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

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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 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 analysis were completed by NEIC and the other radiological analyses were completed by the Environmental Monitoring and Support Laboratory. Radiometric analyses were assigned at the highest priority at each laboratory and were completed in July 1975.

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. Ground water is the principal source of water supply in the study area. Extensive development 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 developed 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. The well fields are located in the urban area and, more recently, 11 kilometers north of the city.

2. Contamination of shallow ground water, largely used for livestock watering, results from the infiltration of 1) effluents from mill tailings ponds, 2) mine drainage water that is introduced to settling lagoons and natural water courses, and 3) discharge (tailings) from ion exchange plants. It is unlikely that seepage from these sources returns to the deep bedrock aquifers. Deterioration of water quality in the latter occurs in the mining areas as a result of penetration or disruption of the ore body coincident with underground mining. 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.

3. 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. In the vicinity of the Anaconda mill, radium and nitrate concentrations in the alluvial aquifer decline with distance from the tailings ponds, but nowhere does either parameter exceed the drinking water limit. 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, primarily due to sorptive capacity of soils in the area.

4. 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 ground water pumped from the mines from 0.05 to 0.62 pCi/l to over 8 pCi/l. Subsequent development work over a two-year period increased the concentration to over 20 pCi/l, or 23 times the natural concentration. If the pattern in Ambrosia Lake is repeated, ultimate concentrations of 50 to 150 pCi/l are expected.

5. Ground water in parts of the shallow aquifer downgradient from the United Nuclear-Homestake Partners mill is contaminated with selenium, and alternative supplies should be developed. The best alternative is deeper wells completed in the Chinle Formation or, preferably, the underlying San Andres Limestone.

6. Seepage from the Anaconda tailings pond at Bluewater is estimated to average 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 waste enters the shallow aquifer, which is a source of potable and irrigation water in Bluewater Valley. From 1960 through 1974, seepage is estimated to have introduced 0.41 curies of radium to the shallow potable aquifer. Adequate monitoring of the movement of these wastes is not underway.

7. 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.

8. The maximum concentration of radium observed in shallow ground water adjacent to the Kerr-McGee mill at Ambrosia Lake was 6.6 pCi/l. Calculated seepage from the tailings ponds occurs at the rate of 491 million liters/year (130 million gallons/year), and has contributed an estimated 0.7 curies of radium to the ground water to date. 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. Wells completed in bedrock and in alluvium along water courses containing mine drainage and seepage from tailings ponds contain elevated levels of TDS, ammonia, and nitrate. One well, now contaminated with 3.7 pCi/l of radium, contained 1.0 pCi/l in 1962. Sorption or bio-uptake of radium is pronounced, hence concentrations now in ground water are not representative of ultimate concentrations.

9. Contamination of the Gallup municipal water supply by surface flows consisting mostly of mine drainage is extremely unlikely because of geologic conditions in the well field. Another well field north of the City will, in no way, be affected by the drainage.

10. 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 as well as gross 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 of the mines.

11. 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 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 is expected.

12. Of the 71 ground-water samples collected for the study, only two potable water supplies have radium-226 in excess of the 3 pCi/l PHS drinking water standard. These are located downgradient from the Kerr-McGee mill and in the Jackpile mining area.

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

14. The lowest reported concentrations (background levels) are summarized as follows:

Radionuclide	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

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

16. No correlation was found relating a gross alpha content greater than 5 pCi/l to a radium-226 content in excess of the 3 pCi/l PHS drinking water standard.

17. 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 determinations of percentage of other radionuclides to gross alpha result can be implied.

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

19. Radium-226 in ground water is a good radiochemical indicator of waste water from mines and mills. It also provides the best means of health evaluations due to the low maximum permissible concentration.

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

1. Environmentally-oriented company sponsored ground-water monitoring programs range from imperfect 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 evident to date are inadequate for measuring environmental levels of radionuclides. Of specific concern are overly high minimum detectable activities and large error terms. Incomplete analysis of radionuclide contents prevails. Few data are reported on other naturally occuring 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.

5. Proven geophysical and geohydrologic techniques to formulate environmental monitoring networks, specify sampling frequencies, and provide data to adjust subsequent efforts are, with few exceptions, not part of the industrial efforts with respect to ground water.

6. Monitoring the effects of the Jackpile and Paguate open pit mines on ground-water quality is non-existent, despite the magnitude of these operations. Whereas background radium concentrations are less than 4 pCi/l, drainage water within the pits contains 190 pCi/l. Radium in two wells used for potable supply and completed in the ore body is also elevated above background, 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 for the various tailings disposal operations is not evident. For the Anaconda Company, the method utilized has not been altered in 14 years and for Kerr-McGee, overland flow into the ponds is erroneously regarded as negative seepage or as an influx of ground water.

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 not readily accessible. No interpretive summary or review-type reports utilizing the monitoring data reported by industry are available from either the State or the USNRC. Liberal mill licensing conditions with respect to ground-water monitoring and water quality impacts were initially established by the U.S. Atomic Energy Commission (USAEC) and have been followed by scant review or no review, in any critical sense, of company operations. The uranium mining and milling industry has not been pressed to monitor and protect ground-water resources. Prior to the present study requested by the State of New Mexico, the efforts put forth by industry to date have largely not been reviewed by regulatory agencies at the State and Federal levels.

TASK: Develop Priorities for Subsequent Monitoring and Other Follow-Up Studies

(See RECOMMENDATIONS)

RECOMMENDATIONS

1. Improved industry-sponsored monitoring programs should be implemented and the data made publicly available 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.

2. Additional legislation at Federal and State levels should be developed to supplement existing authority under the National Polution Discharge Elimination System (NPDES), the Safe Drinking Water Act, and State water quality regulations to effect stricter controls on environmental monitoring and reporting with respect to ground water.

3. 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 its abundance (82,000 pCi/l) in the injected fluid.

4. 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 Tank wells are of principal concern.

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

6. If the verified source of ground-water contamination in the Broadview Acres and Murray Acres subdivisions is the nearby uranium mill, a sound monitoring program should be developed to predict off-site contaminant migration and to determine if there is a need for remedial action.

7. 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.

8. 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. Concentrations of trace metals should also be measured (recommended) for the latter reason.

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 by Mt. Taylor, which separates 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).

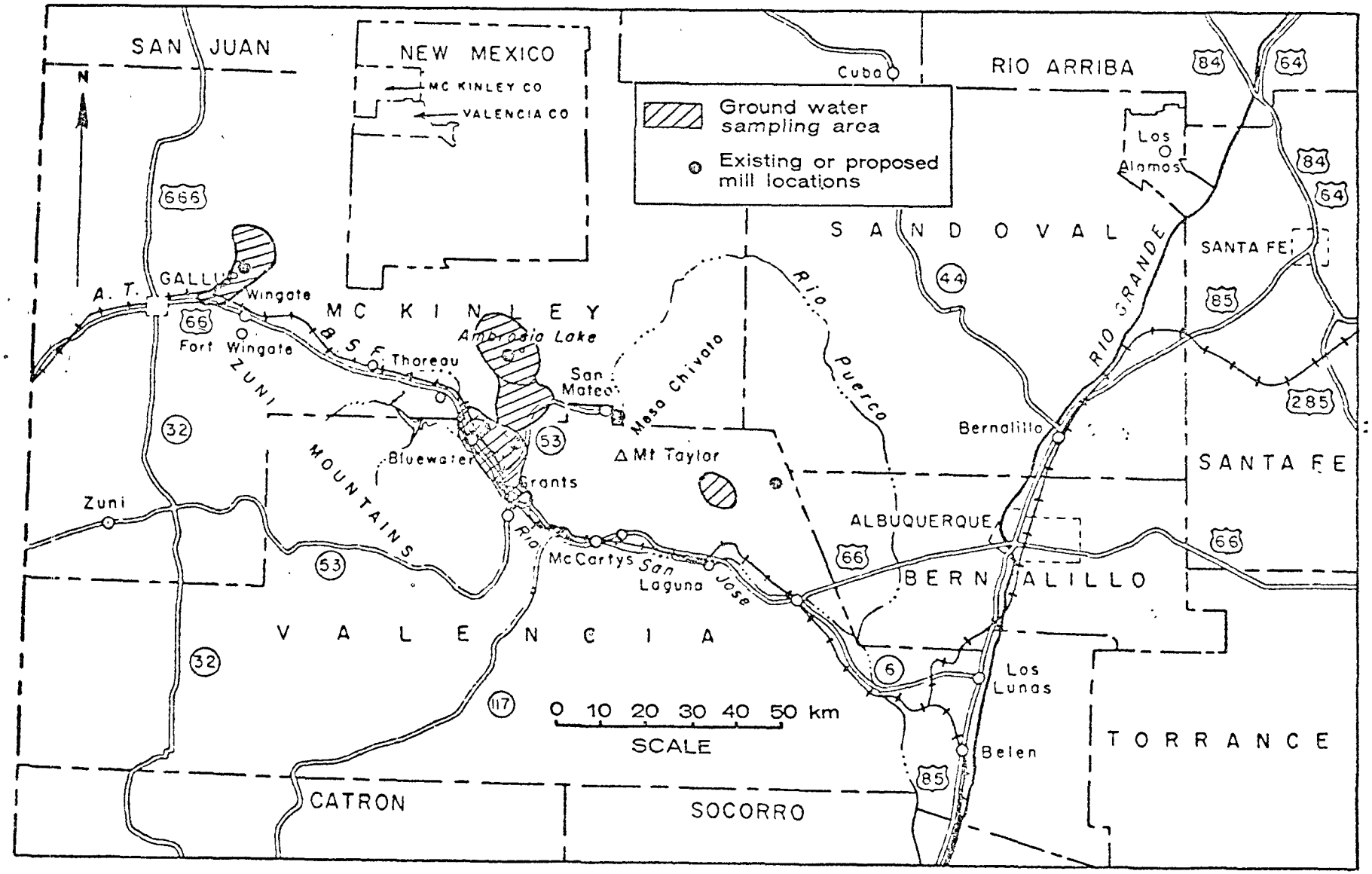


Figure 1. Map of Northwestern New Mexico Showing General Location of Sampling Areas in the Grants Mineral Belt

There are no perennial streams in southeastern McKinley County. These and the natural depressions such as Ambrosia Lake, Casamero Lake and Smith Lake contain 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

The principal industries in McKinley and Valencia Counties of northwestern New Mexico, until relatively recently, 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 metamorphosed into 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. of U.S. Total	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 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 shallow, unconfined aquifers. 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).

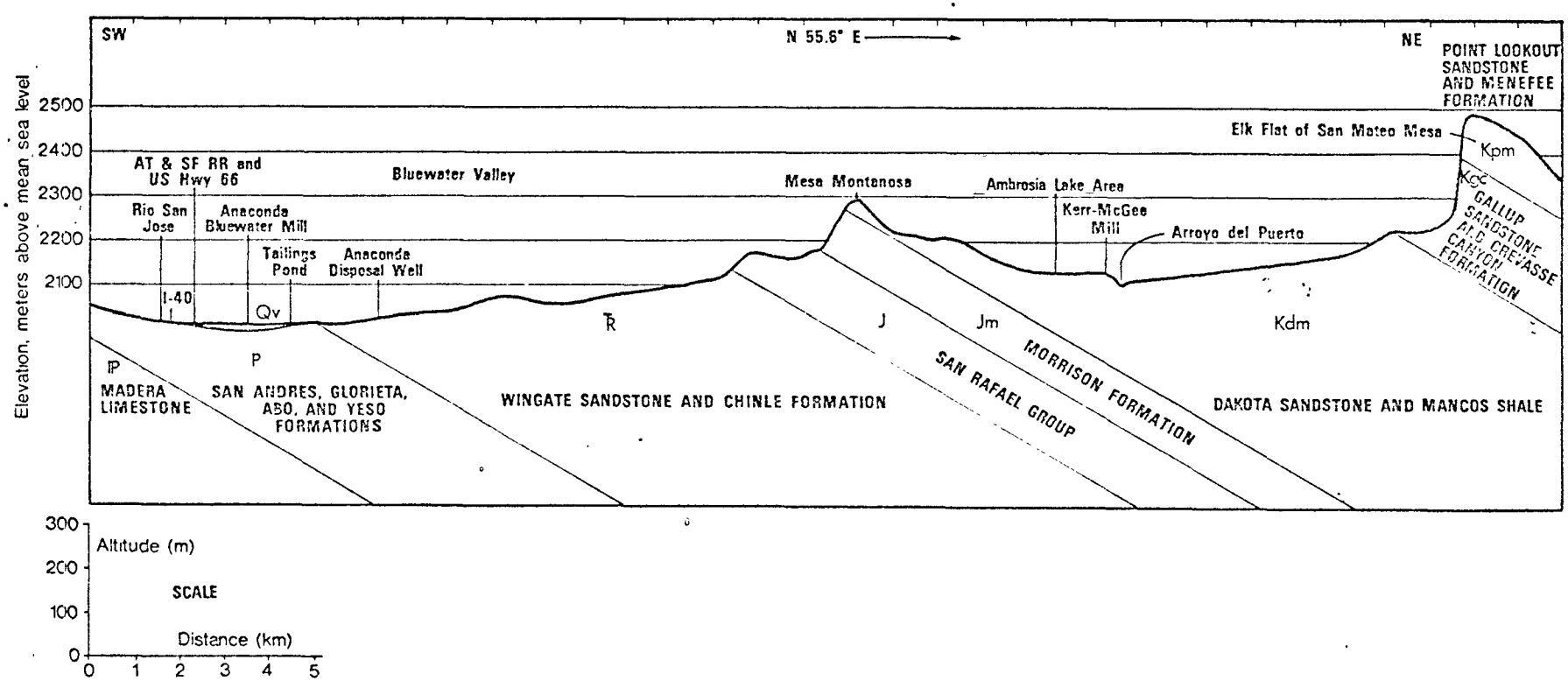


Figure 2. Generalized Structure Section from Bluewater to Ambrosia Lake

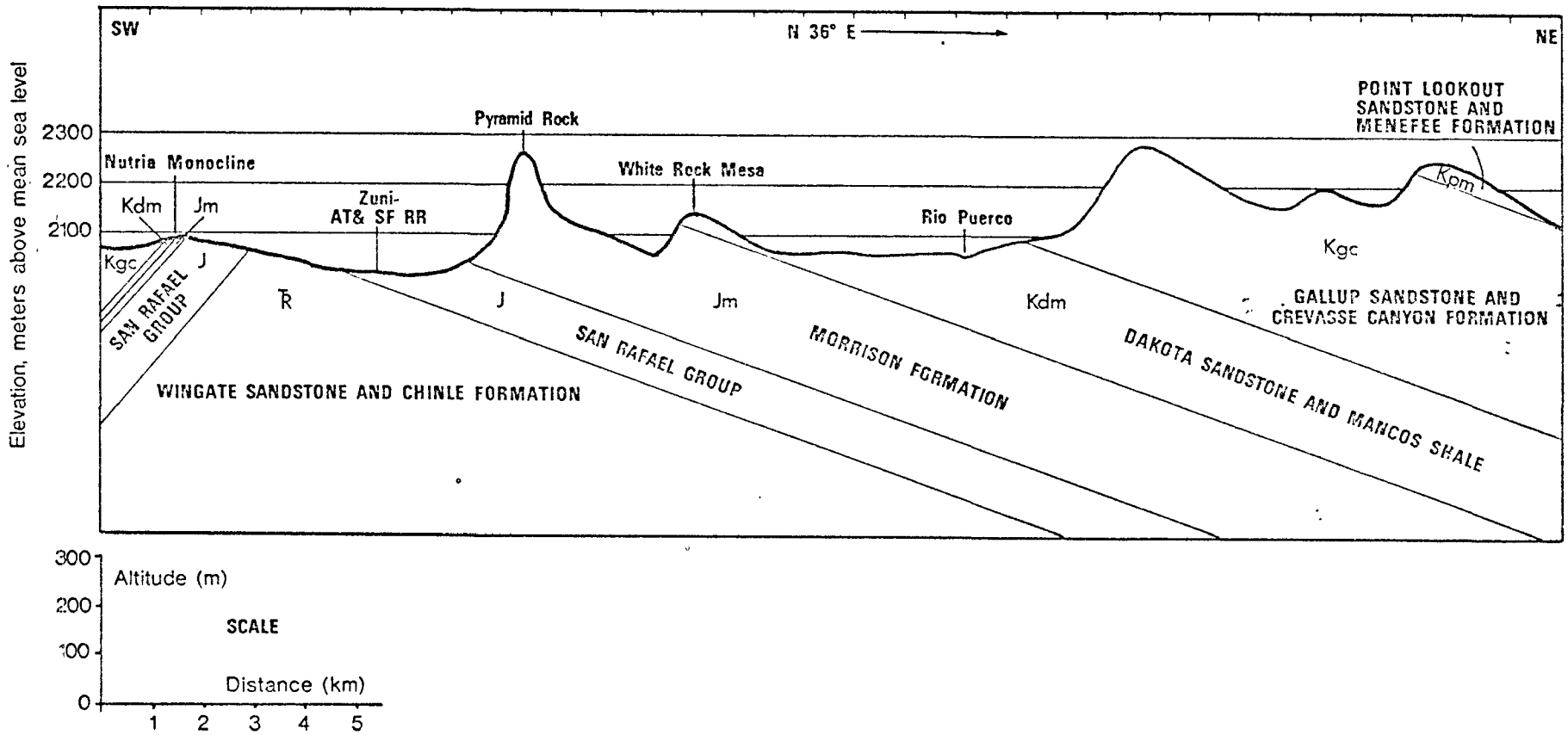


Figure 3. Generalized Structure Section from Gallup to Churchrock Mining Area

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 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, chiefly the Westwater Canyon Member of the Morrison Formation and to a lesser extent, the overlying strata such as the Dakota Formation.

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 m/mo due to dewatering at the United Nuclear and Kerr-McGee mines. Discharge of the mine water transforms 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 not considered aquifers because of the mineralized water naturally present, and the impacts were expected or predicted beforehand. However, 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). 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 may adversely affect the quality of shallow ground water now developed for stock watering, both above and below the confluence with Arroyo del Puerto.

The potential for future problems of water availability for ore processing in Ambrosia Lake have 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 groundwater 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 shallow 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 were 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 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, hence any changes due to disruption of natural conditons cannot be assessed. In the case of the Anaconda waste injection program, for example, there is no information concerning pre-injection concentrations of stable and radioactive chemical species in overlying potable reservoirs possibly 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 onsite 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 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 unknown whether the various company laboratories have the analytical capabilities to accurately analyze for environmental levels of the common radionuclides associated with the uranium mining and milling industry.

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. 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 pound 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 catalogued 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 background 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 activites 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 bedrock aquifers in the Churchrock area mostly include the Dakota Sandstone.

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 +NH_3
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	7.4
9101	Mt. Taylor Mill Works Old Rt. 66	11	10	5	442	351224	1075422	58.5	--	--	1	2/24	PI	12.	6.25	1050	700.	25.	0.04	4.2
9103	Q. 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	118.	51.2	5/72	3	2/27	IP	18.5	7.1	2550	1900.	270.	0.64	9.0
9119	Well #4 (Anac. Co.)	12	11	25	214	351436	1075650	69.	42.1	5/72	3	2/27	IP	17.	7.2	1225	880.	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	1075601	35.1	26.8	2/75	2	2/28	O	11.5	7.8	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.	18.	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.	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	TDS	CONCENTRATION, mg/l CL	NH_3	NO_2 +NH_3
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.	8.8	1725	1300.	39.	<0.01	0.33
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	14.0
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	85.3	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	24.
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	14.
9203	KM-45, Navajo windmill	13	10	8	211	352233	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	6.4	7.45	2150	2200.	36.	0.05	18.
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	7300.	3.8	NS	NS
9209	KM-44	14	9	32	312	352355	1074903	42.1	32.9	2/75	5	2/27	O	14.1	7.1	3100	2700.	17.	0.66	11.
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	79.
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.	0.30	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.	12.
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.	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	TDS	CONCENTRATION, mg/l CL	NH_3	NO_2 +NH_3
Ambrosia Lake (Continued)																	
9214	KM-36-2	14 10 36 422	352352	1075026	17.4	10.1	3/75	5	3/03	O	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	O	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	O	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	O	11.9	7.7	5750	4700.	470.	9.1	16.
9218	KM-5-1	13 9 5 214	352316	1074835	10.4	7.3	3/75	5	3/03	O	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	O	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	27.
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	14.
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

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

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
	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 ± .03					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 Clo Rt. 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± .16
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	880	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	<0.0081	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	8± 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

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
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	9.8 ±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± 8	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	81 ± 5.1	2.8 ± .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	33± 15	0.07 ± .01									
9204	Ingersoll Rand	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-63	56± 25	0.60 ± .02									
9207	KM-S-12	410± 120	1.15 ± .03							0.27 ±.066	0.23±.062	< 0.13
9208	KM-43	49± 35	4.0 ± .1	4.7 ± .40						0.021±.019	< 0.014	< 2.9
9209	KM-44	< 2.0± 10	1.95 ± .04							<0.028	< 0.020	0.68 ±0.53
9210	KM-51	45± 29	0.26 ± .02	0.35 ± .12						<0.023	< 0.0068	0.24 ±0.16
9211	KM-48	< 3.0± 15	0.20 ± .01							<0.013	< 0.0080	2.7 ±0.83
9212	KM-Seepage Return	112,000±3,000	4.9 ± .1	10.0 ± .65								
9213	KM-B-2	8± 32	6.6 ± .1	6.4 ± .47						<0.018	< 0.011	< 0.94
9214	KM-36-2	14± 34	1.18 ± .03	1.5 ± .23	11 ± .78	0.31±.058	6.8 ± .52			<0.015	< 0.014	0.70 ±0.26

(continued)

(continued)
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
	Ambrosia Lake (Continued)											
9215	KM-46	104± 37	2.5 ± .2	2.7 ± .30						0.17 ±.057	< 0.016	< 0.38
9216	KM-47	45± 25	0.64 ± .02							0.079±.038	< 0.013	0.29 ±0.20
9217	KM-50	70± 38	0.94 ± .03	0.72 ± .16						0.055±.035	< 0.018	1.2 ±0.84
9218	KM-5-1	20± 24	0.34 ± .02	0.34 ± .11						<0.021	< 0.016	3.8 ±2.5
9219	KM-5-2	67± 42	0.59 ± .02	0.78 ± .17	12 ± .63	0.27± .039	6.7 ± .37			<0.039	< 0.031	0.96 ±0.64
	Gallup-Churchrock											
9137	Erwin Well	10 ± 9	0.68 ± .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	0.029	< 0.016	0.23± .11
9142	White Well	9 ± 9	0.16 ± .01	0.42 ± .13						0.073±.035	< 0.011	<0.033
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± .16
9222	Puerco Well CRKM-16	2 ± 9	0.57 ± .02									
9223	Pipeline Road Well-CRKM-5	4 ± 9	0.37 ± .02							0.037±.029	< 0.012	0.52± .15
9224	Nose Rock Well CRKM-3	24 ± 12	0.13 ± .01							0.053±.049	< 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
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 Radionuclide Concentrations (pCi/l) by Geographic Area & Aquifer[1]

Radionuclide/Aquifer		Paguate-Jackpile	Grants-Bluewater	UNHP	Ambrosia Lake	Gallup-Churchrock
^{226}Ra	Bedrock	0.31 ± .02	0.14 ± .01	0.06 ± .01	0.16 ± .01	0.12 ± .01
	Alluvium	<0.18[3]	0.13 ± .01	0.16 ± .02	0.23 ± .02	0.11 ± .01
^{210}Po	Bedrock	0.43 ± .14	0.33 ± .15	0.36 ± .20[2]	0.57 ± .19	0.35 ± .19
	Alluvium	<0.39[3]	0.30 ± .14	<0.31[3]	0.27 ± .18	0.27 ± .17
^{230}Th	Bedrock	<0.020	<0.032	<0.033	<0.023	<0.035
	Alluvium	<0.018[3]	<0.013	<0.024	<0.028	<0.051
^{232}Th	Bedrock	<0.013	<0.015	<0.016	<0.013	<0.024
	Alluvium	<0.010[3]	<0.013	<0.013	<0.018	<0.015
^{234}U	Bedrock	---	---	---	---	---
	Alluvium	---	---	<10[3]	<12	<1.8[3]
^{235}U	Bedrock	---	---	---	---	---
	Alluvium	---	---	<0.22[3]	<0.29	<0.053[3]
^{238}U	Bedrock	---	---	---	---	---
	Alluvium	---	---	<7.7[3]	<5.8	<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. ^{226}Ra and U-natural analyses by NEIC, 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.

In the Paguate-Jackpile area, three of the four wells examined are in the Morrison Formation (Jackpile Member).

Table 6 is a compilation of published and unpublished 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 Anaconda Company mill and tailings pile is partially bounded by cultivated areas situated in Bluewater Valley, which contains the town of Bluewater on the western edge. 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. In nearby areas the basalt constitutes a principal shallow aquifer. The San Andres Limestone, the principal bedrock aquifer, also crops out in close proximity to the ponds. Thus, there are means by which wastes from the ponds can enter potable ground water.

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 also possible, but unlikely, that the United Nuclear-Homestake Partners mill could adversely affect ground water in this area.

Radium and nitrate concentrations in ground water are depicted in Figure 5. 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,

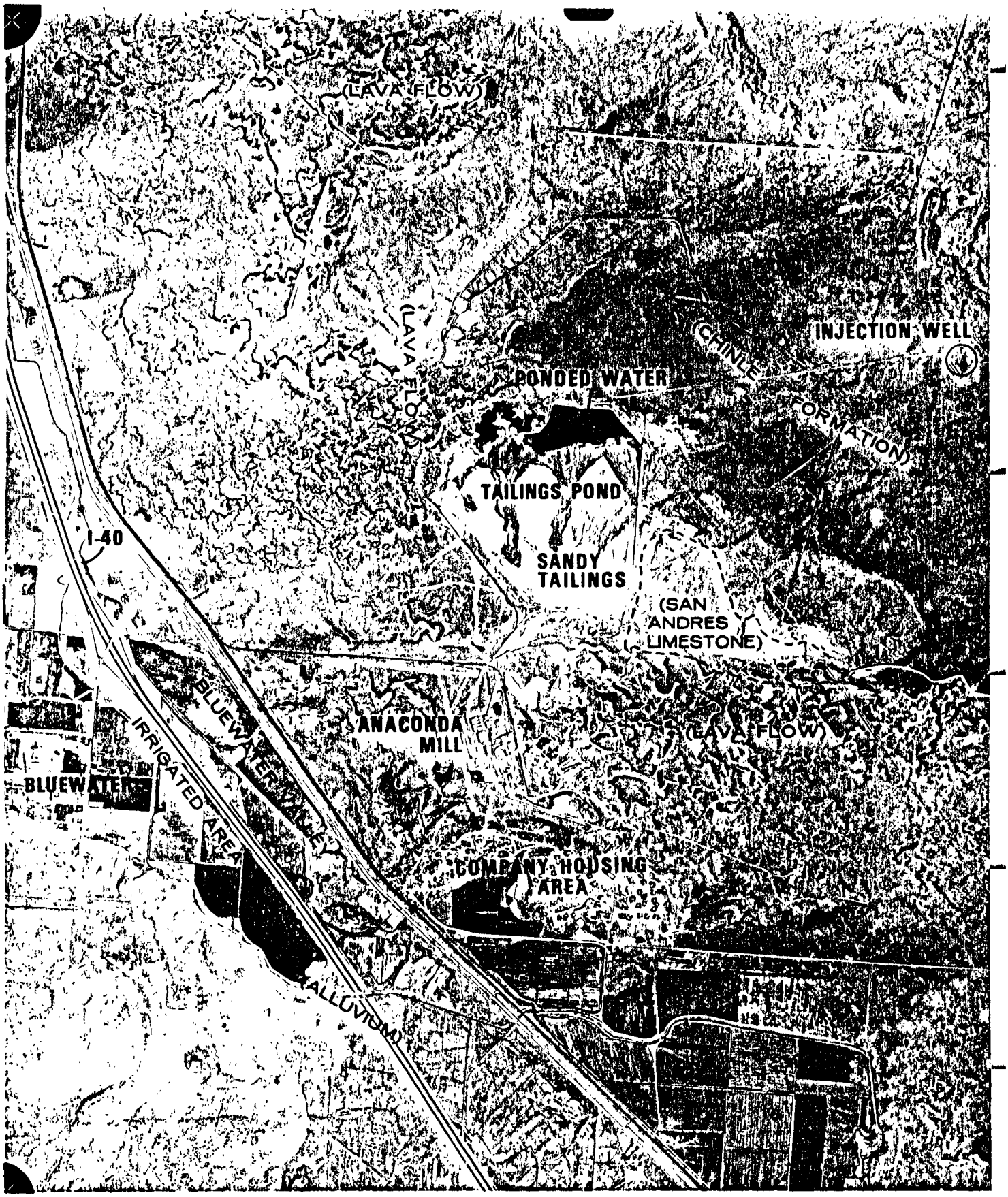


Figure 4. The Anaconda Company Uranium Mill and Tailings Pond-Bluewater

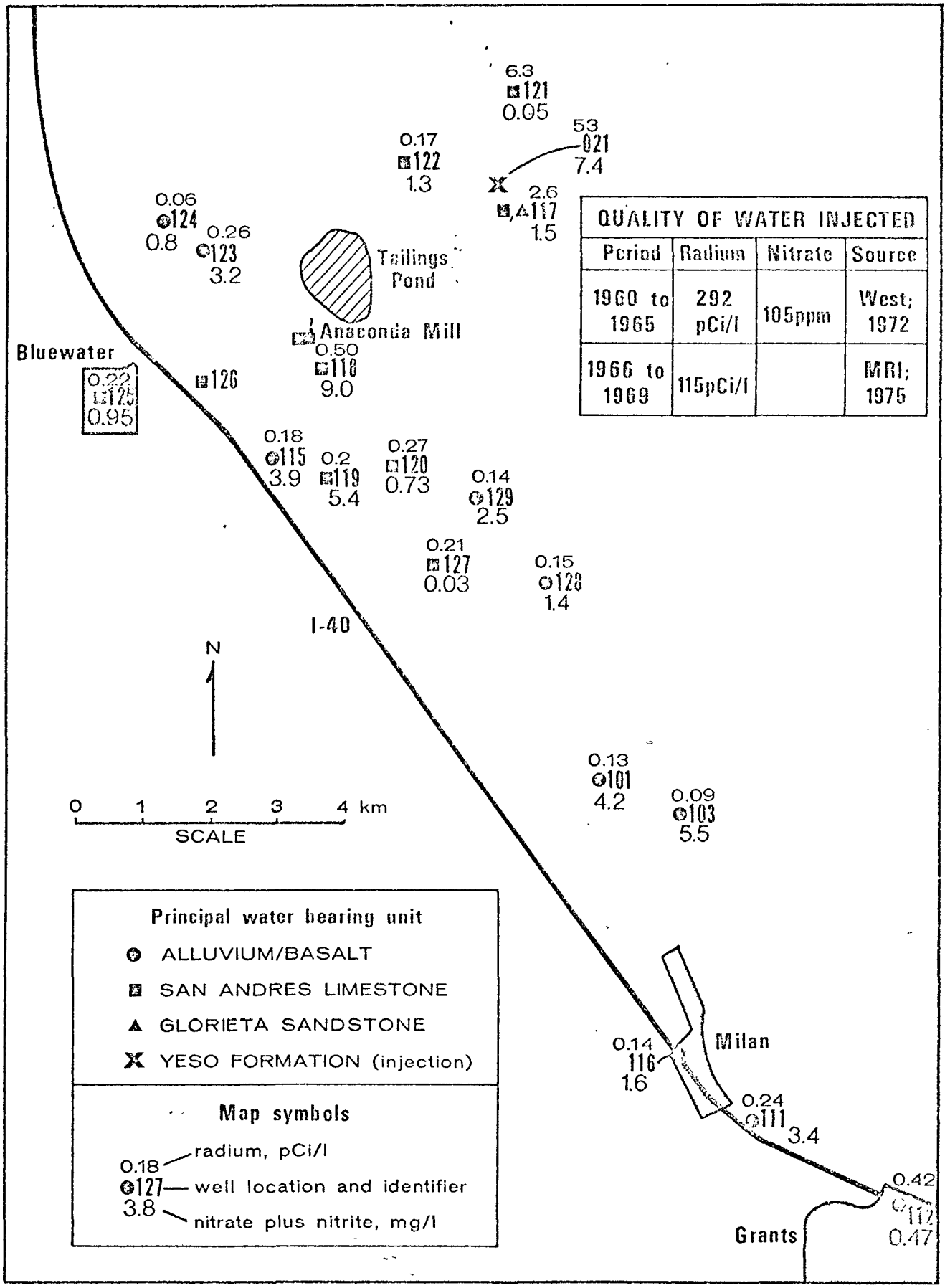
Table 6

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	8	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± 1.3	
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: Letter from F. P. Lyford, U. S. Geological Survey, WRD, Albuquerque, NM to John Dudley, New Mexico Environmental Improvement Agency, dated February 12, 1975.
   - Churchrock: Written communication from W. Hiss and T. Kelley, U. S. Geological Survey, WRD, Albuquerque, NM to John Dudley, New Mexico Environmental Improvement Agency, dated February 14, 1975.
   - Grants-Bluewater-Prewitt: Letter from J. M. Stow, U. S. Geological Survey, WRD, Albuquerque, NM to Eugene Chavez, State Engineer Office, Roswell, NM, dated April 14, 1961.

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.



QUALITY OF WATER INJECTED			
Period	Radium	Nitrate	Source
1960 to 1965	292 pCi/l	105ppm	West; 1972
1966 to 1969	115pCi/l		MRI; 1975

Figure 5. Radium and Nitrate Concentrations in Ground Water in the Grants-Bluewater Area

there is evidence of leakage from the injection zone. Natural uranium and chloride from the monitor well (#9117), Roundy windmill, and North well (#9122) for the period, 1969 through 1973 are increasing with time and vary directly with the volumes of waste injected. The concentration of polonium-210 (2.3 pCi/l) exceeds 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). Contrary to original projections, contamination apparently extends into the San Andres Limestone, according to the partial chemical data for these three monitoring wells.

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 Dept. of Public Health, 1957). Changes in the milling process greatly reduced the nitrate content in the tailings, 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 even larger, but is unknown. Discounting this seven-year period and assuming an average radium concentration of 130 pCi/l in the seepage, 0.4 curies of radium entered the shallow aquifer, which is very definitely potable.

It is strongly recommended that all available chemical data for both pre- and post-injection periods be evaluated, together with monthly or quarterly injection volumes to further confirm or deny the apparent trends. 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. Because of low MPC values, this is particularly true if increasing concentrations of radium-226 are appearing in the aquifers above the injection zone.

Impacts of tailings pond seepage on nearby shallow groundwater are unknown because of the inadequacy of properly located sampling wells. 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 density considerations add further complications. However, seepage is occurring and it is possible that the Company estimates stated above are conservative.

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 the photograph as a dark tan band around the base of the tailings pile is extensive seepage. This 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 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. On the other hand, water quality in the Chinle Formation and the still deeper San Andres Limestone is likely to be unaffected.

Radium concentrations in groundwater (Figure 6) 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 mill's single active monitoring well (#9135). Although below the 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 7) 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 6) support the idea of a tongue of contaminated groundwater in the area between this well and the tailings pile. Heterogeneities in sediment permeabilities, coupled with irregular induced flow gradients resulting 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 groundwater contamination. Nearby wells (#9102, #9107, and #9113)

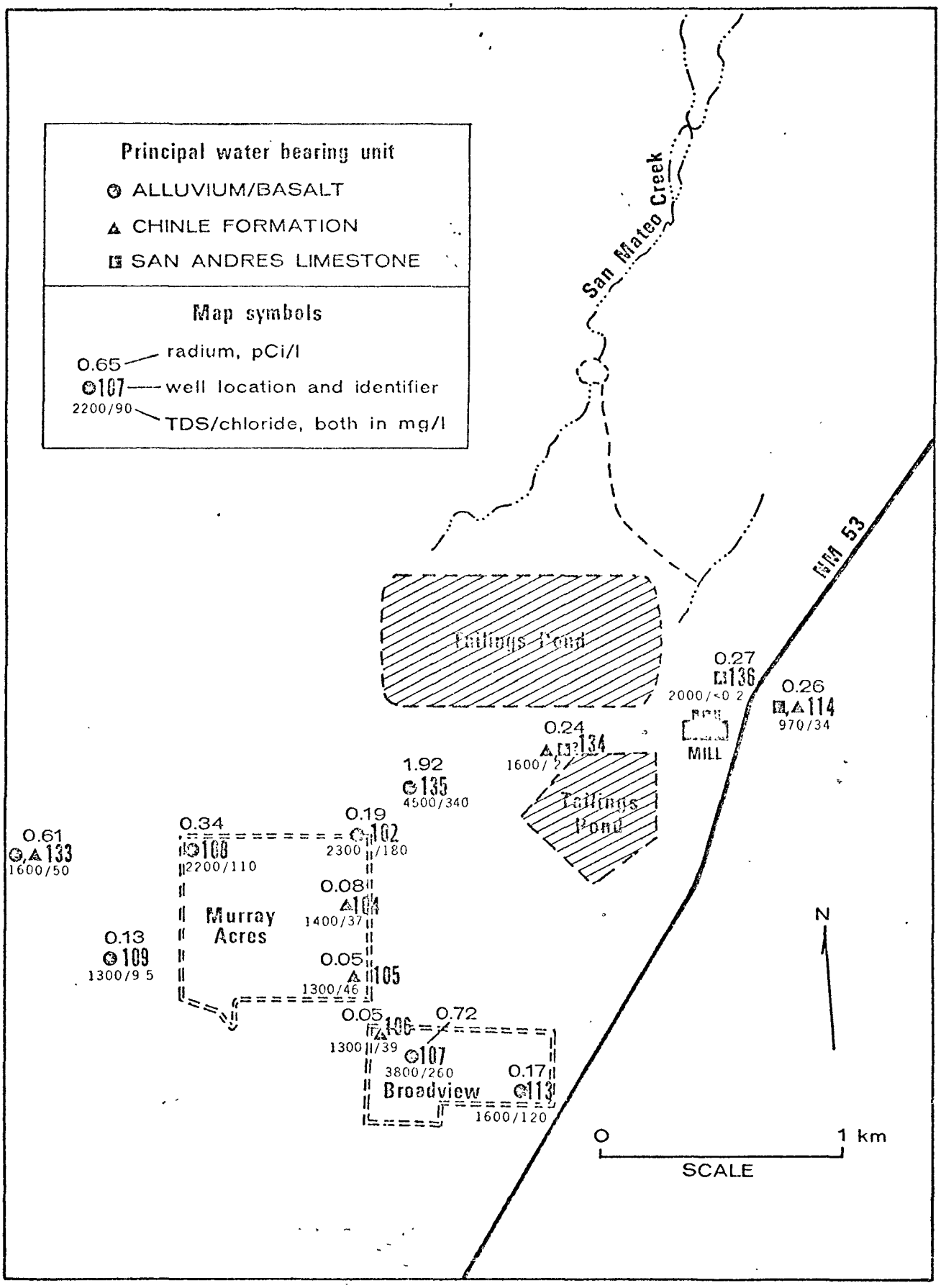


Figure 6. Radium, TDS and Chloride in Ground Water Near the United Nuclear-Homestake Partners Mill

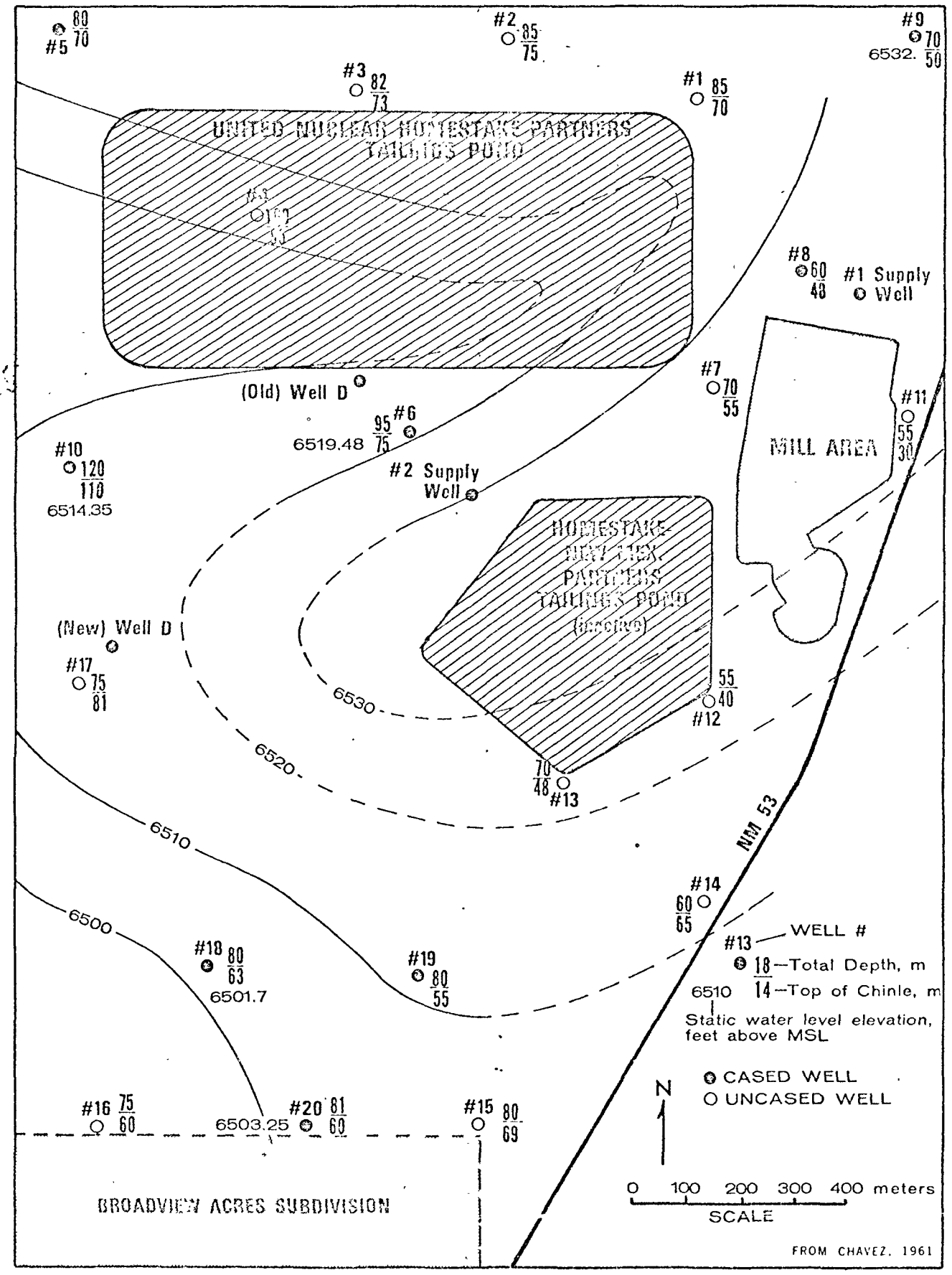


Figure 7. Water Table Contours and Well Locations at the United Nuclear-Homestake Partners Mill Site

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. Analyses for additional wells are in process to further define the source and extent of the 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. Whereas background for polonium-210 is approximately 0.34 pCi/l (Table 5), in wells tapping the Chinle Formation and in alluvial wells removed from suspected contamination, concentrations range from 1.0 to 2.3 pCi/l in wells suspected to be contaminated. Maximum values for polonium-210 are from well D (#9135). The elevated levels 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 groundwater 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.

Ambrosia Lake Area

The Kerr-McGee mill is located on the dip slope of a southeast-facing cuesta. The area is underlain by a thin veneer of silt and clay alluvium over the Mancos Shale. The large network of tailings ponds and water storage reservoirs were 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. At the right center edge of the photograph is the inactive tailings pile at the United Nuclear Corporation mill.

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. The determination of impacts associated with mine dewatering and solution mining exceeded the scope of the study. Of the 22 wells sampled in the area (see Figure 8) 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. It is obvious, however, that seepage from settling ponds, from open channels leading to the two principal streams in the area and the disposition of solutions involved in in-situ leaching remain as unknowns.

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 nitrates goes from an average of less than 1 mg/l to 24 mg/l. The selenium and vanadium data do not indicate widespread movement from the tailings piles. 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, i.e., contamination of the shallow aquifer.

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, but in the adjacent ground water (stations #9207, 9213), only chloride and TDS persist. 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, and average about 1 pCi/l. The maximum concentration of 1 to 4 pCi/l appear approximately 1.5 kilometers east of the main tailings dam.

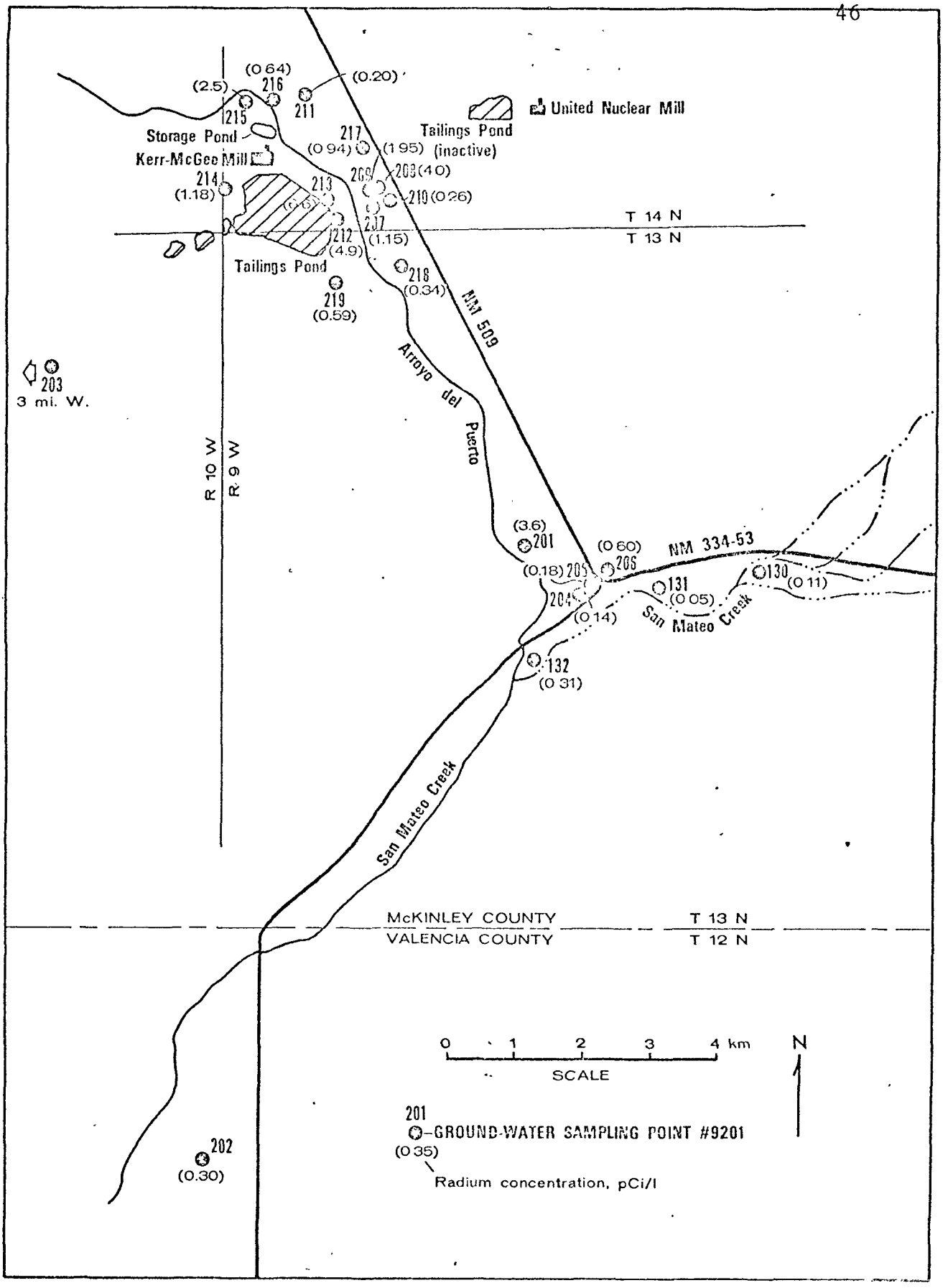


Figure 8. Radium Concentrations in Ground Water in the Ambrosia Lake Area

The general pattern described is in agreement with the migration pattern 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 are 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 is "negative" seepage in the third quarter of each of three years (1972, 1973, 1974). This is interpreted by the company as seepage entering the ponds. The writers consider this highly unlikely and suggest that it is, in fact, overland flow related to thunderstorm activity prevalent at this time of year. Reporting of data in this manner distorts interpretation of the water balance for the tailings ponds by implying, in this case, that no seepage occurred during these periods. More importantly, the influx of overland flow into the ponds prompts questions concerning their stability and overall management.

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 19, 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 could threaten potable ground water in the vicinity of the Puerco River and possibly the Gallup municipal supply. In part, the present study examines whether noticeable groundwater quality deterioration has occurred to date.

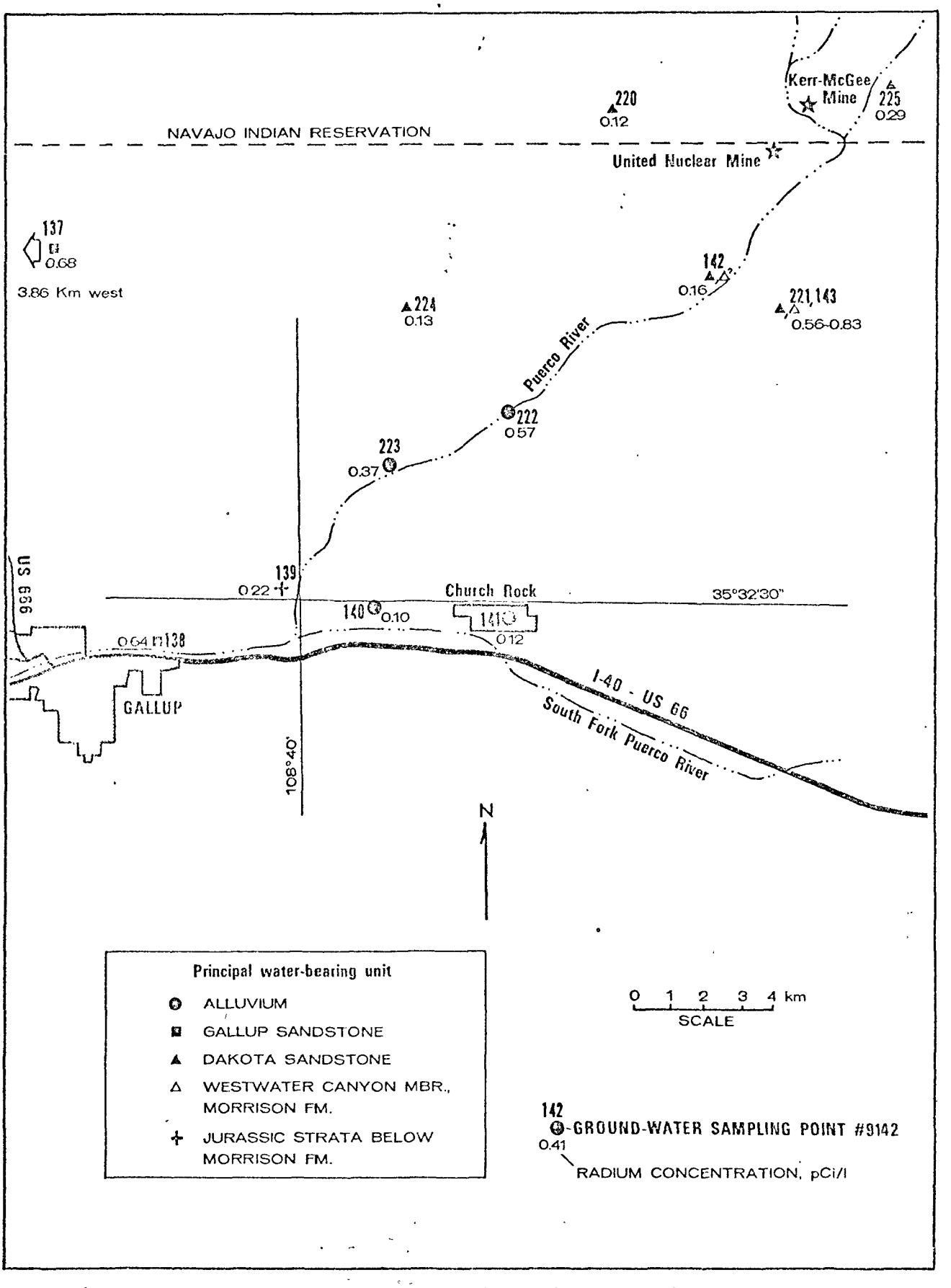


Figure 9 . Radium Concentrations in Ground Water in the Churchrock-Gallup Area

In this setting, sampling in the Churchrock area involved 13 wells located along the Puerco River, South Fork Puerco River and, for control purposes, an adjacent watershed tributary to the Rio Puerco. 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. More suitably located 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 of 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 and, if similar trends seen in the Ambrosia Lake area prevail, ultimate radium concentrations on the order of 50 to 150 pCi/l are likely.

Jackpile-Paguate Area

Sampling in the vicinity of the Jackpile-Paguate open pit uranium mine included four wells located as shown in Figure 10. 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. Consumption should be discontinued because the radium exceeds the drinking water standard of 3 pCi/l.

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 was 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.

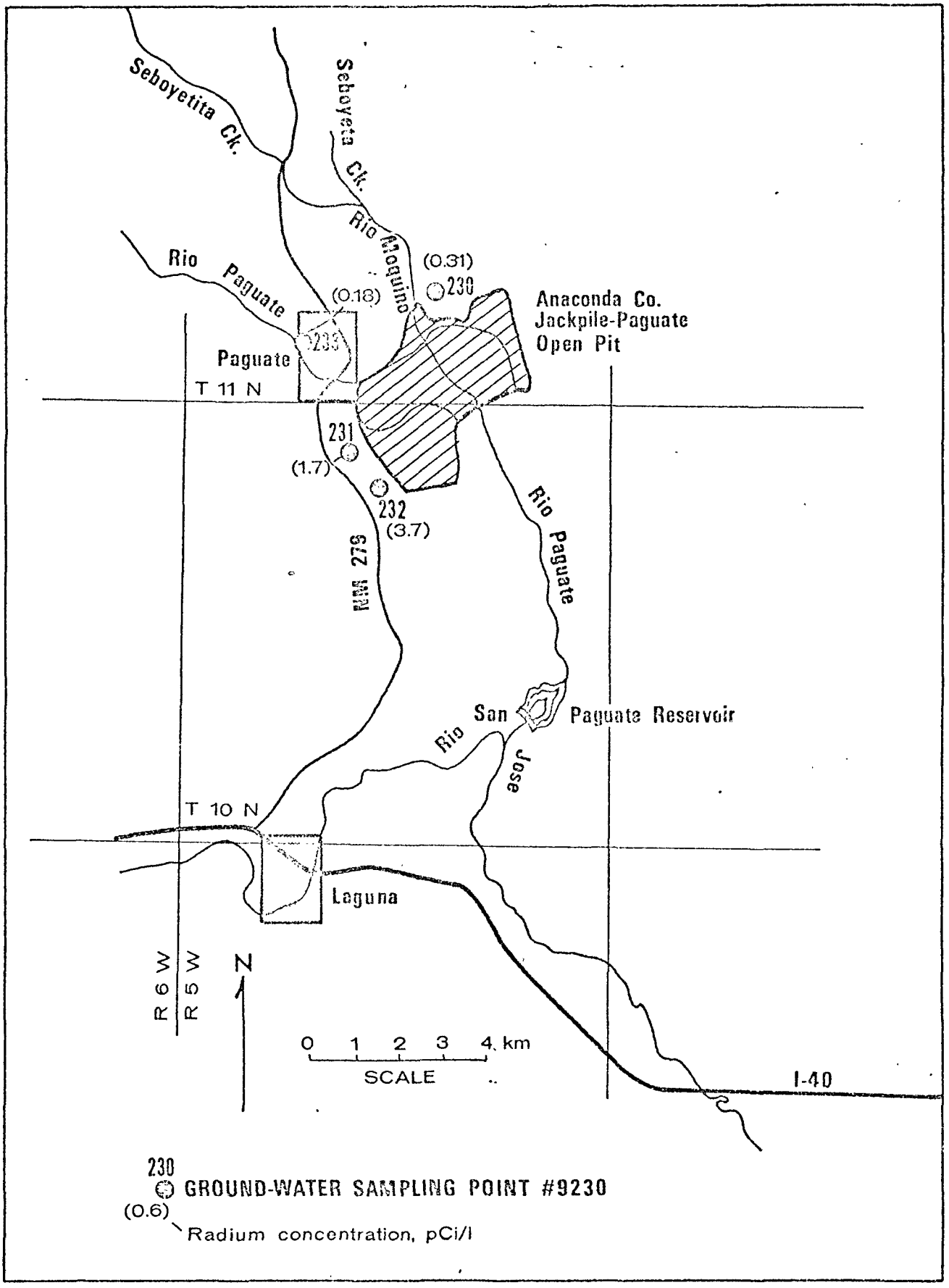


Figure 10. Radium Concentrations in Ground Water in the Paguate-Jackpile Area

Significance of Radiological Data

Regulations and Guidelines

On August 14, 1975, the U.S. E.P.A. 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 may be obtained from this study:

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. The proposed new standard of 5 pCi/l, combined radium-226 and radium-228 contents, is therefore exceeded at these two locations.

4.) Sixty (60) 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; and 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. Table 12 lists the 6 locations and presents the gross alpha and radium-226 results based on NEIC laboratory analysis.

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.

Two of the Kerr-McGee monitor wells, samples from KM-43 (#9208) and KM-B-2 (#9213), also had radium levels in excess of 3.0 pCi/l. Stable inorganic species in the water also render it unfit for human consumption. In addition, the well is not in use for water supply and therefore does not present a health hazard.

Sample #9212, a surface water sample, obtained from the seepage collection pit at the base of the Kerr-McGee tailings pond, had a radium concentration of 4.9 pCi/l. However, this water is certainly not fit for human consumption nor is it used as a livestock or irrigation supply.

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, 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% 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-Homestake Partners mill. The highest radium concentration was 0.72 pCi/l 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.

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 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.

Other Radionuclides

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, 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 which are, respectively, 0.006% and 0.98% of the population guide - MPC.

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). The Paguate sample (#9233) also had the highest lead-210 content of less than 8.7 pCi/l (26.36% of the population guide - MPC).

In summary, exclusive of the radium-226 content, the highest isotopic uranium and thorium, polonium-210, and lead-210 contents for any potable water supply in the Grants Mineral Belt area is less than 28.08% of the total radionuclide population guide - MPC.

It, therefore, seems appropriate to conclude that for routine 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.

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[3]
	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.

3 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).

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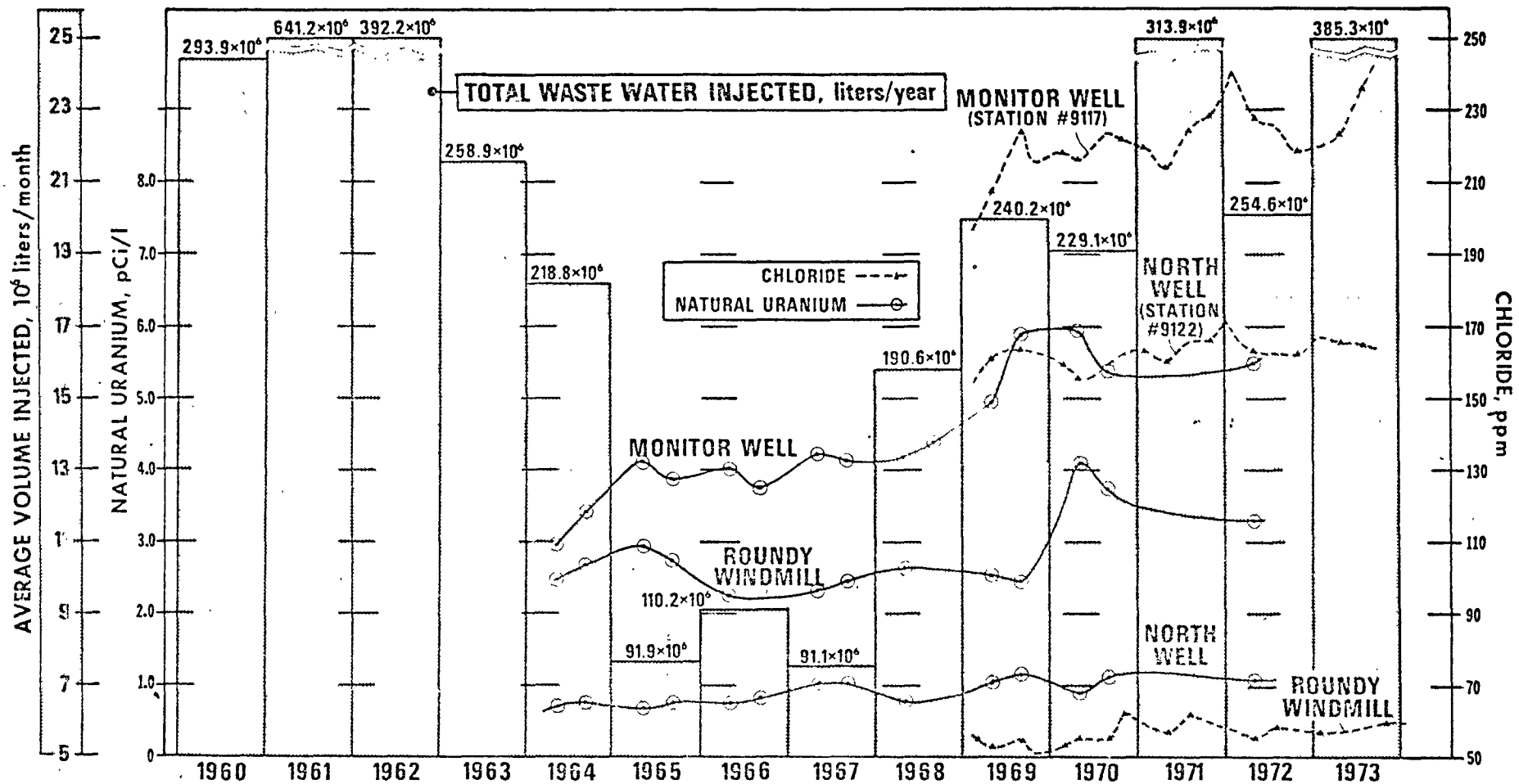

Figure 12. Summary of Waste Volumes Injected via the Anaconda Disposal Well and Water Quality in Selected Monitoring Wells

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 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.

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 groundwater quality with respect to distance from the tailings ponds and with time. 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 9). 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.

Chloride and TDS trends are not well defined. The range for TDS is from 490 mg/l (Mexican Camp) to 2300 mg/l (Monitor well), whereas chloride varies from 6.2 to 270 mg/l. The peak chloride value of 270 mg/l is from Anaconda well #2 (#9118) which also contains 1900 mg/l TDS. Nearby wells in the San Andres Limestone (#9119, #9120, and #9126) average 823 mg/l TDS and 54 mg/l chloride. Cones of depression created by the Anaconda wells may induce downward movement of wastewater in the alluvial aquifer. Farther north, TDS and chloride in the San Andres-Glorieta interval averages 2067 mg/l and 6.5 mg/l. If the increase in TDS is from purely natural causes, chloride would be expected to rise, hence the increase in TDS and decline in chloride may be indicative of contamination.

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.

The EPA gross alpha data reported herein for all of the wells in the vicinity of the Anaconda mill are generally 15 to 20 times greater than company results. Although only the latter are useful for defining long-term trends, the disparity of analytical results warrants further work to determine absolute versus relative concentrations and trends. Of note is the fact that the February 1975 gross alpha data for both wells exceed the proposed 15 pCi/l limit for potable water supplies.

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 (#'s 9118, 9119, 9124, 9125, 9126, 9127,

129) 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.

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 from 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. Whether the earlier data were faulty or were misinterpreted is a matter of conjecture. 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 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 furthere confirm or deny the trends shown in Figure 12. 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. 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.

United Nuclear-Homestake Partners Mill and Surrounding Area

As shown in Figure 13, 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 the photograph as a dark tan band around the base of the tailings pile is extensive seepage. This 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 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. On the other hand, water quality in the Chinle Formation and the still deeper San Andres Limestone is likely to be unaffected.

Significance of Radiological Data

Regulations and Guidelines

On August 14, 1975, the U.S. E.P.A. 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 may be obtained from this study:

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. The proposed new standard of 5 pCi/l, combined radium-226 and radium-228 contents, is therefore exceeded at these two locations.

4.) Sixty (60) 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; and 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.