communities. The population of McKinley County has grown from 27,451 in 1950 to 43,208 in 1970, and that of Valencia from 22,481 to 40,539 (University of New Mexico, Bureau of Business Research, 1972).

Table 1

Uranium Economy of New Mexico

Year	Production (tons or metric tons)	Value	Reserve	Percent of U. S. Total Reserve
1956	1,105,000 tons	$ 24,086,000	41 million tons	66 2/3%
1959	3,269,826 tons	$ 53,463,000	55 million tons	63%
Year ending June 30, 1962		McKinley Co. only $ 57,431,391		
1970	11,574,000 tons	$ 69,970,000		
1974	7,527 metric tons U_3O_8	$102,060,000		42%

1974 Production Capacity of Uranium Mills in New Mexico

Company	Plant Location	Nominal Capacity Tons Ore Per Day
The Anaconda Co.	Grants, New Mexico	3,000
Kerr-McGee Nuclear Corp.	Grants, New Mexico	7,000
United Nuclear-Homestake Partners	Grants, New Mexico	3,500
	Total	13,500
	Total U.S.	28,550
	Percentage in N.M.	47%

References: Midwest Research Institute (1975)
Health & Social Services, State of New Mexico (1975)
WASH 1174-74, The Nuclear Industry, USAEC (1974)

GEOLOGY AND HYDROLOGY

The principal bedrock and alluvial stratigraphic units in the Grants Mineral Belt range in age from Pennsylvanian to Recent (Hilpert, 1963). Figure 2, which is a generalized geologic cross section through the Grants and Ambrosia Lake areas, portrays these units and the dominant structural feature which is the Chaco slope developed on the north flank of the Zuni uplift. Conditions in the Churchrock area are essentially the same.

Pronounced topographic expression of the gently sloping bedrock units is abundantly evident in the Grants Mineral Belt. The sandstone strata on the mesas, actually gently dipping cuestas, form protective caps which resist weathering. The concave slopes and bottom lands form on less resistant units, typically shales and thin-bedded sandstones interbedded with shale. Although geographically less extensive, lava beds and limestone strata also function as caprocks.

Due to the scarcity of perennial surface water bodies, ground water is the principal source of water in the study area. Industrial, municipal, stock, and private domestic wells tap both bedrock and alluvial aquifers. In general, wells of low to moderate productivity are possible in the unconsolidated valley fill which constitutes an aquifer, primarily along the broad valleys of the Rio San Jose and the Rio Puerco. Numerous shallow domestic wells south and southwest of the United Nuclear-Homestake Partners mill also tap the shallow, unconfined aquifer. Part of the water supply for Gallup, and essentially all of that for Milan and Grants, is derived from shallow wells tapping valley fill and interbedded basalt layers (Dinwiddie et al., 1966).

Process water for the various uranium mills is derived from deep wells tapping bedrock aquifers. This is true for the Anaconda Company and United Nuclear-Homestake Partners mills, both of which tap the San Andres Limestone. Part of the feed water for the Kerr-McGee mill is from wells in the Morrison Formation and the more deeply buried Glorieta Sandstone and San Andres Limestone, with the balance coming from treated mine drainage water. Without exception, the operating mines continuously pump ground water as part of the mining operation. Where economical concentrations of uranium

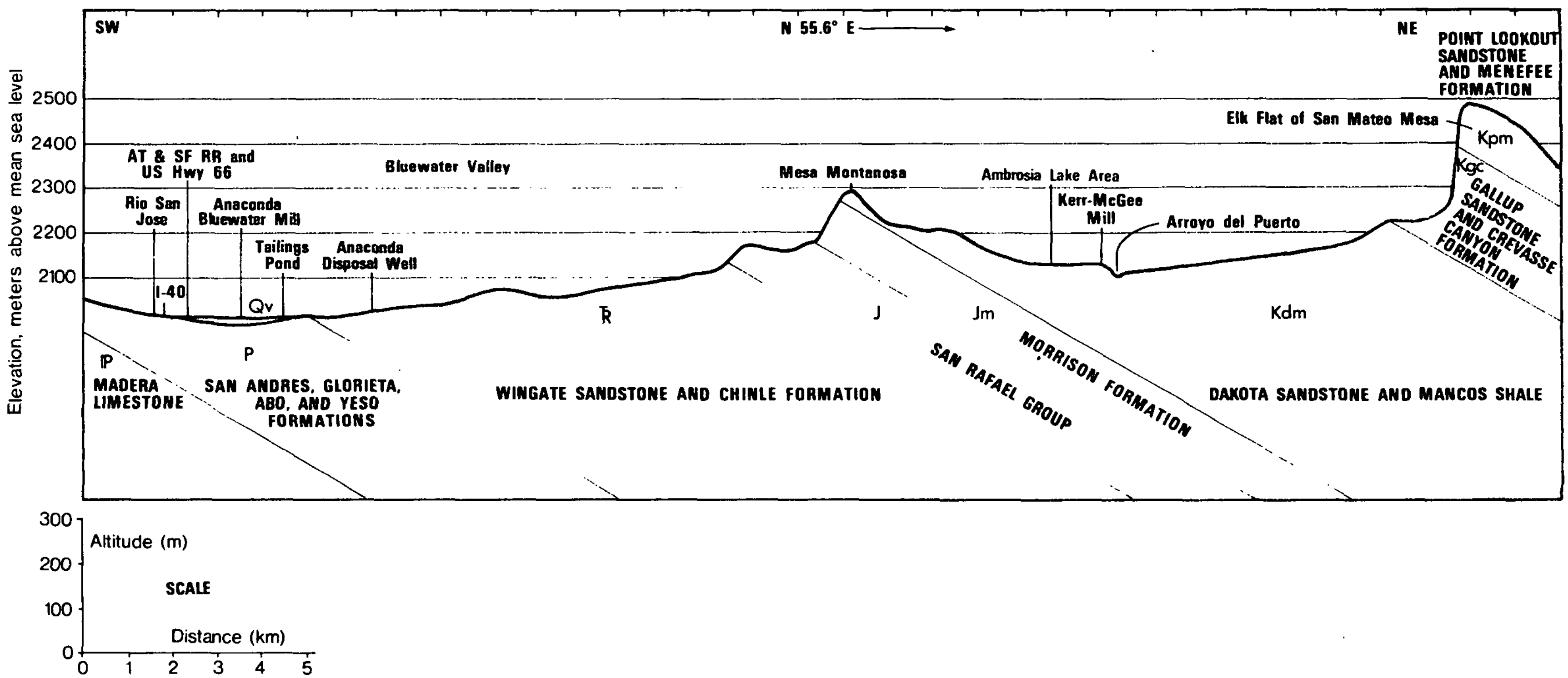

Figure 2. Generalized Structure Section from Bluewater to Ambrosia Lake

are present, ion exchange plants are operated to effect recovery from the waste streams, but radium removal is not practiced. In effect, the various mines are high capacity wells which locally dewater the ore-bearing formations, chief of which is the Westwater Canyon Member of the Morrison Formation. To a lesser extent, the overlying strata such as the Dakota Formation are also affected by dewatering.

The impacts of ground-water pumping and discharge to surface water courses are varied. Declining water levels in the aquifers tapped, and possibly in the adjacent formations, are immediately noticeable. For example, in the Churchrock area, the static water level in the old Churchrock mine is declining about 0.3 meter per month due to dewatering at the United Nuclear and Kerr-McGee mines. Discharge of the mine water has transformed nearby dry washes and ephemeral streams into perennial ones. Rio Puerco, Arroyo del Puerto, and San Mateo Creek are cases in point. Water introduced to these channels will persist until the losses due to bed infiltration, evapotranspiration, and diversion equal inflow. Infiltration of such waters to shallow alluvial aquifers may be adverse, depending on the quality of infiltrating water relative to ambient water quality in the aquifer and the use to which shallow ground water is or will be put. The combination of declining water levels in the deeper, bedrock aquifers and deteriorated water quality in the shallow aquifers may have particularly adverse impacts on stock wells also used by the local populace for potable supply.

Sorption of radionuclides, such as radium on the stream sediments, may result in a buildup of material that will later be dispersed by channel scouring associated with flash flooding. Both the gradual buildup of radium in the sediments and its subsequent redistribution will result in increased levels of radioactivity in the environment as compared to ambient, pre-mining conditions.

Uranium mining and milling in the study area are of particular importance to several aquifers in the study area. Wastes from the Anaconda Company mill in Bluewater have infiltrated via the tailings pile and affected the shallow, unconfined aquifer (Tsivoglou and O'Connell, 1962). Injection of wastes into the deeply buried Abo and Yeso Formations has increased radioactivity and salinity levels therein. Strictly speaking, these are considered aquifers despite the mineralized water naturally present. Should the contamination move upward into potable aquifers and extend too far laterally, injection would likely be terminated. Widespread contamination of the shallow aquifer adjacent to the tailings pond would similarly require abatement.

The Chinle Formation is a source of domestic water in the Murray Acres and Broadview Acres subdivisions downgradient from the United Nuclear-Homestake Partners mill. As will be shown below, the shallow alluvial aquifer in this area is already believed to be contaminated by the infiltration of effluents from the mill.

In the Ambrosia Lake area, contamination of shallow ground water is likely to be a result of infiltration of 1) effluents from the tailings ponds at the Kerr-McGee mill, 2) mine drainage water that is introduced to settling lagoons and natural water courses, and 3) discharges from ion exchange plants. Seepage from the now inactive United Nuclear, Inc., (formerly Phillips) mill tailings pile is also undoubtedly present in the shallow subsurface. The ultimate impact of these waste waters on ground-water quality is unknown. It is unlikely that seepage returns to the deep, bedrock aquifers will occur because of their relatively great depth and the presence of numerous impermeable layers between the shallow alluvial materials and the principal aquifer (Westwater Canyon Member). A possible exception to this occurs in the vicinity of the Kerr-McGee Section 36 mine where drainage enters a nearby holding pond and seeps out the bottom at a rate of about 400 liters/minute. Seepage may move along the underlying San Mateo fault and enter potable aquifers. Very limited volumes of water in the shallow alluvium render it an insignificant source of supply. What water is present near the mining and milling areas is now likely to be contaminated to varying degrees by industrial effluents. The long-term infiltration of radium-laden water along the stream channel of San Mateo Creek, both above and below the confluence with Arroyo del Puerto, may adversely affect the quality of shallow ground water now developed for stock watering.

The potential for future problems of water availability for ore processing in Ambrosia Lake has been cited by Cooper and John (1968). In essence, dewatering of the principal aquifer (Westwater Canyon Member of the Morrison Formation) to facilitate mining may necessitate use of the poorer quality water in the underlying Bluff Sandstone.

Hydrogeologic conditions in the vicinity of the Churchrock mines basically resemble those in Ambrosia Lake with respect to potential impacts of mining and milling on ground water. The potential for contamination of shallow ground-water resources is greatest along the channel of the Rio Puerco. Under natural conditions, shallow ground water was scarce or nonexistent; hence, deeper wells completed in bedrock are required for a reliable supply. With continued infiltration of mine drainage water, at least local saturation of the alluvium may occur and lead to ground water development using shallow wells. However, the radium content of the drainage water discharged to date is excessive for potable or stock use of such water, and long term recharge with mine drainage water is not recommended. The potential for contamination of municipal wells along the Rio Puerco, particularly on the east and west fringes of Gallup, is unlikely.

INDUSTRY-SPONSORED WATER QUALITY MONITORING PROGRAMS

Introduction

A principal goal of the project was to evaluate the nature and extent of water monitoring programs, and data therefrom, as implemented by industry. This presumed that descriptions of the sampling points, analytical procedures, and resulting data would be available for examination upon request to the companies. With the exception of the Anaconda Company, this was not the case.

The inadequacies of industry-supported testing and monitoring programs noted by Clark (1974) include lack of sufficient data, intermittent data, and unreliable data.... conclusions, which are at least not contradicted by the present study.

The most extensive monitoring and testing programs to detect ground-water contamination are conducted by Kerr-McGee and Anaconda. By comparison, United Nuclear and United Nuclear-Homestake Partners have minimal programs both at the mines and at the mills. Therefore, the Kerr-McGee and Anaconda programs, although in need of revision, are a marked improvement compared to inactivity.

Of greatest environmental concern is the discharge of waste water originating from mining and from ore processing. Included in the latter is the discharge stream or tailings from conventional acid and alkaline leach mills and from ion-exchange plants. A third problem area, concerning impacts on ground-water quality from solution mining in the Ambrosia Lake area, is essentially unknown outside the industries involved.

Identification of industrial ground-water monitoring programs, if any, to determine hydraulic and water quality responses to both shaft and solution mining was beyond the scope of the present project. It is expected that solution mining and the use of IX plants, with and without recycling, will gain in popularity, particularly if stricter discharge limits for uranium induce greater capital investment in IX equipment. For this reason, and also because of the heavy ground-water extraction associated with deep mining, deliberate monitoring programs should be implemented and the data made publicly available to detect likely hydraulic and water quality responses.

Adequacy of Water Quality Data and Monitoring Programs

Evaluating the adequacy of a ground-water monitoring program is rather subjective and rarely will there be unanimity of opinion. The diversity of mining activities and geologic or hydrologic settings necessitates great variety in program design. Outlooks and goals of diverse groups also play a large role.

On the basis of the information utilized, the principal deficiencies with ongoing programs can be classified under the following headings:

1. Ground-water monitoring
2. Analytical techniques and reporting procedures
3. Regulatory agency review

Existing ground-water sampling networks range from non-existent to defective. The non-existent networks involve entire operations, as in the case of the United Nuclear Corporation, or portions of operations, as in the case of the solution mining conducted by United Nuclear-Homestake Partners.

The latter's monitoring of a single well at the mill site to determine shallow ground-water contamination is considered grossly deficient. In essentially every instance of mining and milling, baseline ground-water conditions were not defined. Therefore, any changes due to disruption of natural conditions cannot be assessed. In the case of the Anaconda waste management program, for example, there is no information concerning pre-disposal concentrations of stable and radioactive chemical species in overlying potable reservoirs already affected by the wastewater.

Of the active ground-water monitoring programs that were reviewed, great reliance is placed on documenting the quality of water in active wells within the surrounding region. This is laudable with respect to current water use, but not especially productive in terms of defining water quality impacts. In many instances, sampling wells are located hydraulically upgradient or are so far removed from the likely effects of mining or milling as to show no change. Wells of excessive depth, i.e., below the aquifer likely to show change, are also of dubious value as monitoring points. With the exception of a portion of the Kerr-McGee on-site net, wells specifically constructed for monitoring are commonly too few in number and improperly situated with respect to depth and (or) location. Compared to the multi-million dollar uranium industry, producing multi-billion liters of toxic effluents, the ground-water sampling and monitoring programs represent minimal efforts in terms of network design, implementation, and level of investment. There are indications that deterioration in water quality is occurring through time and very possibly in response to the waste volumes disposed of in the last 15 years. With regard to this disposal scheme, there is real question as to whether the data that have been generated have been scrutinized. In other instances, expected adverse impacts of seepage on shallow ground water have not been found because they have either not been sought or have been sought in unlikely locations.

No response to the requests for information regarding analytical methods and reported results was received from three of the four companies contacted. A review of the available records by the authors at the New Mexico Environmental Improvement Agency indicates many deficiencies in the company programs. These deficiencies include lack of information concerning minimum detectable activities for analytical procedures utilized, overly large error terms, poor agreement with outside laboratories, absence of quality assurance programs, inability to detect radionuclides at truly environmental or background levels, and irregular or random sampling frequencies. Analysis for specific radionuclides such as isotopic thorium, lead-210, polonium-210, radium-228, all of which are associated with mining and milling effluents, is rarely done. With the exception of the Anaconda Company, results of monitoring programs to determine background levels of both radionuclides or chemical components are not discussed in any of the reports of the companies. From the data/reports reviewed, it is doubtful that the various company laboratories have the analytical capabilities to accurately analyze for environmental levels of the common radionuclides associated with uranium mining and milling.

During February 11 and 12, 1975, a brief review of available company records, USAEC inspection reports, and mill licenses in the possession of NMEIA was conducted. The following findings are preliminary, as not all of the company records were available at the time of the review:

1. The available records are disorganized and incomplete. A complete copy of each company's radioactive material license and supporting correspondence could not be found. Radiological monitoring data reports were often missing or incomplete. Attachments and maps referred to in correspondence in the records could not be found.

2. Except for the license condition requiring monitoring data related to the Anaconda waste injection program, USAEC licenses for the other uranium mills have never specifically required the establishment of ground-water monitoring networks or reporting of any data pertaining to such monitoring. (Some limited programs have, however, been described in company license applications.)

3. It appears that no effort has been made to review or to summarize the reported monitoring data. No interpretive or summary reports concerning environmental impact have been prepared.

4. Almost no information has been reported by the companies describing their radiochemical analytical procedures, quality assurance programs, or the accuracy and precision of reported results.

5. Review by State and Federal regulatory agencies of reports of company efforts to evaluate the fate of liquid tailings waste effluents (e.g., materials and water balances between input versus evaporation, spillage, or ground seepage and total pond capacity) are essentially non-existent.

Noted deficiencies at the Federal level stem largely from the rather liberal, initial licensing conditions (with respect to ground-water monitoring), perfunctory inspection of company monitoring programs and data, and, in general, the somewhat haphazard manner in which information was filed and cataloged for later reference. Simply put, the uranium mining and milling industry has not been overly pressed to monitor and protect ground-water resources, and what efforts they have put forth have largely not been reviewed.

GROUND-WATER QUALITY IMPACTS

Introduction

The breadth of mining and milling operations in the study area clearly requires additional study if ground-water impacts are to be understood in any detailed or quantitative sense. The following discussion must necessarily be regarded as a preliminary assessment of but a small facet of the overall mining and milling activity. Impacts of inactive operations, such as the Phillips mill, or future impacts from sources under development, such as the Gulf mine and mill in San Mateo or the nearby Johnny M mine, are not addressed herein. Very large voids in our knowledge of impacts on water sources include solution mining practices and dewatering of ore bodies. Essentially no data or interpretive reports are available outside industry circles that describe the hydraulic and water quality impacts of these operations, which may well have the greatest impact of all on ground water.

Contaminated and background concentrations of selected radionuclides, as well as gross and trace chemical constituents, were determined for 71 wells in the study area. These data are presented in Tables 2 through 5. In certain locations, these data relate to surface water phenomena such as natural streams or to manmade features, foremost of which are tailings disposal ponds or streams originating as mine discharge.

The data are discussed by study area and by uranium mining/milling activities therein.

Table 5 summarizes ground-water data from the present study and categorizes the data according to study area and aquifer. These reported values are the lowest concentrations reported for samples collected during the study and may not necessarily represent "true" background or ambient values that may have existed prior to uranium mining and milling activities in this area. For the most part, the values shown for bedrock aquifers are not from the principal ore-producing formations, namely the Westwater Canyon Member of the Morrison Formation. In the Grants-Bluewater area, "bedrock" refers primarily to the San Andres Limestone, whereas near the United Nuclear-Homestake Partners mill, the term includes the San Andres Limestone and the Chinle Formation. At Ambrosia Lake, the Westwater Canyon Member and the Bluff Wingate Sandstones were sampled, whereas

Table 2
Sampling Point Locations and Gross Chemical Data for
Ground-water Samples from the Grants Mineral Belt, New Mexico

NUMBER	DESCRIPTION	T	R	S	Q	LOCATION LAT.	LOCATION LONG.	WELL DEPTH (m)	STATIC WATER LEVEL (m)	DATE MEAS.	SAMPLE POINT TYPE[1]	DATE SAMPLED[2]	WATER USE[3]	TEMP. °C	pH	SP. COND. umhos/cm	CONCENTRATION, mg/l TDS	CL	NH_3	$NO_2 + NO_3$ as N
Paguate-Jackpile																				
9230	Well #4 (Anaconda Co.)	11	5	27	421	350909	1072054	210.	34.9	2/75	3	2/28	PI	17.4	8.8	1100	540.	<0.2	0.05	0.05
9231	Well P-10 (Anaconda Co.)	10	5	4	413	350716	1072214	--	61.6	2/75	8	2/28	PI	36.1	8.3	2500	1200.	0.5	0.08	0.04
9232	New Shop Well (Anac. Co.)	10	5	9	224	350653	1072152	184.	--	--	3	2/28	PI	13.6	8.1	2500	1400.	0.5	0.14	0.05
9233	Paguate Municipal Well	11	5	32	241	350828	1072302	22.9	Art.	2/75	3	2/28	M	15.2	7.5	675	340.	6.6	0.08	0.20
Grants-Bluewater																				
9021	Injection Well (Anac.Co.)	12	10	8	314	351649	1075519	547.4	72.2	4/59	9	2/28	W					65.	69.0	32.8
9101	Mt. Taylor Mill Works Old Rt. 66	11	10	5	442	351224	1075422	58.5	--	--	1	2/24	PI	12.	6.25	1050	780.	25.	0.04	4.2
9103	C. Connerly	11	10	9	221	351212	1075331	37.2	24.4	2/75	3	2/25	P	12.	7.4	1200	880.	33.	<0.01	6.2
9111	C&E Concrete	11	10	22	341	350950	1075257	36.6	24.4	2/75	3	2/26	PI	14.	7.6	775	560.	30.	0.05	3.4
9112	Grants City Hall, Municipal water supply	11	10	26	244	350914	1075117	N/A	N/A	--	1	2/26	M	11.	7.3	1000	730.	32.	0.02	0.47
9115	Auro's Bar & Motel, Cowell House	12	11	24	334	351449	1075718	45.7	--	--	1	2/26	P	14.	7.1	1425	1100.	6.2	0.02	3.9
9116	Milan Well #1	11	10	21	221	351029	1075333	45.7	16.5	10/47	3	2/26	M	17.	7.5	700	500.	14.	0.02	1.6
9117	Monitor Well (Anac. Co.)	12	10	8	332	351650	1075518	191.4	58.3	3/60	1	2/27	O	20.	6.8	2900	2300.	11.	0.03	1.5
9118	Well #2 (Anac. Co.)	12	11	24	234	351527	1075648	138.	61.2	5/72	3	2/27	IP	18.5	7.1	2550	1900.	270.	0.64	39.9
9119	Well #4 (Anac. Co.)	12	11	25	214	351436	1075650	69.	42.1	5/72	3	2/27	IP	17.	7.2	1225	890.	42.	0.13	5.7
9120	Mexican Camp	12	10	30	112	351443	1075617	85.3	43.6	2/47	3	2/27	O	15.	7.5	720	490.	10.	0.04	0.73
9121	Berryhill, Sec. 5 (Anac. Co.)	12	10	5	341	351813	1075512	221.	74.9	1/58	4	2/27	S	20.	7.0	2900	2000.	4.2	0.14	0.05
9122	North Well (Anac. Co.)	12	10	7	143	351731	1075611	76.2	53.9	10/55	4	2/27	O	17.5	7.4	2200	1900.	4.2	0.08	1.3
9123	Engineer's Well	12	11	14	213	351643	1075801	35.1	26.8	2/75	2	2/28	O	11.5	7.3	1625	950.	61.	0.09	3.2
9124	Berryhill House	12	11	11	334	351659	1075823	45.7	37.1	6/56	1	2/28	P	11.	7.5	1800	940.	65.	0.05	0.8
9125	LDS Church-Bluewater	12	11	22	234	351521	1075859	79.2	27.9	12/46	1	2/28	M	5.	7.5	1800	1000.	12.	0.05	0.95
9126	Roundy House Well	12	11	23	231	351532	1075800	91.4	21.2	1/47	1	2/28	P	10.5	7.3	1975	1100.	110.	0.04	6.5
9127	Fred Freas	12	10	30	433	351347	1075552	41.1	--	--	3	2/28	P	13.	7.7	1025	540.	18.	0.03	0.03
9128	Leroy Chapman	12	10	32	211	351338	1075450	41.1	23.	1/47	1	2/28	P	11.	7.6	950	490.	13.	0.03	1.4
9129	Jack Freas	12	10	30	242	351424	1075530	48.8	32.5	2/55	1	2/28	P	11.5	7.5	1325	780.	54.	0.04	2.5

(Continued)

(continued)

Table 2

Sampling Point Locations and Gross Chemical Data for Ground-water Samples from the Grants Mineral Belt, New Mexico

NUMBER	DESCRIPTION	T	R	S	Q	LOCATION LAT.	LONG.	WELL DEPTH (m)	STATIC WATER LEVEL (m)	DATE MEAS.	SAMPLE POINT TYPE[1]	DATE SAMPLED[2]	WATER USE[3]	TEMP. °C	pH	SP. COND. umhos/cm	TDS	CONCENTRATION, mg/l CL	NH_3	NO_2+NO_3 as N
United Nuclear-Homestake Partners																				
9102	G. Wilcox	12	10	27	442	351410	1075217	32.6	--	--	3	2/24	P	14.	6.5	2850	2300.	180.	0.01	5.5
9104	T. Simpson	12	10	27	444	351403	1075217	87.5	--		1	2/25	P	10.	8.4	2050	1400.	37.	<0.01	0.08
9105	Schwagerty	12	10	34	224	351351	1075218	77.7	--		1	2/25	P	11.	7.5	1950	1300.	46.	<0.01	1.00
9106	J. Pitman	12	10	35	332	351345	1075214	89.9	--		1	2/25	P	14.	8.9	1725	1300.	39.	<0.01	0.23
9107	C. Worthen	12	10	35	332	351341	1075208	26.2	5.5	2/75	3	2/25	P	14.	7.4	4000	3800.	260.	0.01	62
9108	Pitney	12	10	27	431	351406	1075246	54.9	--	--	6	2/25	P	14.	7.6	2775	2200.	110.	0.01	3.3
9109	T. A. Chapman	12	10	34	121	351352	1075255	38.1	13.1	2/75	6	2/25	P	14.5	7.5	1700	1300.	9.5	0.01	2.5
9113	C. Meador	12	10	35	144	351336	1075150	36.6	--		1	2/26	P	8.	7.8	2025	1600.	120.	0.01	2.9
9114	Bell	12	10	25	133	351427	1075108	152.4	--		1	2/26	P	17.	8.3	1475	970.	34.	<0.01	0.03
9133	G. Enyart	12	10	27	331	351408	1075312	64.0	15.2	3/75	1	3/02	P	18.	7.6	3000	1600.	50.	0.26	0.97
9134	Well #2 (UNHP)	12	10	26	311	351422	1075146	121.9	21.6	5/56	3	3/03	PI	15.	6.95	1600	1600.	0.2	0.03	0.42
9135	Well D (UNHP)	12	10	26	313	351417	1075208	26.8	16.4	3/75	3	3/03	O	12.	7.2	3500	4500.	340.	1.0	2.6
9136	Well #1 (UNHP)	12	10	26	242	351431	1075117	298.7	40.8	5/58	3	3/03	PI	18.	6.9	1850	2000.	<0.2	0.07	0.28
Ambrosia Lake																				
9130	N. Marquez house well	13	9	23	212	352048	1074527	25.3	15.4	3/75	3	3/01	N	16.	8.9	1300	720.	4.8	0.04	0.06
9131	C. Sandoval windmill	13	9	22	212	352043	1074626	39.6	11.3	3/75	3	3/01	S	14.	8.0	1300	660.	27.	0.06	1.2
9132	N. Marquez windmill	13	9	21	414	352022	1074803	44.2	19.5	3/75	5	3/01	N	14.	7.6	4250	2200.	43.	0.22	106.3
9201	KM-46, P. Harris (Wilcoxson)	13	9	16	411	352114	1074738	76.2	--	--	3	2/26	PS	13.	6.7	3250	1900.	23.	0.14	0.09
9202	KM-52, County Lne Stk Tnk	12	10	12	433	351636	1075037	30.5	14.2	11/55	3	2/26	SP	6.5	7.05	2200	2100.	56.	0.06	62
9203	KM-45, Navajo windmill	13	10	8	211	352238	1075508	108.8	--	--	7	2/26	SP	3.1	8.5	620	400.	6.8	0.02	4.0
9204	KM-49, Ingersoll Rand	13	9	22	121	352050	1074655	90.5	--	--	1	2/26	P	5.4	7.45	2150	2200.	36.	0.05	79.7
9205	KM-47, Bingham	13	9	22	121	352053	1074650	79.2	--	--	3	2/26	P	14.2	7.1	3100	2000.	40.	0.04	4.7
9206	KM-63, Marquez	13	9	15	343	352055	1074647	117.3	--	--	3	2/26	P	13.	7.15	2050	1900.	34.	0.05	4.4
9207	KM-S-12	14	9	32	313	352346	1074911	12.5	0.91	2/75	5	2/27	O	11.9	6.5	>8000	14000.	3100.	0.50	0.04
9208	KM-43	14	9	32	321	352355	1074900	16.2	6.4	2/75	5	2/27	O	13.	7.5	7000	7800.	3.8	NS	NS
9209	KM-44	14	9	32	312	352355	1074902	42.1	32.9	2/75	5	2/27	O	14.1	7.1	3100	2700.	17.	0.66	48.7
9210	KM-51	14	9	32	322	352353	1074850	19.2	8.8	2/75	2	2/27	O	11.9	7.0	6000	6300.	44.	0.30	350
9211	KM-48	14	9	30	432	352430	1074939	16.2	11.3	2/75	5	2/27	O	13.	7.0	4200	4100.	31.	0.90	1.3
9212	KM, Seepage return	14	9	31	442	352342	1074919	N/A	N/A	N/A	3	3/03	-	9.	2.2	>>8000	36000.	3100.	590.	53
9213	KM-B-2	14	9	31	421	352354	1074926	8.2	1.04	3/75	5	3/03	O	8.6	5.5	>>8000	8900.	3400.	0.12	0.25

(Continued)

(continued)

Table 2

Sampling Point Locations and Gross Chemical Data for Ground-water Samples from the Grants Mineral Belt, New Mexico

NUMBER	DESCRIPTION	T	R	S	Q	LOCATION LAT.	LONG.	WELL DEPTH (m)	STATIC WATER LEVEL (m)	DATE MEAS.	SAMPLE POINT TYPE[1]	DATE SAMPLED[2]	WATER USE[3]	TEMP. °C	pH	SP. COND. umhos/cm	TDS	CONCENTRATION, mg/l CL	NH_3	NO_2+NO_3 as N
Ambrosia Lake (Continued)																				
9214	KM-36-2	14	10	36	422	352352	1075026	17.4	10.1	3/75	5	3/03	0	12.5	6.85	>8000	9100.	1700.	2.9	8.0
9215	KM-46	14	9	30	331	352430	1075017	11.6	10.1	2/75	2	3/03	0	13.	6.7	3250	3200.	100.	10.	2.0
9216	KM-47	14	9	30	341	352430	1074959	18.9	7.3	2/75	5	3/03	0	14.2	7.1	3100	2600.	74.	0.80	2.6
9217	KM-50	14	9	32	114	352414	1074901	16.6	14.0	2/75	2	3/03	0	11.9	7.7	5750	4700.	470.	9.1	70.9
9218	KM-5-1	13	9	5	214	352316	1074835	10.4	7.3	3/75	5	3/03	0	13.5	6.95	5000	4800.	61.	0.16	0.40
9219	KM-5-2	13	9	5	141	352310	1074856	10.4	6.0	3/75	5	3/03	0	12.5	7.1	>8000	6700.	1300.	0.08	1.3
Gallup-Churchrock																				
9137	Erwin well	16	18	7	433	353730	1084524	610.	221.0	3/75	3	3/05	M	--	7.85	1225	740.	14.	0.09	0.02
9138	Boardman Trailer Park	15	18	14	243	353159	1084237	91.4	45.7	3/75	3	3/05	P	--	7.6	1450	930.	<0.2	0.50	1.2
9139	G. Hassler	15	17	8	133	353242	1084008	91.4	4.6	3/75	1	3/05	P	--	7.75	1400	880.	98.	0.02	119.6
9140	Dixie well	15	17	9	413	353227	1083835	--	1.2	3/75	3	3/05	N	--	7.7	2400	1500.	<0.2	0.30	0.16
9141	Churchrock Village	15	17	12	333	353222	1083553	65.6	--	--	6	3/05	P	--	7.8	1375	720.	0.5	0.50	0.18
9142	White well	16	16	16	422	353701	1083147	--	2.1	3/75	2	3/05	N	--	8.00	1000	620.	630.	0.01	0.02
9220	CRKM-2, Hardground Flats well	Navajo Reservation				353958	1083404	189.6	--	--	4	3/05	SP	--	9.15	1350	850.	0.	0.03	0.28
9221	CRKM-11, E. Puerco River well (=Togay well, 9143)	16	16	15	431	353638	1083059	96.9	--	--	7	3/05	SP	--	7.65	550	340.	14.	0.04	62
9222	CRKM-16, Puerco well	16	17	25	113	353533	1083551	42.7	7.04	3/75	7	3/05	SP	--	7.25	2200	1600.	0.	34.	0.01
9223	CRKM-5, *Pipeline Rd* well	16	15	33	422	353420	1083810	37.2	10.7	3/75	7	3/05	S	--	7.65	1350	880.	0.	1.4	1.6
9224	CRKM-3, Nose Rock well	16	17	15	131	353709	1083720	207.3	31.4	--	4	3/05	SP	--	8.9	1550	980.	0.	0.07	0.03
9225	CRKM-10, N.E. Pipeline well	Navajo Reservation				354015	1082841	284.1	>91.4	3/75	7	3/05	SP	--	8.05	2650	2300.	8.1	0.12	0.01

Explanation

1 - Sampling Point
- 1-outside faucet
- 2-hand bailed
- 3-pumped (well head)
- 4-windmill
- 5-mobile pump
- 6-kitchen faucet
- 7-holding tank
- 8-wash room
- 9-pre-injection filter discharge

2 - Date Sampled
- 1975

3 - Well Type
- N-not in use
- P-potable
- S-stock
- M-municipal supply
- I-industrial
- O-observation/monitor
- W-waste discharge

Table 3
Selenium and Vanadium Concentrations in Selected Ground-water Samples[1]

NUMBER	DESCRIPTION	Se (mg/l)	V (mg/l)
United Nuclear-Homestake Partners			
9102	G. Wilcox	1.06	<0.3
9107	C. Worthen	1.06	0.3
9113	C. Meador	0.20	0.3
9134	Well #2 (UNHP)	<0.01	1.3
9135	Well D (UHNP)	1.52	0.4
Grants Bluewater			
9117	Monitor well (Anaconda)	0.01	0.3
9118	Well #2	0.01	0.8
9119	Well #4	<0.01	0.9
9120	Mexican Camp	<0.01	1.0
9121	Berryhill, Section 5	<0.01	0.8
9123	Engineer's well	0.01	1.1
9129	Jack Freas	0.02	1.3
Ambrosia Lake			
9132	N. Marquez windmill	.13	< .3
9201	KM-46, P. Harris (Wilcoxson)	<0.01	< .3
9207	KM-S-12	<0.01	0.4
9208	KM-43	.29	0.8
9209	KM-44	.01	<0.3
9211	KM-48	<0.1	0.5
9213	KM-B-2	<0.1	0.6
9214	KM-36-2	.02	<0.3
9215	KM-46	<0.01	<0.3
9219	KM-5-2	0.01	<0.3
Gallup-Churchrock			
9138	Boardman Trailer Park	<0.01	<0.3
9140	Dixie well	<0.01	<0.3
9141	Churchrock Village	<0.01	<0.3
9142	White well	<0.01	<0.3
9221	CRKM-11, E. Puerco	0.01	<0.3
9222	CRKM-16, Puerco well	<0.01	<0.3
Paguate-Jackpile			
9230	Well #4	<0.01	<0.3
9232	New Shop well	<0.01	<0.3
9233	Paguate Municipal well	0.01	<0.3

[1] Analyzed by National Enforcement Investigations Center, Denver, Colorado,

Table 4

Radiological Data for Selected Ground-water Samples[1]

Grants Mineral Belt, New Mexico

Location Number Description	Gross Alpha	Ra-226 NEIC	Ra-226 EMSL	U-234	U-235	U-238	U-nat.		Th-230	Th-232	Po-210
Paguate-Jackpile											
9230-Well #4	< 2.0 ± 6	0.31 ± .02	0.23 ±.095						< 0.029	0.012	0.31 ± .11
9231-Well P-10	10 ± 10	1.7 ± .03							< 0.016	< 0.016	0.29 ± .11
9232-New Shop Well	18 ± 13	3.7 ± .08					0.02	14	< 0.016	< 0.011	0.69 ± .20
9233-Paguate Municipal Well	2 ± 4	0.18 ± .02	0.10 ±.072				0.04	27	< 0.018	< 0.010	0.39 ± .18
Grants--Bluewater Area											
9021 Injection Well Anaconda Company	62,500±1,300	53 ±1	27 ±0.95	10,000±750	420 ±67	11,000±770	130	86,000	82000±1200	51 ± 30	3,100±250
9101 Mt. Taylor Mill Works Old Mt. 66	9± 11	0.13± .01									
9103 Q. Connerly	7± 10	0.09± .01									
9111 C&E Concrete	7± 9	0.24± .01							<0.028	<0.012	0.55± .15
9112 Grants City Hall	19± 13	0.42± .02	0.10± .098						0.046±.038	0.0094±.021	0.26± .10
9115 Cowell House	7± 12	0.18± .01									
9116 Milan Well No. 1	12± 10	0.14± .01							<0.0072	<0.013	0.30± .12
9117 Monitor Well Anaconda Company	180± 40	2.6 ± .1	2.6 ± .30	100± 7.7	3.0± .58	74± 5.7	0.56	379	<0.016	<0.0097	2.3 ± .90
9118 Well No. 2 Anaconda Company	290± 50	0.50± .02	0.21± .09				1.3	860	0.52±.093	0.54±.094	1.1 ± .37
9119 Well No. 4 Anaconda Company	12± 11	0.20± .01	0.18± .089						<0.030	<0.019	0.26± .19
9120 Mexican Camp	21± 12	0.27± .02							<0.017	<0.0053	0.66± .25
9121 Berryhill Section 5	12± 14	6.3 ± .1							<0.0081	<0.0051	0.28± .17
9122 North Well	30± 17	0.17± .01							0.034±.024	<0.0084	0.51± .17
9123 Engineer's Well	20± 13	0.26± .01	0.36± .11						0.033±.026	<0.016	0.48± .26
9124 Berryhill House	16± 12	0.06± .01									
9125 LDS Church--Bluewater	3± 10	0.22± .01							<0.034	<0.012	<0.070
9126 Roundy House	5± 9	0.11± .01							0.040±.031	<0.015	<0.10
9127 Fred Freas	10± 10	0.21± .01	0.28± .11						<0.034	<0.029	0.39± .14
9128 L. Chapman	11± 11	0.15± .01									
9129 Jack Freas	<1.6± 7	0.14± .01	0.87± .29						<0.018	<0.012	0.31± .16

(continued)
Table 4

Radiological Data for Selected Ground-water Samples[1]

Grants Mineral Belt, New Mexico

Number	Location Description	Gross Alpha	Ra-226 NEIC	Ra-226 EMSL	U-234	U-235	U-238	U-nat.		Th-230	Th-232	Po-210
	United Nuclear - Homestake Partners											
9102-G.	Wilcox	< 3 ± 13	0.19 ± .01	0.22±.091	10 ± .73	0.22± .048	7.7 ± .57	0.07	47	<0.021	<0.012	1.0 ± .95
9104-T.	Simpson	13 ± 14	0.08 ± .01							0.048±.029	<0.021	0.31± .14
9105-	Schwagerty	140 ± 30	0.05 ± .01									
9106-J.	Pitman	12 ± 11	0.05 ± .01	0.19±.087						<0.017	<0.010	0.40± .26
9107-C.	Worthen	2500 ±200	0.72 ± .02	0.78±.17				14	9478	0.99 ±.13	0.034±0.031	1.2 ± .52
9108	Pitney	47 ± 23	0.34 ± .02							0.026±.023	<0.013	0.31± .14
9109-T.	A. Chapman	39 ± 17	0.13 ± .01									
9113-C.	Meador	31 ± 17	0.17 ± .02	<0.072				0.08	54	<0.037	<0.042	2.3 ± .69
9114	Bell	42 ± 18	0.26 ± .01									
9133-G.	Enyart	10 ± 12	0.61 ± .03	0.65±.15	5.1±.41	0.15± .04	3.8 ± .31			0.36 ±.078	<0.016	0.95± .24
9134-	Well #2 UNHP	8 ± 11	0.24 ± .01					0.04	27	0.045±.039	<0.026	0.76± .41
9135-	Well D UNHP	400 ± 70	1.92 ± .04	2.8 ±.31	240±16	9.3 ±1.1	240 ±16	2.6	1760	<0.013	<0.018	2.3 ±2.1
9136-	Well #1 UNHP	22 ± 16	0.27 ± .02									
	Ambrosia Lake											
9130	N. Marquez House	3± 6	0.11 ± .01									
9131	C. Sandoval Windmill	18± 13	0.05 ± .01	0.22 ± .10						0.036±.025	< 0.021	< 0.55
9132	N. Marquez Windmill	< 1.0± 9	0.31 ± .02	0.47 ± .14	51 ± 5.1	2.6 ± .23	74 ±4.7	0.10	68	<0.018	< 0.012	0.79 ±0.43
9201	P. Harris	110± 40	3.6 ± .1					1.0	677	0.03 ±.027	< 0.014	0.52 ±0.16
9202	County Line Stock Tank	86± 31	0.30 ± .02							<0.028	< 0.011	0.22 ±0.10
9203	Navajo Windmill	55± 15	0.07 ± .01									
9204	Ingersoll Ranch	8± 13	0.14 ± .01	0.30 ± .11						<0.015	< 0.012	0.61 ±0.21
9205	Bingham; KM-47	170± 40	0.18 ± .01									
9206	Marquez; KM-65	56± 25	0.60 ± .02									
9207	KM-S-12	410± 120	1.15 ± .03							0.27 ±.066	0.24±.062	< 0.13
9208	KM-43	49± 35	4.0 ± .1	4.7 ± .40						0.021±.019	< 0.014	< [illegible]
9209	KM-44	< 2.0± 10	1.95 ± .04							<0.026	< [illegible]	[illegible]
9210	KM-51	45± 29	0.26 ± .02	0.35 ± .12						<0.023	< 0.0068	0.24 ±0.10
9211	KM-48	< 2.0± 15	0.20 ± .01							<0.013	< [illegible]	2.7 ±[illegible]
9212	KM-Seepage Return	112,000±3,000	4.9 ± .1	10.[illegible] ± .[illegible]								
9213	KM-S-2	8± 32	6.6 ± .1	6.4 ± .47						<0.01[illegible]	< 0.011	< 0.54
9214	KM-36-2	14± 34	1.18 ± .03	1.5 ± .23	11 ± .78	0.31±.056	6.8 ± .52			<0.015	< 0.014	0.70 ±0.2[illegible]

(continued)

(continued)
Table 4

Radiological Data for Selected Ground-water Samples[1]

Grants Mineral Belt, New Mexico

Location Number	Location Description	Gross Alpha	Ra-226 NEIC	Ra-226 EMSL	U-234	U-235	U-238	U-nat.		Th-230	Th-232	Po-210
Ambrosia Lake (Continued)												
9215	NM-4c	104± 37	2.5 ± .2	2.7 ± .30						0.17 ±.057	< 0.016	< 0.24
9216	NM-47	45± 25	0.64 ± .02							0.079±.038	< 0.017	0.29 ±0.20
9217	NM-50	70± 58	0.94 ± .03	0.72 ± .16						0.055±.035	< 0.015	1.2 ±0.64
9218	KM-5-1	20± 24	0.34 ± .02	0.34 ± .11						<0.021	< 0.016	3.5 ±2.6
9219	KM-5-2	67± 42	0.59 ± .02	0.76 ± .17	12 ± .63	0.27± .039	6.7 ± .37			<0.039	< 0.031	0.96 ±0.64
Gallup-Churchrock												
9137	Edwin Well	10 ± 9	0.63 ± .03									
9138	Boardman Trailer Park	6 ± 8	0.64 ± .02							0.088±.038	< 0.019	0.27± .20
9139	G. Hassler	14 ± 11	0.22 ± .01									
9140	Dixie Well	6 ± 10	0.10 ± .01	0.15 ± .082	1.8 ± .16	0.053±.022	1.4 ± .14			<0.030	< 0.016	0.50± .20
9141	Churchrock Village	3 ± 7	0.12 ± .01	0.26 ± .10				0.02	14	<0.028	< 0.016	0.23± .11
9142	White Well	9 ± 9	0.16 ± .01	0.42 ± .13						0.073±.035	< 0.011	<0.080
9143	Togay Well (same as 9221)	14 ± 9	0.83 ± .04	0.38 ± .12						<0.044	< 0.034	0.42± .17
9220	Hardground Flats Well-CRKM-2	12 ± 10	0.12 ± .01									
9221	E. Puerco River Well-CRKM-11	17 ± 10	0.56 ± .02	0.21 ± .093						<0.029	< 0.016	0.19± .18
9222	Puerco Well CRKM-16	2 ± 9	0.57 ± .02									
9223	Pipeline Road Well-CRKM-5	4 ± 9	0.37 ± .02							0.037±.020	< 0.012	0.52± .15
9224	Rose Rock Well CRKM-3	24 ± 12	0.13 ± .01							0.053±.040	< 0.036	0.23± .10
9225	N.E. Pipeline Well CRKM-10	12 ± 15	0.29 ± .01							<0.015	< 0.011	0.56± .33

1. Concentrations ± two sigma counting error in pCi/l. U-natural reported as mg/l and in pCi/l, respectively.

Sources of analyses:
Environmental Monitoring and Support Laboratory, USEPA: Ra-226, U-234, U-235, U-238, Th-230, Th-232, Po-210, Pb-210
National Enforcement Investigations Center, USEPA: Gross alpha, Ra-226, U-nat.

All analyses except U-nat. are on the filtered sample and therefore represent the concentrations actually in solution. U-nat. is analyzed using unfiltered water and represents both the dissolved and suspended fractions.

Table 5

Typical Background Ground Water Radionuclide Concentrations (pCi/l) by Geographic Area & Aquifer [1]

Radionuclide/Aquifer		Paguate-Jackpile	Grants-Bluewater	[illegible]HP	Ambrosia Lake	Gallup-Churchrock
226Ra	Bedrock	0.31 ± .02	0.14 ± .01	0.06 ± .01	0.16 ± .01	0.12 ± .01
	Alluvium	<0.13[3]	0.13 ± .01	0.16 ± .02	0.23 ± .02	0.11 ± .01
210Po	Bedrock	0.43 ± .14	0.33 ± .15	0.35 ± .20[2]	0.57 ± .19	0.35 ± .19
	Alluvium	<0.39[3]	0.30 ± .14	<0.31[3]	0.27 ± .18	0.27 ± .17
230Th	Bedrock	<0.020	<0.032	<0.033	<0.023	<0.030
	Alluvium	<0.018[3]	<0.013	<0.014	<0.028	<0.011
232Th	Bedrock	<0.013	<0.015	<0.015	<0.013	<0.024
	Alluvium	<0.013[3]	<0.013	<0.013	<0.018	<0.015
234U	Bedrock	---	---	---	---	---
	Alluvium	---	---	<10[3]	<12	<1.3[3]
235U	Bedrock	---	---	---	---	---
	Alluvium	---	---	<0.23[3]	<0.29	<0.033[3]
238U	Bedrock	---	---	---	---	---
	Alluvium	---	---	<7.7[3]	<6.3	<1.4[3]
U-Natural	Bedrock	14[3]	---	---	---	---
	Alluvium	27[3]	---	54	68[3]	14[3]

(1) Average of lowest reported concentrations of this study. 226Ra and U-natural analyses by [illegible], all other radionuclide analyses by EMSL.

2 Based on Chinle Formation.

3 Results of only one sample reported: therefore, two sigma error of 100% assumed for these values.

bedrock aquifers in the Churchrock mining area mostly include the Dakota Sandstone. In the Paguate-Jackpile area, three of the four wells examined are in the Morrison Formation (Jackpile Sandstone Member).

Table 6 is a compilation of uranium, radium, and gross
Table 6 is a compilation of uranium, radium, and gross
beta concentrations in ground water for various localities in the Grants Mineral Belt. These are largely from the ore bodies or from strata adjacent thereto, and are intended to show natural concentrations of these radionuclides. Despite the wide variations, radium rarely exceeds 10 pCi/l and is commonly less than 5 pCi/l, except in mines or in ponds formed from mine drainage. Dissolved uranium is also enriched in waters associated with active mines and can readily reach concentrations of several hundred pCi/l. Natural background uranium levels are difficult to estimate from the limited data but would appear to be on the order of 20 pCi/l or less. Concentrations markedly greater than the foregoing, particularly if associated with mining and milling activity, may be evidence of degradation.

Bluewater-Milan-Grants

The relationship of the Anaconda Company mill and tailings pile to local geologic and cultural features is shown in Figure 3. Cultivated areas in the photograph are situated in Bluewater Valley which contains the town of Bluewater on the western edge. The irregularly shaped landforms northeast and east of the mill are basalt lava flows which are also the substrate for a portion of the tailings ponds. Also shown is the proximity of the San Andres Limestone to the tailings ponds. The light colored areas in the tailings pond are composed of sand, whereas the darker gray and black patterns indicate wet slimes and free water surface, respectively.

The expected impacts of uranium mining and milling on groundwater in the developed area between Bluewater and Grants can be traced to the Anaconda Company mill. It is unlikely that the United Nuclear-Homestake Partners mill could adversely affect ground water in this area.

Significant introduction of wastes into ground water in the Bluewater area occurs as a result of seepage from the tailings ponds. Past investigators noted the migration of nitrate from the ponds (New Mexico Department of Public Health, 1957). Changes in the milling process greatly

Table 6

Summary of Reported Concentrations
for Radium, Gross Beta and Natural Uranium in Ground Water in the Grants Mineral Belt[1]

Location T	R	S	Q	Source	Depth (meters)	Aquifer[2]	Radium pCi/l	gross β pCi/l	U natural dissolved pCi/l
9	12	11	222	Paxton Spring	Spring	Qb	4.3		1.82
12	11	24	4	Industrial Well	109		0.4		4.27
12	11	24	4	Anaconda Well (Injection)	109	Ps	0.36		
12	12	4	343	Bluewater Lake	Surface		<0.1		0.84
12	10	8	3	Well	442	Pym	0.2±0.1		1.96
13	6	30	100	El Paso Natural Gas Co.		Jmw	8.5±1.7	36 ± 5	
13	8	30	200	El Paso Natural Gas Co.		Kd	2.9±0.6	12 ± 2	
13	9	29	144	Westvaco Mineral Development Co.		Jt	5.1	150	
13	9	29	41	Mine Drift	137	Jt	5.1		139
14	9	28	441	Well		Jmw	1.1		<.07
14	9	32	413	Well	174	Jmw	10 ±2		8.4
14	9	32	221	Mine Drift		Jmw	42		16.1
14	9	17	400	Kermac Nuclear Fuels Corp.		Kd	2.7±0.5	18 ± 3	
14	9	18	400	Kermac Nuclear Fuels Corp.		Jmw	5.6±1.1	37 ± 6	
14	9	28	143	Kermac Nuclear Fuels Corp.	216	Jmw	1.1	69	
14	9	29	312	Phillips Petroleum Co.	224	Jmw	10 ±2	39 ± 7	
14	9	30	200	Kermac Nuclear Fuels Corp.		Jmw	2.0±0.4	12 ± 2	
14	9	32	122	Homestake-New Mexico Partners	196	Jmw	42	49	
14	9	32	314	Homestake-New Mexico Partners	168	Jmw	1.1±0.2	18 ± 4	
14	9	34	422	United Nuclear Company	306	Jmw	1.4±0.3	9.0± 1.5	
14	9	36	313	United Nuclear Company		Kd	27 ±5	75 ±11	
14	9	36	313	United Nuclear Company	457	Jmw	1.2±0.2	6.5± 0.9	
14	10	24	100	Kermac Nuclear Fuels Corp.		Jmw	2.3±0.5	56 ± 8	
15	12	17	123	Homestake-Sapin Partner	372	Jmw	0.2±0.1	9.8± 1.4	
17	12	20	11	Crownpoint Well 1	714	Jmw	0.05		<0.28
17	16	35	14	UNC-NE Churchrock Mine	457	Jmw	0.62		185
17	16	35	14	UNC-NE Churchrock Mine	518	Jmw	0.09		22
17	16	35	14	UNC-NE Churchrock Mine	549	Jmw	8.10		847
17	16	35	12	KM-Section 35, Churchrock Mine	549	Jmw			
23	14	3	13	Gas Company Burnham Well 1	1585	Jmw	0.24		0.05
				Pond in South Paguate pit	Pond		190		170

1. Data sources are as follows:
   - Ambrosia Lake area: Cooper and John, 1968
   - Laguna-Paguate: Lyford, 1975
   - Churchrock: Hiss and Kelley, 1975
   - Grants-Bluewater-Prewitt: Stow, 1961

   Grants-Bluewater-Prewitt:

2. Aquifers:
   - Qb basalt flow
   - Kd Dakota Fm.
   - Jmw Morrison Fm., Westwater Canyon Mbr.
   - Jt Todilto Fm.
   - Ps San Andres Ls.
   - Pym Yeso Fm, Meseta Blancha Mbr.

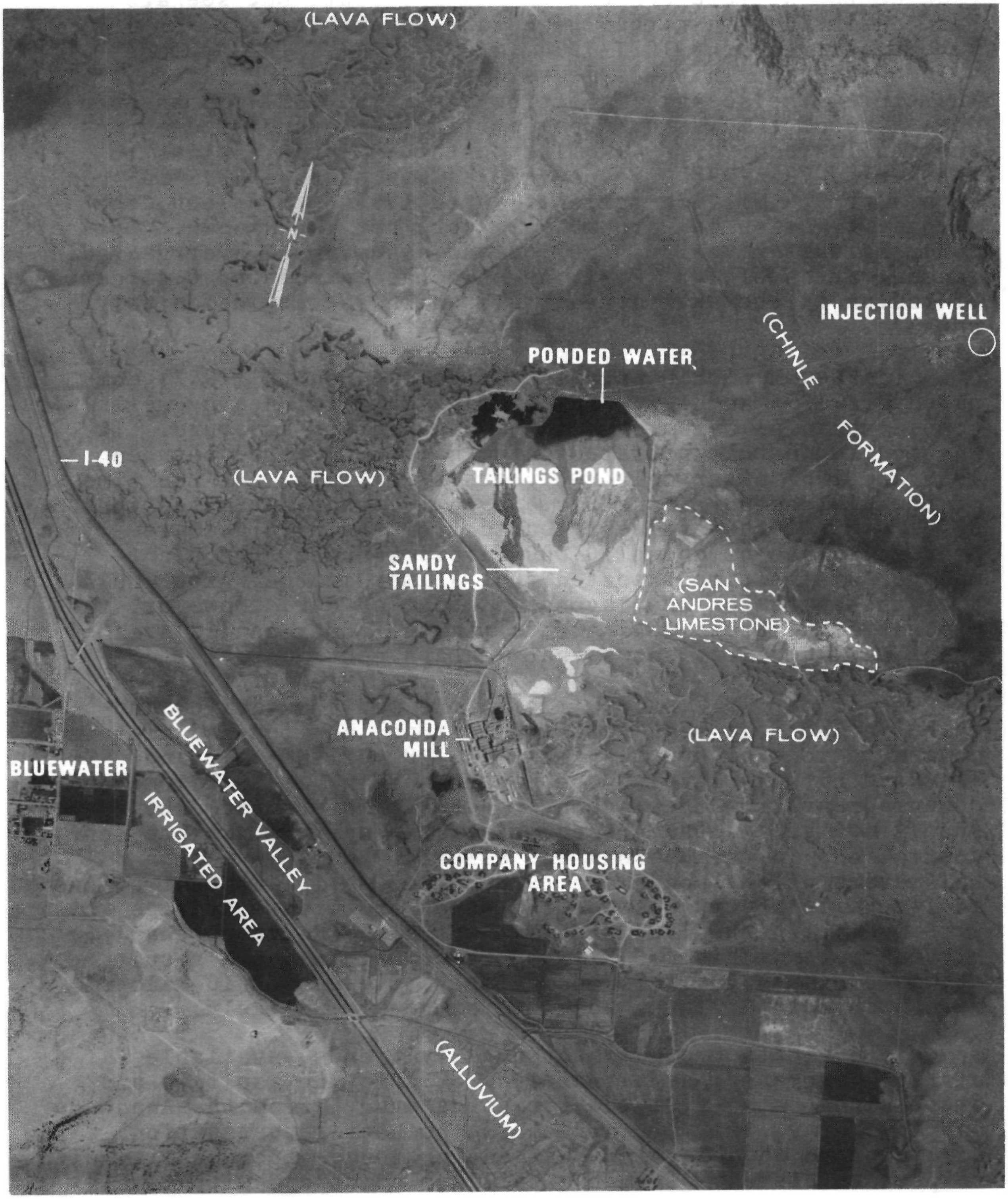

Figure 3. The Anaconda Company Uranium Mill and Tailings Pond-Bluewater

reduced the nitrate content in the effluent, but seepage has continued at a rather high rate, averaging 182.9 x 10^6 liters per year for 1973-1974 (Gray, 1975). The average volume injected in the same period was 348 x 10^6 liters. Therefore, the seepage:injection ratio is 0.53. In essence, one third of the waste stream portion not evaporated enters the shallow aquifer. Assuming that this ratio applies to the period 1953-1960, seepage is estimated at 3200 x 10^6 liters or 845 million gallons. From 1953 to mid-1960, the seepage fraction was probably larger, but is unknown. Discounting this seven-year period and assuming an average radium concentration of 125 pCi/l, seepage has introduced 0.41 curies of radium to the shallow aquifer, which is very definitely potable.

The New Mexico Department of Public Health (1957) compared pre-1955 and 1956-1957 nitrate data for nearby wells completed in alluvium and in the San Andres Limestone. It was concluded that nitrate contamination occurred between 1955 and 1957 after only two years of milling. At the time of the field study (June-Nov., 1956), it was estimated that 87 percent of the effluent leaked from the 28.4 hectare pond at a rate of about 10,000 liters/minute. The plant manager at the time expected that slimes in the waste would seal the bottom of the lagoon in about a year. However, the present loss rate of 347 liters/minute from a ponded area of about 14.4 hectares shows that leakage continues.

As of May 1957, two wells in the shallow aquifer and three in the deep (San Andres Limestone) aquifer had nitrate concentrations of 66 to 84 mg/l (15-19 mg/l NO_3-N), and elevated nitrate levels were present as far as 10 kilometers downgradient from the lagoon or 4.5 kilometers from the Grants supply wells. At the present time, the maximum nitrate concentrations in the bedrock and alluvial aquifers within 4 kilometers of the ponds are 39 and 17.3 mg/l. Concentrations in two wells midway between the ponds and Grants average 21.5 mg/l. In the 1956 study it was also concluded that high nitrate within 4.5 kilometers of Grants was a result of waste disposal. This would imply movement of 10 kilometers in 2 to 3 years, which is extremely unlikely.

To evaluate ground-water quality trends, available nitrate (expressed as nitrate), TDS, chloride, sulfate and gross alpha data (from the foregoing study, from the Anaconda Company (Gray, 1975), and from the present investigation), were plotted to determine changes in ground-water quality with respect to distance from the tailings ponds and with time.

These data show that there is a general lack of marked deterioration in ground-water quality with time; and, with the exception of gross alpha, there is close agreement between the company data and those from the present study. For example, the Fred Freas well (#9127), completed in alluvium, and the Mexican Camp well (#9120), which taps the San Andres Limestone, show essentially no change in TDS, sulfate, chloride, or nitrate for the period 1956 to 1975. The slight decline in TDS in the Fred Freas well is contrary to what would be expected if gross contamination was present. However, the similarity between gross alpha and sulfate fluctuations for the Mexican Camp well suggest that wastes are within the well's area of influence.

The selenium, vanadium, and total dissolved solids (TDS) data for the Bluewater-Grants area generally substantiate the foregoing interpretation and hint at the possibility of contamination of the alluvial aquifer. Selenium ranges from less than 0.01 mg/l to 0.02 mg/l, with most values being 0.01 or less. Vanadium ranges from 0.3 to 1.3 mg/l and is lowest in the Anaconda monitor well (#9117). Concentrations for seven wells adjacent to the Anaconda mill and tailings ponds average 0.89 mg/l, which is two to three times higher than the average for the remainder of the study area (see Table 3). It is suspected that these elevated levels are indicative of contamination, but they may simply reflect the normal concentration of vanadium in the alluvial and San Andres Limestone aquifers. Water supply well #2 at the United Nuclear-Homestake Partners mill is also completed in this formation and contains 1.3 mg/l. Additional sampling is recommended to characterize background and contaminated levels before definite conclusions are drawn. With the exception of the Jack Freas well (#9129), which is used for domestic supply, the selenium and vanadium concentrations are within recommended drinking water standards.

Radium and nitrate concentrations in ground water are depicted in Figure 4. With the exception of the Berryhill Section 5 well (station #9121) and the Anaconda injection well (#9021), radium-226 in both the alluvial/basalt aquifer and in the underlying San Andres Limestone ranges from 0.06 to 0.42 pCi/l. If well #9124 is considered as a background, radium in the alluvial aquifer decreases as a function of distance from the tailings ponds. The elevated radium level in well #9123 is postulated on the basis of a radial flow pattern centered on the tailings ponds and superimposed on the natural ground-water flow which is southeastward. In

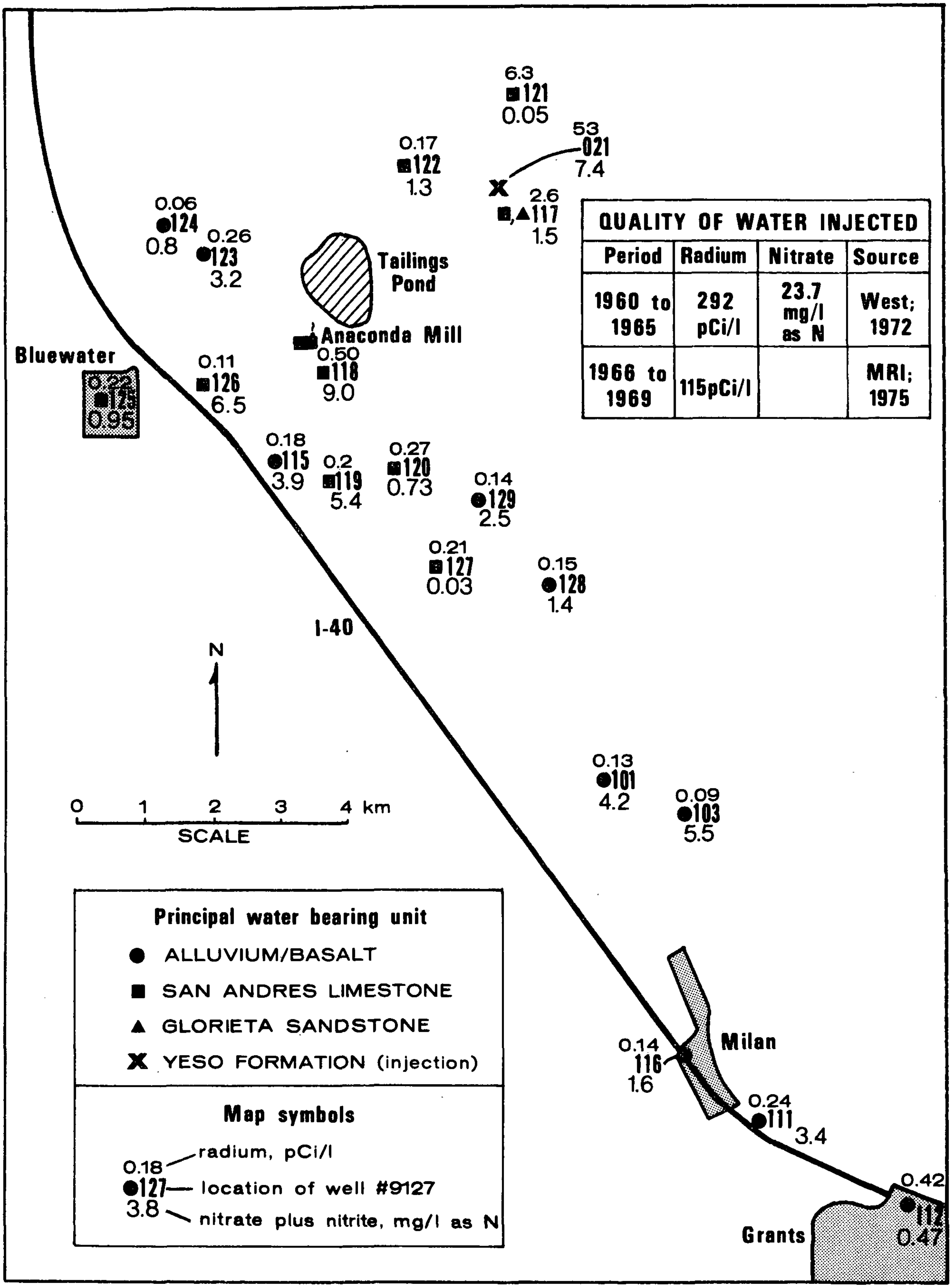

Figure 4. Radium and Nitrate Concentrations in Ground Water in the Grants-Bluewater Area

this direction, wells #9115, #9129, #9128, #9101, and #9103 could also be affected. The gradually reduced concentrations along the flow path may reflect dilution and sorption effects or they may simply be coincidental. For unknown reasons, the trend reverses in the Milan-Grants area, and concentrations begin to increase along the flow path. With the exception of wells #9101 and #9103, essentially the same pattern is true for nitrate. Variations in chloride, which is also a likely indicator of mill effluent, do not fit the pattern for radium and nitrate and, to some extent, weaken the conclusion that contaminants are recognizable in the alluvium.

In the San Andres Limestone and Glorieta Sandstone, radium concentrations range from 0.11 to 2.6 pCi/l (0.11 to 0.50 if well #9117 is excluded) and show no pronounced lateral trends. The highest concentrations (2.6 pCi/l) are in the Anaconda monitor well (#9117) and may indicate contamination (or this may simply be a naturally elevated level in the Glorieta Sandstone). Very few wells tap this formation and water quality is poorly known. Anaconda well #2 (#9118) is also relatively high in radium, nitrate, and polonium-210. It is quite possible that the well is contaminated by downward seepage of wastes from the tailings pond.

The Berryhill Section 5 well (#9121) is listed in the Anaconda Company records as being completed in the alluvium. It is equipped with a windmill and is used for stock watering. However, Gordon (1961) indicates that as of January 1958 there were two wells in the area. The active well, 221 meters deep and completed in the San Andres Limestone, replaced an older well, 107 meters deep and completed in the Chinle Formation. Therefore, contamination of either the Chinle Formation or the San Andres Limestone by injected wastes is occurring insofar as the radium-226 concentration of 6.3 pCi/l in the Berryhill Section 5 well greatly exceeds normal concentrations in either formation (see also Table 4).

Because of excessive seepage from the tailings ponds, the Anaconda Company developed an injection well to dispose of decanted effluent. According to company and U. S. Geological Survey reports (Fitch, 1959; West, 1972), favorable geologic, hydraulic and water quality conditions exist to allow this disposal method. However, subsequent evaluation of the monitoring data and inadequacies in the number and location of monitoring wells make this conclusion questionable.

From 1960 to date, injection has been into the Yeso and Abo Formations at depths of 289.6 to 433.7 meters. Between the injection zone and the lowermost potable aquifer, there is reportedly a relatively impervious sequence of sedimentary rocks, including numerous anhydrite and gypsum beds (Fitch, 1959; West, 1972). When the injection program was conceived in 1960, this sequence was considered sufficient protection for the overlying potable aquifers. Also, it was reasoned that when the waste fluid contacted the gypsum or anhydrite, as well as other disposal zone rocks, an ion exchange occurred between radium (in the fluid) and calcium (in the reservoir rocks), thereby reducing somewhat the radium concentration in the injection fluid.

Based on laboratory tests of the drill cores from the disposal zones, neutralization of the waste effluent was expected to occur. The pH of the formation waters ranges from 7.4 to 8, while the effluent has a pH of about 2.2. It was thought that the acid effluent becomes neutral or slightly basic due to the preponderance of disposal zone waters. Radium solubility would, therefore, decline. The disposal zone waters have been shown to be non-potable due to their brackish quality. Chemical analyses indicate a very high concentration of total dissolved solids, and it was reasoned that contamination of the deeper formations would not deny foreseeable use for the contained water.

Evidence of leakage from the injection zone is shown in Figure 5, which summarizes Anaconda Company data on the volumes of wastes injected from 1960 through 1973. Also shown are trends in natural uranium and chloride from the monitor well #9117, Roundy windmill, and North well (#9122) for the period 1969 through 1973. It is readily apparent that both chloride and uranium concentrations in all three monitoring wells are increasing with time and vary directly with the volumes of waste injected. The concentration of polonium-210 in the Monitor well exceeds that in all other wells in the Bluewater-Grants area and is well above the average of 0.33 pCi/l for six wells in bedrock. Concentrations of chloride and natural uranium in the waste water average 2010 ppm and 7340 pCi/l, respectively, for the period 1960 to 1965 (West, 1972). Radium from 1960 through 1969 averages 221 pCi/l (Clark, 1974). According to the partial chemical data for these three monitoring wells and contrary to original projections, contamination apparently extends into the San Andres Limestone.

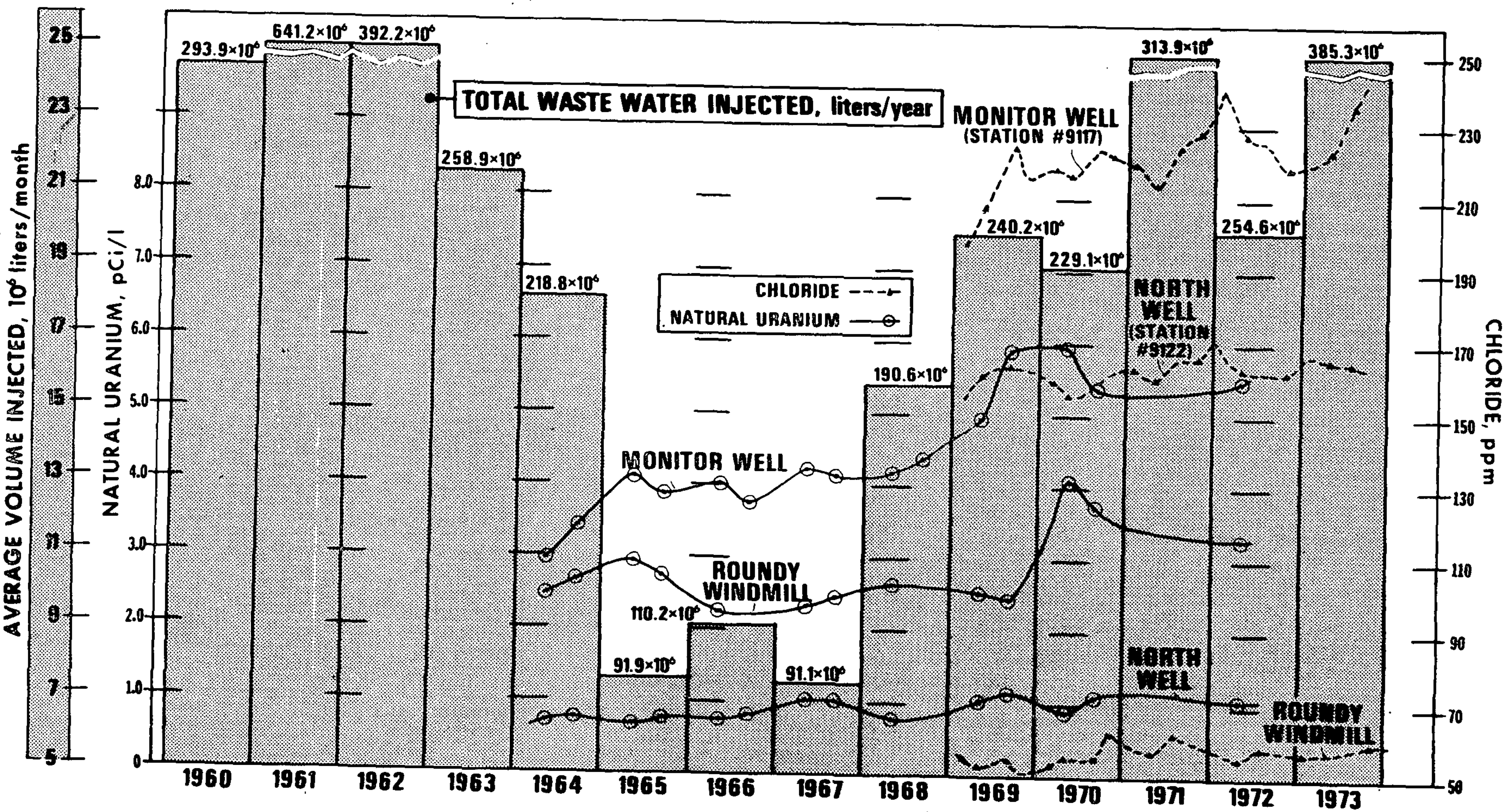

Figure 5. Summary of Waste Volumes Injected via the Anaconda Disposal Well and Water Quality in Selected Monitoring Wells

Sulfate, TDS, and gross alpha in North well (#9122) and in the Monitor well (#9117) are increasing slightly with time. For North well, TDS increased at a rate of about 13 mg/l per year and has gone from 1680 mg/l in June 1956 to 1900 mg/l in February 1975. Gross alpha is apparently increasing about 0.1 pCi/liter per year, but the company analytical results of about 2 pCi/l are markedly below the 30 pCi/l reported herein.

At the present time, ground water developed for potable use does not appear to be adversely affected by the Anaconda disposal practices. This conclusion is based on analyses for seven wells (9118, 9119, 9124, 9125, 9126, 9127 and 9129) completed in bedrock and in alluvium and generally located peripheral to and within 4 kilometers of the tailings ponds. Anaconda supply wells #2 and #4, which show slightly increasing trends for TDS, chloride, or sulfate, are closest to the ponds and are used for potable and mill feed purposes. For the remaining wells, increasing and decreasing trends for TDS and sulfate are present whereas chloride, nitrate and gross alpha results are rather stable. Because of its proximity to the Anaconda tailings ponds and because of its use as a public water supply, the LDS well in Bluewater should be more routinely monitored for nitrate and radium.

In summary, the interpretation of ground-water quality offered by the New Mexico Health Department (1957) is not supported by subsequent data. Concentrations of nitrates and chloride, in particular, are not markedly different today than in the base period from 1953 to 1956. Data for the period 1956 to 1969 may bear out the earlier predictions of gross contamination; but, if so, water quality since 1969 is only slightly changed. For widespread ground-water contamination to quickly occur from 1955 to 1956 and then rapidly attenuate is very unlikely considering the dynamics of ground-water flow and the continuing history of waste disposal. It is a matter of conjecture whether the earlier data were faulty or were misinterpreted. Ground-water flow patterns in the vesicular basalt and interbedded alluvium underlying the northwest pond and portions of the main pond are not described in the available references. Complex permeability distributions and waste density considerations add further complications. However, seepage is occurring and it is possible that the Company estimates stated above are conservative.

The foregoing comments do not imply that ground-water contamination is absent. Gross contamination of nearby wells, or a continuation of the earlier, perhaps erroneous predictions of contamination, is not apparent. The major qualification of these conclusions is that wells properly located and completed for sampling purposes are not available; hence, the extent of contamination is not well understood. Contamination is evident in the North and Monitor wells but is not yet a problem. Available chemical data for pre- and post-injection periods should be evaluated, together with monthly or quarterly injection volumes, to further confirm or deny the trends shown in Figure 5. If the trends shown are valid, thorough reevaluation of the injection method of waste disposal and construction of additional monitoring wells in the Yeso Formation and the Glorieta-San Andres is in order. Such measures are particularly important if increasing concentrations of radium-226 (and possibly lead-210) are appearing in the aquifers above the injection zone.

United Nuclear-Homestake Partners Mill and Surrounding Area

The mill is partially surrounded on the southwest or downgradient side by housing developments and irrigated farm lands, both of which depend on local ground-water supplies. Also obvious in Figure 6 is a darker seepage area around the base of the tailings pile. The seepage is collected and pumped back to the pond above the sandy tailings, but seepage from the pile proper and from the encircling moat can enter the ground-water reservoir. The five-sided polygon adjacent to the mill buildings is an inactive tailings pile that was formerly part of the Homestake-New Mexico Partners mill. In the upper left-hand portion of the photograph is shown the terminus of the San Mateo Creek drainage from the San Mateo and Ambrosia Lake areas.

Three distinct aquifers are present in the area of the mill and surrounding developments. In ascending order, these include the San Andres Limestone, the Chinle Formation, and the alluvium. Water table conditions and a southwestward lateral flow gradient prevail in the latter, with static water levels about 15 meters below land surface. The San Andres Limestone originally was under artesian head, but heavy pumping for irrigation and for industry has removed much of the head once present. Data presented by Gordon (1961) indicate a downwind flow gradient, but the permeability of the Chinle Formation is low, and actual vertical

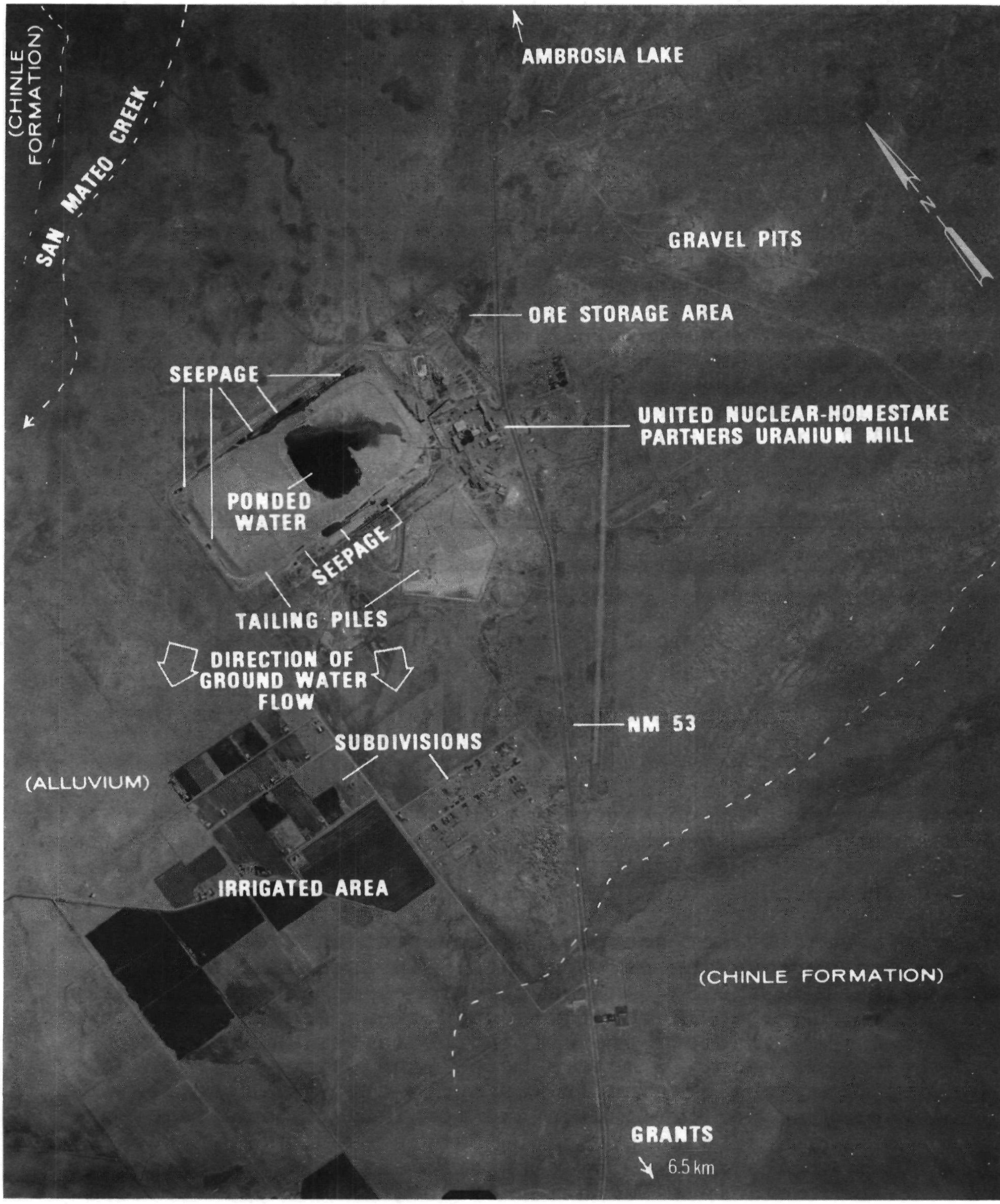

Figure 6. The United Nuclear-Homestake Partners Uranium Mill and Tailings Ponds-Milan

water transfer is probably minimal. The chief significance of these hydrogeologic conditions is that liquid effluents produced by the uranium milling operation are likely to infiltrate at the mill site and travel in a south-southeast direction toward the nearby subdivisions. Water quality in the Chinle Formation and the still deeper San Andres Limestone is likely to be unaffected.

Radium concentrations in groundwater (Figure 7) from the San Andres and Chinle range from 0.05 to 0.27 pCi/l, with a mean of 0.16 pCi/l for six determinations. Realistically, assuming that minimum detectable amount is 0.1 pCi/l versus 0.05, the average increases to 0.18 pCi/l. The peak value from shallow wells tapping the water table aquifer in the alluvium is 1.92 pCi/l in well D, the single active monitoring well (#9135). Although below the PHS drinking water standard of 3 pCi/l, this value does indicate movement of contaminants away from the tailings pond. Attenuation due to sorption may mask a very sharp concentration gradient between this well and the pond. At a distance of approximately 0.6 kilometers from the ponds, radium in the shallow aquifer reverts to levels of 0.13 to 0.72 pCi/l and averages 0.36 pCi/l, or about twice that present in the bedrock reservoirs at depth. Relatively high concentrations (0.72, 0.61 pCi/l) in the Worthen and Enyart wells may reflect plumes or fronts of contaminants that have advanced ahead of the main body. The water table map (Figure 8), prepared by Chavez (1961), portrays an elongated, northeast-trending lobe or mound centered on the smaller tailings pile from the now inactive Homestake-New Mexico Partners mill.

The possibility of ground-water pollution from the United Nuclear-Homestake Partners tailings pond was noted in the early 1960's (Chavez, 1961). Samples from on-site monitoring wells completed in the alluvium contained from 0.8 to 9.5 pCi/l radium despite the fact that ore had been processed for less than two years. These concentrations are markedly above the normal range of 0.1 to 0.4 pCi/l in wells several miles west of the mill and from wells in the alluvium between San Rafael and Grants.

Chloride and TDS data for well #9107 (Figure 7) support the idea of a tongue of contaminated ground water in the area between this well and the tailings pile. Nitrate in this well was 62 mg/l and, therefore, does not meet the PHS Drinking Water Standard of 45 mg/l. Infants and fetuses are particularly susceptible to nitrate poisoning at concentrations above 45 mg/l, and alternate sources of potable water should be utilized. Heterogeneities in sediment permeabilities, coupled with irregular induced flow gradients resulting

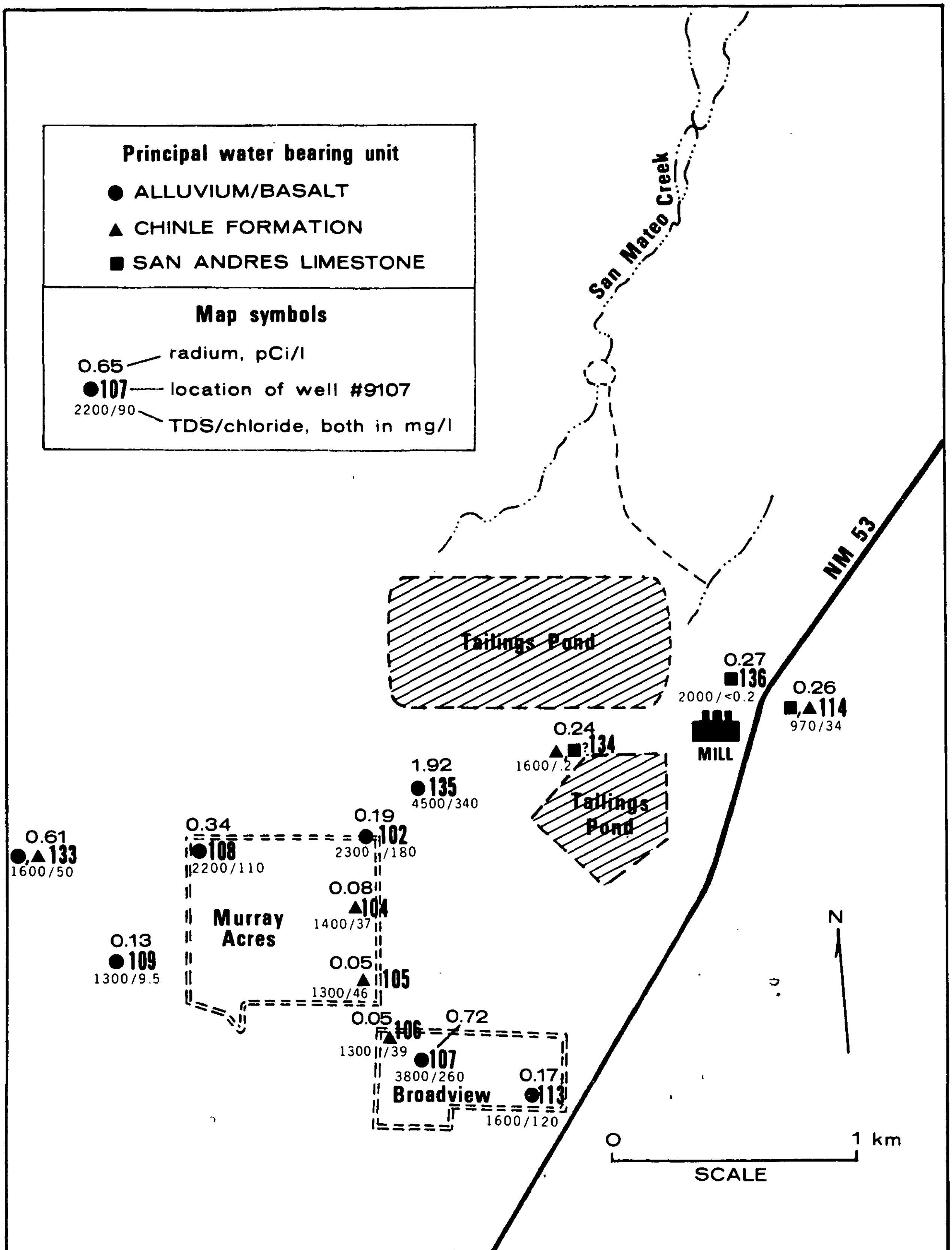

Figure 7. Radium, TDS and Chloride in Ground Water Near the United Nuclear-Homestake Partners Mill

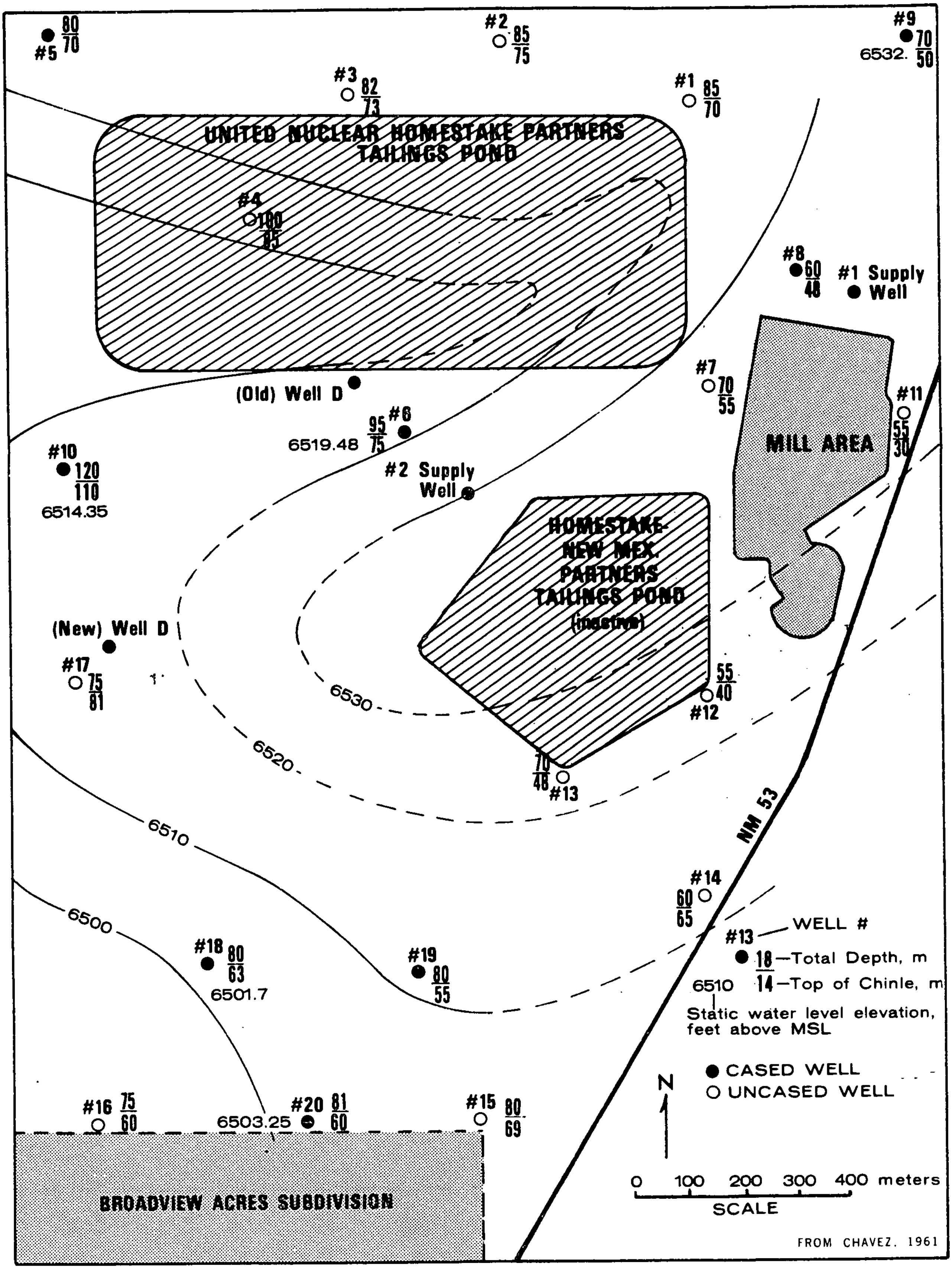

Figure 8. Water Table Contours and Well Locations at the United Nuclear-Homestake Partners Mill Site

from seepage return flows, make definition of the polluted front rather difficult. It is clear that one well (well D, #9135) is inadequate for the task.

Selenium concentrations (see Table 3) in several of the domestic wells located downgradient from the mill are anomalously high and are, perhaps, the best indicator of ground-water contimination. Nearby wells (#9102, #9107, and #9113) contain from 20 to 106 times the recommended maximum selenium concentration of 0.01 mg/l (National Academy of Sciences-National Academy of Engineering, 1972). Two of the wells contain approximately two-thirds of the concentration in the monitor well (1.52 mg/l). The water supply for the mill contains <0.01 mg/l, whereas the seepage collection ponds adjacent to the presently active pile contain 0.92 mg/l. Because of analytical difficulties and differences between laboratories, the selenium data are most useful to show elevated trends rather than necessarily an absolute concentration in the ground-water system. Additional sampling is necessary to more accurately define the extent of contamination.

Elevated levels of polonium-210 are present in well D (#9135) and in other wells (#9102, #9106, #9107, and #9113) downgradient from a suspected contamination front in the shallow aquifer. Background for polonium-210 is approximately 0.34 pCi/l (Table 5) in wells tapping either the Chinle Formation or the alluvium, whereas concentrations range from 1.0 to 2.3 pCi/l in wells suspected to be contaminated. The highest value for polonium-210 was from well D (#9135). The elevated level of polonium-210 in supply well #2 (#9134) cannot be explained.

Provision of an alternative water supply is strongly recommended to avoid consumption of shallow ground water exceeding 0.01 mg/l selenium. Deeper wells completed only in the Chinle Formation and preferably fully cemented in the interval from land surface to 15 meters into the Chinle should be considered minimum. Other alternatives include the construction of high capacity wells nearby, but away from the developments, or placing the developments on the Milan municipal water system.

Ambrosia Lake Area

The Kerr-McGee mill is located on the dip slope of a southeast-facing cuesta in an area underlain by a thin veneer of silt and clay alluvium over the Mancos Shale. Shown in Figure 9 is the large network of tailings ponds and water storage reservoirs built by excavation and by selectively sorting the coarse tailings for retention dams. Discharge from numerous mines and from ion exchange plants gives rise to perennial flow in Arroyo del Puerto which trends north-south. Seepage from the tailings ponds and from the aforementioned sources is evident from the vegetation present in the formerly dry washes. Shown in the upper right corner of the photograph, taken in September 1973, is the inactive tailings pile at the United Nuclear Corporation mill. The ponded water shown on the pile has since evaporated or seeped into the tailings.

Ground-water sampling in the Ambrosia Lake area focused on the Kerr-McGee tailings disposal operation and the combined impact of various ion exchange plant and mine water discharges into San Mateo Creek and Arroyo del Puerto. Because of influent stream conditions, these surface water bodies represent line sources of recharge to the shallow ground-water reservoir. Of the 22 wells sampled in the area (see Figure 10), all but 3 were part of the Kerr-McGee Nuclear Corporation environmental monitoring network. The absence of sampling points near the United Nuclear mill and tailings pile or near the active mines and ion exchange plants precluded study in these areas. Poorly understood are the effects of seepage from settling ponds and from open channels leading to the two principal streams in the area. The disposition of solutions involved *in situ* leaching is also unknown.

Nevertheless, the conservative parameters clearly indicate the infiltration of wastewater. Whereas shallow ground water beneath San Mateo Creek contains about 700 mg/l TDS in the reach above Arroyo del Puerto, the reach below has about 2000 mg/l. Ammonia increases four fold from 0.05 to 0.22 mg/l, and nitrite plus nitrate (as N) go from an average of less than 1 mg/l to 24 mg/l. The recommended maximum in drinking water is 10 mg/l. Selenium and vanadium concentrations in ground water do not markedly increase near the tailings ponds. One exception is well KM-43 (#9208) which contains 0.29 mg/l selenium as well as high radium and TDS. The Marquez windmill (#9132) is also enriched in selenium which further substantiates the TDS, chloride, ammonia, and nitrate data results which show contamination of the shallow aquifer. Nitrate, derived from

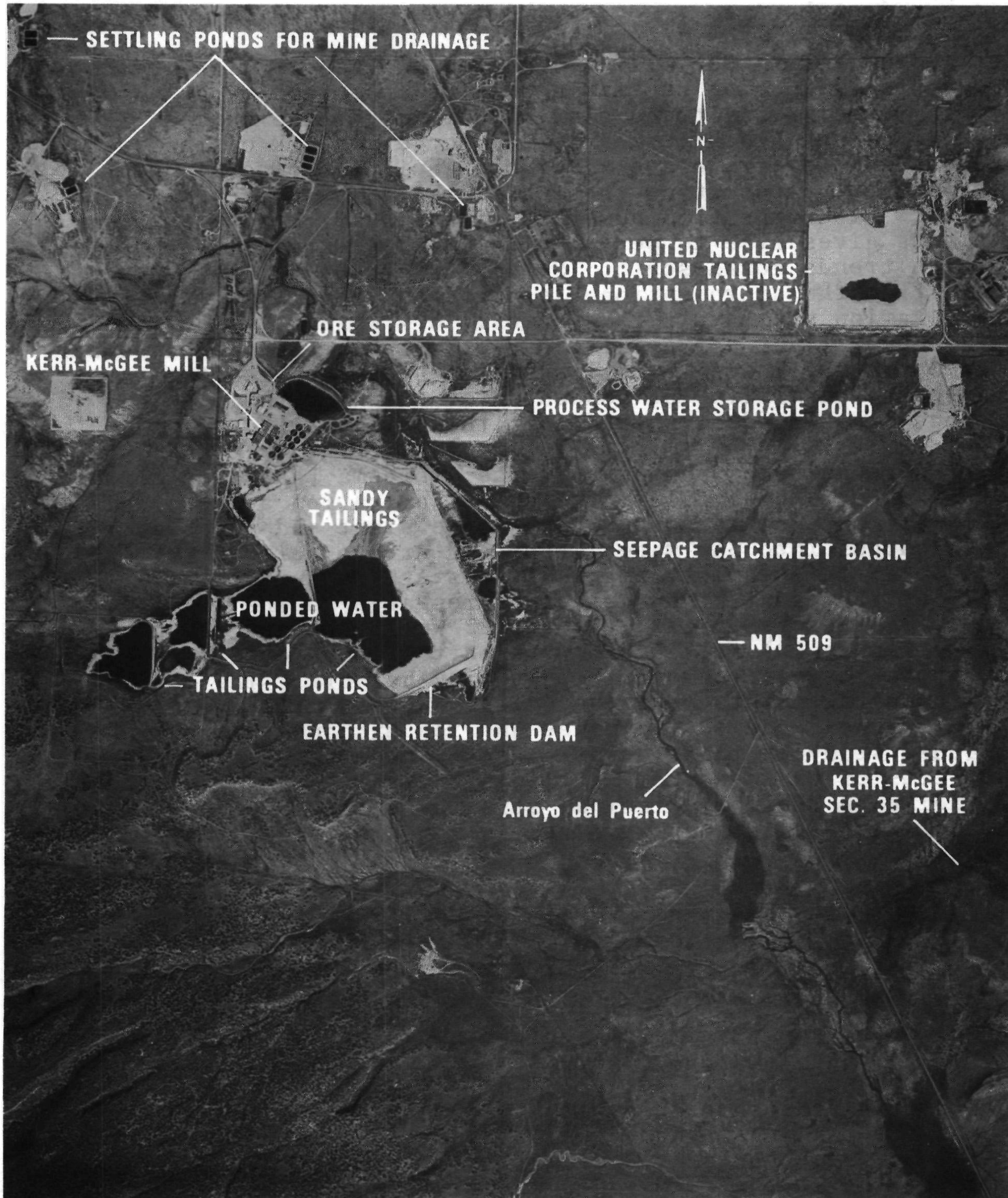

Figure 9. Kerr-McGee Nuclear Corporation Uranium Mill, Tailings Ponds, and Mines-Ambrosia Lake

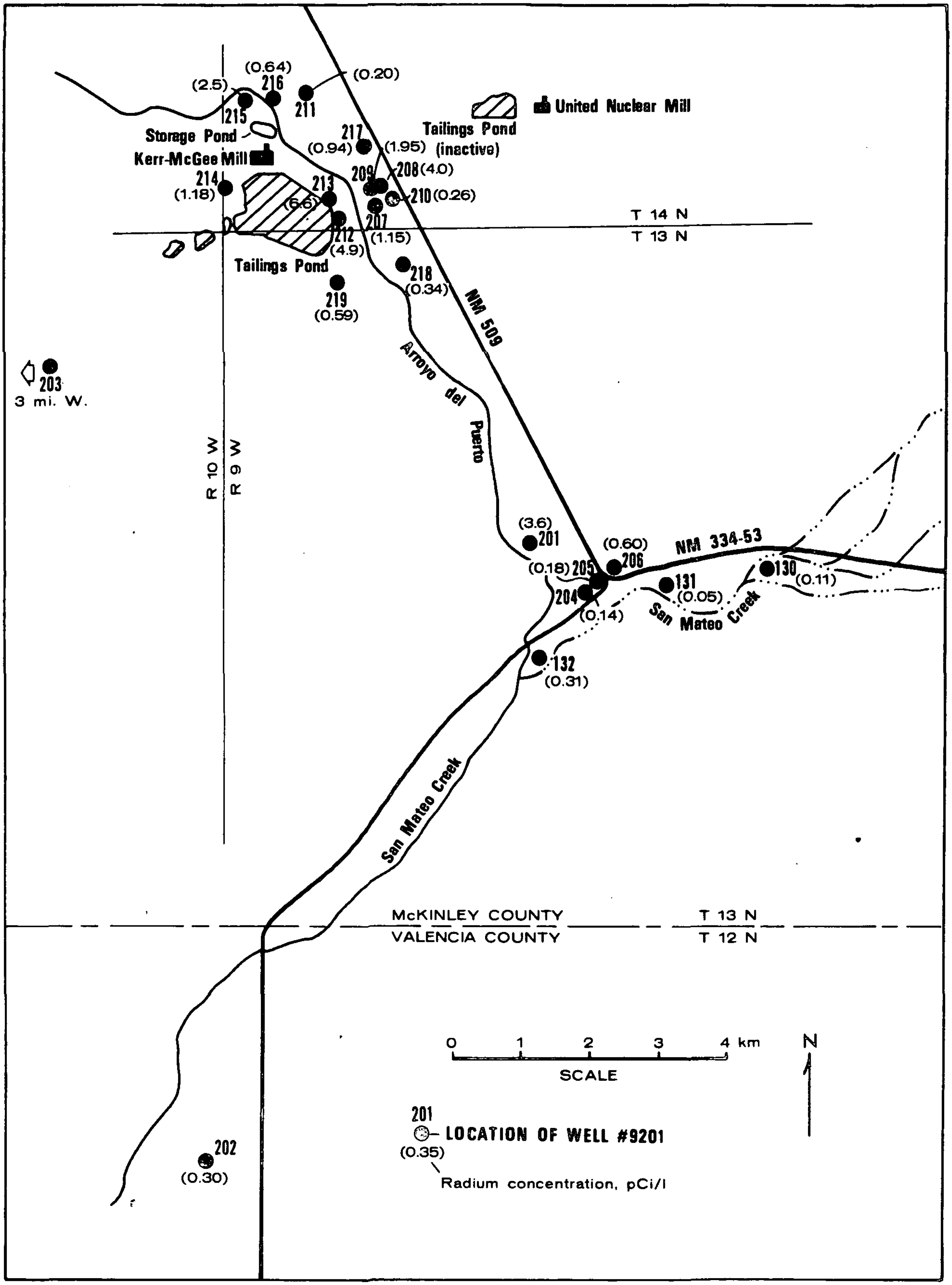

Figure 10. Radium Concentrations in Ground Water in the Ambrosia Lake Area

very high concentrations of ammonia in the mill effluents, persists in shallow ground water. This is particularly true for shallow wells located east of the ponds and along San Mateo Creek, both above and below the county line. The range of concentration exceeding the PHS Standard is 48.7 to 350 mg/l. One of these wells (#9204-Ingersoll Rand) is used for a potable supply, whereas well #9202 is for stock watering.

The concentration of radium in ground water in the vicinity of the tailings piles at the Kerr-McGee mill averages 1.7 pCi/l for the 12 wells sampled. The highest concentration, 6.6 pCi/l, occurs at station #9213 near the base of the seepage catchment basin and probably characterizes the quality of ground-water seeping beneath and through the retention dam. Water in the basin, per se, contains 65 pCi/l radium. Note that high TDS, chloride, ammonia, and nitrate plus nitrite appear in the seepage. Within 1 to 2 kilometers of the tailings pile periphery, radium concentrations in shallow ground water to depths of 17 meters are 4 pCi/l or less.

The foregoing general pattern is in agreement with the migration described by the Kerr-McGee staff at the time of the field study. Despite a concentration of 65 pCi/l in seepage from the ponds, concentrations in the immediately adjacent ground water do not exceed 6.6 pCi/l, and quickly reduce to 4 pCi/l or less. Seepage leaving the property and moving southeastward parallel to Arroyo del Puerto averages 0.47 pCi/l radium.

Despite the relatively localized contamination of ground water adjacent to the Kerr-McGee tailings ponds, serious question remains concerning their adequacy as a means of waste disposal. Company data for 1973 and 1974 reveal that seepage from the ponds averaged 935 liters/minute. Influent averaged 3181 liters/minute; therefore, 29 percent of the wastes entered the ground water and the balance evaporated. Assuming 60 pCi/l in the seepage and a 20-year operating period, 0.6 curies of radium would be introduced to ground water. The company data indicate that the seepage rate was fairly constant at 946 and 924 liters/minute for 1973 and 1974, respectively. Also shown in the water balance are additions to storage in the third quarter of each of three years (1972, 1973, 1974). The writers interpret this as overland flow related to thunderstorm activity prevalent at this time of year. The rapid influx of overland flow into the ponds prompts questions concerning their stability and overall company management practices. The ponds are operated with very little freeboard and the berms or dikes are composed of sandy tailings that are readily eroded, particularly if overflow conditions develop. Catastrophic failure of the tailings ponds could occur.

Churchrock Area

The Puerco River at Gallup was ephemeral until upstream mining operations reached a scale such that wastewater discharge was sufficient to cause perennial flow. At present the combined discharge from the United Nuclear and Kerr-McGee mines, located as shown in Figure 11, is about 16 x 10^6 liters/day and characterized by 8 to 23 pCi/l radium, 700 to 4900 pCi/l uranium, 0.01 to 0.04 mg/l selenium, and 0.4 to 0.8 mg/l vanadium. In terms of radium, selenium, and vanadium, the water is unfit for stock or potable uses and not recommended for irrigation. Infiltration of the mine wastewater represents a remote threat to potable ground water in the vicinity of the Puerco River and possibly part of the Gallup municipal supply. In part, the present study examines whether noticeable ground-water quality deterioration has occurred to date.

Ground-water sampling in the Churchrock area involved 13 wells located along the Puerco River and South Fork Puerco River. For control purposes, an adjacent watershed tributary to the Rio Puerco was also sampled. A single sample from a newly developed well serving the Gallup area was also tested. The sampling points included water used for stock, domestic use, and for public drinking water supplies. Alluvial and bedrock aquifers were sampled in an area of 200 km^2 located generally east and northeast of Gallup.

None of the ground-water samples contain sufficient quantities of naturally occurring radionuclides to constitute a health problem. The radiochemical, trace element, and gross chemical data do not indicate that contamination of ground water is occurring as a result of the mining operations underway. However, two of the wells (#9139, #9221) contain 119.6 and 62 mg/l nitrate, respectively, and, therefore, do not meet the PHS Drinking Water Standard of 45 mg/l. The mine drainage waters contain less than 4 mg/l, hence this is not the source. Consumption of water this high in nitrates is particularly dangerous to infants and the unborn and alternate supplies should be utilized. More suitably located

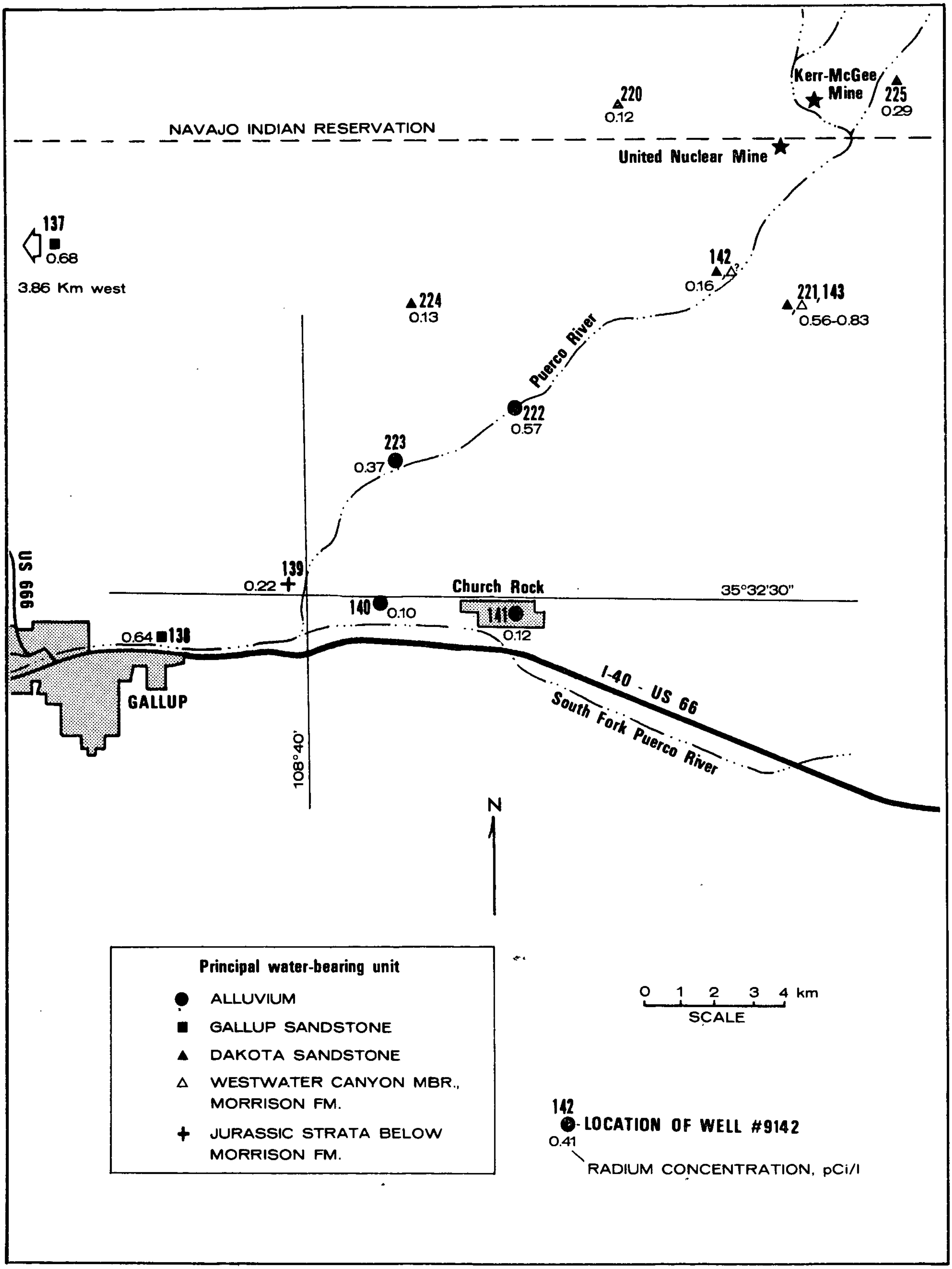

Figure 11. Radium Concentrations in Ground Water in the Churchrock-Gallup Area

sampling points, together with revised analytical programs are strongly recommended improvements to the existing industrial efforts.

By comparison, the effects of mining on the concentration or radium in ground water are pronounced. Present discharge from the Kerr-McGee mine, which is in the development versus mining stage, averages 7.9 pCi/l as compared to 23.3 pCi/l for the United Nuclear mine. The latter is producing ore. In both cases, elevated radium concentrations are present. In large part, these are attributable to mining operations and practices and do not represent natural water quality, evident from samples of ground water collected from 4 wells and 3 long holes, all in the Westwater Canyon Member (Hiss and Kelley, 1975). Radium varied from 0.05 to 0.62 pCi/l compared to 0.28 to 184.8 pCi/l uranium. An additional sample collected in November 1973 from the settling pond discharge at the United Nuclear mine contained 8.1 pCi/l radium and 847 pCi/l natural uranium. Thus, initial penetration of the ore body increased radium at least 10-fold and subsequent mine development work over a two-year period resulted in another three-fold increase. Compared to natural concentrations, radium increased some 23 times. Similar trends also seen in the Ambrosia Lake area prevail, indicating that ultimate radium concentrations on the order of 50 to 150 pCi/l are likely. This has been tentatively confirmed by company, self-monitoring data.

Jackpile-Paguate Area

Sampling in the vicinity of the Jackpile-Paguate open pit uranium mine included four wells located as shown in Figure 12. One of these (#9233) is the Paguate municipal supply which is a flowing artesian well completed in alluvium at a depth of 22.9 meters. The remaining three wells are property of the Anaconda Company and are used for potable supply and for equipment washing, etc. It is believed that all three were former exploration holes that have been reamed out, cased, and equipped with a submersible pump. The water quality is probably representative of the Jackpile Sandstone Member of the Morrison Formation, which also is the principal ore body in the Laguna mining district.

Dissolved radium in water from the Jackpile Sandstone aquifer ranges from 0.31 to 3.7 pCi/l. The latter value is from the new shop well which is a source of potable and nonpotable water for the facility. Continued consumptive use of this water is not recommended because the radium exceeds the PHS Drinking Water Standard of 3 pCi/l.

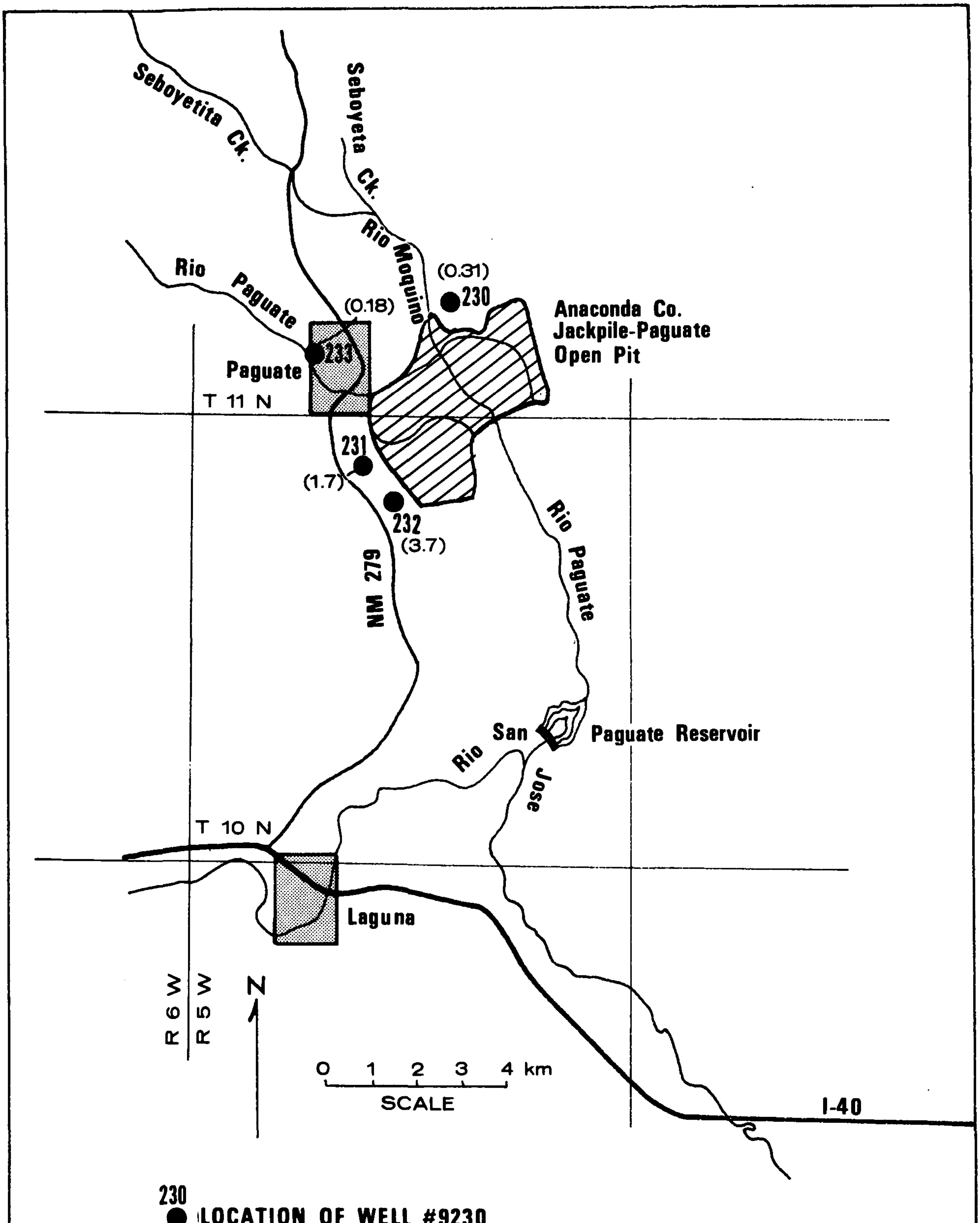

Figure 12. Radium Concentrations in Ground Water in the Paguate-Jackpile Area

The village of Paguate water supply is well below the recommended maximum level for not only radium but also the other isotopes considered in the present study. Selenium, however, is at the maximum recommended level of 0.01 mg/l. It is extremely unlikely that the present shallow-well supply will be affected by mining unless the open pit would be extended close to the well field. Recharge to the shallow aquifer is derived from runoff which infiltrates to the west and north. After percolating southward, it then reappears in a marshy area west of the village. Springs and artesian conditions are likely the result of decreasing transmissivity due to the near surface occurrence of shales and poorly permeable sandstones in the lower reaches of Pueblo Arroyo.

The downstream impacts of the Jackpile-Paguate mine on ground water were not determined because of the absence of suitable sampling points. It is recommended that shallow monitor wells be installed at several points along the Rio Paguate to ascertain the chemical, radiochemical, and trace element species present. Limited coring in the sediment-filled Paguate reservoir would provide data on variations in the radium and uranium content before and during mining. Such data would also provide information on radioactivity associated with sediment transport during periods of peak runoff and erosion.

Significance of Radiological Data

Regulations and Guidelines

On August 14, 1975, the U.S. EPA published in the Federal Register (40 FR158, p. 34323-34328) a "Notice of Proposed Maximum Contaminant Levels for Radioactivity" to be included in 10 CFR Part 141 - Interim Primary Drinking Water Regulations. The following are the proposed maximum contaminant levels for radium-226, radium-228, and gross alpha particle radioactivity:

1. Combined radium-226 and radium-228 not to exceed 5 pCi/l.

2. Gross alpha particle activity (including radium-226 but exclusive of radon and uranium contents) not to exceed 15 pCi/l.

The proposed regulations also discuss maximum contaminant levels of beta particle and photon radioactivity from man-made radionuclides.

Therefore, with respect to these proposed radioactive contaminant levels, the following conclusions were reached:

1. Additional analysis for radium-228 and lead-210 will proceed and be reported in a separate report at a later date.

2. Since radium-228 is a daughter product of thorium-232 and thorium analyses of these waters fluctuated around background concentrations, it appears that the radium-228 content should also be at background levels (i.e., less than 0.02 pCi/l. Hence, the radium-228 content, under assumed equilibrium conditions, should be less than 0.042 pCi/l, the highest reported thorium-232 content.

3. Only two locations out of the 71 ground-water locations sampled have radium-226 concentrations in excess of 5 pCi/l. Therefore, the proposed new standard of 5 pCi/l for combined radium-226 and radium-228 contents is therefore exceeded at these two locations.

4. Sixty of the 71 ground-water locations had gross alpha results in excess of the proposed 15 pCi/l limit; however, the gross alpha results reported here include uranium isotopes. Included in the list of sixty locations are several locations where the gross alpha results are less than 15 pCi/l, but consideration of the 2 sigma confidence level would then indicate a gross alpha possibly in excess of the 15 pCi/l limit.

5. The proposed maximum gross beta limit excludes naturally occurring radionuclides (e.g., lead-210); therefore, there is no presently proposed maximum contaminant level for lead-210. The NMEIA population guide MPC of 33 pCi/l appears to be the only current applicable guideline for lead-210 content.

Since the above radioactivity contaminant levels are proposed and not final interim primary drinking water regulations, the following discussions of the radiological analyses of water samples obtained during this study will be based on the U.S.P.H.S. Drinking Water Standards (1962) and current NRC/NMEIA maximum permissible concentration levels.

Radium-226

Of the 71 ground-water sampling locations of this study, only 6 locations showed radium-226 concentrations in excess of the 3.0 pCi/l drinking water standard (U.S.P.H.S. Drinking Water Standards, PHS Publication

No. 956; 1962). The population guide--maximum permissible concentration (10CFR, Part 20, Table II, column 2, unrestricted areas) is 10 pCi/l for radium-226. Table 7 lists the 6 locations and presents the gross alpha and radium-226 results.

The Jackpile-New Shop well, Paguate (#9232), is a potable water supply having a radium concentration in excess of the drinking water standard. This water need not be used for human consumption since other nearby wells have much lower radium concentrations (e.g., the Paguate municipal supply (#9233) or the Jackpile well (#9230)).

The Phil Harris well, Grants (#9201), is the only other potable water supply with a radium concentration in excess of 3.0 pCi/l. The Berryhill Section 5 windmill, Bluewater (#9121), is used as a stock water supply; and since there are no nearby human consumers, the radium concentration of 6.3 0.1 pCi/l is of no immediate health hazard.

Samples from two Kerr-McGee monitoring wells (#9208 and #9213), located within 800 meters of the main tailings retention dam, contain radium in excess of 3.0 pCi/l. These wells are not fitted with pumps, are in a restricted area, and contain water otherwise unfit for comsumption. For example, TDS varies from 7500 to 8900 mg/l. Therefore, these wells do not constitute a health hazard in terms of dissolved radium. Similarly, station #9212 consists of seepage return water collected at the base of the retention dam. Aside from the radium content of 4.9 pCi/l, the water is in a restricted area, is not used for any purpose, and contains 36,000 mg/l TDS. Therefore, consumptive use and creation of a health hazard is extremely unlikely.

For comparison purposes, Table 8 shows the radium concentrations for municipal water supplies surveyed during this study.

A radium concentration of 0.68 pCi/l from the Erwin well north of Gallup (#9233) was the highest radium concentration for the municipal supplies. It appears that, on the whole, municipal water supplies in the Grants Mineral Belt area do not exceed 23% percent of the drinking water standard of 3.0 pCi/l.

Ten privately owned, potable water supplies were surveyed in the Murray Acres-Broadview Acres and other areas surrounding the United Nuclear-Homestate Partners mill. The highest radium concentration was 0.72 pCi/l

Table 7

Locations with Radium-226 in Excess of the PHS Drinking Water Standard[1]

Location Description	Radium-226[2]		Gross Alpha[2]		Remarks
	Dissolved pCi/l	Two Sigma pCi/l	Dissolved pCi/l	Two Sigma pCi/l	
#9121-Berryhill Section 5 Bluewater	6.3	0.1	12	14	Windmill Stock Feed Water
#9201-P. Harris Grants KM-46	3.6	0.1	110	40	Potable Water Supply
#9208-KM-43 Grants	4.0	0.1	49	35	Monitor Well
#9212-KM Seepage Return-Grants	4.9	0.1	112,000	3,000	Surface Water Sample
#9213-KM-B-2 Grants	6.6	0.1	8	32	Monitor Well
#9232-Jackpile-New Shop Well Paguate	3.7	0.08	18	13	Potable Water Supply

1 PHS Drinking Water Standard, 1962, is 3.0 pCi/l for Radium-226.

2 Radium and gross alpha analysis by NEIC-Denver.

Table 8

Radium and Gross Alpha Concentrations for Municipal Water Supplies [1]

Location Description	Radium-226		Gross Alpha	
	Dissolved pCi/l	Two Sigma pCi/l	Dissolved pCi/l	Two Sigma pCi/l
#9112-Grants City Hall	0.42	0.02	19	13
#9116-Milan City Well #1	0.14	0.01	12	10
#9125-LDS Bluewater	0.22	0.01	8	10
#9137-Erwin Well Gallup	0.68	0.03	10	9
#9233-Municipal Well Paguate	0.18	0.02	2	4
#9141-Churchrock Village	0.12	0.01	3	7

1 Radium and gross alpha results by NEIC-Denver.

at the Worthen well (#9107), and the lowest concentration was less than 0.05 pCi/l at the Schwagerty well (#9105). The average radium concentration for these 10 private wells was 0.26 pCi/l.

Six privately owned, potable water supplies in the Ambrosia Lake area contain 0.07 to 3.6 pCi/l. Of nine privately owned potable water supplies surveyed in the Grants-Bluewater area, the maximum radium concentration was 0.24 pCi/l. Only two privately owned wells were used solely as potable water supplies in the Gallup area. These were the Hassler (#9139) and Boardman (#9138) residences. The radium concentrations at these two locations were 0.22 and 0.64 pCi/l, respectively. The other 8 wells in the Gallup-Churchrock area were used mainly as stock water supplies and had an average radium concentration of 0.35 pCi/l.

<u>Other Radionuclides</u>

Table 9 entitled "Maximum Permissible Concentrations in Water" presents the unrestricted area - MPC and the population guide - MPC for selected radionuclides. The PHS Drinking Water Standard of 3 pCi/l for radium-226 is more restrictive than the population guide - MPC; therefore, the radium content evaluations were based on the 3 pCi/l drinking water standard. The other radionuclide content evaluations are based on the soluble MPC value since filtered ground-water samples were analyzed. The MPC values listed are from the NRC regulations which are also consistent with the NMEIA regulations (June 16, 1973).

Only 3 potable water supplies had complete isotopic uranium analysis - Wilcox (#9102), Enyart (#9133), and Dixie well (#9140). The highest reported results (for the Wilcox well) indicate less than 0.1%, 0.002%, and 0.06% of the population guide - MPC for uranium-234, uranium-235, and uranium-238, respectively.

Of all the potable water supplies analyzed for thorium-230, the Worthen well (#9107) had the highest concentration of 0.99 pCi/l. However, this is less than 0.15% of the population guide - MPC. The Meador well (#9113) had the highest thorium-232 content of 0.042 pCi/l and polonium-210 content of 2.3 pCi/l. These are 0.006% and 0.98% of the population guide - MPC, respectively.

Table 9

Maximum Permissible Concentrations in Water[1]
(Above Natural Background)

Radionuclide		Appendix B Table II, Column 2 (Unrestricted Areas) pCi/l	Population Guide[2] pCi/l
^{226}Ra	Soluble	30	10[+]
	Insoluble	30,000	10,000
^{228}Ra	Soluble	30	10
	Insoluble	30,000	10,000
^{210}Po	Soluble	700	233
	Insoluble	30,000	10,000
^{210}Pb	Soluble	100	33
	Insoluble	200,000	66,667
^{230}Th	Soluble	2,000	667
	Insoluble	30,000	10,000
^{232}Th	Soluble	2,000	667
	Insoluble	40,000	13,333
^{234}U	Soluble	30,000	10,000
	Insoluble	30,000	10,000
^{235}U	Soluble	30,000	10,000
	Insoluble	30,000	10,000
^{238}U	Soluble	40,000	13,333
	Insoluble	40,000	13,333
U-Natural			
	Soluble	30,000	10,000
	Insoluble	30,000	10,000

1 10CFR-Part 20--Standards for Protection Against Radiation--U.S.N.R.C. (April 30, 1975).

2 Population Guide = 1/3 times Unrestricted Area MPC--Table II Values.

+ A maximum permissible concentration of 3.33 pCi/l for ^{226}Ra is the Handbook 69 population guide (i.e., 1/30th of the HB69 continuous occupational exposure limits).

All 6 municipal water supplies were analyzed for thorium-230, thorium-232, and polonium-210. The highest thorium-230 content was for Grants (#9112), with 0.046 pCi/l (0.007% population guide - MPC). The highest thorium-232 content was for the Churchrock Village, with 0.016 pCi/l (0.002% of the population guide - MPC). The highest polonium-210 content was for the Municipal well at Paguate (#9233) with 0.39 pCi/l (0.17% of the population guide - MPC). In summary, exclusive of the radium-226 content, the highest isotopic uranium, thorium, and polonium-210 contents for any potable water supply in the Grants Mineral Belt area is less than 1.72% of the total radionuclide population guide - MPC. Exclusive of the Kerr-McGee seepage return sample (#9212) and the Anaconda injection well sample (#9107), the Worthen private well (#9107) had the highest gross alpha result of 2500 pCi/l. This gross alpha result underestimates the U-natural content reported as 9800 pCi/l (i.e., 98% of the allowable MPC). There are other examples of inconsistencies between gross alpha and natural uranium data. For example, samples #9102 and #9113 have gross alpha results of 3 pCi/l and 31 pCi/l, respectively. Comparable U-natural contents are 49 and 56 pCi/l (less than 0.56% of the U-natural MPC). In general, it appears that the uranium isotopes represent the greatest contributor of alpha activity. Considering the total radionuclide values to be the summation of uranium isotopes, thorium-230, thorium-232, and polonium-210 concentrations, the percentage of total radionuclides compared to gross alpha ranged from 31% (#9219) to 639% (#9102), exclusive of #9132 which has an extremely large discrepancy of results. Therefore, it appears that the gross alpha determinations have underestimated the natural uranium contents. It is doubtful that the gross alpha determination can even be used as an indicator of the presence of other alpha emitters (e.g., U-natural and polonium-210). Since the gross alpha results have such large error terms, no meaningful determinations of percentage of other radionuclides to gross alpha result can be implied.

With respect to the use of 15 pCi/l gross alpha (including uranium isotopes) as a "scan level" to indicate radium contents in excess of 5 pCi/l, only 2 locations fall in this category. Location #9121 had a gross alpha of 12 ± 14 pCi/l and a radium-226 content of 6.3 ± 0.1 pCi/l. Because of the large error term in the gross alpha determination (8 ± 32 pCi/l) for location #9213, this sample would be included in the group of locations having a gross alpha result greater than 15 pCi/1. This location had the highest radium-226 content of all the ground-water locations sampled (6.6 pCi/1). Of the 58 remaining ground-water locations with gross alpha results greater than 15 pCi/1 (range: <3 ± 13 to 2500 ± 200 pCi/1), the radium-226 contents ranged from 0.19 to 0.72 pCi/1, respectively. For ground-water samples with gross alpha greater than 15 pCi/1, the radium-226 concentration ranged from 0.06 to 6.6 pCi/1. Therefore, there appears to be no correlation between a gross alpha level of 15 pCi/1 (including uranium isotopes) and a radium-226 content of 5 pCi/1.

It is appropriate to conclude that for routine radiological monitoring of potable water supplies, isotopic uranium and thorium, polonium-210, and radium-228 analyses are not necessary. Accurate radium-226 and lead-210 analyses for each sample yield the most information for radiological evaluations of drinking water conditions.

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15. SUPPLEMENTARY NOTES

16. ABSTRACT Ground-water contamination from uranium mining and milling results from the infiltration of radium-bearing mine, mill, and ion-exchange plant effluents. Radium, selenium, and nitrate were of most value as indicators of contamination. In recent years, mining has increased radium in mine effluents from several picocuries/liter (pCi/l) or less, to 100-150 pCi/l. The shallow aquifer in use in the vicinity of one mill was grossly contaminated with selenium, attributable to the mill tailings. Seepage from two other mill tailings ponds averaged 674 x 10^6 liters/year and, to date, has contributed an estimated 1.1 curies of radium to ground water. At one of these, an injection well was used to dispose of over 3400 x 10^6 liters of waste from 1960-1973. The wastes have not been properly monitored and have apparently migrated to more shallow, potable aquifers. No adverse impacts on municipal water quality in Paguate, Bluewater, Grants, Milan, and Gallup were observed. No correlation was found between gross alpha greater than 15pCi/l and radium-226 in excess of 5 pCi/l. Company-sponsored monitoring and reporting programs do not describe the full impact of mining and milling operations on ground-water quality. Review by State and Federal agencies has generally been superficial. Improvements in these areas and additional ground-water sampling are recommended.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Ground water, hydrogeology, uranium, water pollution, waste disposal, injection wells, wastes, natural radioactivity, radium, radiation hazards, radioactive wastes, mining, milling, tailings ponds.	Grants Mineral Belt New Mexico Uranium mining and milling.	Radioactive contaminants, Radioactive waste processing, waste disposal.

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

Ground water in the study area is affected by mining and waste disposal associated with mining and milling. Contamination appears in close proximity to the mining and milling centers with the exception of more widespread selenium contamination of shallow ground water adjacent to the United Nuclear-Homestake Partners Mill. Contamination of municipally operated water supplies in the study area is not evident. Potable supplies derived from mine water at four industrial sites exceed applicable limits for selenium in drinking water. Three such systems exceed limits for Radium 226.

Recommendations developed are designed to assist the State in future regulation of uranium mining and milling for the purpose of safeguarding public health and insuring future environmental quality.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Uranium Radioisotopes	BT Radioisotopes	
Ground Water	RT Aquifers; water wells; water table	
Water Quality	RT Water Pollution	
Surface Water	NT Lagoons	
Potable Water	UF Drinking Water	
	RT Public Health	

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