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HOMESTAKE MINING COMPANY
P.O. BOX 98
GRANTS, NEW MEXICO 87020
(505) 287-4456

December 8, 1992

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Mr. Ramon Hall, Director
Nuclear Regulatory Commission
Region IV
Uranium Recovery Field Office
P.O. Box 25325
Denver, CO 80225

Re: License SUA-1471 - Supplement to Environmental Report

Dear Mr. Hall:

Attached are the 5 additional copies of the 1982 Environmental Report for the Homestake Milan Mill Site.

If you need any additional information please contact me.

Sincerely,

HOMESTAKE MINING COMPANY

F. R. Craft
Resident Manager

FRC:jg

Attachments

XC: A. Kuhn
H. Barnes

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Addl Info
93-0138

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Volume I - Text and Tables

State of New Mexico
Environmental Improvement Division
Uranium Mill License Renewal Application
Environmental Report

w/ltr 12/21/92
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HOMESTAKE MINING COMPANY

P.O. BOX 98
GRANTS, NEW MEXICO
87020

October 9, 1984

CERTIFIED MAIL: P 713 183 614

Felix R. Miera, Jr.
Radiation Protection Bureau
New Mexico Environmental Improvement Division
P.O. Box 968
Santa Fe, New Mexico 87504-0968

Re: License No. SUA-708

Dear Mr. Miera;

Pursuant to Homestake Mining Company's letter of September 27, 1984 to you, please find attached the promised MILDOS information. This information is submitted for replacement and inclusion into the Homestake's Environmental Report.

Please replace the information contained in Section C-4, Appendix C and the appropriate Tables and Figures with the attached material. The replaced material can be discarded.

If you have any comments or questions concerning the attached material, please don't hesitate to contact me.

Very truly yours,

HOMESTAKE MINING COMPANY-GRANTS

Edward E. Kennedy
Director of Environmental Affairs

EEK/bgl

xc: C.K. Crossman (w/o attachments)
J.M. Parker (")
R.F. Farrell (")
G.S. Crout (")

HOMESTAKE MINING COMPANY
P.O. BOX 98
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October 30, 1984

CERTIFIED MAIL: P 713 183 622

Felix R. Miera, Jr.
Radiation Protection Section
NM Environmental Improvement Division
P.O. Box 968
Santa Fe, New Mexico 87504-0968

Re: License No. SUA-708

Dear Mr. Miera:

Pursuant to Homestake Mining Company's letter of September 27, 1984, please find enclosed the requested responses for items 6, 8 and 9 of Mr. Crossman's July 23, 1984 letter.

Item 6:

Homestake has submitted a cover material proposal which complies with NMRPR 12-300.B.: requires that stabilization shall be conducted "in such a manner that transport of radionuclides does not exceed the applicable standards in Part 4". Homestake's airborne radionuclide data during the operating phase already demonstrates compliance with Part 4 standards without the benefit of a cover material. The standard goes on to say "Stabilization shall be accomplished by a cover that provides protection of the tailings against erosion for a period of 200 years." The standard contains no specific requirements for biological or hydrological barriers within the cover design. The continued maintenance allowed by NMRPR 3-300.J. and incorporated in the reclamation plan will provide for the control of flora and fauna which could intrude through the cover into the tailings. The proposed rip-rap cover material would act somewhat as a deterrent for small burrowing animals.

As for hydrological barriers, the cover is designed to be 18 inches of compacted, well-graded (clay, silt, and sand) soil. This cover will have permeability values at least one to two orders of magnitude lower than the permeability of the tailings (ave. 10^{-4} cm/sec). Consequently, the infiltration rate through the cover, even if it were a flat surface (which it is not; proposed to be a mound), would be significantly lower than the rate at which the tailings will drain. Although lenses of slimes of very low permeability exist in the tailings, borings show that these are discontinuous and should not significantly retard tailings drainage. The fact that the tailings have significant permeability vertically through the bottom of the pile into the natural soils is demonstrated by the ground water mound under the pile producing the plume which Homestake's interceptor wells are capturing. Therefore, with sharply reduced recharge to the pile (because of the cover) and continued vertical drainage from the tailings, the pile will dewater itself, tailings will consolidate, and moisture content of the tailings will approach residual values controlled by capillary and surface tension. Under these conditions, leaching of soluble species should not be a problem because the tailings medium will not be water-saturated. Instead, the residual moisture will probably become saturated with the soluble species, and precipitation of these chemicals as salts within the tailings will become the dominate phenomenon.

On the subject of "extreme floods", the protective berm is designed to keep the 200 year flood away from the tailings pile, as required by NMRPR 12-300.B. This is clearly addressed in the reclamation design. U.S.G.S. topographic maps indicate that the Lobo Canyon drainage, while poorly defined, separates east of Highway 53 with a minor branch going north of the mill site, and the major going south. Aerial photos show that the major Lobo Canyon drainage passes well south of the mill site. Therefore, Lobo Canyon discharges should have no measureable effect on the tailings embankment, even with the backwater on San Mateo Creek due to Lobo Canyon discharges. The flood plain of the San Mateo Creek widens downstream of the mill, which significantly dampens any potential backwater. By contrast, a real backwater effect results from obstruction of San Mateo Creek by the railroad grade north of Milan, but this has already been accounted for in the flood hydrograph calculations made in 1980 and 1982, on which the design of the protective berm was based.

Item 8:

Homestake's Environmental Report states that their tailings disposal area is located on an active valley floor which "seems to be depositional". Homestake has been asked by the EID to justify this statement. The best, and perhaps the only, reference source for this area is a publication prepared by the United States Geological Survey for the New Mexico State Engineer. The publication is:

Technical Report No. 20
New Mexico State Engineer
Santa Fe, New Mexico

Geological and Ground-Water Resources of the
Grants - Bluewater Area, Valencia County, New Mexico

by

Ellis D. Gordon, 1961, in cooperation with the U.S.G.S.

The chapter of the report which deals with the geology of the area has a discussion of the Alluvium (see Attachment 1). An excerpt describes the Alluvium as follows:

"Deposition of alluvium apparently has continued to the present time. In general, the basal part of the alluvium contains the greatest proportion of sand and gravel. The upper part of the alluvium is composed predominantly of silt and fine sand. The alluvium, together with the interbedded basalt flows in those areas where they are present, generally range in thickness from 100 to 140 feet in the area between Bluewater and Grants".

A local geologist describes the area as follows:

"The past history of the area tells of using Bluewater Creek for irrigation in 1880, and the first dam on the creek was built in 1894. The present dam was built in 1927 and the east irrigation ditch went north of the HMC mill in Section 23, T.12N,R.10W. before turning south to terminate in the triangle formed by the HMC tailings pile, and State roads 53 and 334. HSP farmed in that area for several years before diverting the water from agricultural to industrial use. Farming still continues south of that area as it has for almost 100 years. Erosion cannot be active or the farm land would lose its soil. It is clearly a depositional area.

A review of the USGS 7-1/2' guadrangle maps titled: "Grants", "Milan" and "Dos Lomas" shows some pertinent facts:

1. A gradient of of 10 to 50 feet per mile. This gradient is not conducive to erosion.

2. There are numerous small playa lakes on the alluvial plain filling the valley bottom. These lakes indicate internal drainage areas surround the mill which further limits run-off and erosion.

3. Numerous drainages from the high areas composing the valley sides drop mechanical sediments forming alluvial fans where they

enter the alluvial plain. There the gradient decreases and the load carrying capability is lost.

4. The drainage patterns of the intermittent streams are meandering and discontinuous which indicates lack of erosion power.

5. Contour lines which cut drainage patterns have small upstream arrows showing very shallow drainages.

6. The total run-off of more than 270 square miles has produced no arroyos in the discharge area near Homestake's mill.

Personal observations from living in the area since 1960 and those of old timers which have been contacted in the area include:

1. Sheet type run-off is the most common in the area.

2. The San Mateo Creek Ditch was constructed more to stop sheet run-off crossing NM 53 north of the mill than to control the creek. It has to be dug out every 3 or 4 years because it silts up.

3. The big curve in NM 53 in the NE corner of Section 1,T.12N.,R.10W. has been raised several times where it crosses San Mateo Creek because the creek has deposited san and silt, built natural levees and elevated its stream bed above the original roadbed.

4. Observations of sheet run-off of several inches in depth and more than a mile wide around NM 53 both North and South of NM 334 have been made.

The statement by Ellis D. Gordon that deposition of alluvium is apparently continuing to the present time is probably true on a geologic time scale. The people who have lived and worked in the area for 20 to 40 years have observed little change. The only evidence of any erosion is in the extreme northern part of the area where overgrazing has almost totally removed all vegetation."

Item 9

Homestake has re-evaluated their reclamation program and associated costs. Please find attached several replacement pages for Section C9.0 and Table C9.4 of the Environmental Report. The revised estimates are in 1984 dollars and reflect the add-ons for a private contractor's expenses and profits (interest costs, lease/rental/depreciation, overhead, contingency, profit, etc.) which were not included in the original estimate.

If you have any questions or comments concerning these 3 items, please don't hesitate to contact me.

Very truly yours,

HOMESTAKE MINING COMPANY-GRANTS

Edward E. Kennedy

Edward E. Kennedy
Director of Environmental Affairs

EEK/bgl

xc: C.K. Crossman (EID, Santa Fe)
J.M. Parker
R.F. Farrell
G.S. Crout

TECHNICAL REPORT 20

New Mexico State Engineer
Santa Fe, N. Mex.

GEOLOGY AND GROUND-WATER RESOURCES OF THE GRANTS-BLUEWATER AREA, VALENCIA COUNTY, NEW MEXICO

By

Ellis D. Gordon

Prepared in cooperation with the United States Geological Survey

Attachment 1

Tertiary System

Extrusive Rocks

Basaltic lava flows of late Tertiary age cap the Grants Ridges and La Jara and Horace Mesas, north, northeast, and east, respectively, of Grants. These flows, which were extruded from volcanic vents on the mesas, were deposited on beveled and tilted strata of Triassic, Jurassic, and Cretaceous ages. One of the volcanic vents, on the northeastern mesa of the Grants Ridges, has been exposed by erosion. The flows were deposited on an erosional surface that lies about 750 feet above the present valley floor. The basalt flows at the time of deposition probably were connected to form a continuous sheet of basalt. Subsequent erosion has removed much of the basalt, leaving only remnants capping the high mesas. The basalt was deposited by several different flows, which generally ranged in thickness from 30 to 80 feet; the total thickness ranges from 200 to 300 feet in exposures along the edges of the mesas.

Many springs issue from the basalt along the margin of Horace and La Jara Mesas and at various favorable topographic positions on the mesas. The springs provide water for stock and domestic use at work camps during the summer.

Quaternary System

Deposits of Quaternary age in the Grants-Bluewater area consist of alluvium, landslide and talus material, dune sand, and basaltic lava flows. The deposits of landslide and talus material and the dune sand are areally small and are included with the alluvial deposits in this report.

Alluvium

After the deposition of the late Tertiary basalt flows and the development of the late Tertiary and early Pleistocene(?) cinder cones, the stream courses in the main valleys of the Grants-Bluewater area were eroded to depths of 150 to 200 feet or more below the altitude of the present land surface. Alluvial deposits of silt, sand, and gravel then were deposited in and along the stream courses. These deposits attained a maximum thickness of 30 or more feet and covered most of the valley floor. Basaltic lava flows then filled parts of the valleys. Alluvial deposits continued to accumulate in the valleys adjacent to the basalt flows. Apparently, however, the alluvium accumulated in depths sufficient to cover the older basalt flows only in a few local areas before younger basaltic flows were extruded. Deposition of alluvium apparently has continued to the present time. In general, the basal part of the alluvium contains the greatest proportion of sand and gravel. The upper part of the alluvium is composed predominantly of silt and fine sand. The alluvium, together with the interbedded basalt flows in those areas where they are present, generally ranges in thickness from 100 to 140 feet in the area between Bluewater and Grants. (See table 6.)

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A1.0 EXECUTIVE SUMMARY

Homestake Mining Company-Grants (HMC), the Applicant, has applied for the renewal of the Uranium Mill License for its Uranium Mill and Mine Ion Exchange (IX) plant. This Supplemental Environmental Report is filed to include additional information developed since submittal of the original renewal application, to reflect changes that have occurred, and to include matters occasioned by recent regulatory changes. The facilities have been operating pursuant to Section 3-430 of the New Mexico Radiation Protection Regulations (NMRPR). Prior thereto, the facilities were operated pursuant to Radioactive Material License No. SUA-708 revised by the U. S. Atomic Energy Commission (U.S. AEC). Ore sources are obtained from two underground mines operated by HMC in the Ambrosia Lake mining district north of the mill site. Ores from other sources have been and may continue to be processed at the mill.

A1.1 HISTORY AND PURPOSE OF PERMITTING

The mill is located about 5.5 miles north of Milan, New Mexico (Figure A2-1), in Section 26, Township 12 North, Range 10 West, of Cibola County.

The HMC Mine IX plant is located in the southeastern part of McKinley County, New Mexico, in the Ambrosia Lake area (Figure A2-1). The IX plant is approximately 18 miles northwest of Grants, New Mexico in Section 25, Township 14 North, Range 10 West.

The HMC mill has been a major producer of uranium concentrate since 1958. The milling operation was originally owned and operated as two distinct partnerships, the Homestake-Sapin Partners with a milling capacity of 1,750 tons per day (tpd) and Homestake-New Mexico Partners with a milling capacity of 750 tpd. In November 1961, the Homestake-New Mexico Partnership dissolved and the property was ultimately acquired by the Homestake-Sapin Partnership. In April 1968, the name of the partnership was changed to United Nuclear-Homestake Partners and in March

1981, Homestake purchased United Nuclear Corporation's interest and the operation became Homestake Mining Company-Grants.

Since the Applicant is currently operating in accordance with conditions and stipulations effected and enforced by the New Mexico Environmental Improvement Division (NMEID), this license renewal application is submitted for NMEID approval so that the Applicant can continue milling operations for the next five years.

A1.2 EXISTING OPERATIONS AT THE MILL

The mill employs the alkaline leach-caustic precipitation process for concentrating uranium oxide from ores that have historically averaged from 0.05 to 0.30 percent U_3O_8. The concentrate is a semirefined uranium compound known as yellowcake that averages 87 percent U_3O_8.

The mill has a design throughput capacity of a nominal 3,400 tpd of ore. Currently (March 1982) the milling rate is approximately 800 to 1,150 tons per operating day. The present operating schedule is ten days on and four days off. In the event there is an increased usage for yellowcake, HMC may increase the throughput to the nominal capacity of 3,400 tpd averaged during each quarterly period. Current tailings management at the mill site consists of disposal of the waste products from the milling operations in an embankment located adjacent to the mill. The embankment is divided into two cells designated the east and west ponds. The embankment presently covers approximately 170 acres and is approximately 85 to 90 feet high. The east and west ponds cover approximately 55 acres and 40 acres, respectively, as measured from the crest centerline.

The mill tailings are transported from the mill to the embankment in a slurry form. The tailings are composed of uranium-depleted fine and coarse sand fractions and slimes. The tailings are deposited above ground on the embankment by means of wet cyclones which separate the material into coarse and fine splits. The coarse material is spigotted

along the crest and downstream slope of the embankment and the fine split is discharged into either the east or west pond. The cyclone travels along the crest of the embankment, building the embankment by the centerline method as it moves. The liquid that is deposited in the ponds (east or west) is recycled back to the mill for use in the tailings slurry. The present mode of operation confines disposal to a single pond at a time with the other pond used for evaporation as needed. To date, the tailings disposal area, currently in use, has received about 19.7 million tons of tailings. Details on HMC's tailings management plans are contained in Section C2.0.

In addition to the mill site, HMC operates a small IX plant in the Ambrosia Lake area to recover water-solubilized uranium from the Applicant's mines. Most of the IX tail water, without chemical additives, is recirculated back underground for recovery of more uranium. Water that cannot be recirculated is treated with barium chloride for the removal of radium-226. After treatment, the excess water is discharged to the dry Arroyo del Puerto.

A1.3 PROPOSED CONTINUED TAILINGS DISPOSAL OPERATION

HMC plans to continue use of the existing tailings embankment for the next five-year period. The five-year buildout plan of the tailings embankment has been developed from the following considerations:

- Mill production rate for the next five years was estimated to be 2,000 tons of tailings solids per day.
- The structural embankment must be constructed of the coarse-split tailings, which constitute about 40 percent of the solids in the tailings slurry. Fine-split tailings would be placed in the ponds.
- The crest buildout, or structural embankment, must be sufficient to maintain five feet of freeboard and a 50-foot beach.
- The embankment will be used for the next five years. At the present and anticipated rate of

production, the appropriate safety factor will be maintained by this disposal method.

From the above considerations it was determined that HMC could continue to use the existing tailings embankment for the next five years. Construction of the five-year buildout will be accomplished using the same spigotting procedures currently in use. The cyclone will travel along the crest spreading the coarse split ahead to build the crest and discharge the fine split toward the pond across the beach.

The buildout will start along a new setback crest centerline, 90 feet inboard of the original crest centerline. The coarse tailings will be deposited on this centerline, forming a dike or levee upon the former beach area. The structure should contain all fine tailings and liquid that are discharged into the ponds. The tailings embankment is expected to increase in height and available beach width is expected to decrease over the five year period.

The fine tailings discharged into the pond are expected to produce an average rise of four feet per year in the east pond and three and one-half feet per year in the west pond. These rates of filling should provide ample freeboards of up to 12 feet throughout the five-year buildout.

The embankment buildout at initial setback and at one-, three-, and five-year intervals has been investigated for slope stability, seepage, and liquefaction considerations under normal and severe loading conditions. The basic design has been developed to provide five-year embankment configuration that meets the New Mexico State Engineer's safety factor criteria for uranium mill tailings embankments.

In addition to the tailings management plan for the five-year buildout of the existing tailings embankment, HMC also investigated several alternative tailings management systems. These studies of alternative site and management systems were conducted to identify potential

tailings disposal sites in accordance with recent amendments to NMRPR (NMEID, 1981) and feasible systems to modify or replace the existing tailings disposal system described above.

An alternative site selection study was performed within a seven-mile radius of the present site. The study was performed to identify one to three potential disposal sites that most fully satisfied the alternative site criteria set forth in NMRPR 3-300.K. Sites were evaluated using weight factors to rank the areas and sites within areas. After final evaluations, it was determined that three sites were clearly preferable to other areas or sites in the study region.

For the purpose of comparison, the present mill site was also evaluated against the site selection considerations. Although the evaluations according to specific considerations were very different for the present site compared to the best alternative sites, the present site achieved total ranking comparable to the preferred alternative sites.

Below-grade disposal alternatives for backfilling of mined-out space and disposal in pits or trenches on-site or on alternative sites were evaluated. It was determined that backfilling mined-out space in HMC's mines is impractical because of the distance to the mines and the transportation hazards associated with hauling the tailings. The alternative of below-grade disposal at the present site was discarded due to the proximity of the groundwater in the San Mateo alluvium. Below-grade disposal would place the tailings in a position to contact water-bearing alluvium and contaminate the groundwater.

Other alternative tailings disposal plans that were considered included the following:

- <u>Present Cyclone System</u>
  - Present cyclone method for tailings placement with a new lined evaporation pond for excess decant liquid or collection well water disposal.

- Present cyclone method with a new water treatment system to clean up collection well water for use as mill process water.

- Dry Tailings System

  - Dry tailings disposal using the existing embankment ponds for evaporation.

  - Dry tailings disposal using existing embankment ponds plus a new lined evaporation pond.

  - Dry tailings disposal using only a new lined pond for evaporation.

  - Dry tailings disposal using existing ponds for collection well water evaporation and a new lined pond for tailings solution evaporation.

- Thickened Tailings System

  - Thickened tailings disposal using present ponds for evaporation.

  - Thickened tailings disposal using both existing ponds and a new lined pond for evaporation.

  - Thickened tailings and dry tailings disposal concurrently or in sequence, using a new evaporation pond.

These alternative systems are discussed in detail in Section C3.3.

A1.4 LONG-TERM STABILIZATION

In order to meet the recent NMEID regulations for protection for 200 years against erosion, HMC has developed a permanent long-term stabilization program for the tailings embankment and associated areas. The long-term stabilization program is based on an ultimate buildout of the tailings embankment up to year 2000. The tailings embankment at the end of this time period will be sloped with 4H:1V side slopes and a relatively flat top. The embankment side slopes and top will be covered with 18 inches of soil material obtained from borrow area(s) located north of the existing embankment. In addition, the soil material will be covered with six inches of rock for protection from water and wind

erosion. This proposed cover is calculated to provide protection against water-induced sheet and rill erosion and wind erosion for a period well in excess of 200 years.

In addition, calculations were made to determine the peak discharge and flood plain extent of the 200-year flood event. The calculated discharges were 8,456 and 7,536 cubic feet per second (cfs) for the six- and 24-hour 200-year storms, respectively. HMC has made provisions for construction of a flood protection berm around the north and west sides of the tailings embankment at the ultimate buildout. The 200-year flood event will reach the berm that protects these slopes but the flood event should not overtop the berm. The berm will direct the flood water away from the embankment toe.

Details regarding the long-term impacts are contained in Section C9.0.

A1.5 ENVIRONMENTAL SETTING

The environmental setting subsections presented below provide information on geography, demography, meteorology, hydrology, and geology. This information is used to evaluate the potential impacts on the environment from the continued milling operations. Details concerning the environmental setting are contained in Sections B1.0 through B4.0.

A1.5.1 Geography and Demography

The HMC mill is located in the northern portion of Cibola County, New Mexico (Cibola County has just recently been established and was previously a part of Valencia County). The mill is located in the San Mateo drainage at an elevation of about 6,600 feet. Malpais lava beds, which form low, relatively flat relief, cover large areas west and south of the mill site. Mesas form the high terrain around the valleys with elevations typically between 7,000 and 8,600 feet.

Due to the recent establishment of Cibola County, very little demographic information is available; therefore, information contained in this report describes characteristics of the former Valencia County.

The largest population center in the region is the Grants/Milan area which is located a few miles south of the mill. Grants reported a population of 11,439 persons in 1980, accounting for 18.7 percent of the total Valencia County population.

Mining is an important component of the local economy; however, the unemployment rate in Valencia County (9.0 percent) is relatively high compared to the state (6.9 percent).

Approximately 93 percent of Valencia County is undeveloped rangeland or commercial or noncommercial woodland. Urban areas occupy about three percent of the county land.

There is a significant transient population within the Valencia/McKinley County area. This transient population is comprised of tourists who visit the Mount Taylor district of the Cibola National Forest and the Red Rock and Bluewater Lake state parks.

A1.5.2 Meteorology

The site area has an arid to semiarid continental climate which receives more than 60 percent sunshine each day throughout the year. On an annual basis, winds are moderate and are primarily from the southwest. Average yearly precipitation is about 10 inches. Most precipitation occurs in the summer with generally dry conditions persisting year-round. Air pollutant concentrations in the site vicinity have been determined to be within all applicable air quality standards.

A1.5.3 Hydrology

Surface Water

The surface water regime of the HMC mill site is influenced by the arid to semiarid climate of the region, the relatively medium to high permeability of the soils and the exposed bedrocks of the watersheds.

The San Mateo drainage basin above the HMC mill site has a drainage area of approximately 291 square miles. The only surface water bodies are several stock ponds, some small ephemeral ponds, and an undetermined number of springs on the flanks on Mount Taylor. None of these water bodies are affected by mill operations.

The peak discharge derived from the one-, six-, and 24-hour storms with recurrence intervals of 100 years was determined with the use of a computerized version of the U.S. Soil Conservation Service's (SCS's) synthetic triangular hydrograph method. The 100-year peak discharge for the one-hour storm produces little surface runoff since most of the 1.1 inches infiltrates into the soil. The six- and 24-hour storms produce similar results, showing that the intensity of the six-hour storm is nearly matched by the longevity of the 24-hour storm.

Flood plain determinations were calculated using the U.S. Army Corps of Engineer's (COE's) water surface profile computer program (HEC-2). The calculated 100-year flood of 5,981 cfs will reach the current flood protection berm that protects the west end of the tailings embankment. The berm is at an elevation of 6,582.4 feet, high enough to prevent water from encroaching upon the tailings embankment.

Due to the ephemeral nature of San Mateo drainage, no surface water quality samples are collected or analyzed near the mill site. HMC is collecting discharge water samples from the Mine IX facility. These samples are collected quarterly and analyzed for radionuclide concentrations. Samples collected to date show radionuclide concentrations well below those of the maximum permissible concentrations (MPC's).

Groundwater

HMC has continued its groundwater protection program with the installation of groundwater monitoring wells, collection wells and injection wells since 1976, in agreement with NMEID. A Ground Water Discharge

Plan (GWDP) for the HMC mill was submitted to NMEID in December 1981. The GWDP combined the results of all previous HMC investigations.

The San Mateo alluvium, Chinle Formation, and San Andres Limestone underlie the site. Only the shallowest, the San Mateo alluvium, has been affected by seepage. Some groundwater from each of these three aquifers has been used for domestic, livestock, and to a minor extent irrigation use.

As part of the radionuclide monitoring plan, HMC has monitored groundwater since 1958. The program was extensively expanded in July 1981. Seven wells are now monitored; i.e., three upgradient wells, three downgradient wells, and one well near the closest residence. The quarterly samples analyzed to date show the concentration of radionuclides upgradient and downgradient from the mill to be essentially the same, indicating the tailings disposal area has not elevated the radionuclide concentrations downgradient in the San Mateo alluvial system. Details regarding the hydrology at the site are included in Sections B3.0 and C6.0 of this report.

A1.5.4 Geology

The project area is located on the northeast flank of the Zuni Uplift, a tectonic feature which is characterized by a core of Precambrian crystalline basement rocks partially mantled by Permian and Triassic sedimentary rocks. The Zuni Uplift is surrounded by several tectonic depressions, including the Gallup Sag to the west-southwest and Acoma Sag to the southeast.

Major faults occur along the southwest flank of the Zuni Uplift and a number of minor faults are mapped in the remainder of the region surrounding the project area. No active major or minor faults are known to be in the vicinity of the site.

The site is underlain by Quaternary alluvium to depths of over 120 feet. The alluvium is generally sandy silt; however, two distinct sand and gravel horizons occur at the top and bottom of the unit. The lower sand horizon, which directly overlies the deeper Chinle Formation, is relatively continuous throughout the area and is a source of water supply in the region.

Historically, the region around the site has experienced a low level of seismic activity. The earthquakes in the vicinity of the site are typically microearthquakes of magnitude two or less. The three largest earthquakes recorded since 1962 within a 60-mile radius around the site have been local magnitude (M_L) 3.44 on December 24, 1973; 4.1 (M_L) on January 5, 1976; and 3.7 (M_L) on March 5, 1977.

Based on attenuation curves, a magnitude 6.0 earthquake originating in the Rio Grande Rift at approximately 45 miles from the site would have an estimated maximum peak acceleration of gravity 0.04g and, therefore, would produce little or no significant engineering impact on the site because of the attenuation of the seismic waves and distance. For the purpose of stability calculations, it was assumed that an earthquake of a maximum magnitude of 4.9 occurred in the immediate vicinity of the mill. The effective peak horizontal acceleration of an earthquake of such magnitude at the site would be 0.10g. The tailings embankment stability pseudo-static safety factor is greater than 1.0 even in such an event. The 0.10g figure is larger than calculated by other acceptable methods.

The seismic risk map of the United States, as presented in the Uniform Building Code, indicates the site is located in a Zone 2 seismic risk area.

A1.6 EFFECTS OF MILLING OPERATIONS

The following subsections provide information on the anticipated impacts on man and the environment that could be expected from the milling

operations. Where appropriate, the mitigating measures taken by HMC to reduce these impacts are addressed. In addition, the comprehensive occupational and environmental monitoring programs initiated by HMC to assess adequacy and determine data requirements in order to evaluate potential impacts are provided.

A1.6.1 Radiological Impacts

The most important pathway for radiation exposure to man at the HMC mill is direct inhalation of airborne particulates. Direct external exposure or the ingestion of contaminated substances are minor exposure pathways by comparison.

The U. S. Nuclear Regulatory Commission's (NRC's) most recent dispersion model, MILDOS, has been used to predict radionuclide concentrations and radiation doses to individuals and populations in the mill vicinity. The radionuclide sources evaluated are:

- Yellowcake dryer stack
- Yellowcake roaster and packaging stacks
- Ore handling, storage, crushing and drying areas

The radiological doses resulting from the HMC operations were predicted by the MILDOS code for several specific receptor locations in the mill vicinity. Predictions were made for time intervals so that both operational and poststabilization conditions could be evaluated. The maximum predicted exposures occur between 1986 and 2000 when the mill is assumed to have a throughput of 3,175 metric tons per day for 350 days a year, a figure higher than production at any period in the past. The maximum radiological exposures to individuals residing near the mill would occur at Murray Acres, located 1.8 kilometers (km) southwest of the mill. The maximum predicted exposure is 13 millirems per year (mrem/yr) to the child's lung which is well below the 25 mrem/yr limitation specified by New Mexico's regulations. The exposures predicted during the stabilization and poststabilization periods are very small in comparison to the exposures predicted for the operational period. The

calculations have been based on several conservative assumptions that are likely to overestimate exposure.

Alpha exposures for all personnel working in yellowcake areas are monitored, recorded and presented in this document.

HMC has monitored suspended airborne particulate levels at perimeter sites around the mill since 1977. These data have shown that the average concentrations for natural uranium, thorium-230, and radium-23226 are within the MPC at all sites. Detailed radiological impact assessments are contained in Section C4.0.

A1.6.2 Nonradiological Impacts

Ecology

The vegetation of the area surrounding the HMC mill may be characterized as grassland-desert scrub. Site soils are primarily Prewitt loams, sandy clay loams and clay loams. Wildlife values are typical of disturbed grassland-desert-scrub areas. No surface water is present in the mill vicinity except for the tailings ponds, and no fish are present.

The HMC mill has been in operation since 1958; therefore, the ecological impacts associated with initial construction, including habitat loss and decreases in plant and wildlife populations, increased human population and increased hunting pressure, have already occurred. Details concerning nonradiological biological impacts are contained in Section C5.1

Socioeconomics

Over 17 percent of the total civilian labor force in McKinley and Valencia Counties is occupied by mining and milling employment. In 1980, it was estimated that 2,518 people (employees and their families) were supported by employment at HMC.

The 1980 tax burden of HMC and its employees was $8.7 million. Fifty-one percent of this amount is paid to the federal government and 49 percent is paid to the State of New Mexico.

The total annual city and county governmental expenditures resulting from the presence of the HMC facilities are estimated to equal $2.5 million. The HMC-Grants 1980 direct payroll, less required governmental expenditures, is calculated to equal about $14.9 million annually. It is also estimated that HMC generates as much as $86 million per year in indirect or secondary revenue. When indirect revenues and taxes paid by HMC and its employees are added, lthe annual revenue resulting from the HMC operations exceeds $100 million. All of this income would be lost if the mill and mines were to close prematurely. Details concerning socioeconomic impacts are contained in Section C5.2.

A1.6.3 Impacts on Waterways and Groundwater

The principal radiological contaminants that are mobilized by mill operations include natural uranium, thorium-230, radium-226, and lead-210. There is no indication that mill emissions have increased concentrations of radionuclides in surface water to levels approaching regulatory limits.

HMC is monitoring the impacts of mill operations upon groundwater and the results of this activity are reported in HMC's GWDP. The radionuclide monitoring program is designed to collect data on radionuclide concentrations in both upgradient (control) and downgradient wells.

It is estimated that 153 gallons per minute (gpm) of tailings liquids, based on mill production of 3,400 tpd, seeps from the tailings embankment into the underlying alluvium. All of the radionuclides in these liquids except uranium are immobile and are not migrating with the tailings seepage. However, elevated concentrations of sulfate, uranium, selenium and possibly radium-226 have been detected in groundwater downgradient from the mill. The elevated uranium and radium-226 concentrations do not exceed the state MPC.

HMC has initiated a water injection and collection system to reduce the concentration of contaminants in the groundwater. Continued use of this system is expected to be successful in diluting to acceptable levels any elevated concentrations existing in the groundwater and in preventing any contaminated water from migrating downgradient of HMC's property to other user's wells. Details regarding impacts on waterways and groundwater are contained in Section C6.0.

A1.6.4 Environmental Effects of Accidents

Several conceivable mill accident scenarios could result in the release of radioactive materials to the environment. However, due to the low specific activity of the materials handled at the mill, large quantities of these materials must be released to be of concern to human health and safety. These large release mechanisms are generally not present.

Potential radiological accidents that do not result in a release of radioactive materials include small spills within the mill and a rupture of a pipe in the tailings disposal system. Various systems are utilized to mitigate the effects of such occurrences.

Accidents which could result in small releases of radioactive materials include a gas explosion in the yellowcake drying area and the failure of the air cleaning system serving the yellowcake drying area. The recurrence interval estimated for a gas explosion is one accident per 200 years of plant operation. An air cleaning system failure is considered to be extremely unlikely.

Conceivable accidents which could cause release of large quantities of radioactive materials to the environment include tornado, extreme precipitation, extreme flood and earthquake damage. The consequence of such accidents are discussed herein; however, the likelihood of occurrence of any of these accidents is very small.

Accidents not involving radioactive materials may occur at the mill which could result in release of other hazardous materials that could affect the environment. Because of proper design and stringent safety procedures, however, the potential for such accidents is minimal. Possible nonradiological accidents include leaks and ruptures in chemical storage tanks and pipelines, fires, boiler failures, etc.

Accidents may occur during shipment of process chemicals and ore to the mill and shipment of yellowcake to customers. A spill of anhydrous ammonia is considered the "worst-case" condition for a chemical spill. It is estimated that HMC chemical shipments will cause one accident involving injury to the general public (probably the driver) every 868 years. The consequences of a transportation accident occurring during shipment of uranium ore to the mill are very slight due to the low specific activity of the ore and the ease of cleanup operations. The worst-case accident for yellowcake transportation would involve a truck accident in which the drums rupture, releasing yellowcake. Yellowcake is transported to Metropolis, Illinois, and Gore, Oklahoma, from the HMC mill. It is estimated that one yellowcake release accident could occur every 17 years during shipment to Metropolis and one every 50 years to Gore. The quantity of yellowcake released during an accident is estimated to range from 0.05 to 18 tons. The hypothetical radiological exposure possibilities expected to result from these accidents range from 14 to 200 man-rem. Details regarding the potential for accidents are included in Section C7.0.

A1.6.5 Monitoring and Surveillance Programs

HMC monitoring programs may be divided into two categories: environmental monitoring and occupational monitoring. Environmental monitoring activities include air quality, water quality, biota and soils, and direct radiation monitoring. The occupational program consists of monitoring suspended particulate levels, employee alpha inhalation exposures, radon daughter working levels, direct gamma exposures, and

radiation levels for equipment removal. Bioassays are also conducted as part of this program.

HMC has an established employee training program to assist employees in the safe performance of their work. This training includes instruction in the health protection aspects associated with exposure to radioactive materials or radiation. Details are given in Section C8.0.

A1.6.6 Administration

Activities associated with HMC's Grants operation are conducted under the direction of the HMC General Manager.

Qualifications, training, and previous experience of HMC personnel responsible for developing, conducting, and administering the radiation safety program are included.

Mill security is maintained by fencing the restricted area, posting warning signs in appropriate areas, and control by uniformed guards at the entrance to the restricted area.

The HMC milling operation has an established employee training program to assist employees in safe and efficient performance of work. The radiation safety program was prepared under the supervision of HMC's General Manager, Director of Environmental Affairs, and Radiation Protection Administrator. It is designed to prevent HMC employees and others from exposures to radioactive materials and levels of radiation in excess of the standards incorporated in the NMEID's Radiation Protection Regulations (Parts 4-110 and 4-130). Exposures to radiation and radioactive material will be kept as low as reasonably achievable (ALARA) under HMC's radiation safety program. The procedures are designed to protect employees and visitors from exposure to radioactive airborne dust and surface contaminants in the Precipitation Building, Metallurgical Laboratory and the Ore Crushing Section of the processing

plant. All persons working in or entering these areas are charged with the responsibility to observe the established procedures. Details for all of HMC's administrative activities are given in Section C10.0.

A2.0 THE PROPOSED ACTION

The Applicant, HMC, herein applies for renewal of its Radioactive Material License to continue operation of its uranium mill facilities north of Grants, New Mexico. This Supplemental Environmental Report is filed to include additional information developed since the original renewal application, to reflect changes that have occurred, and to include matters occasioned by recent regulatory changes. The facilities have been operating pursuant to Section 3-430 of the New Mexico Radiation Protection Regulations (NMRPR). Prior thereto, the facilities were operated pursuant to Radioactive Material License No. SUA-708 revised by the U. S. Atomic Energy Commission (U.S. AEC). In addition to the mill and tailings facilities, HMC currently operates an ion exchange (IX) facility and two underground mines in the Ambrosia Lake mining district north of the mill.

A2.1 MILL DESCRIPTION AND LOCATION

The HMC mill is located about 5.5 miles north of Milan, New Mexico, (Figure A2-1). The mill and tailings facilities are located in Section 26, Township 12 North, Range 10 West, in the northern portion of Cibola County. The facilities associated with the milling operation are on property owned by HMC, subject to interests described elsewhere herein.

HMC's IX facility is located in the southeastern part of McKinley County, New Mexico, in an area known as Ambrosia Lake (Figure A2-1). The property is located about 18 miles northwest of Grants, New Mexico, in Section 25, Township 14 North, Range 10 West. Ownership of this property is held by HMC through a mining lease with the Santa Fe Pacific Railroad Company.

The HMC mill, in operation since 1958, processes uranium ore from HMC-owned mines in the Ambrosia Lake area of the Grants Mineral Belt. Ores from other sources in the Grants district have been and may continue to be processed in the mill. The mill utilizes an alkaline leach-caustic precipitation process for concentrating uranium oxide from ores that have

historically averaged from 0.05 to 0.30 percent U_3O_8. The concentrate is a semirefined uranium compound known as yellowcake that averages 87 percent U_3O_8.

Design throughput capacity of the mill is a nominal 3,400 tpd of ore. Present milling rate is approximately 800 to 1,150 tons per operating day. The operating schedule is currently ten days on and four days off. However, if there is an increased usage of yellowcake, the throughput may be increased to a nominal capacity of 3,400 tpd average during each quarterly period.

The small IX plant operated by HMC at Ambrosia Lake is used to recover water solubilized uranium from the Applicant's mines. Most of the ion exchange tail water, without chemical additive, is recirculated back underground for recovery of more uranium. Excess water that cannot be recirculated back into the mine is treated by ion exchange to remove uranium and with barium chloride coprecipitation for removal of radium-226 concentration, and is discharged to a dry arroyo, the Arroyo del Puerto. Concentrated uranium liquors from this plant and from a similar one operated by United Nuclear Corporation (UNC) are transported to the mill for further processing into yellowcake.

A2.2 TAILINGS MANAGEMENT

The waste product from the milling operations, referred to as mill tailings, is composed of uranium-depleted fine to coarse sand and slimes. Tailings are transported in a slurry form via a pipeline to the tailings disposal area immediately northwest of the mill (Figure A2-2). Here, the tailings are deposited above-ground in a rectangular embankment by means of wet cyclones which separate the coarse material from the fine material (slimes). The coarse fraction is spigotted along the crest and the downstream slope of the embankment and the slimes are discharged into the ponds within the embankments. Pond water is recycled back to the mill for use in the tailings slurry line. The cyclones travel along the crest, building the embankment by the centerline method as they move. The

embankment is divided into two cells designated the east and west ponds. The present mode of operation confines disposal to a single pond at a time, with the other pond used for evaporation as needed. This embankment structure and the current mode of operation is expected to remain essentially the same for the duration of the license. However, in order to perserve present stability and enhance future stability of the embankment structure over the next five years, the embankment crest will be moved inboard from the original centerline. This new configuration is discussed in more detail in Section C2.0.

To date, the tailings disposal area currently being used has received about 19,700,000 tons of tailings. The embankment covers approximately 170 acres and is approximately 85 to 90 feet high. The east and west ponds cover approximately 60 percent and 40 percent of the embankment, respectively. Over the next five years, the tailings embankment is designed to receive about 2,000 tons of tailings solids per day, which would be equivalent to a yearly production rate of about 700,000 tons per year (tpy).

A second tailings embankment structure is located immediately southwest of the mill. This disposal area has not received disposal of tailings since January 1962.

A3.0 BACKGROUND INFORMATION

A3.1 OPERATIONAL HISTORY

The HMC mill has been a major producer of uranium concentrate since 1958 when it was originally granted a uranium mill license by the U. S. AEC. Construction on two mill facilities began in 1957 and operations commenced in 1958. The larger of the two mills was organized as Homestake-Sapin Partners with a milling capacity of 1,750 tpd. The smaller mill was organized as Homestake-New Mexico Partners with a capacity of 750 tpd. Both mills were designed to be alkaline leach caustic precipitation mills. Each mill operated independently and had its own tailings disposal facility until November 1961 when the Homestake-New Mexico Partnership dissolved. Homestake-Sapin Partners ultimately acquired the Homestake-New Mexico Partners mill property. In April 1968, through a change in name, Homestake-Sapin Partners became United Nuclear-Homestake Partners. In March 1981, Homestake purchased United Nuclear Corporation's interest and the operation became Homestake Mining Company-Grants (HMC).

A3.2 LICENSING HISTORY AND CURRENT STATUS

Applicant submitted its original Mill License Application to the U.S. AEC and was granted License No. SUA-708. An application for the renewal of the mill operating license was submitted to the New Mexico Environmental Improvement Division (NMEID) thirty days or more prior to the stated expiration date of RML No. SUA-708, and operations have continued pursuant to Section 3-430 of the NMRPR.

The Applicant is currently operating in accordance with conditions and stipulations effected and enforced by the NMEID. Regular site inspections have been made by NMEID representatives and any variances from the license conditions as noted have been corrected and appropriate changes made in operating procedures. Numerous reports are submitted to and reviewed by NMEID in association with HMC's continued operations.

Permits related to the HMC milling operation include:

- National Pollutant Discharge Elimination System Permit No. NM0020389 for discharge of treated mine water into Arroyo del Puerto at the Mine IX plant (currently under adjudication).

- Ground Water Discharge Plan No. DP-102 for protection of the alluvial aquifer near the mill area, 1981.

- Ground Water Discharge Plan No. DP-200 for operations at the mill and associated tailings facilities (currently under evaluation by NMEID).

- Ground Water Protection Plan Agreement-August 18, 1976.

- Ground Water Discharge Plan No. DP-36 covering the IX facility's surge and settling ponds.

B1.0 GEOGRAPHY AND DEMOGRAPHY

This section provides information on the geographic setting of the HMC mill and adjacent areas. The demographic, social and economic characteristics of Valencia (part of which is now Cibola County where the mill site is located) and McKinley Counties are also discussed.

B1.1 GEOGRAPHY

The HMC uranium mill is located in the northern portion of Cibola County, New Mexico, about 5.5 miles north of the community of Milan and 4.5 miles south of the McKinley County/Cibola County line. The mill and tailings facilities are located in Section 26, Township 12 North, Range 10 West. The mill site, county boundaries, and area population centers are shown in Figure B1-1. Figure B1-2 shows the HMC property and adjoining land ownership.

The terrain of the surrounding area is characterized by two drainage areas and surrounding mesas. The San Mateo drainage runs roughly north to south through the middle of the region. It merges with the Rio San Jose Valley in the southern portion of the region. The Malpais lava beds, which form low, relatively flat relief, cover large areas located about three miles to the west and about six miles to the south of the mill. Mesas form the high terrain around the valleys. Elevations of the high terrain are typically between 7,000 and 8,600 feet above sea level. In contrast, the valley floors have elevations of 6,400 to 6,800 feet above sea level. The mill is located in the San Mateo drainage at an elevation of about 6,600 feet. Low elevations in the area have grassland desert scrub and higher elevations are vegetated with pinyon and juniper.

The peak of Mount Taylor, which extends to 11,300 feet above sea level, is located approximately 15 miles to the east of the HMC mill.

The project region has a semiarid to arid climate. The average annual temperature is 50 degrees Fahrenheit (°F). Most of the eight to ten inches of average annual precipitation falls during the summer months. On an annual basis, winds are moderate and are primarily from the southwest.

B1.2 DEMOGRAPHY

B1.2.1 Study Areas

Two separate demographic study areas are evaluated in this report. The larger area encompasses an 80-kilometer (50-mile) radius circle centered on the HMC mill (Figure B1-3). The estimated population of this area is 51,887 persons. Communities located within this area and their populations are listed in Table B1.1.

The smaller study area is a five-kilometer (three-mile) radius circle centered on the HMC mill (Figure B1-4). This area was segmented as shown in Figure B1-4 and the population residing within each sector was determined by a survey of the area. The population of this entire study area is 515 persons.

B1.2.2 Regional Demography

This section describes current and projected demographic characteristics within a radius of 80 kilometers (50 miles) surrounding the HMC mill. The demographic profile focuses upon McKinley and Cibola counties, the two counties in which the majority of the HMC employees reside.

The HMC mill is located in the northern portion of Cibola County. The land area of Cibola County encompasses the western and central portions of what was Valencia County prior to 1981. Due to the recent creation of Cibola County, very little demographic information is available for the county. This report will therefore describe characteristics of the former Valencia County.

Valencia County occupies 5,638 square miles in the west-central portion of New Mexico. The county extends almost 150 miles in the east-west direction. Apache County, Arizona, adjoins Valencia County to the west. Valencia County, McKinley County and the State of New Mexico are sparsely populated. The 1980 population density of Valencia County was 9.8 persons per square mile and the population density in McKinley County was 10.1 persons per square mile. This compares to 10.7 persons per square mile in the state and 62.7 persons per square mile in the entire United States (University of New Mexico, 1981).

The largest population center in Valencia County is the Grants/Milan area which is located a few miles to the south of the HMC mill. Grants, the county seat, reported a population of 11,439 persons in 1980, accounting for 18.7 percent of the total Valencia County population (Middle Rio Grande Council of Governments [MRGCOG], 1981). A second major population center in Valencia County is in the eastern portion of the county near Los Lunas and Belen.

The Valencia County/McKinley County area, like the state of New Mexico, is culturally diverse; the population includes large groups of Navajo and Pueblo people, citizens of Hispanic origin, and Anglo-Americans.

Population totals for Grants, Milan, Valencia County, McKinley County, the state, and the nation are presented in Table B1.2. Grants, Milan, both counties, and the state all grew at substantially greater rates than the nation as a whole between 1970 and 1980 and both counties experienced steady population growth since 1950. Rapid growth during the 1950's (including a 348 percent increase in Grants) was stimulated by a significant expansion of mining and milling activities in the region. The growth rate slowed, however, during the 1960's and the nine percent growth of the two-county area during this period is attributable to natural increase (births minus deaths) rather than substantial immigration. The Grants/Milan area lost 15.5 percent of its population

during the 1960's, reflecting poor market conditions for northwestern New Mexico's minerals industry. This trend reversed during the 1970's, however, as population of the two communities increased 38.1 percent during the decade (University of New Mexico, 1981).

B1.2.3 Transient Population

Tourists constitute the most significant transient population within the Valencia County/McKinley County area. The Mount Taylor district of the Cibola National Forest, which lies within both counties, is the most popular recreational attraction in the area. Recreational use in 1980 in the Mount Taylor district totaled 260,900 visitor days (Wyche, 1981). A visitor day is equivalent to one person visiting the forest for 12 hours. The most popular uses of the forest included general use of undeveloped areas (37 percent of total), campgrounds (27 percent of total), and recreational driving (23 percent of total).

Other important tourist attractions in the area include Red Rock and Bluewater Lake state parks. Red Rock State Park, located in McKinley County, was visited by an estimated 140,000 people during 1980. Bluewater Lake State Park, which is located near the boundary of Valencia and McKinley counties, was visited by 232,253 people during 1980 (Towles, 1981).

B1.2.4 Population Projections

Population projections for the state, Valencia County, McKinley County, and the Grants/Milan area are presented in Table B1.3. A comparison of the projected 1980 population and the actual 1980 count shows that the state population was underestimated by 2.3 percent, the Valencia County population was underestimated by 9.8 percent, and the McKinley County population was overestimated by 11.9 percent. It can be expected that the projections presented in Table B1.3 are in the same range of accuracy.

B1.2.5 Land Use and Ownership

Over 97 percent of the land area of McKinley County consists of rangeland or commercial or noncommercial woodland (MRGCOG, 1981). All other individual land use types including irrigated and dry cropland, urban areas, mining, etc., constitute a very small percentage of the total county land area.

A relatively small percentage (18 percent) of the land area of McKinley County is privately owned. Indian Trust land comprises 62 percent of the county and 22 percent is state and federal land (MRGCOG, 1981). Navajo and Zuni Indian reservations are located within the county.

As much as 93 percent of Valencia County is undeveloped rangeland or commercial or noncommercial woodland. Urban areas occupy about three percent of the county land and all other land use types constitute a small percentage of the total county land area (MRGCOG, 1979).

About 48 percent of Valencia County is privately owned, 25 percent of the county is Indian land, 20 percent is federal land, and seven percent is state owned (MRGCOG, 1979). The Acoma, Acomita, Isleta, Laguna, Canoncito, Ramah, Navajo, Paguate, and Zuni reservations (Pueblos) are located within Valencia County. Land ownership adjacent to the HMC mill is shown on Figure B1-2.

B1.2.6 Employment and Income

Employment data for New Mexico and the two-county area are presented in Table B1.4. Nearly 20 percent of the area's workers are occupied in agriculture and ranching (University of New Mexico, 1981). Government and mining are the two largest nonagricultural employers in the two-county area, with each employing nearly 18 percent of the civilian labor force. The importance of the Grants mining district to the state mining economy is evident from the fact that mining activity in the two counties employs almost 27 percent of the total state mining labor force. The presence of federal agencies such as the Bureau of Indian Affairs and the Indian

Health Service makes government employment particularly important to the regional economy (Kerr-McGee, 1981). Relatively few area workers are em ployed in manufacturing, finance, insurance, and real estate.

Total personal income in the two-county area in 1976 totaled nearly $329 million (Table B1.5). Mining income in the two counties totalled $99.9 million during 1976, representing the single most important income source in both Valencia and McKinley counties during that year (University of New Mexico, 1981). Income earned by HMC mining and milling employees during 1980 equaled $17.4 million. Government and trade sectors are also leading employers in the area.

As of October 1981, the unemployment rates in McKinley County (9.5 percent) and Valencia County (9.0 percent) were considerably higher than those of both the state (6.9 percent) and the nation (8.3 percent) (University of New Mexico, 1981). This high unemployment rate in the area is probably a result of the recent slowdown in the New Mexico uranium industry.

Per capita personal income in the two counties increased by 182 percent between 1969 and 1979 (Table B1.6). This compares with a 163 percent increase in the state and a 137 percent increase in the nation during this period. Nevertheless, the 1979 average income level in the two counties was 30.7 percent below the national level and 18.8 percent below the state level. Because income from mining jobs is relatively high compared to other employment in the area, the average income level in the two counties would be far below the national and state levels except for mining employment.

B1.2.7 Public Services

Public service facilities available in the Grants/Milan area are described in the following paragraphs.

- Educational Facilities - During the 1979-1980 school year, about 4,308 students were enrolled

in the Grants School District. The teacher/student ratio for the year was 1:27. One high school, two middle schools, ten elementary schools, and five kindergartens currently constitute the school district. Two private schools and a branch college of New Mexico State University are also located in the Grants/Milan area (Kerr-McGee, 1981).

- Water Supply - Grants and Milan are supplied with over 6.5 million gallons of drinking water per day by five groundwater wells. Water supplies are currently adequate; however, any significant population growth will require the expansion of existing facilities (Kerr-McGee, 1981).

- Sewage Treatment - An activated sludge sewage treatment plant, designed to serve a population of 20,000, processes wastes from Grants and Milan. This plant operates routinely at 90 percent of capacity and a new sewage treatment facility is planned for construction (Kerr-McGee, 1981).

- Utilities - Electricity is provided to the Grants/Milan area by Continental Divide Electric Cooperative. The Gas Company of New Mexico supplies gas to the area and Mountain Bell provides telephone service (Kerr-McGee, 1981).

- Health Care - Cibola General Hospital, located in Grants, has 42 beds available; however, specialized health care services are generally sought in Albuquerque which has ten hospitals and four public health clinics. A County Health Office is located in Grants (Kerr-McGee, 1981).

- Public Safety - The Valencia County Sheriff's office has a substation in Grants. The entire department has 16 officers and 13 cars (MRGCOG, 1979). The New Mexico State Police force in the Grants/Milan area consists of seven officers and seven cars. There is also a local police force in Grants consisting of 26 full-time personnel. The Grants fire department has 12 full-time and 31 volunteer personnel operating out of two stations with four pumper trucks and one car (Kerr-McGee, 1981).

B2.0 METEOROLOGY AND AIR QUALITY

The HMC site has an arid to semiarid continental climate which receives more than 60 percent sunshine averaged each day throughout the year. On an annual basis, winds are moderate and are primarily from the southwest. Average yearly precipitation is about 10 inches. Most precipitation occurs in the summer with generally dry conditions persisting year-round. Air pollutant concentrations in the site vicinity have been determined to comply with all applicable air quality standards.

B2.1 METEOROLOGY

Meteorological and climatological parameters which describe conditions in the vicinity of the site are wind speed, wind direction, atmospheric stability, mixing depth heights, temperature, humidity, and precipitation. Temperature data have been gathered on-site while information describing wind speed, wind direction, atmospheric stability, mixing depth heights, humidity, and precipitation have been monitored at locations near the site. This became necessary when it had been determined by HMC and the NMEIDthat the quality of HMC's on site meteorological data was not adequate for estimating radiological dose to the public. Stability classifications were applied to the meteorological data by determining net solar radiation measurements. The best available data describing solar altitude and cloud cover in the vicinity of the HMC mill were collected at Gallup, New Mexico. Other meteorological data determined to be applicable for HMC's mill location was obtained from the Anaconda Copper Company at Bluewater, New Mexico, located approximately 5.5 miles west-northwest of the mill. The data has not been adjusted for off-site applicability as no quantitative method exists. However, the terrain at the Anaconda Mill is very similar to the terrain near HMC's mill and no geologic features exist between the two mills which could dramatically affect climatic conditions.

B2.1.1 Joint Frequency Distribution

The joint frequency distribution of wind speed, wind direction, and

atmospheric stability is presented in Table B2.1. Wind speed and wind direction were monitored near the site in 1978 at Anaconda's Bluewater Mill, approximately 5.5 miles northwest of the HMC site (Anaconda, 1981). These data are shown as a wind rose in Figure B2-1. Stability classifications were determined from wind speed and net solar radiation. The best available data describing solar altitude and cloud cover in the site vicinity were collected at Gallup, New Mexico, which is approximately 50 miles west-northwest of the mill. The average wind speed at the site is estimated to be five miles per hour and the prevailing wind direction is from the southwest.

Extremely unstable to neutral stability conditions (classes A through D), which indicate good atmospheric dispersion of pollutants, occur nearly 61 percent of the time at the site. Slightly stable to extremely stable atmospheric conditions (classes E through G) are realized approximately 39 percent of the time, indicating periods of possible elevated atmospheric contaminant concentrations.

B2.1.2 Mixing Depth Heights

Mixing depth heights for the site area are presented in Table B2.2 as reported by Anaconda (1981). Morning and afternoon mixing depth heights are greatest in the spring and summer, and are lowest in the winter and fall. Annually, morning mixing heights average 1,591 feet at the site, and afternoon mixing heights average 9,147 feet.

B2.1.3 Temperature and Humidity

Temperature data for the site, presented in Table B2.3 (HMC, 1981c), are organized according to monthly extremes and averages for the period from January 1978 to December 1980. On an annual basis, the site's mean monthly temperature averages 39°F with July being the hottest month (63°F) and December being the coldest month (20°F). The maximum extreme temperature observed at the site from 1978 to 1980 was 95°F in July and the minimum temperature was minus 23°F in December.

Table B2.4 summarized relative humidity data for the site area (National Oceanic and Atmospheric Administration [NOAA], 1968). The Average

annual relative humidity is approximately 54 percent, with the minimum monthly average relative humidity occurring in May (33 percent) and the maximum monthly average relative humidity occurring in January (75 percent).

B2.1.4 Precipitation

Long-term precipitation data were not collected on-site, but data were recorded at the National Weather Service station at Grants, New Mexico which is about eight miles southeast of the site (Table B2.5). Based on three years of observations from 1978 to 1980, the annual quantity of precipitation at the site is expected to be approximately 10.37 inches. August receives the most precipitation, 1.73 inches, and March registers the least precipitation, 0.30 inches. The Grants area receives approximately 24 inches of snow annually. The site are should annually experience nearly 75 days when 0.01 inches or more of precipitation is recorded.

B2.1.5 Severe Weather

Long-term adverse weather conditions are rate in the HMC site vicinity. However, the site is subject to short-term, intense events such as cloudbursts which can produce runoff and flash flooding. No tornado has been observed in the site area and effects from Gulf Coast hurricanes are limited to possible localized heavy rainfall. Winter storms are not usually accompanied by severe winds so the chance of blizzards or deep snow drifts are minimal.

B2.2 AIR QUALITY

The criteria pollutants measured by the New Mexico Air Quality Bureau (NMAQB, 1980) include total suspended particulates (TSP), sulfur dioxide, nitrogen dioxide, carbon monoxide, and ozone.

B2.2.1 Total Suspended Particulates

TSP concentrations are monitored by the NMAQB at several stations near the site. The annual geometric mean concentration of TSP for 1980 ranged between 37 and 197 micrograms per cubic meter (ug/m^3) at eight stations within 25 miles of the HMC site. The geometric average TSP

concentration for these eight stations was 73 ug/m^3. The federal primary standard for TSP is 75 ug/m^3.

B2.2.2 Sulfur Dioxide

Sulfur dioxide (SO_2) was not monitored by the NMAQB near the site. The closest monitoring station was in Albuquerque, approximately 75 miles east of the site, which recorded an annual average SO_2 concentration of 0.001 parts per million (ppm) in 1980. This value is probably higher than the SO_2 concentrations expected at the site because of the greater quantity of SO_2 sources in the Albuquerque area. The federal standard for SO_2 is 0.03 ppm and the state standard is 0.02 ppm.

B2.2.3 Nitrogen Dioxide

Nitrogen dioxide (NO_2), like SO_2, was not monitored near the site. Data for NO_2 were collected at Albuquerque. The NO_2 concentration was determined to average 0.018 ppm in 1980. This value is higher than would be expected at the site because NO_2 originates primarily from gasoline combustion and Albuquerque has much more automobile traffic than the site area. The federal and state annual mean standard for NO_2 is 0.05 ppm.

B2.2.4 Carbon Monoxide

Carbon monoxide (CO) was monitored by NMAQB at four sites in Albuquerque during 1980. The annual mean concentration of CO at these sites ranged from 0.8 to 1.6 ppm and averaged 1.4 ppm. Similar to NO_2, CO is derived primarily from combustion of fuel. The site area should experience much lower CO concentrations than Albuquerque since it has much less automobile traffic than Albuquerque. The federal standard for eight-hour average CO is 9.0 ppm and the state standard is 8.7 ppm.

B2.2.5 Ozone

Ozone (O_3) concentrations were monitored at four stations in the Albuquerque region with highest one-hour concentrations at the four sites ranging between 0.088 and 0.100 ppm. No average values were reported by the NMAQB. The Albuquerque O_3 data is expected to be higher than site data since O_3 is described as an urban pollutant. The federal one-hour O_3 standard is 0.12 ppm and the state standard is 0.06 ppm.

B3.0 HYDROLOGY

B3.1 SURFACE WATER

The surface water regime surrounding the HMC mill site is influenced by the arid to semiarid climate of the region, the relatively medium to high permeability of the soils, and the exposed bedrocks of the watersheds. The following sections provide descriptions of the regional hydrology and hydrometeorology, drainage basin characteristics, flood flows, floodplain characteristics and water quality characteristics.

B3.1.1 Previous Work

The Ground Water Discharge Plan (GWDP) developed by Hydro-Engineering (1981) presents descriptions of the tailings disposal area and the berm designed to protect the tailings from the 100-year flood. D'Appolonia (1980) presented an analysis of the effects of the 100-year and probable maximum precipitation (PMP) events on tailings pond levels and the effects of the 100-year flood in a report titled "Stability Assessment - Uranium Mill Tailings Pile - United Nuclear-Homestake Partners."

B3.1.2 Regional Hydrology and Hydrometeorology

The HMC uranium mill site is located east of the Continental Divide in the Rio Grande Drainage System of west-central New Mexico (Figure B3-1). The mill site is in the San Mateo drainage. North of the mill the San Mateo is an ephemeral arroyo and flows in direct response to precipitation or snow melt events. There is no distinct channel near the mill, although there may have been one in formerly more pluvial times. A very large precipitation event could result in flow from the San Mateo drainage entering the Rio San Jose drainage. The Rio San Jose is itself ephemeral and flows only in direct response to local rain storms or snow melt. The Rio San Jose discharges to the Rio Puerco which is a tributary of the Rio Grande.

The U.S. Geological Survey (USGS) has maintained stream flow measurement gages on several streams in this region. Table B3.1 provides a summary of drainage area, periods of record, and minimum, mean, and maximum flows. Figure B3-1 shows the locations of the gages. It is evident from Table B3.1 that most flow in this region is ephemeral or intermittent. No definite relationship between the size of the drainage basins and the mean flow or the maximum recorded flow is evident. Variations in watershed characteristics such as vegetation, slope, soil, channel material and differences in water use apparently are great enough that they cancel or overpower a simple relationship between basin size and flow. These differences indicate that it is difficult to predict flow regimes using regional characteristics and that each watershed must be investigated separately.

The climatic characteristics of the area, as discussed in Section B2.0, affect the hydrology of the region in many ways. The low annual precipitation, most of which occurs during brief, intense storms, support only ephemeral stream flow. Even those drainages in higher elevations with increased precipitation and spring snowmelt are predominantly ephemeral since much of the flow is lost to the alluvium. Flows occur primarily as a result of the fairly common summer thunderstorms. These intense storms cause local flash flooding and erosion. The low precipitation and the high temperature cause vegetation, in some places, to be sparse with large amounts of open ground between shrubs or forbs. The open ground, where present, contributes to surface runoff and sheet erosion during the thunderstorms.

B3.1.3 Drainage Basin and Water Course Characteristics

The San Mateo drainage basin above the HMC mill site (Figure B3-2) has a drainage area of approximately 291 square miles. Its shape is roughly circular and it contains a dendritic (tree-branch style) drainage pattern. Maximum relief is 4,724 feet with elevations ranging from 6,576 feet at the outlet to 11,300 feet at Mount Taylor.

Channel slopes in the basin range from nearly zero in the valley floor near the site to almost 50 percent at the higher peaks. Figure B3-3 shows the profile of the San Mateo drainage as well as the Arroyo del Puerto. The slopes on the flanks of the mesas and volcanic cones can vary from five to over 100 percent. The steeply sloping upper reaches of the drainage and its tributaries are commonly incised from 10 to 30 feet into the valley alluvium. Where slopes are low, such as near the mill site, flow follows shallow, poorly-defined, braided channels.

The only surface water bodies are several stock ponds, some small ephemeral ponds, and an undetermined number of springs on the flanks of Mount Taylor. None of these water bodies are affected by mill opera- operations.

Surface materials of the basin vary greatly in character. The Quaternary basalt flows, which cover a portion of the watershed, are relatively unweathered with little or no soil development on the surface. The basalt flows are so highly fractured and broken that infiltration of precipitation is almost immediate. Other highland areas are covered with soils derived from sedimentary and igneous formations, predominantly sandstones and basalt. These soils are usually thin but quite permeable. Alluvial materials fill the valley bottoms to varying depths which in some places exceed 120 feet. The alluvium is generally sandy silt with upper and lower horizons of sand and gravel.

The infiltration capacity of the alluvium varies greatly. Some reaches of the drainage are filled with deposits of well-graded sand into which channel flow infiltrates. Similarly, small arroyos which are tributary to the main drainage and drain mesa slopes may lose their flow by infiltration to the alluvial materials in the low slope areas.

The vegetation of the watershed generally does not provide a complete canopy cover and is sparse in some places, although at the upper elevations of Mount Taylor, pine, spruce and fir forests with understories of shrubs and grass provide 100 percent canopy cover. The vegetation of

the lower elevations consists of bunch grasses, forbs and shrubs, sometimes widely spaced, while pinyon and junipers predominate the intermediate elevations.

B3.1.4 Flood Flows

The peak discharge derived from the one-, six- and 24-hour storms with recurrence intervals of 100 years, as required by NMEID (1981), was estimated with the use of a computerized version of the U.S. Soil Conservation Service's (SCS's) synthetic triangular hydrograph method. This method uses basin soil and vegetative cover characteristics to derive a curve number (CN) that represents the basin's runoff-producing potential. Parameters of basin geometry, such as maximum relief and longest drainage path, are used to calculate a synthetic triangular unit hydrograph. The computer program distributes precipitation over time according to the graph shown in Figure 21-2 of the U.S. SCS National Engineering Handbook, Section 4, Hydrology (U.S. SCS, 1972). This precipitation distribution is then applied to the synthetic hydrograph to calculate the runoff hydrograph.

Input values for this method consisted of basin area of 291 square miles, maximum relief of 4,725 feet, and longest drainage path of 26.0 miles. The combination of predominantly widely spaced vegetation and fairly permeable soils provided a curve number of 70 for the basin as a whole. The precipitation amounts for the 100-year storms with durations of one-, six- and 24-hours were determined through the use of the NOAA Precipitation Frequency Atlas for New Mexico (NOAA, 1973). These amounts, adjusted for area reduction factors, are presented in Table B3.2.

The results of the 100-year peak discharge calculations are also shown in Table B3.2. The one-hour storm produces little surface runoff since most of its 1.10 inches infiltrates into the soil or is intercepted by vegetation and surface depressions. The six- and 24-hour storms produce similar results, showing that the intensity of the six-hour storm is nearly matched by the longevity of the 24-hour storm.

B3.1.5 Floodplain Determination

The U.S. Army Corps of Engineers water surface profile computer program, HEC-2, was used to calculate the surface width, elevation and flow velocities of the 100-year flood near the mill site. The HEC-2 program solves backwater curves for both subcritical and supercritical flows. Input requirements include digitized channel and overbank area cross sections, channel and overbank area roughness coefficients, distances between cross sections, and the stream flow (Hydrologic Engineering Center, 1976).

Figure B3-4 shows the area of interest around the HMC mill site. This site is a complex area of berms, abandoned ditches, closed drainage areas and natural flow braids. The cross sections shown on Figure B3-4 were surveyed with laser-activated surveying equipment in October of 1980 and also in November of 1981.

The resistance to the flow of water provided by channel materials, vegetation, bends and meanders and channel bottom configurations is characterized by the Manning coefficient "n". An n value of 0.05 was chosen for both the overbank and channel areas because the channels are quite small compared to and nearly indiscernible from the overbank areas. The forbs and shrubs of the overbank areas provide the most resistance to flow. The 100-year flood of 5,981 cubic feet per second (cfs) as shown in Table B3.2 for the six-hour storm was used for the maximum flood flow discharge.

Figure B3-4 shows the 100-year floodplain boundary as calculated by the HEC-2 program. Also shown are the water surface elevations at the cross sections. It is evident that the flood will reach the retaining berm that protects the west end of the tailings embankment. This berm, as shown on Figure B3-5, has been built up to an elevation of 6,582.4 feet above sea level by HMC so that none of the flood waters will encroach upon the tailings facility. The retaining berm will direct the flood out and away from the embankment toe.

B3.1.6 Quality of IX Plant Discharge

The IX facility, whose location is shown in Figure A2-1, processes mine discharge water to recover uranium and to reduce the amount of radionuclide constituents. The discharge from the facility has been sampled twice to determine its radionuclide concentrations in accordance with HMC's radiological monitoring plan. The results of the sampling are shown in Table B3.3 while Table B3.4 provides the MPC's for each radionuclide. Comparison of the measured concentration with the MPC reveals that all of the discharge concentrations are well below those of the MPC's. Thus, the IX facility discharge, which empties into Arroyo del Puerto, presents no radiological hazards to any surface water users.

B3.2 GROUNDWATER

The Applicant is continuing its investigation of the hydrogeologic regime and hydrogeochemical data in the vicinity surrounding the mill and tailings disposal area. With respect to groundwater quality, the provisions of the NMEID Radiation Protection Program require HMC to provide information on radionuclides only. However, this section also discusses sulfate and selenium concentrations. The following provides a summary of information that has been collected and compiled to date. The GWDP filed by the Applicant with NMEID provides more detailed information on this subject.

B3.2.1 Previous Investigations

In 1974, the New Mexico Environmental Improvement Agency (now the Environmental Improvement Division, or NMEID) requested that the U. S. Environmental Protection Agency (U.S. EPA) assist in a survey of the uranium mining and milling activities of the Grants Mineral Belt to determine the impact of these activities on surface water and groundwater in the area. A sampling program was undertaken early in 1975. The EPA study concluded that groundwater in part of the shallow aquifer downgradient from the Homestake mill exhibited elevated selenium concentration.

Several residents of two subdivisions south and west of the HMC mill were notified of the elevated selenium concentrations. It was recommended that they refrain from using such water for domestic purposes. Subdivision residents visited HMC's operation to discuss the groundwater situation. HMC voluntarily set up a program to distribute bottled water whose quality met the approval of the NMEID for drinking and cooking purposes. HMC also designed and implemented a complex hydrological assessment to identify the water movement in the alluvial aquifer. The hydrological assessment titled "Ground Water Hydrology of the Alluvium at UN-HP (now HMC) Mill near Milan, New Mexico" (Science and Engineering Resources, Inc., 1976) was prepared after extensive sampling of subdivision wells, existing HMC wells, and over 40 new wells drilled specifically for the study. This report was submitted to the NMEID in October 1976.

A Ground Water Protection Plan Agreement was entered into with the NMEID on August 18, 1976 (United Nuclear-Homestake Partners, 1976). The agreement provides that HMC would design and construct a system to contain seepage from HMC's tailings pile to shallow groundwater in the area, and at the same time, provide a method to reduce selenium levels in the alluvium in the Broadview and Murray Acres subdivisions to background levels, regardless of the source or sources of selenium. The agreement also provides for a cooperative NMEID/HMC groundwater monitoring program to verify the results of the groundwater protection effort.

As a result of the agreement, HMC installed a net of interceptor wells designed to inhibit any potential future tailings seepage from getting beyond that hydrologic boundary, as well as to draw back into the net as much seepage as possible that may have already escaped. In addition, a line of recharge wells was installed on HMC's property, downgradient of the interceptor wells, to inject fresh water from the San Andres aquifer into the alluvial aquifer from which the domestic wells serving the Broadview Acres subdivision produce their water. The purpose of the

recharge well system is to obtain a quality of groundwater, through adsorption, dilution and dispersion, equivalent to that found in background wells. The basic document for this system was a report titled "Modelling, Design and Specifications of the Collection and Injection Systems at United Nuclear-Homestake Partners Mill" dated January 1977 (Science and Engineering Resources, Inc., 1977), which was submitted to the NMEID. An extensive groundwater monitoring program was also implemented. NMEID approval was obtained prior to each phase of this program.

HMC has been operating its Ground Water Protection Program under the agreement since 1976 (United Nuclear-Homestake Partners, 1976). In September 1980, a report evaluating the performance of the corrective system was submitted to the NMEID. The report is titled "Review of Broadview Acres Injection System at United Nuclear-Homestake Partners Mill Near Milan, New Mexico" (Hydro-Engineering, 1980). In addition to the agreement, HMC has been operating under an approved discharge plan (DP-102) for the protection and cleanup of the alluvial aquifer in Murray Acres. It was proposed that these two discharge plans be combined into one overall document.

The GWDP for the HMC mill was submitted to the NMEID in December 1981 (Hydro-Engineering, 1981). The GWDP combined the results of all previous HMC investigations. The GWDP submittal should be referred to for the results of the data submitted to the NMEID to date and for plans for continuing studies.

B3.2.2 Site Hydrogeology

The HMC mill and tailings embankment are located on an alluvial system which extends from the Mount Taylor and Ambrosia Lake areas downgradient to the point where it joins the Rio San Jose alluvial system, which extends from the Bluewater area to south of Milan and beyond (Figure B3-6). Figure B4-2 shows the surface geology of the area. Geologic information has been taken from Thaden and Ostling (1967); Thaden, et al. (1967a); Thaden, et al. (1967b); and Gordon, et al. (1961).

Geologic units can be grouped as follows to simplify the hydrologic setting:

GROUPED GEOLOGIC UNIT	UNITS GROUPED TOGETHER
Alluvium (Qal)	Alluvial deposits, dune sand
Colluvium (Qc)	Colluvial deposits, talus, landslide blocks
Basalt (Qbt)	All basalt flows, cones and dikes
Cretaceous and Jurassic (K-J)	All Cretaceous and Jurassic sedimentary rocks
Chinle Formation (Trc)	Chinle Formation
San Andres Limestone (Ps)	San Andres Limestone

These units were grouped in this manner because the divisions are important hydrological barriers to the three formations (alluvium, Chinle, and San Andres) that underlie the mill site. A discussion of these aquifers is contained in Section B3.2.3. The three uppermost geologic units near HMC's mill are the alluvium, Chinle Formation, and the San Andres Limestone.

The areal extent of the alluvial aquifer is significantly less than the area of alluvial outcrop, because it is saturated in only its deeper portions. The alluvium and basalt flows to the west of the mill form one aquifer system. The Chinle Formation lies under the alluvium, and the Chinle Formation is in turn underlain by the San Andres. The San Andres Limestone is a massive limestone with interbedded sandstones and is the major high-volume water-producing aquifer in the area. The Chinle Formation consists mainly of shales and siltstones with interbedded very fine to fine-grained sandstones (Gordon, et al., 1961). Below the HMC mill, the Chinle Formation is approximately 850 feet thick. Drilling in the area of the tailings piles has shown that the upper portion of the Chinle Formation in this area is shale. The permeability of the shale is low; therefore, the Chinle acts as the bottom of the alluvial aquifer and will retard movement of seepage downward.

Numerous faults are shown on the surficial geologic map, Figure B4-2. Two concealed faults in the area of HMC's tailings disposal site are of interest to this project. Faulting occurred prior to deposition of the alluvium. The prealluvial faulting could have influenced the erosional development of the prealluvial surface but should not be affecting the alluvial aquifer flow system. Correlations of the Chinle sandstones from geophysical logs (see Chapter 3.0 of the GWDP) have shown that the two concealed faults are west and east of the locations shown on the geologic map (Thaden et al., 1967b). The west and east faults are a few hundred feet west and east of the active tailings pile. The east fault is located close to the eastern edge of the inactive tailings pile. Pump tests in the Chinle aquifers (see Chapter 3.0 of the GWDP) have shown that these faults react as impermeable boundaries in these aquifers. The faults near the tailings piles are not significant to this project except that they have bounded the Chinle aquifers to a narrow strip running from the south to the northeast of the tailings.

B3.2.3 Aquifers

As indicated above, three water-bearing formations underlie the mill site. The following is a discussion of the properties of these aquifers.

San Mateo Alluvium

The tailings embankments are located directly upon the San Mateo alluvium. The alluvium trends southwest, being bounded on the northwest and southeast by bedrock highs. In the mill area the alluvial aquifer is about 1.0 to 1.5 miles wide. The alluvium ranges from about 40 to 120 feet thick over the site. The saturated thickness of alluvium ranges from zero to 60 feet. In general, depths to the water table are in the 40- to 60-foot range.

Numerous pumping and recovery tests were performed on alluvial wells. Hydraulic conductivity values typically fall in the range from 10 to 100 feet per day. Transmissivity values range from about 15 gallons per day

per foot (gpd/ft) in areas of little saturated thickness to about 16,000 gpd/ft where the saturated alluvium is thickest. The specific yield of the alluvial aquifer is estimated to be about 0.05 to 0.30.

Groundwater in the San Mateo alluvium is flowing mainly south-southwest on the north side of HMC's mill. The flow direction changes to a more southwesterly direction south and west of the mill (Figure B3-7). The water table gradient upstream of the mill averages 0.0047 feet per foot. The gradient flattens to approximately one-half this value down gradient of the mill. The flux through the alluvial aquifer at the mill site is estimated to be about 58 gpm.

Chinle Sandstone

Certain zones or areas in the Chinle Formation also yield water. The upper portion of the Chinle Formation near the tailings disposal area, however, is shale which may be expected to act as a barrier to vertical groundwater movement. The head difference between wells completed in sandy portions of the Chinle Formation and alluvial wells is approximately 30 to 40 feet, indicating a lack of hydraulic connection.

San Andres Limestone

The San Andres Limestone is the next geologic unit below the Chinle Formation. The Chinle Formation is approximately 850 feet thick at HMC's mill and consists mainly of shales and siltstones. Therefore, a very thick aquitard exists between the alluvial and San Andres aquifers in the mill and tailings disposal areas. The difference in the piezometric heads between the alluvial and San Andres aquifers is in the range of 70 to 80 feet, indicating that flow between the two systems must be retarded. The San Andres aquifer is discussed further, not because of potential contamination by tailings seepage, but because it is the source of water for the mill and Broadview Acres injection system.

Wells 1 and 2, shown in Figure B3-8, are HMC's two San Andres water-supply wells. The water from both of these wells is used in the mill, and water from Well 2 is used in the Broadview Acres injection system. Wells 1 and 2 are 1,000 and 870 feet deep, respectively. The depth to water in San Andres Well 928, which is approximately one mile north of the HMC wells, was 140.25 feet on October 15, 1981 (water-level elevation equal to 6457.4 feet above mean sea level). Slightly (five to ten feet) smaller values of depth to water and water-level elevation would be expected for the HMC wells if their water levels were allowed to fully recover. The direction of groundwater flow in the San Andres aquifer in the area of HMC's mill is mainly toward the east (Hydro-Search, Inc., 1981). Water-level depths were 133.8 and 122.4 feet on May 22, 1958 and October 13, 1955 (Gordon, et al., 1961) for Wells 1 and 2, respectively. This indicates that the water levels were roughly ten feet lower in the San Andres aquifer in October 1981 than they were before the mill began operations.

The transmitting ability of the San Andres aquifer is high and the aquifer's transmissivity was determined to be 460,000 gpd/ft from pumping test data (Gordon, et al., 1961).

B3.2.4 Groundwater Use

The San Mateo alluvium has historically supplied water for domestic, livestock, and minor irrigation uses from individual wells in the Broadview and Murray Acres subdivisions. In the newer Felice Acres subdivision, all wells are required to be completed in an aquifer below the alluvial aquifer. The first known locations of present alluvial water use downgradient of Broadview Acres are Wells 905 and 910 (Figure B3-6), which are about 14,000 feet and 16,000 feet downgradient of the mill tailings piles, respectively.

The Chinle Formation has also historically provided water for domestic and livestock use, and minor irrigation uses from individual wells at Murray Acres and to a lesser extent at Broadview Acres. The Chinle

Formation consists primarily of shale and siltstone, but interbedded fine to very fine-grained sandstones provide water to wells. Domestic wells in the Felice Acres subdivision also obtain water from the Chinle Formation.

The San Andres Limestone is a massive limestone with interbedded sandstones. It is the major high-volume water-producing aquifer in the area. It supplies process water to the HMC mill, as well as water for the Broadview Acres injection system.

B3.2.5 Monitoring, Collection and Injection Wells

Forty wells were drilled in 1975 and 1976 to define the groundwater hydrology of the alluvial aquifer near HMC's mill. Slightly more than 70 additional alluvial wells have been drilled since 1976 to further define the alluvial system and to implement injection and collection systems. The locations of all wells are shown in Figure B3-8.

All of the alluvial wells installed by HMC since the Ground Water Protection Program commenced in 1976 were drilled to a minimum of five to ten feet into the Chinle Formation to ensure that they completely penetrated the alluvial aquifer. Polyvinyl chloride (PVC) casing was used to minimize chemical reactions between the well casing and the groundwater. A blank, or solid, section of casing was placed in the bottom of each hole where the Chinle Formation was penetrated. Slotted casing was then placed in the alluvium through the saturated zone and blank casing was used to complete the well to about 1.0 to 1.5 feet above the ground surface. Coarse blasting sand was used to pack the wells from the bottom to about ten feet above the slotted casing. Pea gravel was then used to fill the annulus to within ten feet of the ground surface, followed by bentonite to about three feet below the ground surface. The hole was then finished with a cement plug.

HMC has monitored ground water to ensure compliance with the AEC and NMEID radiation protection requirements since 1958 when the mill

commenced operations. An expanded monitoring program was commenced in July 1981. Seven wells are monitored on a quarterly basis. Groundwater samples from the wells are analyzed for natural uranium, radium-226, thorium-230, and lead-210. Three of the monitoring wells (Wells P, Q and R) are located upgradient from the mill and tailings disposal area to substantiate background water quality. Three additional monitoring wells (Wells BC, B and I) are downgradient from HMC's mill and tailings disposal area to determine the effects of the operation's tailings impoundment on the regional groundwater in the alluvium. In addition, Well F is monitored downgradient inside the restricted area near the closest residence. Figure B3-8 shows the locations of these wells and Table B3.5 provides the radionuclide analyses.

Additional groundwater sampling for both radionuclide and chemical parameters is conducted by HMC. This sampling is conducted to address HMC's Ground Water Protection agreement or Discharge Plans with NMEID - Water Quality Control Bureau. A summary of the data contained in the Ground Water Protection Plan submitted to NMEID in November 1981 (Hydro-Engineering, 1981) pertaining to the monitoring, collection and injection wells is presented below.

Monitoring Wells

The main monitoring wells at the mill site (Wells P, Q, R, DD, BB2, BC, W2, B, FB, F and I), as shown on Figure B3-8, are monitored for key parameters on a quarterly basis (Table B3.6). Key parameters consist of water level, pH, TDS, sulfate, chloride, uranium, selenium, and molybdenum. Sulfate, chloride, and TDS are included because their concentrations must meet New Mexico State groundwater standards and because they are good indicators of certain minor element concentrations. Uranium, selenium and molybdenum were selected because they have been measured in elevated concentrations in water from the alluvial aquifer. Other parameters monitored on a yearly basis include bicarbonate, carbonate, sodium, calcium, magnesium, potassium, and radium-226. The major constituents are used primarily to check the valence charge

balance of the analyses. A charge balance is computed as part of the monitoring program for these samples. Radium-226 was added to show that this constituent is not being transported at significant concentrations. Samples from the main mill monitoring wells (Table B3.6) are split and labeled differently once a year to demonstrate analytical precision.

Nearly all remaining HMC wells are included in a secondary list of wells which are sampled twice a year. One sample a year is analyzed for all of the major constitutents while the other semiannual sample is analyzed for the modified list of parameters (Table B3.6). All active collection wells are monitored on a monthly basis for water level, sulfate and uranium. These wells are sampled for the complete list of parameters (Table B3.6) twice a year. The discharge from the collection wells is monitored on a weekly basis. The water level management wells (Wells DM, DN, D, DP, DQ, DZ, M1, SO, SP, S and BC) are measured weekly for water levels. Semiannual samples are collected from Deep Well No. 2 to define the injection water quality. Parameters on the State's groundwater regulation list, plus bicarbonate, carbonate, sodium, calcium, magnesium, and potassium are determined for these samples.

Several wells are proposed for monitoring in the Broadview Acres, Felice Acres, Murray Acres, and Pleasant Valley subdivisions. Wells 490 and 492 were drilled and completed only in the alluvium for monitoring purposes. Well 953 has not been drilled but will be located west of Felice Acres in order to monitor the alluvial aquifer downgradient. This well will be installed and sampled in June 1982. Table B3.6 provides information on the wells to be sampled, frequency, and parameters. A few alluvial wells in the region are monitored on an annual basis and analyzed for the long list of constituents.

Collection Wells

The S and D lines of collection wells (on the west and south sides of the tailings pile, respectively) were designed to intercept seepage to

the alluvial aquifer from the active tailings pile, tailings collection channel, and the two decant ponds (Figure B3-8). The collection wells are downgradient of each of these areas and have been in operation since July 1978. The total pumping rate from these wells has been below the proposed discharge rates until recently because several of the wells (Wells SC, S, DA, and EE) have been pumped infrequently as a result of chemical plugging problems and Wells DB and DE have not produced their designed rates.

The total collection rate of 270 gpm as of October 1981 was close to the designed rate of 280 gpm. Wells DB and DE have been redrilled but still do not yield their designed rates. Additional wells between these wells are being drilled to obtain the desired discharge in this area of the D line. The west section (Wells DA, DB, DE, and EE) of the D line has not produced at its designed rate, but the additional wells will enable the pumpage of the desired rates. The east section of the D line has operated above its designed rate. Six additional wells (Wells DI, DJ, DK, DL, TA, and TB) have been added to extend the D line to the east (Figure B3-8). The S line is producing above its designed rate but two new wells (Wells SD and SE) had to be drilled to obtain additional good producing wells. The total discharge of the collection wells was about 100 gpm for the first three years of pumping. Total discharge in October 1981 averaged 270 gpm with 16 wells producing.

A continuous drawdown cone has been developed on the downgradient side of the active tailings pile from north of the S line to east of the D line (Figure B3-8). The SO and SP Wells demonstrate a reversal of flow direction downgradient of the S collection line. The new monitoring Wells DP and DQ, which are between collection Wells DF and DG, demonstrate a reversal in that area of the D line. A reversal has been developed twice in the area of monitoring Wells DM and DN between collection Wells DB and DE, but as of November 1981, did not exist because of low pumping rates in this area. Additional collection wells are being drilled near collection Wells DB and DE to obtain the necessary

pumping rates. Once operational, these wells should enable a reversal to be developed in this area within a few months.

The original Murray Acres collection system program consisted of pumping three alluvial wells (Wells AW, HW, and 801) and pumping commenced on September 16, 1980 (Figure B3-8). Pumping from Well HW has stopped to avoid drawing poorer quality groundwater into the area. Pumping from two additional collection Wells WR2 and WR3, which were installed upgradient of the Murray Acres subdivision, has recently been started. Well 801 was replaced by Well WR1 because of sand accumulation in Well 801.

The purpose of the Murray Acres collection system is to reduce concentrations of adverse water quality constituents in the groundwater in the northeast corner of Murray Acres. Injection of better quality water is proposed after the collection phase of the program. The total pumping rate of the Murray Acres collection wells has averaged about 50 gpm since September 1980. Drawdowns in nearby wells have been only about one-half foot or less, but should increase with time.

The K line of collection wells is located on the southwest side of the old tailings pile (Figure B3-8). The wells are designed to intercept seepage from the old tailings pile. Pumping from these wells has not as yet commenced due to the impermeable nature of the alluvial material in the area. Most of the wells in the area produce less than one gpm. Further evaluation of the area to increase collection rates is currently underway.

Injection Wells

Six injection wells (Wells G, GG, GA, GB, GC, and GD) were designed to inject water along HMC's southern property line to improve the water quality in the Broadview Acres alluvial aquifer (Figure B3-8). The source of the injection water is HMC's Deep Well No. 2, which is completed in the San Andres aquifer. Wells GH, H, Sub-1, Sub-2, Sub-3, and Sub-4 are used to evaluate the water level changes. Consent to use

Wells Sub-3 and Sub-1 for monitoring was lost in September 1978 and May 1979, respectively. Permission to again use Well Sub-3 was obtained in September 1980. A change in the well head of Well Sub-4 made it inaccessible for water level measurements after September 1978. Injection into the extension injection wells (Wells GE, GF, GI, GJ, GK, GL, GM, and GN), which were installed in January 1981, was started in February 1982.

The original injection wells (Wells G, GG, GA, GB, GC and GD) have been operated for three separate periods: from June 3, 1977 to December 30, 1977; from May 8, 1978 to January 24, 1979; and from April 10, 1979 to October 1981. Average total injection rates of 50.5, 76, and 48 gpm were measured for these three periods, respectively. The average for the entire period, including downtime, through October 1981 was 47 gpm. The current injection rate into all of the injection wells as of April 1982 is approximately 350 gpm.

B3.2.6 Groundwater Quality

The San Mateo alluvial system extends upgradient of HMC's mill to the Mount Taylor and Ambrosia Lake mining areas. In the mined areas, waters discharged from the mines enter the San Mateo alluvium. In addition, outcrop areas within the San Mateo alluvial system contain deposits of selenium, uranium, and other heavy metals. Therefore, runoff from these outcrop areas naturally contributes quantities of these substances to the alluvial aquifer.

As part of the radionuclide monitoring plan, HMC initiated a groundwater monitoring program in July 1981. Seven wells, described earlier, are included in the monitoring program. The results of the monitoring are listed in Table B3.5. These results may be compared to the MPC for release beyond the restricted area (NMEID, 1980) which are listed in Table B3.4. Results of the two quarterly samples presented in the table show that radionuclide concentrations upgradient and downgradient from the tailings disposal area are well below the New Mexico MPC standards

for radionuclides. The concentration of radionuclides upgradient and downgradient are essentially the same indicating that the tailings disposal area has not elevated the radionuclide concentration downgradient in the San Mateo alluvial system.

The following discussion on groundwater quality presents a brief summary of the findings from the GWDP (Hydro-Engineering, 1981) on data collected since 1976. The only nonradionuclide parameters that are addressed in detail in this section for information purposes are selenium and sulfate. Details on total dissolved solids (TDS), chloride, nitrate, and molybdenum are contained in the GWDP.

Water quality has been monitored in four alluvial wells (Wells DD, P, Q, and R) upgradient of the HMC mill since 1976 (Figure B3-8). All water quality parameters have met New Mexico standards (Table B3.7) except for TDS, sulfate, and selenium. In 1976, sulfate concentrations in the four upgradient wells ranged from 864 to 1,940 milligrams per liter (mg/l). By 1981, the concentrations measured were 723 to 1,580 mg/l. Selenium concentrations ranged from 0.08 to 0.23 mg/l in 1976 and 0.02 to 0.17 mg/l in 1981. The concentrations are upgradient from the mill, and thus do not include contributions from seepage of tailings liquid.

Elevated concentrations of TDS, sulfate, uranium, selenium, nitrate and molybdenum have been detected in groundwater from alluvial wells in the mill area and downgradient of the mill in some wells in the Broadview Murray Acres subdivisions. TDS, sulfate, selenium, nitrate and molybdenum concentrations upgradient of the tailing pile have been observed to be above the State groundwater standards. The GWDP (Hydro-Engineering, 1981) provides detailed information concerning downgradient chemical parameters. A more complete discussion of mill-related water quality impacts and efforts to mitigate them is provided in Section C6.2.3, Groundwater Contamination and Extent.

The water quality of the alluvial aquifer just downgradient of the Murray Acres and Pleasant Valley subdivisions was sampled from Wells 939, 940, and 942. The major constituents show concentrations very similar to concentrations in HMC's background wells. The minor element and radionuclide concentrations are below the maximum background levels and below the New Mexico numerical standards.

The first known locations of present alluvial groundwater use downgradient of Broadview Acres are Wells 905 and 910. The major water quality constituents at these two locations show concentrations lower than those measured from HMC's background wells. Minor element and radionuclide concentrations are below groundwater standards.

The water quality in the San Andres limestone is fairly good. Sulfate and selenium concentrations have occasionally been found in excess of State numerical standards, although lower than natural background levels in the alluvial aquifer. Other parameters have concentrations similar to or lower than background levels in the alluvial aquifer. The maximum concentrations of selected constituents in injection water from Deep Well No. 2 are presented in Table B3.8. Injection of Deep Well No. 2 water into the alluvial aquifer should achieve a dilution of constituents in the alluvial groundwater in and around Broadview Acres.

B4.0 GEOLOGY AND SEISMOLOGY

B4.1 REGIONAL GEOLOGY

The project area is located on the northeast flank of the Zuni Uplift (Figure B4-1), a tectonic feature which is characterized by a core of Precambrian crystalline basement rocks, partially mantled by Permian and Triassic sedimentary rocks. The Zuni Uplift is surrounded by several tectonic depressions, including the Gallup Sag to the west-southwest, the Acoma Sag to the southeast, and the San Juan Basin to the north. These negative tectonic features are generally underlain by late Paleozoic, Mesozoic, and Cenozoic sedimentary rocks.

The Precambrian core of the Zuni Uplift crops out in a northwest-trending, elongate mass approximately 45 miles long and six miles wide, centered 15 miles southwest of the project area. Sedimentary rocks that flank the uplift dip gently away from the Precambrian core to a maximum thickness of over 14,000 feet in the center of the San Juan Basin, located approximately 100 miles north-northeast of the project area.

Late Cenozoic volcanism resulted in deposition of a wide range of extrusive volcanic rocks in a broad belt extending from the southern edge of the Zuni Uplift northeast to Mount Taylor and beyond. Major eruptive centers include Mount Taylor, located approximately 15 miles east of the project, El Tintero which is located 10 miles northwest of the site, and the Zuni Mountains, centered approximately 30 miles southwest of the project.

Major faults occur along the southwest flank of the Zuni Uplift, and a number of minor faults are mapped in the remainder of the region surrounding the project area. Faults associated with the Zuni Uplift are generally northwest-trending, steeply-dipping reverse faults, which have resulted in tilting of the Precambrian core and overlying Mesozoic sedimentary strata to the northeast. Minor steeply-dipping normal and reverse faults in the region around the project area generally trend

northeast and displace rocks as young as Tertiary in age. However, none of these faults are considered to be active.

B4.2 SITE PHYSIOGRAPHY AND GEOLOGY

B4.2.1 Physiography

The project area lies in the Colorado Plateau Physiographic Province at an elevation of about 6,600 feet (Figure B4-2). The site is surrounded by mesas ranging in elevation from 7,000 to 8,600 feet which define a roughly circular valley approximately 10 miles in diameter. Mount Taylor, the tallest peak in the region, is 11,300 feet in elevation and is located 15 miles east of the site. Slope gradients in the area generally range from zero to five percent in valleys and on mesa tops, and from five to over 100 percent on the flanks of mesas and on the few nearby volcanic cones and peaks.

The project area lies in the San Mateo drainage. The San Mateo drainage runs roughly north to south and connects with the Rio San Jose near the town of Milan. The southern portion of the drainage has been modified extensively by diversion and other features. The ephemeral flow consequently reaches the Rio San Jose only during very extreme discharge events. Flow in the Rio San Jose, itself ephemeral, would join the Rio Puerco if sufficient in volume. The Rio Puerco drainage is connected to the Rio Grande Valley.

Where the gradient is steep in the northern San Mateo drainage, intersecting arroyos are commonly incised from 10 to 30 feet into valley alluvium. Where gradient decreases, incision is minimal and flow is contained in wide, shallow, poorly defined channels or there is no channel at all and flow, if any, occurs as sheet flow. Some incised reaches of the San Mateo drainage north of the site have been partially filled with deposits of clean, loose sand, and except when there is high discharge, the flow disappears. A number of small tributaries which drain mesa slopes similarly terminate to become underflow at their debouchment onto the valley floor.

Small catchments or basins occur on the gently sloping, wide valley surface along the lower reaches of the San Mateo drainage. Most of these basins are on low areas that appear to be former channels from previously more pluvial times. Lava flows west of the site that were erupted from El Tintero have diverted or blocked flow paths of a number of very small drainages. Basins have formed along the edge of the lava flows where the drainage courses have been blocked.

B4.2.2 Stratigraphy

The region is underlain by Precambrian crystalline rocks, Pennsylvanian to Cretaceous sedimentary rocks, and Miocene to Quaternary volcanics (Figure B4-1). Two major unconformities are present. One is between the crystalline basement rocks and the sedimentary sequence, and the other is between the sedimentary rocks and the volcanics. The geologic map of the study area is shown in Figure B4-2 and the type-stratigraphic column illustrating the stratigraphic, lithologic, and age relationships of the rocks is shown in Figure B4-3. Information on the geology in the vicinity of the site is derived from Thaden and Ostling (1967), Thaden, et al. (1967a), Thaden, et al. (1967b), and Gordon, et al. (1961). Precambrian crystalline basement rocks are exposed in the Zuni Mountains southwest of the site. These Precambrian rocks are comprised of granite, schist, and gneiss, with schists exposed along the contact with sedimentary rocks in the Zuni Uplift.

Unconformably overlying the Precambrian basement locally are undifferentiated Pennsylvanian sedimentary rocks, which include interbedded sandstone, limestone, and shale. Limestone units in the Pennsylvanian section may belong to the Sandia and overlying Madera Formations. Pennsylvanian rocks were encountered in deep boreholes west of the mill site; however, they do not crop out near the site.

The oldest sedimentary rocks exposed in the region belong to the Permian Abo Formation, which lies unconformably on the Precambrian core of the Zuni Uplift. The Abo Formation also was encountered overlying

Pennsylvanian sedimentary rocks in deep wells west of the mill site. The Abo Formation is dominantly red siltstone and claystone with sandstone and limestone nodules or inclusions, and interbedded sandstone and limestone lenses.

Overlying the Abo Formation is the Permian Yeso Formation, which is comprised of the basal Meseta Blanca Member, a middle transitional unit, and the upper San Ysidro Member. The Meseta Blanca Member is generally a red to orange, massive, fine-grained sandstone. The transitional unit grades from the Meseta Blanca Sandstone upwards into the San Ysidro Member, which is composed of light red to maroon or mottled, fine-grained, cross-bedded sandstone, with interbedded claystone and evaporites near the top of the unit.

The Permian San Andres Formation overlies the Yeso Formation, and is composed of the basal Glorietta Sandstone Member and the upper San Andres Limestone. The Glorietta Member is composed of white to gray or buff, medium- to coarse-grained quartzose sandstone, and thin, interbedded siltstone. The sandstone contains both cross-bedded and planar-bedded units. The upper portion of the Glorietta Sandstone is tightly cemented, probably as a result of downward migration of calcium carbonate from the overlying limestone, whereas the lower portion of the unit is soft and friable. Iron pyrite is commonly disseminated throughout the sandstone unit. Total thickness of the Glorietta Sandstone Member is approximately 200 feet near the mill site.

Overlying the Glorietta Member is the San Andres Limestone Member, which is exposed several miles southwest of the site (Figure B4-2). The San Andres Limestone is comprised of a 20 foot thick basal unit of dense gray limestone with streaks and zones of coarse-grained calcite, overlain by a 15 foot thick middle unit of yellow, cross-bedded to massive sandstone, and in turn overlain by an 80 foot thick upper unit of grayish-yellow and brown to red, dense limestone with interbedded yellow, fine- to medium-grained, cross-bedded to massive sandstone. The

San Andres Formation is an important aquifer and yields large quantities of water to major users in the area.

The Triassic Moenkopi Formation unconformably overlies the San Andres Formation. The Moenkopi Formation is comprised of pale reddish-brown and grayish-red arkosic and micaceous sandstone, cross-bedded near the top with planar beds near the base, and interbedded with lenticular pebble conglomerate and layers of mudstone galls. The Moenkopi Formation is discontinuous, and ranges from zero to 26 feet thick near the mill site.

Unconformably overlying the Moenkopi Formation is the Triassic Chinle Formation. Beneath the mill and tailings impoundments, the Chinle Formation unconformably underlies the Quaternary alluvium. The Chinle Formation contains five members. Sandstone beds within the Chinle Formation locally yield water for domestic, stock, and irrigation use.

The lower member of the Chinle Formation is a variegated clayey and silty sandstone, interbedded with lenticular white, yellow, purple, and brown cross-bedded conglomeratic sandstone. Thickness of the lower member is approximately 300 feet.

The Sonsela Sandstone Bed of the Petrified Forest Member is the second lowest unit of the Chinle Formation. The Sonsela Sandstone Bed is the only stratigraphic unit of the Petrified Forest Member recognized in the Grants area. It is composed of white, pale yellowish-brown, yellow, and brown conglomeratic sandstone, with interbedded white, blue, purple, and brown claystone. The Sonsela Sandstone Bed is approximately 290 feet thick in the region.

The middle member of the Chinle Formation is comprised of reddish-brown, planar-bedded siltstone. Thickness of this unit is approximately 400 feet.

The Correo Sandstone Member is a pale grayish-red, fine-grained, cross-bedded arkosic sandstone with minor interbedded gray to pale brown pebble conglomerate. Thickness of the Correo Sandstone Member is approximately 75 feet.

The upper member of the Chinle Formation is composed of dark purplish-red and pale bluish-gray limy siltstone, interbedded with olive-gray to dark greenish-gray silty limestone in the top 180 feet, and with reddish-brown, planar-bedded siltstone in the bottom 150 feet. Total thickness of the upper member is approximately 330 feet.

The mesas which surround the lower portions of San Mateo valley are underlain by Jurassic and Cretaceous sedimentary rocks that are over 1,000 feet in total thickness. The Jurassic and Cretaceous sequence is composed mainly of sandstone, with some claystone and siltstone near the top of the section, and a prominent limestone in the middle of the sequence. The Jurassic/Cretaceous sequence is both topographically and stratigraphically above the mill site. These strata will not affect, or be affected by, operations in San Mateo Valley, so a detailed discussion of the rock types will not be made.

Tertiary volcanic activity centered around Mount Taylor resulted in deposition of basalt flows unconformably on the Cretaceous sedimentary rocks. These basalts now cap mesa tops to the south and east of the project area, and range from 10 to 50 feet thick.

Volcanism in the Quaternary Period resulted in deposition of the Malpais basaltic lava flows that had origins in the Zuni Mountains and El Tintero. The lava is very vesicular which gives it a clinkery appearance. The basaltic lava is very fresh, with little to no soil development on the surface. The flows are highly fractured and broken, with wide, open fractures. Total flow thickness in the vicinity of El Tintero is approximately 120 feet.

Quaternary alluvium fills the valley bottoms to depths of over 120 feet. The site is underlain by Quaternary alluvium (Figure B4-2). The alluvium is generally sandy silt; however, two distinct sand and gravel horizons occur at the top and the bottom of the unit. The lower sand horizon, which directly overlies the Chinle Formation beneath the site, is relatively continuous throughout the area and is used as a domestic aquifer in the region. The upper sand is discontinuous and may be lenticular.

B4.2.3 Structure

The geologic structure of the project area is related to the two dominant tectonic features of the region, the Zuni Uplift to the southwest and the San Juan Basin to the north-northeast. Major deformation of the Precambrian basement and the Late Paleozoic and Mesozoic sedimentary sequence occurred during the Laramide Orogeny, which took place between late Cretaceous and Eocene time (about 80 to 40 million years ago). Uplift in the area of what is now the Zuni Mountains, and subsidence of the San Juan Basin, established a regional dip to the north-northeast of approximately three to five degrees.

Major tectonic activity during the Laramide Orogeny resulted in formation of northwest-trending high angle reverse faults and uplift of the Zuni Mountains. A number of younger faults in the San Mateo and Rio San Jose valleys trend northeast and displace Tertiary volcanics, but not Quaternary volcanics (Figure B4-2). One of these, the San Mateo fault zone, lies approximately one mile west of the HMC mill. Individual vertical displacements on branches of the San Mateo fault zone range from five to 270 feet (Figure B4-4). Total vertical displacement of the fault zone is approximately 450 feet down to the southeast. Ancient movement of the faults has altered the otherwise relatively uniform regional dip of sedimentary rocks which underlie the site, although local dips are still rather gentle to the north-northeast (Figure B4-4).

B4.3 SEISMICITY

The project area is located within the southern part of the Colorado Plateau in northwestern New Mexico, a tectonically stable block characterized by a low level of seismicity. A number of geologic faults pass near the site (Figure B4-2); however, they are considered to be inactive since they do not displace nearby lava flows of Quaternary age (less than 1.8 million years) or express youthful geomorphic features indicative of active faults.

The historical seismicity in the region around the site indicates a low level of seismicity, as shown in Figure B4-5. The seismicity map was compiled from felt reports within a 60-mile (100-kilometer) radius centered around the Ambrosia Lake Quadrangle (located just north of the HMC mill) for events prior to 1962, and from instrumentally recorded earthquakes for the period from January 1, 1962 through December 31, 1980 (Sanford, 1981). The earthquakes in the vicinity of the site are typically microearthquakes of magnitude 2 or less. The three largest earthquakes recorded since 1962 within a 60-mile radius around the site have been local magnitude (M_L) 3.44 on December 24, 1973; 4.10 (M_L) on January 5, 1976; and 3.70 (M_L) on March 5, 1977. Of these, the closest to the site was the local magnitude 3.4 whose epicenter was several miles east of the site.

An analysis of the instrumentally recorded earthquakes within a 60-mile radius around the Ambrosia Lake Quadrangle (including the site) for the time period 1962 to 1980 was performed by Sanford (1981). Based on analysis of the number of earthquakes and their magnitudes, the maximum earthquake in the area is estimated to be a magnitude 4.9 during a 100-year period. By comparison, the largest historical earthquake recorded in the region is a magnitude 4.1.

The seismic activity in the site region may be associated with two main geologic features, the southern perimeter of the San Juan Basin and the Jemez lineament (Sanford, et al., 1981). The northwesterly trend of

epicenters immediately north of the site occurs near the transitional boundary between the San Juan Basin and the Zuni Uplift. It is hypothesized that this trend of seismicity is associated with buried faults of Late Pennsylvanian-Early Permian age within this transition zone (Sanford, et al., 1981). The northeasterly trend of epicenters northeast of the site are coincident with the Jemez lineament. This structure trends southwestward from northeastern New Mexico across the Rio Grande Rift and through the southern part of the Colorado Plateau. It is defined by numerous volcanoes of Pliocene and Pleistocene age, including the Mount Taylor volcanic center east of the site. The section of the lineament northeastward from Mount Taylor is believed to be particularly active (Sanford, et al., 1981).

The most prominent concentration of seismic activity within New Mexico occurs along the Rio Grande Rift, a chain of structural depressions extending roughly north-south through the central part of the state from the Colorado border to Mexico. The rift is approximately 45 miles east of the site at its closest approach. The majority of the earthquakes within the rift have occurred in the segment between Belen and Socorro. The segment of the rift nearest the site, the Albuquerque Basin, shows significantly less activity compared to the Belen-Socorro region.

The Belen-Socorro region was the site of the strongest earthquake centered in New Mexico during the past 100 years. The earthquake occurred near Socorro, approxiately 95 miles southeast of the site, on November 15, 1906, with an estimated magnitude of 6.5 (Northrup, 1976). Recent studies of fault scarps by Machette (1978) within the rift near Albuquerque suggest that a major earthquake of magnitude seven or greater capable of producing surface rupture may occur on the order of once every 90,000 to 190,000 years. This suggests that a future large magnitude earthquake may be centered in the Rio Grande Rift; however, the probability of such an event occurring is extremely low. For typical engineering design considerations, estimates of the magnitude of the 100-year earthquake are generally more useful. Based on historical

records, Sanford, et al. (1972) estimate that a magnitude 6.0 is probable every 100 years for the Rio Grande Rift.

Estimates of seismic risk for the area of the site have been performed by Algermissen and Perkins (1976), the Applied Technology Council (1978), and are also contained in the Uniform Building Code (International Conference of Building Officials, [ICBO], 1976). Algermissen and Perkins have estimated the peak horizontal bedrock acceleration due to earthquakes having a 90 percent probability of not being exceeded in 50 years for the entire contiguous United States. Based on their analysis, the mill site is located in a zone that could experience maximum horizontal bedrock accelerations of 0.04 times the acceleration of gravity (g).

The Applied Technology Council (1978) estimated the effective peak accelerations in the United States corresponding to a 90 percent probability of not being exceeded in 50 years. In this analysis, the effective peak acceleration for the mill area was estimated to be 0.05g. The seismic risk map of the United States, as presented in the Uniform Building Code (ICBO, 1976), indicates that the HMC site is located in a Zone 2 seismic risk area. This means that buildings in this area could experience moderate damage from earthquakes corresponding to intensity VII on the Modified Mercalli scale.

To assess the influence of seismicity on the site, the two potential earthquakes of interest are an earthquake whose epicenter is in the vicinity of the site and a more distant but larger earthquake originating from the nearest active source, the Rio Grande Rift. The 100-year earthquake for the Rio Grande Rift was estimated to be a magnitude 6.0 (Sanford, et al., 1972). Based on attenuation curves by Schnabel and Seed (1973), a magnitude 6.0 earthquake originating in the Rio Grande Rift at approximately 45 miles from the site would have an estimated maximum peak acceleration of 0.04g and, therefore, would produce little to no significant engineering impact on the site because of the

attenuation of the seismic waves with distance. An earthquake occurring in the site vicinity is projected to be of magnitude 4.9, based on the 100-year earthquake analysis of Sanford (1981). For an earthquake of minimum magnitude 4.9 in the immediate vicinity, the effective peak horizontal acceleration would be approximately 0.10g (Sanford, 1981). The 0.10g value is considered the maximum effective peak horizontal bedrock acceleration for the HMC site. This value is higher and more conservative than the accelerations postulated for the area by Algermissen and Perkins (1976) and the Applied Technology Council (1978). These relatively low accelerations lead to the conclusion that the project site is located in an area in which seismic risk is within acceptable limits.

C1.0 URANIUM ORE MINING AND MILLING ACTIVITIES

HMC mines, located within 18 miles of the HMC alkaline leach plant, provide ore to the plant which is capable of processing daily 3,400 tons of raw ore containing 0.16 percent uranium into 10,200 pounds per day of marketable uranium yellowcake. Described below are the mining and milling operations used by HMC including process methods, inputs of raw materials, and outputs of products, by-products and wastes. Waste emission control practices employed at the mill are also presented herein.

C1.1 MINING OPERATIONS

HMC - Grants operates two uranium mines in Sections 23 and 25, 18 miles north of the mill site. Production occurs in the Westwater Canyon Member of the Morrison Formation at a mining depth of 642 to 801 feet. Both mines use the room and pillar mining method to recover the primary and redistributed ores. Uranium ore is made up of the coffinite and uraninite minerals of which coffinite represents 99 percent.

C1.2 MILLING OPERATIONS

Uranium ore is processed at the mill by the alkaline leach-caustic precipitation process. The major features of the mill are shown on Figure C1-1.

The process by which uranium yellowcake is produced from uranium ore at the HMC mill is shown in Figure C1-2 and begins with the ore receiving section where truckloads of raw ore are weighed, moisture is sampled and lot locations at the ore storage pad are assigned. At the crushing and sampling section raw ore is crushed, dried if necessary, and sampled. Crushed ore is fed to the storage section where it is loaded into fine ore bins. From the raw ore storage section, ore is mixed with reagents and ground further at the grinding section. Uranium is extracted from the ore in a two-stage leach circuit section. First, ore is aerated in a solution of sodium carbonate and sodium bicarbonate under pressure. In the second part of the leaching circuit the uranium ore/sodium,

carbonate-bicarbonate solution is agitated at atmospheric pressure, producing a uranyl tricarbonate solution which is passed onto the filtration section. By means of filtration and clarification, soluble uranium is separated from the slimes. Solids are disposed at the tailings pond and the "cleaned" uranyl tricarbonate solution is mixed with caustic soda forming sodium carbonate and sodium diuranate which is known as yellowcake. Finally, the yellowcake is delivered to the packing, storage and shipping section where it is dried and packaged in 55-gallon drums for shipment. In an intermediate step within the precipitation section, vanadium is removed from the yellowcake by roasting and leaching to provide a low-vanadium yellowcake.

Each major step in the extraction of uranium from ore and the processing of uranium into yellowcake is detailed in the following sections.

C1.2.1 Ore Receiving Section

Ore for processing is received at the ore receiving section (Figure C1-1, Nos. 1 and 2) from various mines in the district which are located six to 18 miles from the mill. The ore is delivered to a designated lot by trucks in loads of 22 to 28 tons with lots varying from 200 to 2,500 tons. Usually lots consist of the ore received from one mine in one day.

Each truckload of ore is weighed upon arrival at the mill, and the ore is assigned a location and a lot number. The ore is then dumped in this specified area on the ore pad, and the empty truck is weighed. A sample is taken from each truckload of ore as it is weighed to determine the ore moisture content, which in turn is used to calculate the dry tons of ore in each lot.

C1.2.2 Crushing and Sampling Section

C1.2.2.1 Crushing

The concrete portion of the ore pad contains a subgrade hopper that is covered with a grizzly (Figure C1-1, No. 3) which has 18-inch openings

through which ore passes. The ore hopper discharges onto an apron feeder which has a variable speed drive and is controlled by the crusher operator. The apron feeder discharges through an anchor chain curtain, over a stationary grizzly, and onto a 42-inch conveyor belt. The crusher feeder belt discharges the ore onto a wobbler feeder which allows the minus two-inch fraction of the ore to bypass the crusher. The crusher is a twin rotor Universal Impact Breaker (Figure C1-1, No. 4).

Crusher discharge and wobbler feeder undersize are combined and elevated by means of conveyor belts to two, six-foot by 12-foot vibrating screens which are covered with a three-quarter-inch by four-inch slotted screen. The screen oversize falls onto a return belt for recycle to the crusher, and the screen undersize drops onto a conveyor and is transferred to the sampling plant.

C1.2.2.2 Drying

Ores that contain more than eight percent moisture may require drying. This is accomplished in a 10-foot diameter by 80-foot long, co-currently fired, rotary dryer (Figure C1-1, No. 5). The feed to the dryer is the wobbler feeder undersize and the crusher discharge. The dryer discharges the ore at about five percent moisture onto a conveyor belt which returns the ore to the vibrating screens. The dryer burner has a capacity of 70 million BTU per hour, and it can be fired with either natural gas or fuel oil.

C1.2.2.3 Sampling

The sampling plant consists of four stages of Geary-Jennings reciprocating samplers (Figure C1-1, No. 6). The first stage sampler operates on the entire crushing plant output and discharges the sample into a small surge bin. The surge bin contains a load sensing device that controls the speed of the belts feeding the remaining samplers to ensure a steady stream of falling ore for each sampler. A roll crusher

inserted in the sample line between the second and third samplers reduces the particle size from three-quarter inch to one-quarter inch.

The final sample, collected in a drum, is equivalent to one pound of sample for each four tons of ore. The sample is dried, split down and prepared for assay.

C1.2.3 Fine Ore Storage Section

The fine ore storage section (Figure C1-1, No. 7) consists of four ore bins which are 35-feet inside diameter by 50-feet tall, and contain a total live load of 6,000 tons of ore. Since each lot of ore must retain its identity until the ore reaches the ore bins, there is very little blending of the ore prior to milling. A conveyor belt transports the ore from the sample plant to the top of the fine ore bins, and a belt tripper is used to discharge the ore into any one of four ore bins or into a truck hopper for return to the ore pad.

C1.2.4 Grinding Section

C1.2.4.1 Grinding

The feed to the grinding circuits is withdrawn from the fine ore bins by means of two belt feeders under each bin. One feeder is manually controlled, and the other feeder is automatically controlled. The feeders discharge onto a collecting belt for transfer to the ball mill feed belt. The ball mill feed belts contain weight sections which supply the load signals for the Con-O-Weigh weight meters. The meters in turn vary the speed of the automatic feeders to maintain a constant feed to the ball mills. Two ore bins supply the feed for each grinding circut.

The grinding circuit consists of two, 10-foot inside diameter by 5.5-foot long, Hardinge conical ball mills (Figure C1-1, No. 8). Each mill operates in closed circuit with a six-foot WEMCO spiral classifier. At a feed rate of 73 tons per hour, a grind of five percent plus 48 mesh and 35 percent minus 200 mesh is produced. The ball charge in each mill is approximately 22 tons, and the ball make-up consists of

equal weights of 2- and 2.5-inch forged steel balls. Each ball mill is driven by a 400-horsepower, 4,160-volt, wound rotor motor directly geared to the ball mill. The ball mills operate at 20 revolutions per minute or 83 percent of critical speed. Grinding is conducted at 65 percent solids in a sodium carbonate (Na_2CO_3) and bicarbonate ($NaHCO_3$) mill solution containing 45 grams Na_2CO_3 per liter and seven grams $NaHCO_3$ per liter. The classifiers overflow at 20 percent solids.

The classifier overflow from either primary grinding circuit can be fed through a 20-inch cyclone that is connected closed circuit with a Denver six-foot by six-foot ball mill that is belt driven by a 200-horsepower, 480-volt motor. The cyclone underflow sands are fed to the regrind mill containing approximately four tons of one-inch forged steel balls and discharges a product of about five percent plus 65 mesh.

C1.2.4.2 Thickening

The classifier overflow from each grinding circuit is pumped by a six-inch Wilfley slurry pump to a 20-inch Krebs cyclone. The cyclone overflow is discharged into the feed launder of a 100-foot diameter thickener (Figure C1-1, No. 9), and the cyclone sands bypass the thickener. A polyacrylamide flocculent is mixed with the thickener feed to aid in settling and clarification. The thickened slurry is removed from the thickener by a Dorrco diaphragm pump at 40 percent solids. The thickener underflow and the cyclone sands are recombined in the leach circuit preheat tank at 52 to 54 percent solids. The overflow from the thickeners flows by gravity to a mill solution storage tank for recycle to the grinding circuits.

C1.2.5 Uranium Leaching Section

The extraction of the uranium from the ore is accomplished in a two-stage circuit consisting of a 4.5-hour leach at 60 pounds per square inch (psi) pressure and 200°F followed by an 18-hour leach at atmospheric pressure and 170°F. Leaching is accomplished in an aerated solution containing 45 grams Na_2CO_3 per liter and seven grams $NaHCO_3$ per liter. The extraction obtained from leaching varies from 85 to 95

percent depending on the type and grade of the ore. The grade of the ore has averaged 0.175 percent U_3O_8, and the leach residue averages 0.01 percent U_3O_8 over the life of the operation.

The chemistry of the alkaline leaching system involves the oxidation of any tetravalent uranium to the hexavalent state using the oxygen available in the air. The hexavalent uranium dissolves in the presence of carbonate alkalinity to form a uranyl tricarbonate complex ion according to the following reaction:

$$2UO_2 + O_2 + 6Na_2CO_3 + 2H_2O \rightarrow 2Na_4UO_2(CO_3)3 + 4NaOH + 2H_2O$$

The uranium will not dissolve in a sodium carbonate solution because the hydroxide alkalinity formed with the complex ion causes the ion to decompose. In a solution containing sodium bicarbonate, the hydroxide alkalinity is neutralized immediately, and the reaction proceeds as follows:

$$2UO_2 + O_2 + 6Na_2CO_3 + 4Na_2HCO_3 \rightarrow 2Na_4UO_2(CO_3)3 + 4Na_2CO_3 + 2H_2O$$

C1.2.5.1 Pressure Leaching

Pressure leaching is accomplished in two separate circuits, each containing eight autoclaves (Figure C1-1, No. 10). Each circuit can be operated as a series of eight autoclaves or divided into two circuits of four autoclaves. The first unit in each leaching circuit is a preheat tank in which the thickener underflow and the cyclone sands are recombined and heated to 150°F. A two stage centrifugal pumping system is used to pump the preheated slurry into a splitter tank where the slurry can be divided into two streams for feed to the autoclaves.

The autoclaves are 12-feet in diameter by 16-feet high, domed pressure tanks equipped with a top mounted mixer. Each tank has two turbine-type, 42-inch diameter impellers mounted on a 14-foot, four-inch diameter shaft. Oxidation air is fed into the bottom of the autoclaves

through a 30-inch bubble-cap diffuser. Pressure in an autoclave circuit is maintained by an automatic bleed-off valve on the pipe header connected to each autoclave. Heat for leaching is supplied by three sets of two-inch steam coils in the first autoclave in each circuit of four. The remaining autoclaves have only one steam coil which is used to hold operating temperature if necessary. Temperature and pressure in the autoclave circuit are maintained by automatic controls.

The flow through the autoclaves is fed by gravity, and the feed to each autoclave enters the slurry surface and discharges from the bottom through an internal riser. A six-inch drop between autoclaves provides the head for flow through the six-inch piping in the circuit. The operating volume of each autoclave is approximately 11,000 gallons. The discharge from the last autoclave in each circuit of four flows into a letdown tank. The level in the letdown tank is maintained by a capacitance-type probe and level controller. From the letdown tank, the leached slurry discharges through a concentric tube heat exchanger that cools the slurry from 200°F to 180°F. The pressure of the system provides the energy to push the partially leached slurry through the letdown control valve, the heat exchanger, and 900 feet of pipe to the atmospheric leach circuit.

C1.2.5.2 Atmospheric Leaching

The atmospheric leaching circuit consists of nine Pachuca tanks (Figure C1-1, No. 11) which are 19 feet in diameter by 38 feet deep. The slurry from the pressure leach circuit is added to the top of the first Pachuca tank, from which it flows by gravity through the tanks and into an elevated pump sump.

Four 10-inch air lifts provide agitation for each Pachuca, and heat for the circuit is provided through steam jackets on the air lift pipes. Additional air for oxidation is supplied through five three-quarter-inch pipes suspended from the top of each tank. The air enters the slurry approximately three feet from the bottom of the tank.

C1.2.5.3 Filtration

The removal of the soluble uranium values from the leach circuit discharge is accomplished with three stages of filtration. Each filter stage contains five 650 square-foot and two 570 square-foot rotary drum vacuum filters. The filters (Figure C1-1, No. 12) are 11.5 feet in diameter and are equipped with polypropylene grids. A heavy duty nylon filter cloth is used to cover the filters, and 14-gauge stainless steel wire is wound on the filters to retain the filter cloth.

The discharge from the secondary leaching circuit is pumped to the filter feed tank by means of four-inch Wilfley pumps and 800 feet of pipeline. The feed to the first stage of filters is pumped from the filter feed tank through a pipe loop by means of a five-inch Wilfley slurry pump. Each of the first-stage filter tubs has a level controller which operates a valve on the feed line. A dilute solution of flocculent is pumped into the filter feed line on the discharge side of the pump. The filter feed and flocculent are mixed by flow through the piping and the feed valves and into a small mixing chamber on each filter tub. The feed to each first-stage filter enters at the center of the tub.

The first-stage filter cake is washed with a hot filtrate solution from the third stage of filters. The filtrate is sent to clarification, and the first-stage filter cake discharges into repulpers for repulping with third-stage filtrate. The repulped slurry flows by gravity through an agitated sump and into the second stage of filters. Flocculent is added to the first-stage repulper solution to aid in second-stage filtration.

The second and third stage of filters are operated in much the same manner as the first stage, except that recarbonated barren solution from the precipitation circuit is used as a filter wash and as solution repulper on the second stage. Recycled tailings pond solution, or water, is used as a wash on the third stage. The wash solution for each stage of filters is maintained at 100°F. The second-stage filtrate is

sent to the mill solution circuit, and the third-stage filtrate is used as wash and repulper solution on the first stage of filters. The filter cake from the third stage of filters is repulped with recycled tailings solution and slurried for tailings disposal. The loss of soluble uranium in the tailings slurry averages three percent of the uranium in the mill feed.

C1.2.5.4 Clarification

The filtrate produced by the first stage of filters is the pregnant solution for the precipitation circuit, but the solution must be clarified before precipitation to remove slimes that have penetrated the filter cloths. The clarification is conducted in a thickener in which the major portion of the contaminants settle.

C1.2.5.5 Tailings Embankment

The filter cake from the third stage of filters is repulped with recycle solution from the tailings pond and transferred through launders to a tailings slurry tank which overflows into a launder and over a Geary-Jennings reciprocating sample cutter. The tailings sampler operates continuously and discharges into a small Wilfley pump for transfer to a second sampler. The second sampler operates intermittently and is used to obtain the final tailings sample.

The tailings embankment (Figure C1-1, No. 14) contains a 170-acre, two-cell pond (east and west ponds) enclosed within an artificial starter dike constructed from the clay in the pond area to a height of 10 feet. Subsequent dike construction has been and is now accomplished by pumping the tailings slurry with 30 to 40 percent solids through a truck mounted, 20-inch cyclone. The cyclone deposits the sands on the dike crest and front slope to build out the embankment, and the slimes and tailings solution flow into the pond. The present embankment is approaching 85 to 90 feet in height. The disposal of tailings is handled by three, eight-inch centrifugal pumps in series and a cyclone

truck. The pumping capacity is 1,500 gpm of tailings slurry when pumping through 4,000 feet of nine-inch pipeline and a 20-inch cyclone.

The slimes in the cyclone overflow settle in the tailings pond, and the tailings solution is recovered through two centrally located decant towers. The recovered solution flows from the decant towers through an underground pipe system into a pump basin and is returned to the mill by means of a 1,200 gpm pump and 2,500 feet of eight-inch pipeline. Tailings recycle solution is used in the filter building for wash on the third stage of filters and for repulping of the final tails.

C1.2.5.6 Tailings Pond Ion Exchange

Before the reclaimed tailings pond solution (TPS) returns to the third-stage filters, the solution is treated in a continuous ion exchange column for further removal of soluble uranium. Fifty to 90 percent of the soluble uranium, which would otherwise be lost and remain in the tailings pond, is recovered.

The pregnant eluates from the TPS IX (Figure C1-1, No. 15) and Mine IX are processed further to recover the uranium values. The solution is first acidified to a pH of 3.0 with hydrochloric acid (HCl). The uranium is then precipitated using sodium hydroxide (NaOH). After several hours of settling, the barren solution is removed and reused. The remaining sodium yellowcake slurry is pumped into the precipitation circuit for continued processing for vanadium removal and conversion into "low sodium" yellowcake as described in the following sections.

C1.2.6 Precipitation Section

C1.2.6.1 Precipitation

The uranium exists in the pregnant solution (Figure C1-1, No. 16) as the complex uranyl tricarbonate ion, which is stable at a pH lower than 11.0. When the pH is raised to above 12.0 with caustic soda, the bicarbonate ion and the uranyl complex ion reacts with the caustic to form sodium carbonate and sodium diuranate. The latter salt, a yellow

precipitate, is commonly called sodium yellowcake (SDU). This is accomplished by the following reaction:

$$2Na4UO_2(CO_3)_3 + 6NaOH \rightarrow Na_2U_2O_7 + 6Na_2CO_3 + 3H_2O$$
$$NaHCO_3 + NaOH \rightarrow Na_2CO_3 + H_2O$$

Precipitation is conducted in a two-stage circuit in which the pregnant solution is mixed with recycled yellowcake to increase the soluble uranium content and then mixed with caustic soda to precipitate the uranium as yellowcake.

The pregnant solution for precipitation is pumped from a storage tank through a concentric-tube heat exchanger to heat the solution from 125°F to 150°F. The heat is obtained by cooling the pressure leach discharge from 200°F to 180°F.

The technique of recycling yellowcake to a redissolving tank was developed to achieve a more complete precipitation of the uranium in the original pregnant solution. The dissolving tank operates with a yellowcake recycle equivalent to 500 percent of the uranium in the incoming pregnant solution. In five hours of contact with the pregnant solution, a portion of the yellowcake dissolves, and the soluble grade of the solution increases from approximately 2.5 grams of U_3O_8 per liter to approximately 7.5 grams of U_3O_8 per liter. The precipitation efficiency of the circuit varies with the level of soluble uranium in the feed. Based on the grade of the incoming pregnant solution, the precipitation efficiency will vary from 92 to 94 percent on straight pregnant solution to better than 98 percent with a 100 percent increase in the soluble uranium in the pregnant solution. Undissolved yellowcake in circulation does not substantially affect the precipitation.

The precipitation circuit consists of nine agitated tanks (Figure C1-1, Nos. 17 and 18) which have a retention time of 12 hours. A solution of 50 percent caustic soda is metered into the first tank to affect the

precipitation of the yellowcake. The caustic may also be added to the pipeline feeding the tank to change the characteristics of the precipitate and the efficiency of precipitation, which are affected by the point of addition. A sufficient quantity of caustic is added to the circuit to neutralize the sodium bicarbonate in the pregnant solution and to maintain an excess of 5.5 grams of NaOH per liter of barren solution.

The yellowcake slurry from the precipitation circuit flows into a 40-foot diameter by 12-foot deep thickener (Figure C1-1, No. 19) which is equipped with a 12-foot diameter by eight-foot deep feed well. The thickener is insulated with a floating two-inch styrofoam lid and two inches of fiberglass insulation on the sides. Because the thickener operates at 170°F to 180°F, the insulation is necessary to prevent evaporation and heat loss which create thermal currents that hinder settling. The thickener underflow is pumped at 35 to 40 percent solids to the vanadium removal section or to the yellowcake dissolving tank for recycle. The thickener overflow is pumped through a filter press for final clarification and then to caustic barren storage.

C1.2.6.2 Recarbonation

The caustic barren solution produced in the precipitation circuit contains sodium carbonate and a small quantity of sodium hydroxide. To reuse the barren solution, the caustic must be converted to sodium carbonate and sodium bicarbonate. This conversion is accomplished in two packed towers in which the caustic barren solution is contacted with boiler flue gas. The CO_2 in the flue gas neutralizes the sodium hydroxide and converts some of the carbonate to bicarbonate. The recarbonated barren solution, with two to five grams of $NaHCO_3$ per liter, is sent to the filter building for use as wash on the second stage of filters.

C1.2.7 Vanadium Removal Section

The primary precipitation of yellowcake produces a product which, when washed and dried, will assay 75 to 77 percent U_3O_8, five to six percent V_2O_5, and two to 2.5 percent CO_2. Although the uranium content is satisfactory, removal of the excess vanadium and carbonate is required before the yellowcake is acceptable to the upgrading process plants.

The removal of the vanadium and, quite incidentally, carbonate from the yellowcake is accomplished by roasting followed by water leaching. The yellowcake thickener underflow is pumped to a disc filter to dewater the slurry, and the filter cake is agitated with a small quantity of sodium carbonate before being fed to the yellowcake roaster.

Yellowcake roasting is accomplished in an 8.5-foot diameter, six hearth Pacific furnace (Figure C1-1, No. 20). The feed to the furnace is dried on the top hearth and reaches 1,600°F by the time it leaves the fourth hearth. The fifth and sixth hearths hold the yellowcake at temperature. The calcined yellowcake discharges into a water cooled screw conveyor which cools the yellowcake to approximately 200°F before final quenching. Water is used to dissolve the vanadium and carbonate contaminants in the yellowcake. The leached yellowcake slurry is collected in a 16-foot diameter by 10-foot deep thickener, and the thickener overflow containing the vanadium is filtered and sent to vanadium storage. The vanadium solution containing eight percent V_2O_5 is presently sold to a nearby vanadium producer.

In order to meet specifications for sodium content in yellowcake for processing into uranium hexafluoride by others, an additional processing step is required to complete the flow sheet. Vanadium solution contained in the yellowcake slurry in the 16-foot yellowcake thickener underflow is removed on a 4.5-foot diameter by six-foot long vacuum drum filter. Then the yellowcake is washed on the filter and repulped with water. The yellowcake containing approximately 7.5 percent sodium is dissolved with sulfuric acid at a pH of 2.2 in a six-foot diameter by eight-

foot deep agitated tank. The overflow from this tank discharges into a six-foot by six-foot tank where ammonia is added to maintain a pH of 7.4. The uranium reprecipitates as an ammonium yellowcake (ADU) containing less than one-half percent sodium. This product is filtered and washed with an ammonium sulfate solution on six-foot diameter by eight-foot long vacuum drum filters, dried on a four-hearth Pacific Roaster, and packaged as described under the section on Packing, Storage and Shipping.

C1.2.8 Packing, Storage and Shipping Section

The filter cake from the second yellowcake filter discharges into an agitated sump and is pumped to the yellowcake dryer. Yellowcake drying is accomplished by an 8.5-foot diameter four hearth Pacific Furnace (Figure C1-1, No. 21) which is fired to about 1,000°F. By the time the yellowcake reaches the bottom, the moisture has been removed and is discharged through a "delumper" and into a hopper, where it is held until packaging.

Yellowcake is packaged in 55-gallon open head drums. A vibrator under the drum loading station (Figure C1-1, No. 22) is used to settle the contents of each drum. After the drums are sampled, sealed and weighed, the drum is washed and placed in a security storage area (Figure C1-1, No. 23) until it is shipped. Each drum is stenciled with the letters "LSA" to identify the contents as having low specific activity.

Each drum contains a maximum of 1,000 pounds of yellowcake and about 40 drums comprise a lot. The average lot of yellowcake assays 87 percent U_3O_8, 0.3 percent V_2O_5, and less than two percent water, and a normal lot contains about 36,000 pounds of U_3O_8.

C1.3 MILL WASTES AND EFFLUENTS

The following sections describe the gaseous, liquid and solid waste effluents originating in the HMC mill. The physical, chemical and radiological characteristics of the released materials are described as

are the rates at which these materials are emitted (Figure C1-3). The release rates are compared to state environmental quality standards.

C1.3.1 Tailings

Numerous nonradioactive and radioactive wastes are generated by the processing of uranium ore in the HMC mill. Tailings represent the largest waste product, accounting for nearly all of the ore solids. The HMC mill presently generates about 800 to 1,150 tons of dry tailings daily; the maximum capacity is 3,400 tons of ore throughput per day. The tailings consist of about 30 percent slimes (less than 200 mesh) and 70 percent sands (solids greater than 200 mesh). The slime material consists of various clay-like silica complexes of Al, Fe, Mg, Ca, Na, K, Mn, etc. The slime component of the tailings has the highest concentration of radioactive elements, with uranium values almost double those of the sands. The radium activity of the slimes is about 630 picocuries per gram (pCi/g), the thorium activity is about 0.081 pCi/g, the lead activity is about 840 pCi/g, and the U_3O_8 concentration in the slimes is about 0.011 percent.

The sand component of the tailings is about 99 percent silica with small amounts of U, Mo, and Se. The radium activity of the sands is about 65 pCi/g, the thorium activity is about 0.0116 pCi/g, the lead activity is about 99 pCi/g, and the U_3O_8 concentration is about 0.004 percent.

During periods of peak ore processing (i.e., 3,400 tons of ore processed per day), about 350 gpm of liquids are discharged to the tailings disposal area. At the current production rate of about 1,100 tpd, 150 gpm of liquids are discharged to the tailings disposal area. The tailings liquid contains various substances including CO_3, HCO_3, Se, SO_4, Cl, Mo, V_2O_5, and U_3O_8; the pH is 10.3 (Hydro-Engineering, 1981). The radium activity of liquids in the tailings is in the range of 200 picocuries per liter (pCi/l) and there is virtually no thorium activity in the liquids. It has been estimated conservatively that tailings

liquids flow from the embankment into the groundwater at a rate of approximately 153 gpm (Hydro-Engineering, 1981). This rate is high for current conditions because it assumes a throughput of 3,400 tons of ore processed per day. The impacts to waterways and groundwater resulting from this liquid discharge are described in Section C6.0.

C1.3.2 Other Emissions

Other liquid and airborne emissions generated by the HMC mill are listed in Table C1.1. This list includes both radioactive and nonradioactive components. The activity levels of the radioactive emissions are listed in Table C1.2. These data were developed by Impact Environmental Consultants, Ltd. (1981) and they were used as input to the MILDOS computer code to perform the radiological analysis of the HMC mill. All of these values are based on the mill's maximum ore processing rate. The radiological impacts of these emissions are described in Section C4.0.

Uranium ore dust is dispersed to the atmosphere from the ore storage pad, the grizzly, and the crushing and drying operations. The ore storage pad and the grizzly are watered as needed to control excessive dust. The ore crushing, transfer and drying operations are vented through a bag filter having an efficiency of 99 percent.

The mill precipitation building houses four sources of airborne emissions: the vanadium roaster, the vanadium quench tank, the yellowcake dryer and the yellowcake packaging area. Exhaust from the vanadium roaster exits the mill through a rotoclone in series with a hydrofilter. The operation of this machinery is monitored by a draft gauge and visual observation of fluid flow from discharge lines. Readings are recorded at two hour intervals. Monitoring devices are provided to turn the vanadium roaster off and to sound an alarm in the event that solution flow stops.

Dust emissions from the vanadium quench tank are contained by a plastic curtain and exhausted through a tray type wet dust collector. Operation of an exhaust fan and the solution discharge from the collector are observed to monitor performance of the dust collector.

Exhaust from the yellowcake dryer exits through a rotoclone in series with a variable venturi wet scrubber. A draft gauge and the fluid discharge are observed to monitor the operation of this equipment. An automatic shut off and alarm monitor is provided.

The yellowcake packaging area is exhausted through a wet rotoclone and equipment operation is monitored by observation of a draft gauge and fluid flow. No automatic shut off or alarm is provided because this machinery is located adjacent to an operator's station and is subject to continuous observation.

Based upon yellowcake emissions measured during periods when the mill is operating at maximum capacity, the total annual yellowcake emission is estimated to be 1,353 pounds. The yellowcake emission rates can routinely vary by a factor of from two to five when sampling is conducted without any controls on mill operating parameters (U.S. NRC, 1980b). The radiological impacts of these airborne emissions are described in Section C4.0.

Other mill emissions include dust from the tailings pile, SO_2 and NO_2 from combustion of natural gas, and domestic sewage. The estimated annual quantities of these emissions are presented in Table C1.1.

C1.3 3 Compliance with Standards

The discharge of tailings liquids from the tailings embankment which ultimately reaches groundwater will not cause New Mexico standards to be exceeded. HMC has submitted its Ground Water Discharge Plan (GWDP) (Hydro-Engineering, 1981) which demonstrates compliance with the New Mexico standards. Section C6.2.5 includes a discussion of measures

being taken to maintain compliance. All other emissions from the HMC mill comply with applicable standards.

C2.0 EXISTING TAILINGS MANAGEMENT SYSTEMS

HMC's present tailings management system has been in existence since the beginning of operations in 1958. The tailings embankment now covers approximately 170 acres and is 85 to 90 feet high. In order to continue use of the existing tailings embankment for the next five-year time period, HMC developed a tailings management plan that would allow continued buildout of the existing tailings embankment and still maintain embankment stability. Details of this management plan are contained herein.

C2.1 DESCRIPTION OF PRESENT TAILINGS MANAGEMENT

Tailings from the milling operation are deposited in an embankment located adjacent to the mill. The embankment, divided into two cells designated the east and west ponds, covers approximately 170 acres and is approximately 85 to 90 feet high. The east and west ponds cover approximately 55 acres and 40 acres, respectively, as measured from crest centerline.

Tailings are transported from the mill to the embankment in a slurry form, and deposited by cyclone as described in Section C1.2.5.5. The cyclone travels along the crest, building the embankment as it moves. The present mode of operation confines disposal to a single pond at a time, with the other pond used for evaporation. When tailings are released into one pond, some of the tailings solution water is transferred to the other pond by use of the decant system or a pumping system. In this manner, both ponds are used to maximize evaporation.

C2.2 TAILINGS MANAGEMENT PLAN

This section presents the tailings management plan that HMC proposes to use to build out and operate the embankment for the next five years. Tailings management activities will vary with the actual production rate. The plan describes the evolving physical configuration of the embankment, the methods of developing the embankment, stability assessments, and

monitoring of embankment performance. Plans and sections of the embankment depicting the buildout configuration at initial setback and at one, three, and five years are discussed in Description of Buildout, Section C2.2.1. Methods for placing tailings and maintaining slopes, keyed to specific times or buildout levels, are presented and discussed under Construction Procedures, Section C2.2.1.4. The assessments of slope stability, seepage and liquefaction potential at the three selected buildout levels are presented in the Stability Assessment, Section C2.2.2. Embankment Monitoring, Section C2.2.3, describes the monitoring program by which the embankment buildout conditions will be recorded and evaluated. Specifications for the five-year buildout of the tailings embankment are contained in Appendix A.

C2.2.1 Description of Buildout

The five-year buildout plan of the HMC tailings embankment has been developed around the following considerations:

1. Mill production rates
   The planned production rate of the mill for the next five years is estimated by HMC to be 2,000 tons of tailings solids per day. Because production will vary and some shut-down will occur from time to time, this figure is considered to be the maximum sustained production.

2. Embankment operational requirements/constraints
   HMC's milling process and established method of tailings disposal imposes several practical constraints and requirements on the management plan of the existing embankment:

   - The structural embankment must be constructed of the coarse-split tailings, which constitute about 40 percent of the solids in the tailings stream. The fine split is not suitable for use as structural material and must be placed in the pond. No materials other than the coarse-split tailings are feasible for use in embankment buildout, and to preserve pond capacity all the coarse split is used on crest construction.

   - The crest buildout, or structural embankment, must be sufficient to maintain at least five

feet of freeboard and a 50 foot beach, in accordance with licensing requirements.

3. Service life of the embankment

The embankment is expected to be used for the next five years. At the present and anticipated rate of production, the appropriate safety factor will be maintained by this disposal method. The present method of tailings placement (cycloning and centerline buildout) will be used so long as the appropriate safety factors are produced. Alternate buildout methods will be implemented if cycloning and centerline buildout, because of production rates, would not yield the appropriate safety factor.

4. Possible alternative use of the embankment

If a new disposal facility is developed, the present embankment could be used either for evaporation or for secondary recovery of uranium, or both. Regardless of which use is elected, interim stabilization measures would be applied to the embankment to inhibit erosion. The secondary recovery alternative could be attractive because the tailings contain residual uranium which could be extracted by leaching. The embankment could be made an integral part of the tailings circuit; i.e., decant water returned from a new disposal facility could be piped into the ponds of the embankment to evaporate or to leach the residual uranium. The leachate would be recovered by wells or drains at the bottom of the embankment and returned to the mill for processing.

These considerations are fundamental to a tailings management plan. The plan developed in this document has been formulated around these considerations as well as the requirements for embankment stability. Mill production rates, operational requirements and constraints, and the five year licensing period were considered to be constants, or fixed parameters, which the management plan must incorporate. Future use and stabilization of the embankment were considered in the plan development but were treated as nonrestrictive factors to be addressed in detail at a later date.

C2.2.1.1 Initiation Phase

Assuming all other factors are constant, as the crest elevation increases by centerline construction along the original crest centerline, the safety factor decreases. In mid-1980, the crest elevation along the east side and east end of the south side of the embankment reached levels which resulted in static safety factors less than 1.5. Consequently, remedial work, consisting of an 80 to 100 foot setback of the crest and resultant lessening of the outer slope height, was performed in those areas in December 1980, when disposal was shifted to the west pond. Other portions of the embankment would also reach the limiting factors of safety with continuation of centerline construction along the original centerline. Consequently, the buildout plan is initiated by eliminating or correcting the safety factor reduction with the establishment of a new crest centerline setback approximately 90 feet upstream, or inboard, of the original centerline on both the east pond and the west pond (Figure C2-1).

A new crest has been established around the entire perimeter of the east pond by moving the remainder of the old crest inboard approximately 90 feet to provide a centerline upon which the five-year buildout will start (Figure C2-2). This movement was accomplished by scraping or dozing the existing crest material inboard while the east pond was dormant (no disposal taking place) during the first half of 1981.

A setback of approximately 90 feet of the crest centerline will be performed on the west pond, which will be allowed to become temporarily dormant after the summer of 1981, while the east pond is used for disposal. Already started in 1981, the west pond setback will be accomplished by direct deposition of coarse tailings along the new setback centerline established along the old beach. In contrast to the procedure used on the east pond, the old west pond crest will be abandoned and left in place. The new crest will be constructed of coarse tailings deposited directly by the cyclone truck.

At the end of the initiation phase, the typical slope configurations will be as shown on Figure C2-1. The front slopes of the embankment will retain the positions and geometries of the pre-initiation configuration. During subsequent tailings disposal, the coarse tailings will be deposited along the setback centerline as the crest builds out, leaving the original front slope intact. The plan view of the pond at the end of the initiation phase is shown on Figure C2-2.

One localized modification of the front slope will be necessary to permit five years of buildout on the east pond. This modification will be the addition of a buttress of coarse tailings on the front slope along a portion of the east side of the east pond, as discussed later in Section C2.2.1.3. The need for other modifications may become apparent as the buildout proceeds and will be determined from embankment monitoring and scheduled geotechnical inspections and analytical updates.

C2.2.1.2 Buildout Phase

During the buildout, tailings will be deposited by the centerline method along the new crest. Coarse tailings will be deposited in horizontal lifts of eight feet or less to build the crest required to contain the pond areas. These lifts will be built by pouring the coarse tailings ahead of the cyclone and allowing the tailings to stand at their natural angle of repose. The height of each lift will be determined by the thickness of tailings which can be spread and stabilized in the design configuration in a given pass of the cyclone. This method of buildout should produce plan views and profiles at one, three and five years as shown in Figures C2-3, C2-4, C2-5, and C2-6 for the east and west ponds. During this buildout phase the central divider dike and access ramps for the decant structures will continue to be built along their present centerlines.

This buildout plan has both advantages and drawbacks when incorporated into the overall tailings pond operation. The advantages are:

- Secondary movement or regrading of coarse tailings to enhance slope stability will be minimized. However, some slope maintenance grading might be required.

- A smaller quantity of coarse tailings (compared to the previous buildout scheme) will be required with time to raise the crest and maintain the required freeboard.

- The pond surface-to-downstream toe distance will increase, thereby increasing the length (l) of the seepage path of water moving through the embankment from the pond to the toe. The increased seepage distance will help to offset the increase in hydraulic head (h) of the water as pond elevation increases, thereby restricting the hydraulic gradient (h/l).

- Embankment stability should immediately improve and should remain better than in the previous buildout plan throughout the buildout period.

Drawbacks of the inboard centerline construction method are:

- Pond area will be reduced by 20 percent, thereby reducing total evaporation surface and pond capacity.

- The stability of the slope will become more dependent on the phreatic water level within the embankment, because the critical failure circles will penetrate deeper in the embankment and will extend to or below the phreatic surface with time.

- A more rapid increase of crest height will occur, requiring greater pumping heads.

The most important operational drawback to the inboard crest is loss of pond capacity. The impact of pond capacity loss will be offset by utilizing the temporarily dormant pond as an additional evaporation surface. The capability to remove water from one pond to the other presently exists and the use of this system or an upgraded transfer system should provide sufficient pond surface to insure adequate evaporation even during the winter months.

One aspect of inboard centerline construction that was initially considered to be a possible drawback was the dependency on beach material to support the buildout crest. There was some concern early in the development of this plan that the materials underlying the original beach might be weak, compressible fines. However, recent test borings and laboratory tests on samples of those materials indicate little difference between those materials and the coarse-split tailings in terms of strength parameters. This topic is discussed later under the stability assessment.

C2.2.1.3 Localized Modifications to the Buildout

The setback of the crest on the east pond will average 90 feet with the typical east pond section having an approximate 2:1 (H:V) slope on the front face. One particular area along the east side of the east pond, designated Section 4-4' and shown on the initiation and one-year buildout plans (Figures C2-2 and C2-3), has a steeper than 2H:1V front slope and an 80 foot present setback. This area was investigated separately from the rest of the east pond and was found to have an approximate two-year limitation on centerline buildout before stability considerations necessitate a change in mode of disposal. The condition at this section can be corrected by building up the front face with coarse tailings until a buttress with a 2H:1V front slope is developed and an additional twenty-five feet of bench is added.

The relationship of the buttress and additional bench to the present geometrical configuration of cross section 4-4' is shown on Figure C2-7. This remedial measure will require the cyclone to stop at the critical section and place coarse tailings onto the front slope using an extended spigotting trough. During placement of tailings on the front slopes, no increase of crest height would occur on the embankment. However, since buildout along the setback crest will occur at relatively rapid rates over the first two years, adequate excess freeboard (greater than the required five feet) should be available to accommodate the fines while the coarse tailings are being placed on the front slope.

This area on the east pond, depicted in Figure C2-2, must be altered before levels beyond the two-year buildout are surpassed. Figure C2-4, the buildout plan at three years, shows the embankment contours after placement of the tailings buttress.

To enhance the east pond embankment stability for the fifth-year buildout stage, a buttress will be placed around the perimeter of the east pond toe. Starting in the fourth year of operation, or when the east pond crest reaches elevation 6,692, the buttress will be placed at the toe of the east pond. The buttress will consist of unsaturated tailings stripped from the crest, hauled to the toe and placed and compacted in two-foot lifts. Alternatively, "dry" (unsaturated) tailings might be conveyed directly from the mill and placed in lifts as described above. The buttress will attain a minimum top elevation of 6,600 feet and a top width of 40 feet with an outer slope of 2H:1V by the time the embankment crest reaches elevation 6,696.

Other localized modifications may be necessary during the course of the buildout; however, under present design conditions, the need for other modifications is not apparent. Factors such as phreatic level, actual crest setbacks at initiation, actual tailings production and changes in tailings properties could necessitate modifications at localized areas of the embankment. These factors will be monitored by periodic surveys, cyclone underflow sampling, and other means described in Appendix A and Section C2.2.3. As a whole, the embankment should perform well through the entire five years of the planned buildout. Analyses to support this buildout plan are presented in Section C2.2.2.2.

C2.2.1.4 Construction Procedures

Construction of the five-year buildout will be accomplished using the same spigotting procedures in use presently. The cyclone travels along the crest, spreading the coarse split ahead to build the crest and discharging the fine split toward the pond across the beach.

The buildout will start along the new setback crest centerlines, 90 feet inboard of the original crest centerlines. The coarse tailings will be deposited on this centerline, forming a dike or levee upon the former beach area. This structure should retain all fine tailings and water that are discharged into the ponds. The new coarse tailings embankment is expected to increase in height and the available bench width is expected to decrease at the rates shown in Table C2.1.

Fine tailings discharged into the pond are expected to produce an average rise of four feet per year of sediment in the east pond and three and one-half feet per year in the west pond. These rates of filling in the ponds should provide ample freeboards of up to 12 feet throughout the five-year buildout. In no case would the freeboards be less than five feet.

All construction techniques are expected to remain basically the same as presently practiced. Maintenance of the front slopes and bench areas to repair weathering or erosion will be performed, as necessary.

C2.2.2 Stability Assessment of the Embankment Buildout

The embankment buildout at initial setback and at one, three and five years has been investigated for slope stability, seepage and liquefaction considerations under both normal and severe loading conditions. In general the basic design portrayed in Figures C2-2 through C2-6 has been developed to provide a five year embankment configuration that meets the New Mexico State Engineer's safety factor criteria for uranium mill tailings embankments.

C2.2.2.1 Field and Laboratory Program

In early April 1981, additional field work was performed on the dried beach areas of the dormant east pond. These investigations were undertaken to extend the general tailings characterization up to 200 feet in back of the original crest centerline. The locations of the five functional piezometers installed during this program are shown on Figure C2-2. Three of the borings were located along the planned setback crest

centerline of the east pond. These borings penetrated a silty sand material with about 20 percent of the material passing the No. 200 sieve. This type of material is very similar to the materials at the present crest centerline sampled during field investigations for the November 1980 Engineer's Report (D'Appolonia, 1980). The other three borings were situated approximately 200 feet from the present crest centerline or 100 feet behind the planned new crest centerline. This series of borings penetrated a very large section of very silty sand with the silt accounting for up to 40 percent of the total material volume.

The laboratory strength and consolidation characteristics of the very silty sand encountered during the field program were determined during May 1981. Since the silty sands encountered along the proposed new crest centerline had physical properties identical to previously tested materials, no additional strength testing was performed. Therefore, the strength of the slope, when evaluating the stability against the possibility of a normal outward slope failure, was based on the consolidated-undrained triaxial strength values (29 degrees friction angle and zero cohesion) for the tailings reported in the November 1980 Engineer's Report. The very silty sand materials encountered inboard of the new crest centerline were tested under both undisturbed and remolded conditions with consolidated-undrained triaxial strength parameters of 29 degrees friction angle and 180 pounds per square foot (psf) cohesion. The unconsolidated-undrained triaxial strength parameters were determined to be zero degrees friction angle and 1,800 psf cohesion. Since the consolidated-undrained strengths of the very silty sand were identical to the previously tested cleaner centerline materials, it was concluded that the behavior of the material under the new setback crest would be similar to the material under the old crest under similar load conditions. The time-rate consolidation characteristics of the very silty sand have also been investigated to determine if strength-versus-time effects might play a role in potential failure of the slope. The results have indicated that the consolidation times are very rapid and

no appreciable pore pressure buildup should be expected due to rapid crest buildout.

C2.2.2.2 Static Slope Stability

The material properties for the static slope stability analysis were taken from the Engineer's Report (D'Appolonia, 1980). The unit weights and laboratory strength parameters of both native soil and tailings are stated in Table C2.2 along with the strength parameters for very silty sand tailings determined in the May 1981 laboratory program.

In the static stability analysis, hypothetical circular failure arcs extending from the toe areas of the tailings embankment up to the beach area were used to investigate stability, as depicted in Figures C2-8, C2-9, and C2-10. Although sliding wedge failure surfaces were also analyzed, they produced higher safety factors than circular arcs and, therefore, hypothetical circular failure arcs govern stability. The upper or termination limits of the hypothetical failure circles were set by allowing the pond surface to be at its maximum elevation while maintaining a 50-foot beach and allowing all hypothetical slope failures to result in less than five feet of freeboard. This criterion produces hypothetical failure circles which generally exit on the backside of the crest or the upper limits of the beach. Hypothetical failure circles that resulted in freeboards of five feet or more after failure are not critical because compliance with the State Engineer's five-foot freeboard criteria would be maintained. Hypothetical failures in the buildout crest only, or in combination with the front tailings slope, were also investigated and showed equivalent or higher composite factors of safety than a hypothetical complete toe-to-crest embankment failure.

The phreatic surfaces used in the stability analyses are based on present conditions. The present phreatic levels under the embankment crest represent a reasonable estimate of the future levels because of the roughly constant value of hydraulic gradient with buildout (Section C2.2.2.4, Seepage Assessment) and because the phreatic level below the

crest is relatively insensitive to large pond level fluctations. Therefore, the phreatic levels under the embankment crest and downstream slope used for the analysis are identical to the present measured levels. Figure C2-11 shows the typical flow regime expected in the embankment. This phreatic level is in turn connected to the pond surface by a sloped phreatic surface with an approximate 1:1 slope. The steeply sloped drop in phreatic level is a conservative or upper bound location for any potential fully saturated zone. Much of the area below this steeply dropping or transition zone probably is and will continue to be partially saturated and have much greater strength than an equivalent fully saturated zone.

The phreatic level in the native soils also was assumed to remain constant at the present measured levels, under which condition static slope failure would be confined to the tailings. If the phreatic level within the native soil rises to the base of the tailings under the toe area of the embankment, the static slope stability safety factor will be lowered. Therefore, although the analyses have been performed assuming a low native soil phreatic level, the monitoring of the native soil piezometers are of importance, since a rise in level could lower the safety factors reported herein.

The static slope stability analyses for the one-, three- and five-year buildouts of the embankment are shown on Figures C2-8, C2-9, and C2-10, respectively. The generalized procedure of slices, a limit equilibrium method of analysis, was used to determine the critical slope stability safety factors. The minimum safety factor is 1.5 at the end of the five-year buildout. All hypothetical failure circles are deep circles extending below the phreatic surface. These hypothetical critical circles are quite different from those which were applicable to the old centerline configuration, which were shallow toe-to-crest circles completely above the phreatic level.

The modification of Section 4-4', as described earlier, has been analyzed and is presented on Figure C2-7. The modification provides a 1.5 or greater safety factor up to the five-year buildout level. If the planned modification were not to be undertaken, the section along the east side of the east pond labeled Section 4-4' on Figures C2-2 through C2-5 would fall below a static safety factor of 1.5 between the two- and three-year buildout levels, assuming a mill throughput rate of 2,000 tpd. The slope stability for Section 4-4' without implementation of this proposed construction is also shown on Figure C2-7, which shows that the safety factor would drop to 1.3 at the final buildout level.

The stability analyses indicate that the minimum static slope stability safety factor of 1.5 set by the State Engineer of New Mexico would be met with the planned buildout presented herein. The five-year buildout levels are the maximum estimated levels and any lower levels will remain above the 1.5 limits as shown by the one- and three-year slope stability analyses (Figures C2-8 and C2-9).

C2.2.2.3 Pseudo-Static Slope Stability

The effect of earthquake loading on the stability of the embankment has been investigated using pseudo-static loadings to account for the accelerations of an earthquake. Loss of strength due to strain softening was not considered, since the tailings were assumed, for purposes of calculations, to be at a minimum strength condition. The effects of loss of strength due to liquefaction of the saturated tailings is covered in a later section.

Pseudo-static loading is determined by the regional seismicity, which was addressed previously in Section B4.3. Under the analysis of the Applied Technology Council (1978), the effective peak acceleration for the mill area was estimated to be 0.05g. The application of the analysis of Algermissen and Perkins (1976) showed the mill site is located in a zone that could experience maximum horizontal bedrock accelerations of 0.04g. A 100-year earthquake originating in the

Rio Grande Rift would have an estimated maximum peak acceleration of 0.04g. Nevertheless, in performing the pseudo-static slope stability analysis, a more conservative assumption was made; that is, that an earthquake of magnitude 4.9 occurred in the immediate vicinity. This would result in an effective peak horizontal acceleration of 0.10g. Under this level of acceleration the minimum pseudo-static slope stability factor is 1.2 after five years of buildout, at an assumed mill throughput rate of 2,000 tpd. The pseudo-static slope stability factor is greater at lesser production rates or shorter buildout periods. The failure modes for pseudo-static loading are shown of Figures C2-8 through C2-10. This five-year buildout plan provides an adequate pseudo-static slope stability factor under conservative assumptions.

C2.2.2.4 Seepage Assessment

The saturated flow section under the HMC embankment is generally separated from the native soil groundwater by a fairly impermeable surface layer over the native sands. This separation produces an independent flow regime in the tailings embankment which consists of a downward seeping source, the pond, and a horizontally flowing outlet zone measured under the embankment with the use of both slotted screen and Casagrande porous-tip piezometers. These two zones of the flow regime are connected by a transition zone, the extent of which depends on the location of the pond surface. Piezometric levels indicate that at the highest potential pond level (condition producing a 50-foot beach) this zone is limited to the area under the 50-foot beach and does not extend below the embankment crest. The flow regime described above is expected to apply to the planned buildout configuration as well, and is shown on Figure C2-7 for the east pond after five years of buildout.

The flow through the outlet zone in this flow regime is controlled by laminar flow in a porous media, or by Darcy's Law:

$$V = ki$$

V = flow velocity
k = permeability
i = gradient (h/l)

The permeability (k) is a material parameter and is assumed to remain fairly constant through the longer flow channel produced by the setback crest. The gradient (i) is dependent on both the head (h) and the length of flow path (l), both of which increase with increased build-out. Although the increase in flow path length is largely a one-time jump when the crest is setback, the head slowly increases until reaching a maximum at five years. Thus, the velocity upon initiation of the setback crest is reduced to 75 percent of the pre-setback state, but with the slow increase of (h) the flow velocity will reach approximately the same velocity as the pre-setback state at the five-year buildout.

The flow regime in the downward seepage zone may consist of either downward seepage under fully saturated conditions or seepage through a partially saturated zone. In the partially saturated mode of seepage, the pond acts as a source supplying water to a mound which builds within the tailings pile. The rate at which water can leave this mound, either through the exit pipe (outlet zone) or by leaking through the bottom and into the native soil, controls the actual position of the phreatic surface shown on Figure C2-11.

The transition zone is where the downward flowing water begins to change to a horizontal flow due mainly to the obstruction to further downward flow created by the low-permeability native soil, which effectively deflects the seepage outward through the base of the tailings pile. The transition zone is probably partially saturated with zones of perched water caused by the stratification of the old beached materials through which the flow is occurring. Although a partially saturated condition greatly increases the inherent stability of the material in the transition zone, this overall effect has been conservatively disregarded in favor of assuming total saturation in the transition zone, which would produce the highest potential phreatic surfaces.

The embankment under the high flow conditions measured in the summer of 1980 on the east pond performed well without any signs of internal piping, seepage-produced sloughing, or failures in the main embankment

surface. Therefore, the maximum seepage velocities projected for the five-year buildout configuration should be similar to the summer 1980 conditions and well within the safe limits of operations at the HMC embankment. The potential for seepage-induced instabilities will continue to be monitored indirectly by observations of the seepage face location and by changes in the piezometer levels within the embankment.

C2.2.2.5 Liquefaction Assessment

The liquefaction of loose sands placed by hydraulic techniques is a possible failure mechanism for uranium tailings. A liquefaction failure may result from either cyclic loading, produced by an earthquake, or may occur due to a monotonic loading produced by slope movement in a static slope failure. In both cases the loading must occur rapidly enough to cause excess pore pressure.

The potential for earthquake-induced liquefaction of the pre-setback embankment was previously investigated in the Engineer's Report (D'Appolonia, 1980) and has since been updated to represent the initial setback stage with the latest available piezometric data. The effect of the five-year buildout over the new crest centerline will substantially increase the confining pressure near the bottom of the tailings embankment. This increase in confining pressure will increase the average shear stress induced by the earthquake, but will at the same time increase the effective confining stress by the same degree, thereby producing no net change in the shear stress-to-confining stress ratio and conversely no change in the factor of safety against liquefaction assuming a relatively constant phreatic surface during buildout.

The totally saturated zone under the pond will become more susceptible to earthquake-induced liquefaction as buildout occurs. The area under the pond is not a critical area for total embankment stability and a total loss of strength in this zone would not produce embankment failure.

The safety factors for earthquake-induced liquefaction are given in Table C2.3. The toe region of the front slope would be susceptible to liquefaction during an earthquake. The earthquake accelerations were conservatively assumed to be 0.10g horizontal and 0.07g vertical for purposes of calculation. The loss of strength in the toe zone has been shown, in the Engineer's Report (D'Appolonia, 1980) and by the updated analyses, not to produce a potential total slope failure (the embankment slope without the toe material remains at a safety factor above 1.0). This phenomenon has been analyzed again for the five-year buildout configuration on both ponds with the resulting safety factors above 1.0 for both ponds. The remainder of the saturated zone under the embankment has a very high safety factor against earthquake-induced liquefaction. Therefore, the analysis indicates that liquefaction failure of the embankment through the five-year buildout is not a potential failure mode.

The potential for liquefaction induced by monotonic loading is directly tied to the possibility of sudden and rapid slope movement within the saturated tailings zone. For those cases where the critical potential slope failures extend down into the saturated tailings, a static slope failure would very likely produce monotonic liquefaction of the tailings along the base of the embankment. However, the use of a minimum 1.5 safety factor for static failure surfaces extending through the saturated tailings provides effective protection against static failure and, therefore, against a monotonic liquefaction failure.

C2.2.3 Embankment Monitoring

During the embankment buildout, the physical conditions and phenomena affecting the embankment will be monitored. A program of visual observations and instrumentation, which has been developed and practiced previously, will be continued during the buildout. The program consists of water level measurements in the embankment, measurement of embankment deformations by movement point surveys, and visual observations of pond level, beach width, slope conditions, and seepage. Periodic reports on

the tailings embankment condition are submitted to the State Engineer's Office.

C2.2.3.1 Piezometers

The water levels within the embankment (the phreatic surfaces) have been measured with piezometers since April 1977. In 1980, 19 additional piezometers were installed to increase the number of measuring points and to replace some of the original piezometers in which function was questionable. These piezometers consist of open-well, slotted pipes installed in the tailings and slotted pipe installations sealed in the natural soils below the tailings. They have been shown to give reliable measurements of phreatic levels in both tailings and the natural soil. Casagrande porous-tip piezometers installed in March 1981 have been used to check and confirm the reliable functioning of the slotted pipe piezometers in the tailings. Five new piezometers to monitor buildout areas were installed on the east pond in April 1981 at locations shown in Figure C2-2.

During the embankment buildout addressed in this plan, additional piezometers to be located by HMC will be installed to extend phreatic level measurements in an upstream direction over the setback crest position and associated beach. Depending on changes that develop in the phreatic surface during buildout, more piezometers will be installed as needed along sections and positions shown in Figure C2-2.

The existing piezometers, together with those which will be added, will provide data for determining the phreatic surface and, in turn, the flow regime in the embankment. These data are necessary for the assessment of embankment stability and the operation of the ponds.

C2.2.3.2 Movement Monitoring

The deformations of the embankment are being monitored by survey of movement points established on the embankment. Deformation measurements will provide useful information on the behavior of the embankment from

which evaluations of stability and, in turn, operational decisions can be made. Results of the deformation measurements are reported to the State Engineer's Office on a monthly basis.

The hydraulic method of tailings placement creates a material mass which can densify, settle, and deform laterally as it dries or becomes subject to greater loading. If deformations occur, their direction and magnitude will be used to identify the phenomena occurring and to evaluate their effects on the stability and operation of the embankment. Survey monuments (movement points) have been established at the locations shown in Figure C2-2. The monuments consist of a four inch diameter steel pipe, set into the embankment surface, on which a metal plate and pin has been mounted. Monuments located in active tailings disposal locations might be covered periodically by tailings and will, therefore, be extended or replaced if they are covered. The monuments will be surveyed on a minimum of a monthly basis using a Keuffel-Esser Vectron and Autoranger II, or the equivalent. These devices have the following accuracies:

- Vectron - three seconds
- Autoranger - ± 0.01 feet at two miles

Both lateral and vertical displacements will be recorded and plotted versus time.

C2.2.3.3 Visual Monitoring

In addition to the foregoing instrumentation monitoring, visual surveillance of the embankment is being performed and observations systematically recorded. Visual observations provide regular and rapid assessments of overall embankment conditions and an effective way of detecting such phenomena as piping, rapid erosion, or surface slumping. Specific visual monitoring requirements have been established and are performed on a daily schedule.

The daily visual observations by a company qualified engineer, scientist, or management representative will include the following:

- Complete circuit of the embankment to observe for:
  - piping or sudden increase in seepage at toe
  - slumps, sloughs, or slides along the crest or slope
  - heave or outward displacement of the toe
  - rapid erosion of rills or gullies into the slope
- Condition of tailings slurry pipeline, especially signs of leakage, separation of couplings, or breakage
- Measurement of solution elevation
- Observation of minimum beach width

The NMEID will be notified within 24-hours of unusual conditions which would lead to failure of the system and result in a release of tailings or waste into unrestricted areas.

C3.0 ALTERNATIVE TAILINGS MANAGEMENT SYSTEMS

In accordance with Section 3-300.K of the New Mexico Radiation Protection Regulations (NMRPR), analyses of alternative tailings management systems have been performed. These analyses consist of an evaluation of alternative sites for disposal of mill tailings and of alternative tailings disposal methods. In the alternative sites analysis, sites within a seven-mile radius were evaluated to determine the most favorable sites for use as potential tailings disposal sites. Details of the alternative sites study are presented below in Section C3.1.

For the alternative disposal methods analysis below-grade disposal, neutralization of tailings, recycling of tailings liquid, dewatering of tailings material, and several other alternative tailings disposal methods were examined. The alternative methods were evaluated for feasibility, economics, health and safety, and environmental impacts. Details on these alternative methods are presented in Sections C3.2 and C3.3 below.

C3.1 ALTERNATIVE SITE STUDY

An alternative site study was conducted to identify potential tailings disposal sites for the HMC mill in accordance with recent amendments to the Radiation Protection Regulations of the New Mexico Environmental Improvement Board (Section 3-300.K.1). The full text of the recently completed alternative site study by D'Appolonia (1982) is included in this report as Appendix B. The alternative site selection study was preliminary in nature and was based entirely on existing data; no original site specific data were generated. This section provides a summary of the alternative site study.

A seven-mile radius around the HMC mill was used to define the study region. The seven-mile radius was considered appropriate because it generally includes all the area around the site surrounded by high mesas, land having a wide variety of physical features, and differing

populations. It was determined that no significantly different characteristics would be encountered by increasing the radius by several miles. The economics of transporting tailings beyond the seven-mile radius would generally preclude a larger radius, and as transportation distance increases, so does the risk of accidental release during transport, other factors being constant.

C3.1.1 Method of Study

The alternative site study was performed to identify one to three potential disposal sites which meet the broad objectives of NMRPR Section 3-300.K.1. The specific criteria of evaluation include:

a. remoteness from populated areas;

b. hydrologic and other natural conditions that contribute to the continued isolation of pollutants from useable groundwater;

c. location where long-term geologic stability exists and gully erosion is not a hazard;

d. engineered and natural site characteristics such that the site is so well protected from flood damage that any transport of radionuclides and the resulting radiation exposure to the public therefrom, as a result of damage from a flood of such magnitude that it could be expected to occur but once in one hundred years, shall not exceed the standards provided in Part 4;

e. protection from wind erosion of tailings;

f. suitability for long-term reclamation and minimal continued maintenance and monitoring;

g. location where seismic risk is within acceptable limits;

h. location which minimize conflicts with archeological, wildlife and recreational values; and

i. economic and technological feasibility.

An evaluation rationale was developed around these objectives which included formulation of an evaluation methodology and identification of technical and environmental issues that influence site suitability. The methodology used in evaluating the potential sites was required to be objective, credible, and repeatable. The methodology that was developed included an initial screening process followed by a two-step ranking process. It consisted of the following elements:

Preparations for Site Selection

- Data acquisition.
- Determination of study region.
- Determination of site selection considerations; i.e., the issues and factors influencing selection.

Screening of Study Region

- Identification of exclusion criteria from the list of considerations.
- Screening of unacceptable areas from the study region.

Development of Ranking System

- Arrangement of remaining considerations according to topical categories.
- Determination of relative importance of categories and of considerations within categories, and assignment of weight factors accordingly.
- Determination of the standards or indices for each consideration to be used in evaluating areas and sites.

First Step Ranking

- Evaluation and ranking of large areas in the study region by the five most important categories.

Second Step Ranking

- Subdivision of the top two ranked areas into sites and evaluation and ranking of those sites against all considerations.

Following basic data acquisition and determination of the study region, the specific site selection considerations were established for the study that reflected either site characteristics or impacts important to tailings disposal site selection. From the list of considerations, exclusion criteria were selected for use in the screening process. A screening process was used to preclude, for the purpose of the study, certain possible alternative sites from further consideration. For example, while a site located within an area which would receive flow during a 100-year flood could easily be protected from such a flood by a berm, a site within the 100-year floodplain was excluded from further consideration because the favorable features at such sites could be duplicated at nearby sites not within the 100-year floodplain. The exclusionary criteria used were:

- 100-year floodplain
- Potentially active or active faults
- Landslide areas
- Municipal, industrial, and residential areas
- Major transporatation corridors
- Underground mined-out areas

After the exclusionary criteria were applied, the remaining areas were subject to evaluation whereby remaining considerations were grouped according to topical categories and the relative importance of each category and consideration to alternative site selection was assessed (Appendix B, Table 1). The relative importance of each category and each consideration was indicated by its weight factor, a number from one to ten. Ten indicates the highest impact or importance, one the lowest. Category weight factors indicate relative importance with respect to other categories, and consideration weight factors reflect importance as related to other considerations within the same category. Being at two different levels, category weight factors cannot be compared to consideration weight factors.

After weight factors were determined, the considerations were used to evaluate and rank the areas and the sites within areas. A numerical evaluation system was used to avoid the problems with qualitative terms and to provide an index of the measured values used in evaluating many considerations. In contrast to weight factors, which indicate the importance of a consideration or category, evaluation numbers indicate the level of satisfaction, suitability, or desirability of the conditions at an area or site related to each consideration. The sum of the evaluation numbers for each area or site indicates the most desirable area or site for development of a new or alternative tailings disposal facility.

The ranking process involved a two-step evaluation. In the first step, the nonexcluded portions of the study region were divided into nine areas on the basis of physical or geographic boundaries and ranked according to the five most important (highest weight factor) categories, excluding economics. These categories included groundwater, surface water, remoteness from habitation, geomorphology, and proximity to the mill.

The two top-ranked areas were subdivided into nine sites which were ranked in step two of the ranking process. In this second step, all categories of considerations were used to evaluate the potential sites because one or more of those sites would be selected and a complete evaluation of all considerations is desirable, regardless of their respective impacts on the ranking.

Economics was not used in the first step and was evaluated separately in the second step of the ranking process in order to minimize its influence on site selection. However, the NMRPR specifically provide for economic and technological feasibility in evaluating alternative sites and existing sites. An economic evaluation was performed in the final ranking process. The importance of economic considerations is very considerable because any selection that renders the system uneconomic

will have socioeconomic consequences that are deleterious. If the HMC mill operations become uneconomical and the mill is forced to close, severe social disruptions (dislocation of families, erosion of the tax base, and reduction of educational/health/social services) would occur. The economic well-being of the mill facility is of importance to the regional population, their government and to HMC.

C3.1.2 Evaluation and Ranking of Potential Sites

Within the seven-mile radius, extensive portions of the region were eliminated from further siting consideration because of the exclusion criteria. The criterion responsible for eliminating the most area is the 10 percent maximum slope gradient restriction. Municipal, industrial, and residental areas eliminated much of the southern part of the region. The presence of lava removed much of the western part of the region. Mesa tops, which are capped by basalt, were also eliminated. The 100-year floodplain disqualified the central portion of the San Mateo valley, which bisects the study region. Major transportation corridors and underground mined-out areas were eliminated in the southern and northern ends of the region, respectively. There were no active or potentially active faults within the study area requiring exclusion. All landslide areas were on slopes greater than 10 percent and were excluded by both criteria.

The remaining land was divided into nine areas, as shown in Figure C3-1, and individually ranked. Based on evaluation and ranking of the areas, the two areas designated as Areas D and E were judged to be superior to the other alternative sites. The two areas are contiguous and located north-northwest of the mill. These two areas are more suitable than the others in terms of impacts to groundwater, surface water, geomorphology, and remoteness from habitation. The major advantages of Area D are its remoteness from habitation and its small, self-contained watershed free of floodplains. Additionally, groundwater resources appear to be sparse in Area D. This is desirable in terms of seepage potential and water use. Area E is also relatively removed from habitation in comparison to

other sites. Being relatively close to the mill is an advantage to Area E. The only obvious drawbacks to Area E appear to be the presence of a small floodplain and the alluvial soils underlying the site that may pose a potential seepage problem.

The candidate Areas D and E were subdivided into nine potential alternative sites of 0.5 to 1.5 square miles that were evaluated and ranked with respect to the entire set of considerations (Figure C3-1). Of the nine potential alternative sites, those designated as Sites 5, 6, and 8 received the highest rank numbers and are considered the most favorable of the candidate sites for use as alternative tailings disposal sites for tailings generated after the buildout of the present system is complete.

These three sites were rated the highest or nearly so in the most heavily weighted categories--groundwater, surface water, remoteness from habitation, and geomorphology. By examining all of the considerations, including economics, Site 8 received the highest ranking number followed by Site 5 and then Site 6.

C3.1.3 Evaluation of Present Site

For purposes of comparison, the present mill site was also evaluated against the site selection considerations. Although the ranking evaluations according to specific considerations were very different for the present site compared to the best alternative sites, the present site achieved total ranking comparable to the preferred alternative sites. The following discussion compares the present site with the best of the alternative sites, and discusses the suitability of the present site in terms of the Section 3-300.K.1 criteria:

a. Remoteness from Populated Areas

When the present site was constructed, it was remote from populated areas. Since then, subdivision populations have appeared to the south and west of the site. Alternative Areas D and E are more

remote from populations than the present site, but there is no assurance that populations will not develop near Sites D and E if they are used. Despite the proximity of populations to the present site, the prevailing wind is away from the populated areas and toward vacant areas. Further, the airborne releases to the present populations meet all applicable regulations. Even if there is a stability failure of the tailings, the tailings are not likely to flow off the HMC restricted area to the nearby subdivisions.

b. Groundwater

There are portions of alternative Areas D and E that provide better natural protection of groundwater than the present site because there is a smaller amount of groundwater and water-bearing alluvium. During the operation of the groundwater protection plan, compliance with the New Mexico groundwater regulations will be achieved at the present site. In the long term, such as 200 years, the stabilization of the present site will preclude significant seepage to groundwater, as recharge and driving head in the tailings will be eliminated. Nevertheless, the groundwater consideration is the one which most strongly favors the D and E areas over the present site.

c. Long-Term Geologic Stability and Gully Erosion

The seismological regime at the present site is the same as that of the alternative sites, and all of them have favorable seismic characteristics both for the long and short terms. There are no active faults or potentially active faults at the present site or the alternatives studied. The present site and the alternative sites have similar characteristics of geologic stability.

Gully erosion is to a very large degree influenced by slope. The present site is characterized by very flat slopes, as are the best of the alternative sites. The gentle slope at the present site is an important factor in its favor, both in the short term and for

long periods, such as 200 years. The present site may more properly be characterized as depositional, rather than erosional, and is very easily protected from gully erosion for very long periods of time.

d. Flood Protection

Flood protection under the NMRPR Section 3-300K.1.d is evaluated in terms of engineered and natural site characteristics. In evaluating existing sites or alternative sites, the evaluation designated is for engineered or natural protection from flood damage so that any transport of radionuclides and the resulting radiation exposure to the public therefrom will not exceed the standards provided in Part 4 as a result of damage from a flood of such magnitude that it could be expected to occur but once in a 100 years (NMRPR Section 3-300.K.1.d). For stabilization, a 200-year period is used (NMRPR, Part 12).

There is an engineered feature at the present site, a berm, which provides protection of the tailings from a flood of such magnitude that it could be expected to occur but once in a 100 years. At the time of stabilization, the present site can and will easily be protected from a flood of such magnitude that it can be expected to occur but once in a 200-year period.

The berm protection will protect populations outside the restricted areas from any release exceeding the Part 4 standards due to 100-year floods.

e. Wind Erosion

The existing tailings embankment at its present height does not provide as effective a natural protection from wind erosion of tailings as would sites in alternative Areas D and E if low profile tailings are deposited there. However, the present site complies with the applicable airborne release standards of Part 4. A recent

NMEID study (Buhl, et al., 1982) has shown that radon concentrations around the present site do not exceed assumed background at measuring stations off the HMC property. Furthermore, HMC chemically treats portions of the present tailings to retard wind erosion.

After operations cease, the stabilization treatment will protect against wind erosion from tailings for 200 years, and thus will be comparable to other sites for such a period of time. At the present site, the prevailing winds are generally away from inhabited locations.

f. Long-Term Stabilization and Minimal Continual Maintenance and Monitoring

The present site is not markedly different from the best alternative sites in terms of stabilization and minimal continual maintenance and monitoring. There are several factors bearing on this subject in terms of the site, as opposed to method, such as flood potential, slope, geologic stability, groundwater, and gully erosion potential.

Flood Potential - The present site is easily protected from floods over very long periods of time by simple and reliable engineering measures such as berms. The lack of discernible channels and the gentle slope in the area of the present site are favorable features in that such flooding that occurs should involve relatively low velocities and will encourage deposition rather than erosion. Maintenance of berms, if necessary, is straightforward and can be easily monitored by visual observations.

Slope - The gentle slopes in all directions at the present site tend to lessen flood water velocities and discourage gully erosion. Erosional forces decrease with slope, other factors being equal. Deposition is favored on low slopes. Relatively gentle erosional forces lessen the

need for long-term maintenance, reduce the necessary frequency of monitoring, and allow the use of simple, rather than complex, engineering protection.

Geologic Stability - Seismic risk is not a significant factor in long-term stability of the site. Any resumption of volcanic activity near the site would likely be depositional, even in geologic time frames, and would have other impacts eclipsing those of the attendant disruption of tailings.

Groundwater - The aspect of the site which will require the most elaborate maintenance and monitoring is seepage to groundwater. However, this should not be a long-term problem in terms of, say, 200 years because gravity drainage should dewater the tailings in a much shorter period of time. Once tailings disposal has been stopped, seepage will decrease significantly with time and eventually cease. However, for a number of years after disposal is stopped, the groundwater protection program will be required to be operated by HMC assuming its discharge plan is approved. The proposed protection plan is detailed in the GWDP. Several of the better alternative sites would require less maintenance and monitoring in this respect than the present site, particularly if lined ponds are employed, because they have less near-surface groundwater flow or less alluvium, or both. However, the total cost of switching to such a site would be far more costly than the higher maintenance and monitoring at the present site, particularly when present yellowcake prices are considered. Further, switching to an alternative site would not decrease the need for maintenance and monitoring at the present site, and would result in two sites where monitoring might be necessary.

Gully Erosion - The gentle slopes at the site and the ease with which flood protection is provided makes the present site favorable in terms of long-term maintenance and monitoring against gully erosion. Head cutting to the north would be away from the present site, and deposition should be favored near and at the present site.

Disturbance by Animals - Some commentors have claimed that disturbance by burrowing or grazing animals is the principal threat to long-term stability of tailings. The present site is about equal to the alternatives in this respect. Further, the New Mexico Continued Care Fund should provide a large annual income to fend off disturbance of such animals. Also, the rock cover included in the proposed stabilization plan (Section C9.0) will discourage grazing or burrowing.

Other Factors - While not particularly a site selection factor, the use of above-grade disposal of tailings at the present site will result in a stabilized mound with points of greater steepness than would be encountered by sub-grade or below-grade disposal. To reduce the erosion potential of the stabilized tailings at the present site, the final slope configurations will be flattened. Section C9.0 addresses final regrading of the slope at the present site. Below-grade disposal at the present site would place tailings closer to groundwater, but at some of the alternative sites, below-grade disposal would be more feasible, and in such locations erosion potential of the tailings themselves would be reduced compared to the present site. An argument against below-grade disposal has been that if a problem does develop with below-grade tailings, it may be very difficult to correct.

It would be expected that wind erosion of the stabilized tailings embankment at the present site would be a more significant factor than if a below-grade disposal system were used at another site. However, the use of an alternative site would not reduce the wind erosion consideration at the present site, which will require monitoring in any event. If tailings deposition at the present site were to be discontinued now, and deposition commenced at another site, the total height of the present structure would not increase, and some ultimate lessening of wind erosion potential might occur. However, this possible advantage would appear to be more than offset by the necessity of wind erosion monitoring at two sites, rather than one.

No consideration at all is given to the concept of moving the existing tailings to a new site. Not a single case of illness due to the existing tailings disposal has been documented. The process of moving the existing tailings and constructing a below-grade system would seem much more likely to result in harm or death to humans than leaving the tailings at their present location, and stabilizing them in accordance with the NMRPR. Further, if problems developed at a below-grade site, the correction of those problems could be far more complex than would be involved at the present site. Furthermore, moving the tailings to a new site with below-grade disposal may involve a cost of $3 to 5/ton.

A factor of considerable significance in New Mexico is the existence of the Continued Care Fund. Uranium mills in New Mexico contribute at the rate of $0.10 per pound of U_3O_8 contained in yellowcake produced until a total contribution of $1,000,000 for a respective mill is reached, exclusive of accumulated interest. This will result in a sizeable sum in New Mexico for correction and monitoring not available in other jurisdictions. If a mill has contributed $1,000,000, and that sum is invested at 12 percent compounded annually over a 15-year remaining life, the fund from that mill will amount to $5,473,566 when the mill life is complete. The annual interest from such a sum at 12 percent is $656,828. The actual sums will vary with interest rates and mill life.

The existence of the Continued Care Fund in New Mexico makes maintenance and monitoring considerations in site selection less significant than in less prudent jurisdictions, such as those regulated by the U. S. NRC.

C3.2 ALTERNATIVE TAILINGS DISPOSAL METHODS

C3.2.1 Below-Grade Disposal Methods

No disposal of tailings below-grade is being performed by HMC, nor is any planned. However, possible below-grade disposal methods which have been considered include:

- Backfilling of mined-out space.
- Disposal in pits or trenches on the present site.
- Disposal in pits or trenches on an alternative site.

Each of these methods is technically feasible; i.e., the technology of each is well developed, and there are no insurmountable engineering problems in implementing these methods.

Mine Backfilling

A typical mine backfilling operation involves several handling steps. Normally a specific area is set up in or near the tailings disposal area to act as a holding area for tailings to be used in the backfilling system. If cyclones are being used, the coarse fraction (cyclone underflow) is most often stockpiled. Once deposited, the coarse tailings are allowed to drain for two weeks or more until reaching a moisture content of between seven and ten percent. The drained sand is then transported by truck to a sand plant where it is mixed with recycled mine or mill waters to yield a slurry of approximately 65 percent solids. The slurry is then pumped underground through mine shafts or cased boreholes and into designated backfill areas. These areas are sealed off from adjacent workings by means of drain walls, which allow the decanted liquid to return to the mine drainage system, eventually commingling with natural mine waters and returned via pumps to the waste water treatment system or IX facility.

Although the system described above may be considered typical, there are several modifications which may make it more efficient and thus less costly. The first modification deals with placing a cyclone station at the mine portal or shaft thus eliminating costly material handling and providing a general streamlining of the system. The second modification deals with dewatering of the cyclone underflow. The separated coarse tailings could be dewatered and/or reslurried on site rather than going through a natural drainage process. The only reason that tailings are

dewatered by draining, as in the previously described typical system, is to facilitate handling by earthmoving equipment.

The practice of backfilling with tailings is favored where there is need to enhance the stability of the ground being mined for safety and enhanced and more efficient ore recovery. The present HMC mines are relatively shallow and dry compared to the newer, deeper mines in the district. Other factors being constant, mine stability in the Grants District decreases with increasing depth and occurrence of groundwater. The need for sandfilling has not yet become an operational requirement in these mines. The distances involved would favor use of tailings from Ambrosia Lake mill sites, rather than the HMC tailings, to backfill the HMC mines in Ambrosia Lake.

The obvious benefit associated with mine backfilling as a means of below-grade disposal is the removal of tailings from the surface environment, thereby reducing the contaminant exposure to man and the surrounding environment. However, backfilling of mined-out space in HMC's mines is economically and environmentally impractical because of the distance to the mines and the transportation hazards of moving tailings to those mines. The HMC mines are between six and 18 miles from the mill. Transport of tailings over these distances would require haulage by truck along State Route 53 or pumping in slurry form by pipeline. Truck loading and haulage would be expensive, about $1.50 per ton-mile (Achhorner, 1982). Reexcavation and transport of tailings also increases the health hazard to workers who would be exposed to fugitive dust and radon released in the handling process. In addition, the increased truck traffic would increase the potential for accidents along State Route 53. A pipeline of sufficient length would be very expensive and require several pumping stations. In addition, a slurry pipeline would be subject to risks of breakage and spillage.

Disposal at Present Site

Disposal in pits or trenches at the present site could be performed in a manner generally similar to mine backfilling. However, despite the economic advantages of locating a below-grade disposal facility at the present site, disposal below-grade at the present site is not feasible because of the relationship of the site to the San Mateo drainage floodplain and the groundwater in the San Mateo alluvium of the valley. Due to the limited depth to which below-grade disposal can be taken (because of the need to remain well above groundwater), below-grade disposal would cover a larger area than above-grade disposal of equal volume. Consequently, pits or trenches would have to extend into or adjacent to the floodplain and would require extensive protection against inundation during floods. Unless impermeably lined, the pits or trenches could place tailings in a position to contact water-bearing alluvium and could bring contaminated water close to or in contact with the water table. The apparent environmental advantages of a lined pit would be offset by the difficulty of dewatering the deposited tailings, the possibility of imperfections in the liner, and the difficulty of correcting leakage problems.

A pit or trench concept usually includes a separate evaporation pond to hold the decant tailings liquid. Thus, either the present evaporation ponds would be used or new ponds built. Consequently, below-grade disposal at the present site would increase the potential for groundwater contamination, would probably require separate evaporation ponds, and could counteract HMC's efforts to improve the San Mateo alluvium groundwater quality as discussed in the GWDP (Hydro-Engineering, 1981). No net environmental benefits would be provided with this type of below-grade disposal.

Disposal at Alternative Site

Below-grade disposal is one option for consideration in the design of a disposal system at an alternative site. This option has been included

in the study of alternative sites in Section C3.1. Depending on specific site conditions, below-grade disposal could be a feasible method for use at a site where surface water and groundwater conditions are favorable and where soil and rock depths and characteristics allow construction of protected pits or trenches with low risk of seepage to nearby groundwater resources. If technically feasible, below-grade disposal at an alternative site would reduce the fugitive dust potential and possibly the risk of erosion by surface water runoff or release of tailings by breach of retention structures. However, detailed technical, economic, and environmental assessment of the below-grade option at alternative sites cannot be performed until more data are available. These assessments would need to examine the possible negative effect on groundwater versus the relatively low erosion hazard of below-grade disposal, the merits and drawbacks of liners, the difficulties of dewatering below-grade tailings, and the associated need for above-grade evaporation ponds. The present above-grade disposal method does not involve these concerns.

C3.2.2 Neutralization of Tailings

The HMC milling operation uses an alkaline leach process. Therefore, neutralization of tailings would have insignificant benefit as an alternative tailings management method.

C3.2.3 Recycling of Tailings Liquid

The existing tailings disposal system includes recycling of tailings liquid. The decanted liquid is drawn from the ponds by a decant tower in each pond, both of which connect to pipes which return the liquid to the mill. The returned tailings liquid is used again in the mill circuit as described in Section C1.0. Alternative tailings management methods incorporating the recycling of tailings liquid are addressed in Section C3.2.5. Therefore, a separate discussion of liquid recycling is not provided here.

C3.2.4 Dewatering of Tailings Material

Dewatering of tailings material prior to disposal is fundamental to or incorporated in several alternative methods discussed below in Section C3.2.5.

C3.2.5 Other Alternatives

Several alternative tailings disposal methods have been considered as modifications to or replacements for the existing tailings disposal system described in Section C2.1. Each one of the alternatives could be used at the existing disposal site but would differ from the present system either in terms of tailings liquid handling or tailings placement, or a combination of both. For most of these alternatives, the technical and economic feasibilities cannot be determined precisely until design studies are performed.

An alternative disposal method might be selected and implemented for the following reasons:

- To increase the stability of the tailings embankment.
- To increase the solids storage capacity of the embankment (extended operating life).
- To preserve or increase the pond areas and, in turn, both their liquid storage capacity and evaporation.
- To reduce seepage from the ponds to the groundwater system to improve health and environmental benefits.
- To dewater the tailings ponds at an earlier date.
- To augment secondary recovery of soluble uranium.

To accomplish one or more of these objectives, several alternative methods have been identified under three types of handling systems:

- Present Cyclone System (System A)

  A1 - Present cyclone method for tailings placement with a new lined evaporation pond for excess decant water or collection well water disposal.

  A2 - Present cyclone method with a new water treatment system to clean up collection well water for use as mill process water.

- Dry Tailings System (System B)

  B1 - Dry tailings disposal using the existing embankment ponds for evaporation.

  B2 - Dry tailings disposal using existing embankment ponds plus a new lined evaporation pond.

  B3 - Dry tailings disposal using only a new lined pond for evaporation.

  B4 - Dry tailings disposal using existing ponds for collection well water evaporation and a new lined pond for tailings solution evaporation.

- Thickened Tailings System (System C)

  C1 - Thickened tailings disposal using present ponds for evaporation.

  C2 - Thickened tailings disposal using both existing ponds and a new lined pond for evaporation.

  C3 - Thickened tailings and dry tailings disposal concurrently or in sequence, using a new evaporation pond.

The characteristics, feasibility, advantages and disadvantages, and circumstances favoring the use of each of these alternatives are discussed below.

Discussion of Alternative Disposal Methods

A - Present Cyclone System Alternatives

Alternative A1 - Present cyclone method with new evaporation pond. The existing method of cycloning the slurried tailings to separate coarse and fine splits would be used to build the embankment as described in Section C2.1. A new lined evaporation pond would be constructed north of the embankment to hold and evaporate the decant water and/or collection well water which exceeds the capacity of the present embankment ponds. This alternative, illustrated schematically in Figure C3-2, is technically and economically feasible, involving practices presently in use at some other mills.

This alternative has several advantages, including:

- Continued use of the existing tailings placement system (no additional cost, proven effectiveness).
- Increased evaporation capacity without increased seepage.
- Containment of water removed from the collection wells.

Some disadvantages are associated with this alternative, namely:

- Ultimate buildout limited by stability considerations.
- Cost of the new evaporation pond and its reclamation.

This alternative would be appropriate only if the combined water volume from the mill (decanted slurry water) and the collection wells exceed the combined evaporation and storage capacities of the existing ponds. Cyclone placement results in an outer embankment slope near the natural angle of repose of the coarse tailings; therefore, the ultimate buildout of the embankment is limited by the factor of safety which declines with increasing crest height. Consequently, this alternative is limited to

buildout to elevations where static factors of safety drop to 1.5. Alternative A1 can be considered appropriate for a limited period of buildout during which additional evaporative capacity would be needed.

Alternative A2 - Present cyclone method with new water treatment system. The present tailings disposal method would be continued, and a new treatment system would be used to clean up the water pumped from the collection wells described in Section B3.2.5. This water would be used as mill process water, replacing most or all of the water presently drawn from deep wells for this purpose, as shown in Figure C3-2. The treatment system would result in a reduction of water input to the tailings embankment. The technology for this kind of treatment system exists; therefore, this alternative is technically feasible.

The water treatment alternative offers several advantages including:

- Continued use of the existing tailings placement system.
- Reduction in deep well pumping costs.
- Conservation of deep water resources.
- Double benefit from collection wells - ground-water protection and mill water source.
- Net reduction in water input to the tailings pond, reducing seepage potentials.

The disadvantages of this alternative include:

- Ultimate buildout capacity limited by stability considerations.
- Capital and operating costs of a new water treatment system.

Alternative A2 would be appropriate if limited buildout capacity can be tolerated in the long term or if this alternative is followed by another which would extend embankment life. The water treatment system could be attractive if its capital and operating costs plus reduced deep well pumping costs compared favorably with the costs of maximum deep well pumping.

B - Dry Tailings System Alternatives

Alternative B1 - Dry tailings disposal using only existing ponds for evaporation.

Dry tailings disposal would involve replacement of the present cyclone disposal system with a system for dry handling and placement of tailings. The existing slurry transport system, cyclone separation, and dual spiggoting (fine and coarse splits) would be abandoned and replaced with a conveyor system and earthmoving equipment.

To handle and place tailings as solid material, or "dry" material as opposed to slurry, the tailings would be removed from the last vacuum filter or dryer and fed through a hopper to a new belt conveyor. The conveyor would transport the solid tailings, which are likely to have a moisture content of 18 to 25 percent, to one or more dumping locations at the toe of the embankment. Earthmoving equipment (scrapers, dozers, graders) would pick up the tailings at the dump points, transport them and place them in lifts along the embankment toe. After placement, the tailings will be spread and compacted by dozers and graders to build a controlled outer embankment slope of 4H:1V. The dry tailings disposal method is illustrated in Figure C3-3.

The mill process liquid, which is discharged with the tailings slurry in the present system, would be discharged to the existing ponds for evaporation. The fraction of this fluid seeping to the groundwater would be intercepted by the collection wells and returned to the ponds.

The concept of dry tailings placement is technically possible, but putting the concept into an operative system is dependent on several factors which are being studied. The most critical factor is the maximum moisture content at which tailings can be transported by conveyor. If the present moisture extraction process in the mill

cycle cannot reduce tailings moisture content enough to allow dry handling, an additional drying step would be required. If moisture contents cannot be reduced sufficiently by any mechanical processes, then it is likely that some chemical characteristic of the tailings or solution is responsible for moisture retention. In this case, a chemical treatment might be required to facilitate moisture extraction.

Other factors which could influence the feasibility of dry tailings disposal include:

- Optimum versus actual moisture content of placed tailings. If moisture contents are more than a few percent above optimum, extra air-drying time and discing of placed tailings might be necessary.

- Methods of control of seepage exiting from the present embankment toe. If the dry tailings, which would contain both coarse and fine fractions, are not free-draining, a drainage system might be necessary to intercept seepage at the old toe of the coarse tailings slope.

- Chemical characteristics of the tailings which could affect the compactability of the tailings. Grain coatings, precipitates, or flocculents might have some influence on the compaction characteristics of the tailings.

Studies to characterize and assess the influence of these factors and to evaluate possible methods of treatment are being performed. The results of these studies will be used to determine the feasibility of dry tailings disposal at HMC and, if appropriate, to develop design parameters for the system.

The results of the studies are expected to show that dry tailings disposal is feasible. Based on this expectation, the dry tailings method offers several advantages:

- Expanded storage capacity at the present embankment, sufficient to accommodate tailings output for the entire operating life of the mill.

- Enhanced stability of the embankment due to the development of a compacted outer slope at 4H:1V.

- Preservation of present pond area and evaporation capacity.

- Development of embankment slopes to stabilization configuration during disposal, minimizing second handling of tailings during stabilization.

The advantages are sizeable but are not without some trade-off against disadvantages which include:

- Capital and operating costs of a new conveyor system and earthmoving equipment.

- Possible costs of an additional drying stage or chemical treatment.

- Relocation of roads and ancillary facilities around the embankment to make room for construction of the flatter outer slope.

- Cost of a drainage system around the toe of the existing embankment slope.

Alternative B1, if technically feasible, could be attractive if cost trade-offs show that the cost of implementing dry disposal can be at least offset by savings in the stabilization costs (earthmoving) which would not be incurred with this alternative. Increased stability and prolonged operating life of the embankment would remove the need to develop an alternative disposal site, a major cost and environmental benefit by itself. On balance, it appears that this alternative could be appropriate for use in the ultimate buildout of the embankment for the operating life of the mill.

Alternative B2 - Dry tailings disposal using both existing ponds and a new lined pond for evaporation.

This alternative is identical to Alternative B1 except for the addition of a lined evaporation pond (Figure C3-3). The new pond would provide additional storage and evaporation capacity in the event that the capacities of the existing ponds in the embankment were not sufficient for the water input. The technical feasibility of Alternative B2 is the same as for Alternative B1. The advantages of Alternative B2 in addition to those of Alternative B1 lie in the benefits derived from the new pond:

- Expanded liquid storage and evaporation.
- Possible reduction in liquid input to the embankment ponds which might reduce the phreatic level in the embankment and reduce seepage to the groundwater.

The disadvantages of this alternative, in addition to those of Alternative B1, are:

- Capital and operating costs of a new pond.
- Stabilization, maintenance, and monitoring costs.
- Environmental disturbance caused by the new pond.

To make selection of Alternative B2 attractive, dry tailings disposal must be appropriate and there must be a need either for increased liquid storage and evaporation capacity or for a gradual transition of liquid disposal from existing to new ponds. A transition to a new pond could become appropriate if it would be advantageous to allow the old ponds to gradually dry in preparation for stabilization.

Alternative B3 - Dry tailings disposal using only a new evaporation pond.

The method of tailings placement in this alternative is identical to that for Alternatives B1 and B2, with the same feasibility, advantages,

and disadvantages of dry disposal. The difference between this alternative and Alternative B2 is the exclusive use of a new evaporation pond for liquid disposal in this case (Figure C3-3). If all tailings are placed dry, all liquids (mill process water, collection well water, and other mill liquids) could be pumped directly to a lined evaporation pond.

Distinct advantages, in addition to those already discussed for dry tailings disposal, could be realized from this alternative including:

- Elimination of water input to the tailings pile leading to gradual drying of the pile. Seepage from the pile would decrease sooner and final stabilization of the pile could occur at an earlier date following operations.
- Containment of water from the collection wells.
- Increased stability of the tailings embankment as the old ponds dry up at an earlier time.
- Increased capacity of dry tailings storage in the dried pond areas.

The disadvantages, beyond those previously described for dry tailings disposal, include:

- Capital and operating costs of a new pond.
- Additional stabilization, maintenance, and monitoring efforts and costs associated with the lined evaporation pond.

These are similar disadvantages which were cited previously for Alternative B2.

<u>Alternative B4 - Dry tailings disposal using existing ponds for collection well water evaporation and a new lined pond for mill process water evaporation.</u>

In principal, this alternative is nearly the same as Alternative B2. The difference is in the specific use of each pond (Figure C3-3).

Collection well water, with lower ion concentrations than the mill process water, would be returned to the old ponds on the pile to flush contaminants from the pile. Before being returned to the pond, this water could be recycled through the mill for extraction of uranium. The mill process water would be sent directly to the new evaporation pond.

The feasibility of this alternative lies in the efficiency of flushing the pile with collection well water. Laboratory or bench scale tests might provide the information necessary to assess this feasibility. The distinctive advantages over other dry disposal alternatives are:

- Gradual reduction of residual uranium and other soluble ions in the tailings pile.
- Possible secondary recovery of uranium.

The disadvantage of this alternative which is different from those of other dry disposal alternatives is the cost of a separate system for collection well water and secondary extraction, if used.

This alternative could be the appropriate selection if the processes of flushing the pile and of secondary extraction from collection well water are both technically and economically feasible.

C - Thickened Tailings System Alternatives

Alternative C1 - Thickened tailings disposal using present ponds evaporation.

In the thickened tailings disposal method, a heavy slurry is pumped to the top of the tailings embankment and poured at the perimeter of the ponds to form a series of relatively flat cones (Figure C3-4). The method consists of:

- Mixing of the tailings extracted from the last drying stage in the mill with a quantity of water just sufficient to create a pumpable slurry.

- Pumping of the thickened tailings (heavy slurry) to the old pond areas.

- Allowing time for the cones to drain and densify. Drainage of cones produces less free water than does the present cycloning method.

- Redistribution and compaction of drained tailings as necessary to build up the embankment. This could include moving drained tailings to the toe of the embankment to be placed and compacted in the same manner as dry tailings.

The feasibility of the thickened tailings method will be studied if dry tailings disposal is shown to be unfeasible. The feasibility depends on several factors, including:

- The minimum water content required for pumpability.

- The slump angle of the coned tailings.

- The permeability and water content after drainage (specific retention) of the tailings.

- The density and strength characteristics of the drained tailings.

The advantages of this alternative must be considered on the assumption that dry tailings disposal would be unfeasible. Under such circumstances, the advantages are:

- Better control over placement of tailings than currently achievable with the cyclone method.

- More rapid stabilization of tailings.

- Reduction of the amount of water entering the ponds.

The disadvantages are:

- Some loss of pond capacity.

- Limited buildout unless drained tailings are placed at the embankment toe.

- Secondary distribution (handling) of tailings.

- Additional costs of heavy pumps and pipes.

At best, this alternative would be used only if dry tailings methods were unfeasible and pond storage capacity would not become critical. Under other circumstances this alternative probably would be used as an interim measure until additional pond capacity could be developed or until another placement method could be devised.

Alternative C2 - Thickened tailings disposal using both existing ponds and a new lined pond.

The characteristics of this alternative are identical to Alternative C1 except that a new pond would be used for additional water storage and evaporation (Figure C3-4). In this alternative the pond area of the old ponds would not be critical because only a limited amount of tailings water would be discharged and all other water would be sent to the new evaporation pond. Therefore, a large percentage of the old ponds could be used for permanent disposal of tailings, i.e., the coned tailings would be left in place until the volume of the ponds was almost filled with tailings. The feasibility of this alternative is the same as that of Alternative C1 with respect to tailings placement. However, the addition of a new pond gives this alternative better feasibility with respect to water storage and evaporation, but has the disadvantage of the cost associated with a new evaporation pond.

Alternative C2 has the following advantages:

- The same as those listed for Alternative C1.
- More water storage/evaporation capacity than Alternative C1.
- More capacity (in the old ponds) for tailings storage, because less tailings water would be discharged.
- Filling of the old pond areas to near-final stabilization contours, saving stabilization earthmoving costs.

The disadvantages of this alternative are:

- Second handling of tailings to build the outer slope of the embankment to a 4H:1V gradient if

the existing embankment is to be used throughout the operating life of the mill, or

- Limited buildout capacity determined by the decrease in stability.
- Costs of a new evaporation pond.
- Additional stabilization, maintenance, and monitoring cost associated with a new evaporation pond.

Alternative C2 would be appropriate if dry tailings disposal is not feasible and additional water storage/evaporation capacity is necessary. In this case Alternative C2 could be the most attractive alternative method for continued use of the existing embankment.

Alternative C3 - Thickened tailings and dry tailings methods used concurrently or in sequence, with a new evaporation pond.

This alternative is a combination of Alternatives B3 and C2. If the physical characteristics of the tailings vary enough to cause dry disposal to be feasible only part of the time, then thickened tailings might be used to handle disposal at other times. If dry tailings disposal is feasible but significantly more expensive than thickened tailings disposal, the former could be used initially to build the 4H:1V embankment slopes to final embankment height, then the thickened tailings system could be used to fill in the old ponds to near-final stabilization contours.

The advantages of this combination of methods are:

- Final slopes are nearly established by initial placement (no second handling), resulting in earthwork cost savings.
- Variations in tailings characteristics can be accommodated better.
- Other advantages of both methods, described previously, can be realized.

The disadvantage with this dual-system alternative is the cost--this alternative involves the highest capital expenditure of all the alternatives. A minor disadvantage would be the greater complexity of the system and the related manpower involved in its operation. Other combinations or variations of alternatives are also possible. The most effective alternative system will be developed after the feasibility of dry tailings disposal or thickened tailings disposal has been established and the cost factors have been defined.

Course of Action for the Licensing Period

For the licensing period here involved, the Applicant does not propose use of the alternatives because the present system, with the planned buildout, will be in compliance with the regulations. The construction of a new evaporation pond would involve a very significant capital expenditure during a time in which uranium prices are far lower than in recent years. The current interest rates place an unusually high cost on any capital expenditures. These expenditures, if incurred in the near future, would be in competition with funds to be expended in any event in connection with the GWDP (Hydro-Engineering, 1981). Further, if the lining system of a new evaporation pond did not perform satisfactorily, more, not fewer, problems would exist.

Mill throughput during the five-year licensing period is expected to be far less than capacity. However, at a later time, when prices and mill production might increase, the alternatives could become far more attractive when increased height of the present system would require more consideration of alternative methods.

C4.0 RADIOLOGICAL IMPACTS

The operation of the HMC mill produces solids, liquids and gases, some of which are radioactive. Although the operations described in this report are designed to limit the release of radionuclides to levels that are as low as reasonably achievable (ALARA), some impact to the environment and to mill workers results from those releases.

This section discusses the radiological impacts of mill operations on the surrounding area and population. Radiation doses to individuals and populations in the mill vicinity, as predicted by the MILDOS code, are presented in Section C4.2. Occupational radiation doses to employees in the mill are presented in Section C4.3.

The monitoring program described in Section C8.0 illustrates the extent to which both operational and environmental programs have been established to confirm that release rates are within regulatory limits.

C4.1 SOURCES AND PATHWAYS OF ENVIRONMENTAL RADIATION

Radionuclides released to the environment by mill operations can affect man by several direct and indirect pathways. These pathways, shown in Figure C4-1 include direct external radiation from nuclides deposited on the ground and from cloud immersion, inhalation, and ingestion of meat, vegetables, and milk. The inhalation of airborne radionuclides contributes the greatest percentage of the total dose to specific organs. Ingestion of meat, vegetables, and milk may also contribute to the total dose to organs. Direct external exposure from the ground and clouds is not significant compared to inhalation and ingestion.

Sources of airborne effluents from the Homestake Mining Company uranium mill are shown in Table C4.1. Source terms for these locations or processes are based on site specific data and are described in Section C4.2.1. The operational life of the mill is described by ten time intervals (time steps) starting from 1956 and ending with the year 2005, the end of the three year period after mill closure and completion of reclamation.

C4.2 DOSE CALCULATIONS

The U.S. Nuclear Regulatory Commission's (U.S. NRC's) recent computer code, MILDOS (Strenge and Bander, 1981) has been used to predict the transport and behavior of airborne effluent radionuclides in the environment and to compute estimated dosed to individuals and populations in the vicinity of the mill. Results of computer code calculations are only estimates of potential radiation doses from uranium mill effluents and can over estimate dose. These calculated values cannot be used to imply real radiation doses. Actual doses should be calculated only on the basis of measured concentrations from environmental radiological monitoring.

The following sections describe the input to the MILDOS computer code (C4.2.1) and the results (C4.2.2)

C4.2.1 MILDOS Input

Determination of particulate and radon gas concentrations from mill operations are used by MILDOS to predict the environmental radionuclide concentrations and the resulting radiological doses to man in the vicinity of the mill. The documentation for the code (Strenge and Bander, 1981) contains extensive details related to the operation of the code. Because the pathways and sources of environmental radiation are complex and depend on time, environmental conditions, demography, and mill operations, several parameters must be evaluated in order to calculate dosages. Those parameters include the following categories:

- Mill operational conditions
- Meteorological parameters
- Radionuclide sources
- Food chain parameters
- Population parameters
- Receptor locations and numbers

Natural background radiation is not considered by MILDOS in calculating dose rates or particulate concentrations.

C4.2.1.1 Mill Operational Conditions

Operational conditions at the mill will affect both the rate and total quantity of radionuclides emitted from the HMC mill. Table C4.1A

presents the average amount of ore processed per day for each time period from 1956 to the present and projects mill throughput up to year 2000. (Actual start up of operations began in 1958; however, time step 1 includes the accounting period from 1956 through 1958.) Each time period is entered into the MILDOS computer code as a "time step" funtion which includes a factor to proportion the radionuclide source strengths as a multiple of the reference throughput which occurs during time step 8. The maximum future radiological impacts to the environment and to people occur during time step No. 8 when the mill is projected as processing 2000 tons of ore per day. Time steps 9 and 10 occur after mill operations have been terminated and no additional radionuclides are released from the mill.

For the purpose of the calculation, an average throughput of 2000 tons per day for a 335 day period (one work year) has been used for time step 8 (1987 to 2000), the reference time step. This assumption may overstate what the actual production rate will be by a large amount, assuming the mill is operating at that time. The MILDOS computations show that even at this reference operating capacity, the projected maximum future capacity, there is compliance with both the 500 mrem all-sources limit of Part 4 of the NMRPR and Section 3-300 of the NMRPR, limiting actual exposure to a member of the public to 25 mrem per annum (radon and its daughters and mill tailings sources excluded).

C4.2.1.2 Meteorological Parameters

Meteorological input for MILDOS requires average annual wind frequencies in 16 wind directions, in six wind speed categories, and in six atmospheric stability categories. These data were obtained in 1978 at the nearby Anaconda Bluewater mill, located 5.8 miles west of the HMC mill. The data were published in NUREG/CR-1133, Appendix, and are shown in Table B2.1 and Figure B2-1.

In addition, MILDOS input requires the average annual mixing height (DM). This value, the harmonic mean of the measured morning and evening mixing heights, is 826.0 meters. This value is based on the Albuquerque, New Mexico data (reported in English units) shown in Table

B2.2. Albuquerque is the only station in the vicinity of the mill recording mixing heights.

C4.2.1.3 Radionuclide Sources

The six sources of airborne radionuclide particulate effluents and radon gas emissions utilized by the MILDOS code are:

- Yellowcake dryer
- Yellowcake roaster and packaging
- Ore handling and storage
- Grizzly
- Ore conveyor and crushing
- Ore dryer stack

The yellowcake dryer source includes the yellowcake dryer and the yellowcake roaster discharge. The yellowcake roaster and packaging source includes the yellowcake roaster and the yellowcake packaging, sampling and incineration process. These sources are illustrated on Figure C4-2. MILDOS input requires all sources to be located on an X-Y-Z grid relative to an arbitrary origin, which for this analysis is the base of the yellowcake dryer stack. All sources are considered point sources, with no area to be specified except for the ore storage area which is 0.028 km^2 (6.92 acres). Stack and source location data are presented in Table C4.2.

For each source, the release rate in curies per year (Ci/yr), or specific activity in picocuries per gram (pCi/g), must be entered into MILDOS. The following paragraphs summarize the calculations and assumptions used in arriving at these values. Source emission rates are summarized in Tables C4.3 (yellowcake stacks) and C4.4 (other sources). Conversion of English to metric units accounts for small variations in the final calculated values.

The release rate from each of the six sources of airborne radionuclides was calculated on the reference throughput capacity of the mill, 2000 tons per operating day for a 335 day operating year. These hypothetical maximum release rates, however, are used in computing predicted airborne radionuclide concentration and estimated radiation doses for time step 8 (1987 to 2000) only. The mill is not expected to operate at this high rate during the entire five-year

period however, are used in computing predicted airborne radionuclide concentration and estimated radiation doses for time step 8 (1987 - 2000) only. The mill is not expected to operate at this high rate during the entire five-year period covered by this license application. Release rates for the 1981 - 1983 time period (time step 6) are modeled on a daily throughput of 875 tons. Current release rates (time step 7, 1984 - 1986) are based on a throughput of 500 tons/day for 190 days/year.

Yellowcake Operations

Yellowcake emissions from the HMC mill are:

Stack ID	U_3O_8 Release Rate (lb/hr) Operating	Down	Stack Exit Vel. (m/sec)	Stack Diameter (m)
Yellowcake Dryer	0.219	0.0030	6.48	0.40
Roaster Discharge	0.091	0.0034	6.40	0.44
Yellowcake Roaster	0.104	0.028	12.36	0.40
Yellowcake Packaging, sampling, incineration	0.091	0.0034	14.62	0.46

U_3O_8 release rates were measured by isokinetic stack sampling during the period 3/82 through 5/84. The values shown above are averages of approximately eight individual measurements per individual stack.

Annual U_3O_8 stack emissions for time steps 6, 7, and 8, (1981 - 1983, 1984 - 1986, 1987 - 2000) were calculated on the basis of the following operating schedules:

	1987 - 2000 Full operation	1981 - 1983 Reduced Operation	1984 - 1986 Reduced Operation
Yellowcake dryer	12 h/d, 335 d/y	8 h/d, 12 d/mo	8 h/d, 6 d/mo
Roaster discharge	24 h/d, 335 d/y	24 h/d, 12 d/mo	8 h/d, 6 d/mo
Yellowcake roaster	24 h/d, 335 d/y	24 h/d, 12 d/mo	8 h/d, 6 d/mo
Yellowcake packaging, sampling, incineration	12 h/d, 335 d/y	8 h/d, 12 d/mo	8 h/d, 6 d/mo

For each source, total annual operating time for the specified time period was multiplied by the emission rate under operating conditions and the product added to the product of the annual down time and the emission rate under "down" conditions. Total annual yellowcake dryer emissions were combined with total annual roaster discharge emissions. Yellowcake roaster discharge emissions were combined with yellowcake

packaging, sampling, and incineration emissions.

Annual emission in pounds of U_3O_8/year was converted to Ci/year by the following equation:

(lb U_3O_8/year) (456 g U_3O_8/lb U_3O_8) (0.848 g U-238/g U_3O_8) (3.33 x 10^{-7}Ci U-238/g)

The total annual U-238 emissions for the combined sources are as follows:

	1987 - 2000	1981 - 1983	1984 - 1986
Dryer and Roaster Discharge	0.208 Ci/y	0.0776 Ci/y	0.0296 Ci/y
Roaster and packaging	0.158 Ci/y	0.0817 Ci/y	0.0473 Ci/y

For prior time periods in which the ore throughput exceeded 2000 tons/day, the mill was assumed to be operating under a full operating schedule. For time periods in which ore throughput was less than 2000 tons per day, the U-238 emissions were assumed to be proportional to ore throughput.

MILDOS input requires a factor equal to the exit velocity times the stack diameter. To arrive at a single source value for the paired stacks, the actual exit velocity times stack diameter for each stack was calculated and a weighted average taken for each pair based on annual emissions.

Isotopic analysis of HMC yellowcake (Kalkwarf, 1979) showed Th-230 and Ra-226 present at 3.3 percent and 0.95 percent, respectively, of the U-238 activity. Pb-210 was assumed present at 0.10 percent of U-238 activity (U.S. NRC, 1980a). The respective emission rates are summarized in Table C4.3.

Ore Specific Activity

HMC reports the specific activity of ore to be in the range of 719 to 865 pCi of natural uranium per gram (pCi U-nat/g) of ore with an average ore grade of 0.14 percent U_3O_8.

Using the arithmetic average specific activity of 792 pCi U-nat/g of ore, the specific activity of each radionuclide in the ore was calculated as follows:

1) The radioactivity of natural uranium is the total activity from U-238 plus U-234. Each of those radionuclides would then account for half the natural uranium activity, i.e., 0.5(792 pCi/g) = 396 pCi/g.

2) Secular equilibrium was assumed in the ore which means the specific activities of U-238, U-234, Th-230, Ra-226, and Pb-210 are all equal to 396 pCi/g of ore.

3) The ratio of radioactivity in the fine portion of the ore to the activity in the bulk ore is reported to be 2.5 (U.S.NRC, 1980b; Sears, et al., 1975). Under the conservative assumption that only the fine portion of the ore becomes dust, the specific activity of U-238, U-234, Th-230, Ra-226 and Pb-210 in dust each becomes:

$$2.5(396 \text{ pCi/g}) = 990 \text{ pCi/g}$$

Ore Handling and Storage

Ore stored and handled in the milling process may contain some quantity of moisture which limits dusting during the initial milling operations. The following calculations, except for stored ore, which includes a factor to account for watering ore piles to control dust, do not take moisture and its limiting effects on dusting into account, and may, therefore, result in somewhat high dusting rate values.

The dusting rate from the initial ore dumping for the reference time was calculated by:

$$\frac{0.024 \text{ kg dust}}{m^3} \times \frac{m^3}{1.79 \text{ metric tons}} \times \frac{2000 \text{ tons}}{\text{day}} \times \frac{0.912 \text{ metric tons}}{\text{ton}} \times$$

$$\frac{335 \text{ days}}{\text{yr}} \times \frac{10^{-3} \text{ metric tons}}{\text{kg}} = 8.20 \text{ metric tons dust per year}$$

where:

$$\frac{0.024 \text{ kg dust}}{m^3} = \text{Uranium ore load out factor (U.S. EPA, 1980)}$$

$$\frac{m^3}{1.79 \text{ metric tons}} = \text{Inverse of the ore density}$$

$$\frac{2000 \text{ tons}}{\text{day}} = \text{Average daily mill processing rate, time step 8 (1987-2000)}$$

$$\frac{335 \text{ days}}{y} = \text{Number of days of mill operation per year}$$

The dusting of stored ore was calculated by:

$$Es = 0.01 \ (a) \ (i) \ (K) \ (C) \ (L^1) = 1.03 \ \frac{\text{tons dust}}{\text{acre - yr}}$$

where:

Es = dusting rate
a = 0.01, suspended particulate fraction for sandy soil types
i = 134, soil erosion factor in short tons per acre per year
K = 1.0, surface roughness factor
C = 110, climatic factor
L^1 = 0.7, field width factor (PEDCo, 1976)

Assuming an amount of ore sufficient for 10 days production, the total exposed surface area of stored ore is approximately 0.028 km^2 (7 acres) at full production. The exposed surface area of stored ore was assumed to be independent of daily throughput. This is a conservative assumption and could lead to an overestimation of dusting from this source for periods when the mill is operating at less than full schedule. In addition, a 25 percent control factor (or 75 percent release factor) for "watering as needed to control nuisance dust" (Impact Environmental Consultants Ltd., 1981), is assumed to calculate the dust produced from the stored ore by:

$$\frac{1.03 \text{ short tons dust}}{\text{acre-year}} \times \frac{0.912 \text{ metric tons}}{\text{ton}} \times$$

$$7 \text{ acres} \times 0.75 = 4.90 \text{ metric tons/yr}$$

Combining the annual dust emissions from ore handling and from ore storage and converting to curies per year (Ci/yr) for each radionuclide emitted, except radon, the emission rate was calculated by:

ore handling = 8.20 metric tons dust/yr
ore storage = 4.90 metric tons dust/yr
total dust = 13.10 metric tons dust/yr

$$\frac{13.10 \text{ metric tons dust}}{\text{yr}} \times \frac{10^6 \text{g}}{\text{metric ton}} \times \frac{990 \text{ pCi}}{\text{g}} \times \frac{10^{-12} \text{Ci}}{\text{pCi}}$$

$$= \frac{1.30 \times 10^{-2} \text{ Ci}}{\text{yr}}$$

Since Th-230, Ra-226, and Pb-210 are assumed to be in equilibrium with U-238 the activity of each nuclide is presumed to be equal to the activity of U-238. For time periods other than 1987 - 2000, the dusting rate from initial ore dumping is presumed to be proportional to annual tons processed while dusting from stored ore was presumed to constant.

Grizzly

The 8.20 metric tons of dust per year was calculated in the same manner as in previous section discussing ore handling and storage. The conversion to Ci/yr for each nuclide except radon was calculated as above giving an annual emission from this source of 8.12×10^{-13} Ci. For time periods other than the reference period (1987 - 2000) the emissions are assumed to be proportional to annual tons of ore processed.

Conveying, Crushing, and Transfer Drops

These operations take place indoors and, with the exception of the last five of the total 14 conveyor-transfer drops, are all vented through the same bag filter, which provides 99 percent emission control (Midwest Research Institute, 1977). As the last five drops are still indoors, 85 percent emission control was assumed. Dust emissions from each source were:

Conveying: (0.1 kg/metric ton ore conveyed) (0.01) = 1×10^{-3} kg dust/metric ton (PEDCo, 1976)

Crushing: (0.16 kg/metric ton ore crushed) (0.01) = 1.6×10^{-3} kg dust/metric ton tertiary crushing (Sears, et al., 1975)

Transfer Drops: (0.012 kg/metric ton for each of 9 drops) (0.01) (9 drops) $= 1.08 \times 10^{-3}$ kg dust/metric ton
(McCutcheon and Iverson, 1976)

Transfer Drops: (0.012 kg/metric ton for each of 5 drops) (0.15) (5 drops) $= 9.00 \times 10^{-3}$ kg dust/metric ton
(McCutcheon and Iverson, 1976)
Total dust emission = 1.27×10^{-2} kg dust/metric ton ore
The total dust emission from this source is converted to Ci/yr for each radionuclide except radon by:

$$\frac{1.27 \times 10^{-2}\text{kg dust}}{\text{metric ton ore}} \times \frac{2000 \text{ tons}}{\text{day}} \quad \frac{0.912 \text{ metric tons}}{\text{ton}} \times \frac{335 \text{ days}}{\text{year}}$$

$$\times \frac{10^{3}\text{g}}{\text{kg}} \times \frac{990 \text{ pCi}}{\text{g}} \times \frac{10^{-12}\text{Ci}}{\text{pCi}} = 7.69 \times 10^{-3} \text{ Ci/yr}$$

Annual emissions are presumed to be proportional to tons of ore processed annually.

Radon from Ore Conveyor and Crushing

Storage of ore in five ore bins for less than one month is sufficient for the concentration of Rn-222 gas to build up to its equilibrium value of 396 pCi/g of ore. Because these ores are crushed to very fine particles, it is assumed that all the available Rn-222 is released in the subsequent conveyor transfer drops.

The Rn-222 emanation factor of 0.2 for finely ground ore is used to calculate the yearly Rn-222 production from the ore conveyor and crushing by:

$$0.2 \times \frac{396 \text{ pCi Rn-222}}{\text{g}} \times \frac{10^{6} \text{ g}}{\text{metric ton}} \times \frac{2000 \text{ tons}}{\text{day}} \times$$

$$\frac{0.912 \text{ metric ton}}{\text{ton}} \times \frac{335 \text{ day}}{\text{year}} \times \frac{10^{-12} \text{ Ci}}{\text{pCi}} = 48.4 \text{ Ci/yr}$$

Radon emissions are proportional to tons of ore processed annually.

Radon from Ore Pad

The amount of Rn-222 available for release from each gram of ore as a result of Ra-226 decay during storage is given by the following expression (U.S. NRC, 1980b):

$$Rn = E(Ra) \quad T = 143 \text{ pCi/g}$$

where:

Rn = Rn-222 concentration
E = 0.2, emanation factor
(Ra) = 396 pCi/g, Ra-226 concentration in ore
= 0.693/3.83 day Rn-222 half life = Rn-222 decay constant
T = 10 days, supply of ore on pad

An amount of ore sufficient for 10 days production was assumed to be present on the ore pad 365 days per year. At the reference production of 2000 tons of ore per day, this gives the Rn-222 emission of:

$$\frac{143 \text{ pCi}}{\text{g}} \times \frac{2000 \text{ tons}}{\text{day}} \times \frac{0.912 \text{ metric tons}}{\text{ton}} \times \frac{10^6 \text{g}}{\text{metric ton}} \times \frac{365 \text{ days on pad}}{\text{year}} \times \frac{10^{-12} \text{Ci}}{\text{pCi}} = 95.2 \text{ Ci/yr}$$

Radon emissions from the ore pad were also presumed to be proportional to the amount of ore processed annually.

Ore Dryer Exhaust

This source operates a maximum of 50 hours per year during full production, so that only a small fraction of the ore production passes through the ore dryer. The ore dryer exhaust is equipped with a dust collector of 97 percent efficiency. The U.S. NRC has estimated that ore drying could result in 10 times as much dust released as in tertiary crushing (Sears, et al., 1975), so a factor of 1.60 kg dust/metric ton ore dried was used.

The number of Ci/yr for each radionuclide except radon from this source was calculated assuming a maximum capability for the ore dryer of 200 tons/hour. (This capacity was based on an assumed maximum potential ore processing capability of 3500 tons per day, 6000 hours/year).

$$\frac{200 \text{ tons ore}}{\text{hr}} \times \frac{0.912\text{MT}}{\text{ton}} \times \frac{50 \text{ hrs dryer operation}}{\text{yr}} \times \frac{1.6 \text{ kg dust}}{\text{metric ton}} \times$$

$$\frac{10^3\text{g}}{\text{kg}} \times 0.03 \times \frac{990 \text{ pCi}}{\text{g}} \times \frac{10^{-12}\text{Ci}}{\text{pCi}} = 4.40 \times 10^{-4} \text{ Ci/yr}$$

The annual emission for the reduced schedules are proportional to the operation time for the ore dryer (30 h/yr).

C4.2.1.4 Food Chain Parameters

The MILDOS food chain parameters consist of two types of input: first, the fractional feed requirement for grazing animals satisfied by locally grown pasture grass; secondly, food production rates for vegetables, meat and milk. Fractional feed requirements for individual animals satisfied by pasture grasses are assumed to be 100 percent. This value probably overestimates the actual feed requirement satisfied by pasture grasses. For the population of grazing animals, the fraction satisfied by local forage is assumed to be 50 percent. Food production rates were input based on statewide averages (Strenge and Bander, 1981), which are probably greater than actual production rates in the vicinity of Grants. Food chain parameter values are given on Table C4.5.

C4.2.1.5 Population Parameters

MILDOS requires the enumeration of population in 16 radial sectors from the origin (Yellowcake Dryer Stack) within specified radial distances from the origin. The population by sectors is shown in Figures B1-3 and B1-4 (Section B1.0, Geography and Demography). The population projections for each time step, as a ratio to the 1978 population, are listed on Table C4.6. These values are based upon national population statistics (Strenge and Bander, 1981).

C4.2.1.6 Receptors

Dose estimates and radionuclide concentrations in air are calculated for several receptors located in the vicinity of the mill. The receptor locations are shown on Figure C4-2 and are listed by location and distance from the origin, the yellowcake stacks, in Table C4.7. The nearest downwind residence is based on the predominantly west northwest wind direction.

C4.2.2 MILDOS Output

This section summarizes the results of the MILDOS computer predictions of radiological doses and airborne radionuclide concentrations at specific receptor locations in the vicinity of the HMC mill. The MILDOS printout is included in Appendix C. The estimated radiation doses and/or airborne radionuclide concentrations are presented for each time period (time step) of operations from start-up through stabilization of the mill property.

The MILDOS computer code calculates estimated annual radiation doses to four representative types of individuals residing at specific receptor locations in the vicinity of the mill: infant, child, teenager, and adult. MILDOS computes two types of radiation doses: total dose from all sources and dose from all sources excluding radon and its short-lived daughters (40CFR190 dose). The total annual dose includes doses for all radionuclides, U-238 through Pb-210, for all mill related sources. The 40CFR190 dose for mill sources only is applicable to Section 3-300.M of NMRPR (NMEID, 1980) since this regulation excludes radon and its daughter products, contributions from tailings, and contributions from natural background. Section 3-300.M limits the radiation dose to any organ of any individual in occupied locations to 25 mrem/year. For the purpose of calculation in MILDOS only normal emissions from the mill sources were used. These sources are listed in Table C4.1.

In addition, MILDOS computes estimated population dose commitments for the vicinity of the mill (within 80 km) and over the entire population.

Radionuclide concentrations in air are calculated for all receptors, occupied and unoccupied. For unoccupied receptors, boundary locations and HMC monitoring stations, MILDOS compares airborne concentrations with applicable Maximum Permissible Concentrations and computes the fraction of the MPC for each nuclide and the combined fraction of MPCs.

Estimated dose commitments to individuals living in the vicinity of the mill are shown in Tables C4.8 through C4.12. The time step 8 (1987 -

2000) shows the highest doses due to the fact that the mill was projected to be in full operation at that time (335 days/year). The occupied receptor closest to the mill and most greatly affected by mill emissions is Broadview Acres. The child is the most important individual due principally to the contribution to bone and lung doses from milk ingestion. Estimated total doses to the child and the adult by pathway (Broadview Acres, 1987 - 2000) are shown in Table C4.15.A.

Other important occupied receptors include the nearest resident to the northeast and Murray Acres. Doses to individuals in the nearest towns, Milan and Grants, and doses to individuals at the nearest downwind (SE) residence are considerably lower due to the greater distances from the mill.

Doses were estimated for Vista Montana, a currently unoccupied receptor, as a matter of interest, since it is a potentially occupied area. However, it does not fall under the Section 3-300.M 25 mrem/year regulation. These doses are shown in Table C4.13.

The maximum doses to the child at Broadview Acres for present or postulated future operating conditions of the mill are 25.7 mrem/year to the lung; 12.2 mrem/year to bone; and 0.918 mrem/year to the whole body (1987 - 2000). Several conservative assumptions are made in the input mill data which overestimate the emissions; thus for practical purposes, these doses are within the 25 mrem/year limit. In addition, the production value used for that time period may be overestimated. Radiation doses to the child at Broadview Acres for current operating conditions are 5.69, 3.22, and 0.325 mrem/year for lung, bone, and whole body respectively. All doses are within the 25 mrem/year limit.

Doses are reduced greatly during the reclamation and post reclamation periods when the mill is shut down. All estimated doses at all occupied receptors are below 1 mrem/year for those periods.

Table C4.14 lists estimated total doses for occupied or potentially occupied receptors for current and future time periods. The radon

contributes very little to the doses, less than 1.0 mrem in most cases, except for the bronchi, and less than 5 mrem/year for the bronchi.

Table C4.15 presents the estimated annual population dose commitments for each time step. The annual estimated population dose commitment is the product of the estimated radiation dose in rem/year for each spacial interval in a circular grid around the mill and the number of people residing in that interval. For example, a dose of 0.005 rem/year (5 mrem/year) to 100 people produces an annual estimated population dose commitment of 0.5 person-rem/year.

The estimated population dose commitments show the highest doses occurring in time step 8 (1987 - 2000). Table C4.15 indicates that the bone and the lungs would receive the highest doses of the organs considered. Doses are due predominantly to inhalation of uranium and its daughter products during mill operation. The lung dose is due almost entirely to inhalation; however, a significant component of the bone dose is due to ingestion of vegetables.

For unoccupied receptors, boundary locations and HMC monitors, the MILDOS code compares airborne radionuclide concentrations with Maximum Permissible Concentrations (MPCs) for the specific nuclides. These concentrations and fractions of MPCs are shown in Table C4.15.B. All computed fractions of MPCs are considerably less than 1.0.

The highest predicted airborne radionuclide concentrations occur at the ESE boundary line. The total fractions of MPCs at that location for time step 8 (1987 - 2000) when the mill is projected to operate at full capacity, is 0.227. Regulatory limits for release of radionuclides to unrestricted areas are not exceeded at any location for any time period.

C4.3 OCCUPATIONAL IMPACT

Alpha exposure for all personnel working in yellowcake areas are calculated based on mill air samples and employee's time cards. Results of these calculations are shown on histograms in Figure C4-3 and are tabulated in Appendix D, Table 1. Each employee's alpha exposure as a per-

cent of the maximum permissible concentration (percent MPC) where MPC = 1×10^{-10} uCi/ml, was calculated weekly and grouped into the categories illustrated on the histograms.

The mean, median, and maximum exposures all indicate increasing exposures from 1977 to the 1978-1979 time period and decreasing exposures from 1979 through 1981. In 1981 most of the radiation exposures at the HMC mill occurred in the five to ten percent MPC category.

C4.4 ENVIRONMENTAL IMPACT

From 1977 through June 1981, HMC monitored suspended airborne particulates at eight perimeter sites around the mill. The current suspended particulate monitoring program, which began in June 1981, is described in Section C8.0. The data from the former program are tabulated in Appendix D, Table 2. These data are plotted for individual sampling sites as a function of time on Figure C4-4 (A through I). During 1980, Taylor View Park and HMC Environmental Laboratory were sampled as the same location. HMC's Environmental Laboratory is contained in what used to be a private residence in a small community called Taylor View Park located just east of North Highway 53, across from HMC's mill. During 1977, HMC purchased this area to include within their restricted area. Tables C4.16 through C4.18 show mean concentrations, standard deviations, and the number of observations for each radionuclide by year. Net concentrations which result from the subtraction of background concentrations from observed values are likewise presented in the tables. The background concentrations, as measured at Swaggerty's residence located just outside the south-southwest corner of HMC's property, are:

Natural Uranium	$2.96 \times 10^{-14} \pm 2.92 \times 10^{-14}$ uCi/ml
Thorium-230	$4.12 \times 10^{-17} \pm 3.04 \times 10^{-17}$ uCi/ml
Radium-226	$6.97 \times 10^{-14} \pm 5.22 \times 10^{-14}$ uCi/ml

Tables C4.16 through C4.18 show that the average calendar year concentrations for natural uranium, thorium-230 and radium-226 are within the MPC at all sites (NMEID, 1980, Appendix A) for the time period shown

(1980 and January through June 1981), including Broadview Acres, the nearest residence.

C5.0 NONRADIOLOGICAL IMPACTS

This section describes the beneficial and adverse nonradiological impacts associated with the presence and operation of the HMC mill. Of particular interest are the ecological and economic aspects of the mill operations. The economic consequences of premature mill closure are also described.

C5.1 PHYSICAL AND BIOLOGICAL SYSTEMS

C5.1.1 Air Emissions

The nonradiological atmospheric emissions of the HMC mill are discussed in Section C1.3. The ambient air quality conditions in the region are described in Section B2.2.

C5.1.2 Ecology

The HMC mill has been in operation since 1958; therefore, the ecological impacts associated with initial construction, including habitat loss and decreases in plant and wildlife populations and increased population and hunting pressure have already occurred. In this section, the existing soil, vegetation and wildlife resources within the mill site vicinity and impacts of the existing mill are discussed.

C5.1.2.1 Description of Existing Conditions

The soils of the mill site and nearby surrounding area are in the Penistaja-Prewitt-Moriarty association (Maker, et al., 1974). Site soils are primarily Prewitt loams, sandy clay loams, and clay loams which occur on nearly level to gently sloping flood plains and terraces adjacent to intermittent drainages and Moriarty clay or silty clay loams which occur in finely-textured alluvium. Both soils are deep, calcareous, and occur on slopes of zero to two percent. Prewitt soils are well to moderately well suited for irrigation (class 2) and Moriarty soils are slightly less suited for irrigation (class 3).

Prior to start up of mill construction activities in 1957, the land was used for grazing and some farming. The vegetation was grassland-desert scrub. Relatively undisturbed desert-scrub vegetation currently exists in the vicinity of the mill. Although the area includes bottomland along the ephemeral San Mateo drainage, no riparian habitats are present.

During November 1981, the U.S. SCS (1981) mapped and conducted range condition transects on areas around the tailings pond and mill site. Classifications included sandy, loamy, former cropland, bottomland and 70 percent sandy/30 percent swale range sites. Production ranged from 239 to 2,295 pounds of grazeable forage per acre, plant density ranged from three to 49 percent, and condition varied from poor to good. Range trends were generally improving. A total of 10 transects were conducted in the bottomland, sandy, loamy, and swale types. These sites are described below. Nomenclature is according to Gay and Dwyer (1980).

Four transects were conducted in the bottomland type. Production was estimated at 383, 890, and 2,295 pounds per acre along three transects and not measured at the fourth. Alkali sacaton (*Sporobolus airoides*) was the primary species along the two transects with the greatest production. Kochia (*Kochia americana*) was the primary species along the other two transects, both of which were formerly cultivated and are now undergoing succession. Bottlebrush squirreltail (*Sitanion hystrix*), Russian thistle (*Salsola kali*), and four-wing saltbush (*Atriplex canescens*) were other common species.

Three transects were conducted in the sandy range sites. Production was estimated at 296, 773, and 1,207 pounds per acre. Range condition was fair and range trend improving at all three sites. Common grasses including Indian ricegrass (*Oryzopsis hymenoides*), three-awn (*Aristida sp.*), and spike dropseed (*Sporobolus contractus*). Blue grama (*Bouteloua gracilis*) and galleta (*Hilaria jamesia*) were also common along one transect. Other common species included broom snakeweed (*Xanthocephalum sarothrae*) and four-wing saltbush.

Two transects were conducted in the loamy range sites. Production ranged from 396 to 787 pounds per acre. Condition ranged from fair to good and range trend was improving. Blue grama and galleta were the common grasses. Four-wing saltbush was also common. Kochia constituted 30 percent of the production along the transect with the highest production.

One transect was conducted in the swale range site. Production was 448 pounds per acre. Range condition was poor and trend was improving. Blue grama and galleta were the predominant species.

Wildlife values are typical of disturbed grassland-desert scrub areas. Less variety and numbers of terrestrial wildlife are expected than in undisturbed areas, due to the presence of the operating mill. No surface water is present in the mill vicinity except for the tailings ponds and no fish are present. Any flow in the San Mateo drainage is ephemeral and does not support a fishery.

The mill site vicinity is within mule deer summer range. The La Jara Mesa mule deer winter range is present to the east of the mill on the mesa but does not include the mill site vicinity (Meneely, et al., 1979). The Mount Taylor elk range is also located east of the mill but elk probably do not occur in the vicinity of the mill because of lack of suitable habitat.

No species currently listed as endangered by the federal government (U.S. Fish and Wildlife Service, 1981) or New Mexico (Hubbard, et al., 1979) are expected in the near vicinity of the mill site. Peregrine falcons are potential but unlikely migrants. Bald eagles have not been recorded in the county (Hubbard, et al., 1979). No prairie dog towns are present in the near vicinity of the mill; therefore, black-footed ferrets are unlikely residents.

Several species of small mammals, jackrabbits and cottontails, and birds typical of grassland-desert scrub habitats are expected to be the common wildlife species in the near vicinity of the mill. Characteristic species may include the desert cottontail, black-tailed jackrabbit, silky pocket mouse, Botta's pocket gopher, deer mouse, Ord's kangaroo rat, western meadowlark, horned lark, western rattlesnake and lesser earless lizard.

C5.1.2.2 Ecological Impacts

Impacts associated with mill construction and operation, in particular direct displacement and habitat alteration, have occurred previously. Wildlife population in the area have adjusted to mill operation, loss of habitat, and increased pressure from the increased population. Ongoing impacts from continued operations and population pressure include increased soil erosion, wildlife harassment, and increased hunting pressure. Some impacts to wildlife can be expected from the tailings and materials in the plant vicinity. Wildlife use of the immediate mill vicinity is expected to be low because of the high level of disturbance. Some use of the tailings ponds by waterfowl and shorebirds occurs, although impacts are expected to be minor. Impacts may be expected through uptake of effluents in vegetation near the tailings.

Other secondary impacts are possible from impacts to the groundwater quality and air quality. Such impacts on vegetation and wildlife are expected to be relatively minor.

C5.2 SOCIOECONOMIC IMPACTS

This section describes the social and economic benefits and costs of the HMC mining and milling operations. Mining operations are addressed because they are dependent upon continued milling operations; if the HMC mill were to cease operations, HMC may be forced to close the mines as well.

C5.2.1 Benefits of Mining and Milling Operations

As indicated in Section B1.2 and Table B1.4, mining and milling activity occupied 7,886 people in McKinley and Valencia counties during 1980 (Valencia County characteristics are described here due to the lack of data on recently created Cibola County). This represented 17.5 percent of the total civilian labor force in the two counties and almost 27 percent of the total state mining labor force. HMC mining and milling operations employed 734 employees in December of 1980. This constituted 9.3 percent of the mining and milling labor force in the two-county area and 2.5 percent of the state total. Currently, 529 people are directly employed by HMC.

An estimate of the total number of people that are supported directly by the HMC payroll can be obtained by multiplying the number of mining and milling employees in 1981 by 3.43, the average number of people per household in north-central New Mexico in 1979 (MRGCOG, 1979). This method, which assumes that the HMC employee is the only income earning member of the family, indicates that approximately 1,815 people are supported by direct income from the HMC mining and milling operations. Using this method, it is estimated that 2,518 people were supported by HMC in 1980.

By dividing the total annual HMC mining and milling payroll (approximately $17.4 million in 1980) by the number of people estimated to be supported by the mine and mill operations during 1980 (2,518), it may be estimated that the 1980 per capita personal income of individuals supported by HMC mining and milling employment equalled $6,910. This compares with 1979 per capita personal income statistics of $5,393 for McKinley County, $6,078 for Valencia County, and $7,483 for New Mexico (University of New Mexico, 1981). Also, by dividing the 1980 payroll by the 734 employees employed as of December 1980, the average salary for the HMC employee was $23,706.

The Cooperative Extension Service of the U. S. Department of Agriculture (Coppedge, 1981) reports that in New Mexico every job in a basic industry such as mining and milling generates 0.74 supporting jobs. Furthermore, it is estimated that each basic industry job generates 1.12 households, 0.04 retail trade establishments, 1.07 passenger car registrations, 0.91 school children and 3.59 additional people in the region. Using these values and the current direct HMC employment of 529 persons, it is estimated that HMC mining and milling operations currently support 392 indirect jobs in the region. Also, according to this method of estimation, the HMC operations account for 593 households, 21 retail trade establishments, 566 passenger car registrations, 481 school children and 1,899 additional people in the region.

In Grants each dollar of revenue earned in a basic industry is estimated to generate approximately five dollars income to businesses supplying supporting goods and services (Giles, 1982). Of the current 529 HMC employees, 92 percent reside in Grants, Milan and San Rafael, 7 percent live in Acoma, Acomita and Laguna, and 0.7 percent live in Prewitt, Bluewater and Thoreau. Only 0.3 percent of the HMC employees reside in Albuquerque and over 99 percent of the employees live in the McKinley/Valencia County area. Assuming that 99 percent of the employees also lived in the area in 1980, as much as $86 million in indirect or secondary revenue was generated in the region during that year as a result of HMC mining and milling operations.

The taxes paid to the state and federal governments by HMC and its employees are itemized in Table C5.1. The 1980 tax burden of HMC and its employees was $8.7 million. The greatest individual taxes are federal income tax withholdings and the state severance tax. Of the total $8.7 million paid in taxes by HMC and its employees, $4.4 million, or 51 percent of the total, is paid to the federal government and $4.3 million, or 49 percent of the total, is paid to the State of New Mexico.

In addition to HMC's contribution to the regional economy, HMC employees constitute an important component of the social structure in Grants, Milan and Valencia County. The HMC operations provide a source of secure income to the local population and lend stability to local residency patterns. The company employs many members of minority groups, with 52 percent of the total HMC employees being Hispanic, American Indian, Asian or Black. HMC has an active affirmative action employment program. Social benefits resulting from HMC include corporate donations to local and regional charities, public service organizations, park improvement efforts, etc.

C5.2.2 Costs of Mining and Milling Operations

The costs incurred by the City of Grants and Valencia County to provide services to the population supported directly and indirectly by the HMC operations are itemized in Table C5.2. Total annual city and county governmental expenditures resulting from the presence of HMC facilities are estimated to equal $2.5 million. About eight percent of this total is expended by Valencia County and most of the remainder is expended by city governments (principally Grants and Milan).

Social costs associated with the presence of the HMC operations include demand for public services such as schools, fire and police protection, waste water treatment and other similar services. Public services are generally adequate in the Grants/Valencia (Cibola) County area with the possible exception of water supply and waste disposal services. These limitations constitute the primary constraint to economic development in Valencia County (MRGCOG, 1980).

C5.2.3 Costs of Closing HMC Operations

During the period following 1977, political and economic conditions influencing the uranium oxide production industry changed dramatically. Prior to the late 1970's, both government and industry sources were optimistically predicting continued growth in the industry. However, beginning in the late 1970's, many producers began to show

reluctance to commit resources to new development. This trend has continued to the present time and decreased production in 1980 alone resulted in the layoff of about 1,257 industry workers in the Grants uranium district (Kerr-McGee, 1981). Decreased demand for uranium oxide, inflationary pressures, increased foreign competition and regulatory requirements have all contributed to this decline in the industry.

In light of these adverse uranium oxide production conditions, HMC could be forced to close the mill prematurely. The HMC mill is currently operating at only 25 percent of capacity. The importance of continued HMC employment at its mill and mines is emphasized by the difficult conditions in the uranium industry in northwest New Mexico. The comments of the Uranium Environmental Subcommittee (UES) and Kerr-McGee Nuclear Corporation in the matter of Proposed Amendments to the Radiation Regulations before the Environmental Improvement Board of the State of New Mexico, August 7, 1981, identified the following mines, mills or projects which had been closed, mothballed or postponed:

- Anaconda Jackpile open pit mine, once the largest producer in the country - closed;
- Kerr-McGee Rio Puerco mine - closed;
- Bokum Resources mine and mill at Marquez closed before production achieved after more than $60,000,000 spent;
- United Nuclear St. Anthony mines - closed;
- Kerr-McGee Nuclear Section 24 mine - closed;
- Exxon in situ project, Marquez - not started;
- Homestake Section 15 mine - closed;
- Kerr-McGee Nuclear Section 17 mine - closed;
- United Nuclear Sandstone mine - closed;
- Phillips Nose Rock Project - mothballed ($140,000,000 spent, no production achieved);

- United Nuclear Ann Lee mine - closed;
- Gulf Mineral San Mateo mill - no decision made to build;
- Homestake Section 32 mine - closed;
- Conoco-Wyoming Mineral Crownpoint project - mothballed.

During the hearing itself, the Sohio Western mining and milling operations were closed, throwing 300 more out of work. Asked if any workers would be transferred to other operations, Sam Shaw, Vice President of Uranium Operations for Sohio Western Mining, said there are no other operations to which to go.

Since the UES comments were filed, the Homestake Section 13 mine has closed, the Anaconda mill has closed, employment has been reduced at Gulf Mineral, and the Ranchers' Johnny M has been closed. Unemployment in this industry is very high.

Premature closure of the HMC mill would impact many sectors of the economy. Increased unemployment resulting from closure would likely increase public assistance costs to local governmental jurisdictions; state unemployment insurance expenditures would increase. Local housing markets and businesses would also be significantly disrupted; in fact, the recent slowing in the uranium industry has already had a substantial impact upon the housing market in the Grants/Milan area (Kerr-McGee, 1981).

The costs to the community of closing the HMC operations can be evaluated by estimating the revenues that would be lost if the mill were to cease operations. As mentioned previously, closure of the mill may also result in the closing of the mines that supply uranium ore to the mill. An estimate of the net revenue generated from HMC operations can be made by comparing the statistics presented in the two previous

sections. The direct HMC payroll, minus the estimated required governmental expenditures, indicates a net direct economic benefit of about $14.9 million annually. When estimated indirect revenue and taxes paid by HMC and its employees are added, the annual revenue resulting from HMC operations exceeds $100 million. It can be expected that virtually all of this revenue would be lost if the mill and the mines were to close prematurely.

Premature closure of the HMC operations would also disrupt social conditions in the Valencia (Cibola) and McKinley Counties area. Early mill closure would force many HMC employees to leave the region to seek employment elsewhere. Unemployment, underemployment and associated social problems would be expected to increase if the mill and mines were to close. Many planned public activities such as school, road, and park improvements would be delayed or cancelled as a result of lost government revenues.

C6.0 IMPACTS ON WATERWAYS AND GROUNDWATER

HMC has evaluated the impacts on waterways and the groundwater regime from the data collected over the years as discussed in Section B3.0. This section provides the details on the potential impacts on the groundwater regime associated with the milling operation and the methods used to comply with current regulations.

C6.1 SURFACE WATERWAYS

This section provides an analysis of possible impacts to the surface waterways near the HMC mill. The impacts produced from normal mill operations as well as conceivable large-scale accidents are discussed. Additional mill-related accidents are discussed in Section C7.0.

C6.1.1 Surface Water Bodies

The HMC mill and tailings embankment are situated within the San Mateo drainage. This drainage is ephemeral and flows only in response to intense thunderstorm events. Flow produced during the spring snowmelt period rarely travels as far as the mill site before being trapped in stock ponds or infiltrating into the alluvium to become underflow. A very large flow in the San Mateo drainage could reach the Rio San Jose approximately seven miles downstream near Milan. The Rio San Jose is also ephemeral at this point. This alluvial bed is also highly permeable and flows are often lost to the alluvial aquifers. No reservoirs, ponds or lakes are present downgradient of the mill in the San Mateo drainage. Several stock watering ponds, ephemeral ponds, and springs exist upstream from the mill but are not affected by mill operations.

C6.1.2 Sources of Contamination

The principal radiological contaminants that are mobilized by mill operations include natural uranium, thorium-230, radium-226, and lead-210. Contamination of surface waterways may be caused by losses of radionuclides in either particulate or dissolved forms. The particulate forms which may be lost to the atmosphere are reduced by scrubbers within the mill processes and by stabilization of tailings to prevent

wind and water erosion and transport. However, collection by scrubbers and stabilization of tailings is not completely effective and small amounts of radioactive contaminants are lost to the atmosphere. These particulates, after falling on land surfaces, can collect in surface waterways by overland flow following precipitation. The impacts of these concentrations are minimal because small quantities of material are diluted by large volumes of water and sediment. No indication exists that particulate releases have increased radionuclides in surface water to levels even approaching regulatory limits.

Liquids containing radionuclides also present a potential impact to surface waterways. Minor spills might occur from coupling leaks, faulty valves, crushed pipes and other occurrences. The tailings embankment retaining berm and the surface runoff collection system as shown in Figure B3-5 would contain spills of this type.

It is anticipated that even under extraordinary circumstances radionuclides from minor spills would not leave the mill site. These spills would flow only a short distance before infiltrating into the alluvial materials or be contained by the retaining berm situated one-quarter mile downstream of the mill (Figure B3-5). The impacted areas could be cleaned up easily by a mechanical loader and truck operation. Even if the spill were large enough to cause materials to enter the alluvial aquifer, they would be contained in the pumpback-injection system described in Section B3.2.5.

C6.1.3 Impacts of Large Scale Events

A potentially more hazardous type of contaminant source would be an event that releases large amounts of radionuclide contaminants to the surface waterways. While considerable engineering design and operational precautions are employed to reduce the possibility that such events would occur, analysis of the impacts helps in planning for remedial action. Large scale events could include a breach in the tailings embankment or rupture of the tailings slurry pipeline.

C6.1.3.1 Extent of Contamination

At present the maximum amount of tailings liquid impounded within the tailings structure is approximately 50 acre-feet or 16.3 million gallons (Hydro-Engineering, 1981). This amount is divided into two cells (east and west cells) separated by a berm of tailings materials. HMC's radioactive materials license contains several requirements concerning operations of the tailings facility. These requirements include:

- Maintenance of at least five feet of freeboard from the top of the embankment crest at its lowest point to the solution level of the pond.
- Monthly surveys of embankment crests and pond elevations.
- Maintenance of 50 feet of beach from the embankment to the pond's edge.
- Positioning of the tailings distribution line to the inside of the embankment crest.
- Lighting of all sides of the embankment for continual inspection.
- Presence of two operators equipped with two-way radios at all times to inspect tailings movement and embankment conditions.
- Automatic tailings line flow alarm.

In addition to these extensive precautions, HMC has constructed a retaining berm approximately one-quarter mile to the south and southwest of the tailings facility (Figure B3-5). In the event of a tailings embankment breach or a tailings pipe rupture, this berm will retain and hold spilled liquids, precluding any further movement on the surface. Any tailings liquid that might spill from the ponds will quickly infiltrate into the alluvial soil. The suspended particulates will remain on the surface, but the material will be thinly deposited. The infiltrated liquid will undergo the same chemical processes as described in the GWDP (Hydro-Engineering, 1981) for the tailings liquid movement underneath the tailings structure.

C6.1.3.2 Areas/Users Impacted

The area that would be impacted by the release of a large amount of tailings liquid or other liquids containing radionuclides is extremely small as it is bounded by the flood protection berm around the tailings embankment as well as the retaining berm that exists one-quarter mile downgradient from the site. Since there are no surface water users in the San Mateo drainage downgradient of the mill, none will be affected.

C6.1.4 Impact from Mine IX Plant Discharge

The treated discharge from the IX plant flows into Arroyo del Puerto where it flows only a short distance before infiltrating into the normally dry arroyo. Section B3.1.6 describes the quality of the discharge. The radionuclide concentrations measured in two samples were well below New Mexico's MPC's. Thus, the discharged water will produce no harmful radiological impacts on surface water users.

C6.2 GROUNDWATER

HMC is continuing its investigation of the hydrologic regime in the vicinity surrounding the tailings embankment. These investigations are continually updating both hydrologic and hydrochemical data at the site. Data on impacts of groundwater collected between 1976 and 1981 have been compiled in the GWDP (Hydro-Engineering, 1981) which was submitted to NMEID in December 1981. The detailed study of groundwater impacts caused by the milling operation is contained in this document.

This groundwater impact section addresses the expanded radionuclde monitoring program initiated by HMC in July 1981 to comply with NMEID Radiation Protection Regulations. This program monitors natural uranium, thorium-230, radium-226, and lead-210 in three upgradient wells (for background information), three downgradient wells, and one well in the vicinity of the nearest residence as discussed in Section B3.2.4. Additional monitoring for natural uranium and radium-226 is conducted in conjunction with the data collection program of the GWDP.

Currently HMC has 42 groundwater monitoring wells. These wells are used to evaluate the extent of any radionuclide or chemical contamination. Figure B3-8 shows the location of these wells.

C6.2.1 Aquifers

As discussed in Section B3.2.3, three aquifers are present beneath the site. These are the San Mateo alluvium, Chinle Sandstone, and San Andres Limestone aquifers. All three aquifers are sources of groundwater for domestic, livestock, and minor irrigation use.

The alluvial deposit that is referred to as the San Mateo alluvium is comprised of Quaternary alluvium fill. The alluvium fills the valley bottoms to depths of over 120 feet. The lower sand horizon which directly overlies the Chinle Formation beneath the site is relatively continuous throughout the area and is the major water-bearing zone in the alluvium.

The Chinle Formation consists of shale and siltstone with interbedded very fine to fine grained sandstones. The sandstone units are the water bearing zones of this formation.

The San Andres Limestone aquifer is the lowest of the three aquifers. This is a major deep aquifer in the area of the mill and provides the water supply for the mill and some adjacent areas.

Due to the thickness and impermeability of the Chinle Formation underlying the San Mateo alluvium, the Chinle and San Andres aquifers are protected from any potential contamination from the milling operation.

C6.2.2 Potential Sources of Contamination

A potential source of contamination associated with the milling operation is the tailings liquid and slimes fraction that are separated by the cyclones and deposited in the east and west embankment ponds. Although the tailings liquid is decanted and circulated back through the

mill, some seepage, estimated to be 153 gpm based on mill production of 3,400 tpd (Hydro-Engineering, 1981), seeps from the ponds into the underlying alluvium. A second potential source of contamination is the tailings liquid seeping laterally through the relatively free draining coarse tailings of the embankment dike. "Marginal" weeping is intended to occur from the toe of the embankment. Liquids weeping from the toe of the tailings embankment are received in collection ditches around the embankment. Liquids in the collection channel are routed to two sumps located on the south side of the collection channel from which the liquids are generally pumped to the IX facility and recirculated in the mill circuit. However, if the calcium carbonate precipitation in the collection channel is sufficient to cause scaling problems in the IX facility, the liquids in the collection channel are pumped directly from the sumps into the tailings embankment ponds. Although there is a potential for seepage into the alluvium from the collection ditches, it should be noted that the principle source of discharge addressed by the GWDP is seepage from the two ponds in the tailings embankment.

The movement of some of the tailings contaminants in the groundwater is controlled by factors that are important to both hydrologic and chemical transport. Factors that are important in affecting contaminant flow at the HMC tailings disposal area include:

- Permeability of the San Mateo alluvium,
- Permeability of the Chinle Formation,
- Groundwater chemistry, pH, and temperature,
- Solubility of the contaminant compounds,
- Stability of the dissolved complexes,
- High pH of the tailings liquid (10.1 to 10.3), and
- Sorptivity and dispersivity of the dissolved species.

The solubility of many of the metals and radionuclides present in the tailings liquid generally increase in acid solution. Since the pH of the tailings liquid is above 10, these metals and radionuclides would tend to precipitate. The distribution coefficients of the radionuclides, which increase with increasing pH, represent a ratio of a chemical species partitioning between solid and liquid phases and are indicators of a species' expected attenuation by the hydrogeologic medium. Therefore, because of the alkaline groundwater conditions at the site, most radionuclides are expected to remain immobile. Other elements such as sulfate, however, are less susceptible to retardation effects and are transported more readily along the flow path.

C6.2.3 Groundwater Contamination and Extent

Information obtained from the expanded radiological groundwater monitoring program that HMC initiated in July 1981 shows that concentration of natural uranium, radium-226, thorium-230, and lead-210 are well below the MPC standards (Table B3.4). The data show that the radionuclide concentrations are essentially the same upgradient and downgradient from the tailings disposal area. All radionuclides, except uranium which is discussed below, appear to be immobile and are not migrating with the tailings seepage from the pond. Because of the low concentrations of radionuclides in the San Mateo alluvial system, there has been no impact on the groundwater regime.

The following discussion provides additional information concerning the groundwater contamination and extent of migration for sulfate, selenium and uranium. This information is a summary of data that is contained in the GWDP that was prepared by Hydro-Engineering (1981)and provided to NMEID in December 1981.

Elevated concentrations of sulfate, uranium, selenium, and possibly radium-226 have been detected in groundwater from alluvial wells in the mill area and downgradient of the mill in some wells in the Broadview and Murray Acres subdivisions. Concentrations of these ions are especially high in wells adjacent to the tailings piles, as would be

expected. Figures C6-1, C6-2, and C6-3 show the extent of sulfate, selenium, and uranium contamination as it existed in 1976 before the installation and operation of the collection and injection systems. Figures C6-4, C6-5, and C6-6 show the configuration of the contaminant plumes in late 1981.

Sulfate is generally a conservative ion and should move at about the same speed as the natural groundwater flow. The migration of other conservative ions, such as chloride and bicarbonate, should approximate that of sulfate. A comparison of the 1976 and 1981 sulfate concentration maps (Figures C6-1 and C6-4) reveals that the primary difference between the two is that in 1981 high sulfate concentrations extended farther to the southwest, the direction of natural groundwater flow. However, the original Broadview Acres injection system (Wells G, GG, GA, GB, GC, and GD) appears to have decreased sulfate concentrations in and around the western portion of that subdivision as exemplified by a decrease in the sulfate concentration in Well 445 from 2,220 mg/l to 1,220 mg/l. A sulfate concentration of 1,220 mg/l is within the natural background range of 723 to 1,580 mg/l, discussed in Section B3.2.6. Operation of the extension injection wells (Wells GE, GF, GI, GJ, GK, GL, GM, and GN) to the east may be expected to decrease sulfate concentrations in wells in the eastern portion of Broadview Acres, where sulfate concentrations in some wells have increased substantially since 1976. To date, the Murray Acres collection system (originally Wells AW, HW, and 801, now WR1, WR2, and WR3) has shown no effect on sulfate concentrations in wells in that subdivision.

According to the GWDP (Hydro-Engineering, 1981), selenium is an example of an ion which may exhibit some retardation in its movement in groundwater. A comparison of the 1976 and 1981 selenium concentration maps (Figures C6-2 and C6-5) reveals a pattern similar to that for sulfate. For example, the selenium concentration in Well W has increased from 0.81 mg/l to 2.26 mg/l since 1976. Continued operation of the D and S lines of collection wells should stop the flow of selenium-contaminated

water towards Well W (and the residences beyond), allowing selenium concentrations in that area to return to natural background levels.

Selenium concentrations in wells in the western portion of the Broadview Acres subdivision show a significant diminution of selenium concentrations (e.g., down from 1.50 mg/l to 0.03 mg/l in Well 443), probably reflecting the presence of the original line of injection wells in that area. Operation of the extension injection wells to the east may be expected to decrease selenium concentrations in wells in the eastern portion of Broadview Acres where selenium concentrations in some wells have doubled since 1976 (e.g., up from 0.67 mg/l to 1.32 mg/l in Well 431). The only wells in Murray Acres subdivision to show selenium concentrations significantly above 0.05 mg/l are Well AW (1.13 mg/l) and Well 802 (0.37 mg/l). These high concentrations may be directly attributed to pumping at Well AW drawing contaminated water toward these wells. Pumping the Murray Acres collection system will decrease these locally high concentrations in time.

Uranium probably travels as a uranyl carbonate complex which is fairly mobile under the conditions present in the San Mateo alluvial aquifer. Figures C6-3 and C6-6 show changes in uranium concentrations from 1976 to 1981 essentially similar to those for sulfate and selenium. The Murray Acres collection system appears to be effective in drawing groundwater with high uranium concentrations toward it and not letting it pass through into the subdivision.

In general, continued operation of the injection and collection systems should be successful in diluting to acceptable levels any water which has already been contaminated, and in preventing future contamination from migrating downgradient of HMC's property to other users' wells.

C6.2.4 Groundwater Use

Water from the three aquifers has historically been used for domestic and livestock use and to some extent irrigation. The San Mateo aquifer

is used by individual wells in the Broadview and Murray Acres subdivisions. The Chinle Formation aquifer provides groundwater for individual wells at Murray Acres and to a lesser extent to individual wells in Felice Acres, a subdivision south of Broadview Acres, where restrictive covenants require wells to be drilled into aquifers below the San Mateo alluvium.

When it was discovered that some groundwater from San Mateo alluvial wells had elevated levels of certain contaminants, HMC initiated a program to provide bottled water for domestic use to mitigate the impact. In addition, the GWDP (Hydro-Egnineering, 1981) was designed to protect and restore the water quality of the San Mateo alluvium. The nearest wells in this aquifer that could be affected by HMC milling operations are in Broadview and Murray Acres. HMC's property boundary adjoins Broadview Acres on the south and Murray Acres on the west. The Applicant's GWDP has been developed and put into operation to improve the groundwater quality in individual user wells and reduce the impacts to area users.

C6.2.5 Methods to be Used to Comply with Regulations

This subsection describes in summary form the methods proposed to be utilized, including processes expected to occur naturally, to comply with the regulations. These methods are considered with reference to the possible effluent discharges described below.

There are several pathways by which effluents from the mill might be discharge to groundwater. These are:

- Seepage from the tailings ponds.
- A break in the slurry pipe from the mill to the tailings facility.
- Seepage from the collection channel.
- Seepage from the two return sumps on the south side of the tailings facility.

- Structural failure of the tailings embankment.

- Breach of the tailings embankment due to flooding.

Each of these potential discharges is discussed in detail in the GWDP (Hydro-Engineering, 1981). A summary of the detailed information on the above pathways contained in the GWDP is discussed below.

Seepage from the Tailings Area

The active tailings embankment rests directly upon the alluvium. The tailings embankment does not contain a plastic liner. The solid portion of the structure consists of sands and slimes through which liquids can, and do, seep. A water balance calculation, made to estimate the amount of seepage which might occur from the tailings embankment, indicates that seepage up to 153 gpm can occur when the milling rate is 3,400 tpd (Hydro-Engineering, 1981). Because there is flow of groundwater in the alluvium beneath the tailings embankment, seepage from the embankment will be carried southwesterly, primarily towards Murray Acres. The contaminant levels in the tailings liquids exceed the New Mexico standards listed in Table B3.7. There will be a decrease in the contaminant concentration of the tailings liquid due to dilution as it moves towards the HMC property line. However, the dilution that will occur is not relied upon exclusively to establish compliance with the regulations.

In order to prevent a violation of the regulations, HMC proposes to utilize a series of collection wells around the south and west portion of the tailings embankment. These wells are now in place and pumping. The collection wells now operating around the tailings facility are Wells SA, SB, SC, SD, SE, DA, DB, DE, EE, DF, DG, DH, DI, DJ, DK, DL, TA, and TB (Figure B3-8). Many have been pumped for a considerable period of time. The HMC collection wells have already established the essential element of a collection system; that is, the cones of depression created by the individual wells now overlap. The collection system is more fully described in Section B3.2.

The collection wells are now pumping at a combined rate of approximately 300 gpm, far higher than the operating rate in the past. The rate of collection is now much greater than the seepage rate. The higher pumping rate has been accomplished by completing additional wells and by treating a calcium carbonate scaling problem in the wells with dilute organic polyphosphonate. The calcium carbonate scaling created severe operational problems in the past which reduced collection well production. The organic polyphosphonate treatment appears to be successful. However, individual collection wells will require periodic replacement or repair.

The collection wells will provide protection against seepage to the south and west. The gradient and southerly flow of the groundwater in the alluvial aquifer will provide protection to the north. The alluvium does not carry usable amounts of water to the east.

The collection system is pumping at a rate which will create a slope in the water gradient south and west of the tailings facility towards the collection wells. This local change in gradient will result in the collection wells not only creating a barrier to future seepage flow, but also pulling back and collecting past seepage (Hydro-Engineering, 1981). This reversal in gradient has already been demonstrated at the facility. A reversal was achieved and maintained for the period from December 1979 through January 1980, as well as for the period from October 1980 through January 1981. These reversals were achieved at a pumping rate less than is presently used.

At present, alluvial water from the north flows under the tailings embankment. This flow would "spread" any seepage from the tailings embankment assuming there were no collection wells. In order to provide a greater margin of protection, HMC proposes to pump water from the alluvium north (upgradient) of the tailings facility, transport it by pipe and reinject it into the alluvium between the tailings embankment and Murray Acres.

According to the GWDP, this reinjection system has the following advantages:

- The withdrawal of water upgradient of the tailings embankment will flatten the hydraulic gradient under the site, which will enhance the collection of seepage to the south and west of the tailings facility.

- Injection downgradient will increase the capability of the collection system to reclaim past seepage through the reversal of the hydraulic gradient.

- The water injected will also reduce by dilution any contamination in the northern portion of Murray Acres.

- The recharge mound formed by the injected water will assist containment by creating an artificial barrier to southward flow from the seepage source.

- The use of this system will also make the collection wells at the tailings embankment more efficient in maintaining interlocking cones of depression and reversal of hydraulic gradient at lower pumping rates.

- Use of this system will prevent the tailings collection wells from depleting the water available to wells in Murray Acres.

The collection system south and west of the tailings embankment will also protect the Chinle Formation. To date testing in wells drawing only from the Chinle has not disclosed concentrations which indicate that seepage from the tailings has migrated through the Chinle shale. About 200 feet of shale separate the top of the Chinle from the water-bearing portions of the Chinle. Low vertical permeability will cause the seepage to be transmitted south and west through the alluvium rather than vertically through the Chinle. The NMEID, however, has asked HMC to study the possibility that projected faults in the Chinle in the vicinity of the mill could provide an avenue of vertical migration. HMC and the NMEID have recently agreed to conduct a drilling program for this purpose.

In summary, the system to collect seepage from the tailings embankment will result in off-property discharges in accordance with the regulations. The collection system is installed and properly functioning at this time. The addition of the pumping wells north of the tailings facility and injection wells near Murray Acres will enhance the present system.

Possible Break in Slurry Line

Tailings are transported in a slurry form to the tailings embankment by pipeline. The liquid portion of the slurry has the same radionuclide and chemical characteristics as the free liquid in the tailings embankment after settling. If the pipeline breaks or decouples, spillage of the slurry will occur. Because of the operational procedures described below, the spillage itself would be insignificant in terms of impact on groundwater. A more significant problem would arise if the spillage from the pipeline eroded away the tailings embankment, allowing the tailings liquid to escape with associated solids.

A break in the slurry line will not cause a violation of the regulations under the present system for the following reasons:

- Spillage from the line at the tailings embankment itself would be collected in the collection ditches along the toe of the embankment. An automatic slurry line flow alarm system has been installed which will allow mill shut-down to occur within a few minutes. Thus spillage will in any event be minimal.

- The pipeline is maintained on the inside edge of the embankment crest so that spillage will not erode away the freeboard. A five foot vertical freeboard is maintained above the elevation of the tailings pond liquid. A horizontal beach of fifty feet from the top of the inside embankment crest to the pond's edge is maintained. Therefore, if the pipeline breaks on the embankment crest, the tailings slurry will flow toward the pond.

- Two tailings facility operators are stationed at the tailings embankment during all operations. One operates the cyclone truck, while the other inspects the tailings embankment. They are provided with radio communication. Any loss of slurry flow will be noticed and reported immediately.

- A berm has been constructed approximately one-quarter mile south of the tailings pond to contain any HMC property liquids and solids that might escape.

If spillage from the pipeline does reach the collection channel, seepage of the liquid fraction would be within the perimeter of the collection wells and would be collected. If liquids from an erosional tailings breach escaped beyond the perimeter of the collection wells, some adsorption would take place in the soil. Considerable buffering would thus occur before spillage could reach groundwater.

Seepage from the Collection Channel

The collection channel around the tailings embankment receives liquid weeping from the toe of the tailings embankment. The radionuclide and chemical characteristics of this liquid are approximately the same as those of the liquid in the tailings facility. The collection channel also receives water from the Murray Acres collection wells. The collection channel is not lined and some seepage will occur.

Seepage from the collection channel is within the perimeter of the collection wells around the south and west sides of the tailings facility. The collection wells will thus intercept any seepage from the collection channel. Seepage from the collection channel will, therefore, not result in a violation of the regulations.

Seepage from the Return Sumps

Liquids received in the collection channel are routed to two sumps. These sumps are not lined and are on a line with the collection wells. Thus, seepage from the sumps will be collected by the collection wells. The regulations will not be violated by seepage from the sumps.

Structural Stability of Tailings Embankment

If the tailings embankment failed due to structural instability, liquids in the tailings pond could be released. Such a liquid release would carry some of the solid tailings with it. The release that occurred on February 5, 1977 resulted from erosion of the freeboard by a break in the slurry line rather than from a structural failure. However, the release from a structural failure would generally resemble the release of February 5, 1977. The release of February 5, 1977 had little or no affect on groundwater quality. The primary defense against a release from structural failure is the maintenance of structural stability.

A stability assessment was prepared by D'Appolonia in November 1980. It has been submitted to the New Mexico State Engineer and is incorporated herein by reference. All portions of the tailings embankment were brought up to a static slope stability factor of safety of 1.5 or greater. All other stability criteria including pseudo-static slope stability under earthquake loading, potential for seepage forces causing piping and sloughing, liquefaction potential under earthquake loading, and performance during severe hydrologic events were concluded to be satisfactory. HMC submits a report on the safety and stability of the tailings embankment each quarter to the New Mexico State Engineer.

Stability assessments make calculations on the basis of phreatic levels in the embankment. HMC has installed piezometers in the embankment to provide actual measurements of the phreatic levels. These measurements are made at least monthly and submitted to the State Engineer for evaluation on a monthly basis.

D'Appolonia has prepared an assessment of the stability criteria for the tailings facility during its next five years of buildout. The stability assessment and related buildout plan for the next five years are presented in Section C3.0.

If a release does occur, protection is provided by the berm located approximately one-quarter mile south of the tailings pond. Mechanical clean-up of tailings would be necessary in the event of a release.

Flooding

The tailings embankment is located on very flat ground. There is no surface channel approaching the mill, although historically there may have been a definable channel. A flood will spread widely over the flat ground. The tailings embankment is located in an area which, except for engineered protective structures, would be partially within the 100-year flood plain. For many years, HMC has provided flood protection to the tailings embankment and collection channel. The flood protection for the tailings embankment and collection channel was increased to a 100-year flood standard as a result of the D'Appolonia stability assessment (1980). Recent amendments to the radiation regulations of the New Mexico Environmental Improvement Board provide for flood protection evaluation against a 100-year flood event during active operations.

Even if a larger flood were to occur, the tailings embankment itself would be stable, as shown by the November 1980, stability assessment (D'Appolonia, 1980). Liquid in the collection channel would be commingled with flood water if a flood overtopped the flood protection berm. The amount of liquid in the collection channel is relatively minor - a few acre feet. A flood which would overtop the HMC berm would contain a large amount of water, although the actual acre feet of flood water would be speculative. Dilution and dispersion would make any effect from liquid in the collection channel insignificant. Under current radiation regulations of the New Mexico Environmental Improvement Board, the flood protection will be increased to a 200-year flood event upon deactivation of the facility.

C7.0 ENVIRONMENTAL EFFECTS OF ACCIDENTS

The probability of occurrence of accidents in the mill operations and resulting environmental effects are discussed in this section. Accidents that might release radioactive or hazardous materials to the environment as well as accidents not involving these hazardous materials are evaluated. The types of accidents which are addressed include mill and tailings system accidents involving radioactivity, nonradiological mill accidents and transportation accidents. A discussion of contingency response plans and options is also included.

C7.1 MILL AND TAILINGS ACCIDENTS INVOLVING RADIOACTIVITY

C7.1.1 Radiological Accident Classification

The radioactive materials handled at the HMC mill have low specific activities because the average ore grade is only about 0.18 percent uranium. Due to this low specific activity, very large quantities of these materials must be released to the environment to cause concern for human health and safety. Although the quantities of these materials handled at the HMC mill might be large, considering the design nominal throughput of 3,400 tpd, mechanisms for the release of such large quantities of hazardous materials are generally not present.

For this analysis, potential mill accidents involving radioactive materials are grouped as follows:

- Trivial incidents or accidents not resulting in a release of radioactive materials to the environment;
- Single radioactive releases to the environment that are small when compared to normal annual releases from the HMC mill; and
- Single radioactive releases that are large when compared to normal annual mill releases.

C7.1.2 Trivial Incidents

The following mill operations accidents involving radioactive materials would not result in the release of radioactive materials to the environment:

- Spills - Uranium bearing solutions are contained in numerous tanks, troughs, and pipelines in the grinding, leaching, filtration and precipitation phases of the milling process. Human error and/or mechanical failure may be expected to cause some spills during these operational phases. However, all of these operations are housed within processing buildings which are equipped with floor sumps designed to contain spills and eliminate environmental releases.

  Clarifier and thickener tanks are located outside process buildings but a drainage area around these tanks confines spills to the immediate vicinity. Spills of sufficient volume to flow to drains are discharged to a holding tank and they are reprocessed.

- Rupture of a Pipe in the Tailings Disposal System - The tailings disposal system utilized at the HMC mill is described in Section C2.0 of this report. A tailings operator is present onsite at all times during operation to inspect the tailings distribution line for possible problems. This operator is equipped with a two-way radio for instant communication with the mill operators. Furthermore, a line flow alarm system is provided to notify operators should a pipeline breach occur. It is estimated that a maximum of five minutes would elapse from the time of a pipeline failure to the time when pumps in the tailings pipeline system would be stopped.

  Any tailings solids released as a result of a break or rupture in the tailings pipeline would tend to accumulate in the immediate spill vicinity. The maximum distance liquids could flow is short (on the order of 100 yards), due to the presence of a collection ditch located downslope from the tailings pond. Released tailings solids, liquids and any contaminated soil and

vegetation would be recovered and deposited in the tailings pond.

The U.S. NRC considers pipeline ruptures and leaks, overflows or ruptures of vessels containing radioactive solutions to be "trivial" accidents not warranting detailed analysis (U.S. NRC, 1980b).

C7.1.3 Small Releases of Radioactivity

The accidents described below could result in small releases of radioactivity to the environment:

- Gas Explosion in the Yellowcake Drying Area - A natural-gas-fired four hearth furnace dries yellowcake discharged from the second yellowcake filter. This furnace operates at a temperature of about 1,000°F. Dry yellowcake (less than two percent water) discharged from this furnace moves through a delumper and into a hopper, where it is held until packaged. The off-gas from the dryer is vented to the atmosphere through a scrubber. An explosion in the dryer or the natural gas piping could destroy the ventilation system ductwork and disperse yellowcake into the packing, storage and shipping area.

  The consequences of an explosion are limited by the amount of radioactive material that can be suspended in the air in the packing, storage and shipping room. This value is estimated to be about 6.25×10^{-6} pounds per cubic foot (lb/ft^3) (U.S. NRC, 1980b). The volume of the packing room is estimated to be 2,250 ft^3. If it is conservatively assumed that all of the material suspended in this room is swept into the atmosphere when the room is ventilated, the maximum amount of yellowcake vented to the atmosphere would equal 1.41×10^{-2} lb.

  The probability of such an accident is estimated to be 5×10^{-3} failures per plant year (U.S. NRC, 1980b). This is a recurrence interval of one accident per 200 years of plant operation.

- Failure in the Air Cleaning System Serving the Yellowcake Drying Area - Off-gas from the yellowcake dryer containing entrained solid particles of yellowcake passes through a wet

scrubber before it is vented to the atmosphere. The wet scrubber received a flow of about six pounds per hour (lb/hr) of yellowcake dust and it removes about 99 percent of this dust. A failure of the wet scrubber could result in some release of radioactivity to the environment. However, HMC's wet scrubber systems are designed such that, in the event solution addition is partially or totally interrupted, the air flow being exhausted is automatically shut down. The scrubber fan actually provides the draft which allows air flow through and combustion to take place within the dryers. With the scrubber system inoperable, the dryer itself cannot continue to function. Therefore, no air flow through the dryer is possible and the discharge of radioactive dust from the dryer to the atmosphere is negligible.

Two types of scrubber failures are considered to be possible but extremely unlikely: (1) a sudden total failure; and (2) a gradual system failure. In the case of a sudden failure, scrubber monitoring equipment would sound alarms, and operations would be halted by an automatic shut-off system until the scrubber is repaired. The U.S. NRC (1980b) conservatively estimated that this kind of failures could result in the release of about 25 lb of insoluble uranium oxide particles in the respirable size range. A gradual system failure would be more likely to occur; however, the radiological consequences of such an occurrence would be less than those expected for a complete system failure.

C7.1.4 Large Releases of Radioactivity

Some conceivable accidents could cause release of large quantities of radioactive materials to the environment. These potential accidents include damage to the mill and yellowcake dispersion from a tornado and release of tailings slurry as a result of an earthquake, flood or dike failure. The following sections describe the likelihood and potential radiological consequences of these accident scenarios.

Tornado - Mill structures are generally not designed to withstand tornado force windspeeds. A tornado passing through the mill site could pick up significant volumes of solutions, ore, yellowcake, and tailings containing elevated levels of radionuclides and other potentially toxic materials and transport

them for many miles before depositing them. The pickup and release of other heavy materials such as metals, glass, and concrete could also result in physical damage to persons and structures in the surrounding area.

The probability of a tornado passing through the HMC mill site during the operational lifetime of the project is extremely low. Using data developed by Thom (1963), the annual probability of a tornado striking a given point in the millsite area is 1.5×10^{-4} tornados per year. The recurrence interval of such an incident is estimated to be approximately 6,700 years.

- Extreme Precipitation - Even if the 24-hour Probable Maximum Precipitation (PMP) event for the mill site of 19.8 inches occurred (D'Appolonia, 1980), that amount of precipitation alone would not cause the tailings pond to overtop. A five-foot freeboard, from the top of the embankment crest at its lowest point to the pond solution level, is maintained in compliance with HMC's Radioactive Material License requirements. Furthermore, a 50-foot beach is maintained from the inside dike edge to the pond edge. Pond operators monitor the freeboard and beach regularly, ensuring that no overtopping of the embankment can occur, either through tailings disposal or heavy rainfall.

- Extreme Flood - The current tailings storage area flood protection system is adequate to protect the tailings pile from a 100-year storm event (D'Appolonia, 1980). It has also been determined that a flood produced by the PMP will not produce critical safety factors less than 1.0 in the tailings embankment (D'Appolonia, 1980).

- Earthquake - Failure of the tailings dike due to earthquake is also unlikely because the pseudo-static stability analyses of the embankment for the design basis earthquake, using 0.1g maximum peak acceleration (D'Appolonia, 1980) show that the embankment has safety factors over 1.0. Other calculations place the maximum peak acceleration at 0.04g and 0.05g. The buildout design for the next five years (Section C2.0) also provides for adequate resistance to the design earthquakes. The HMC site is situated in an area characterized by low to moderate seismic activity and historical earthquakes have generally been of low magnitude and intensity.

A further discussion of the effects of earthquakes is included in Section C6.2.5.

The U.S. NRC (1980b) developed an analysis of the consequences of tornado damage to a hypothetical uranium mill. This analysis uses a very conservative approach since it is not possible to predict accurately the total amount of material that would be dispersed by a tornado. The U.S. NRC analysis indicates that about 25,100 lb of yellowcake could be lifted by a tornado passing through a mill. Atmospheric dispersion modeling of this event, using conservative assumptions, predicts the maximum exposure at a distance of approximately 2.5 miles from the mill. This exposure results in the 50-year hypothetical exposure possibility to the lungs of approximately 8.3×10^{-7} rem (U.S. NRC, 1980b).

The environmental effects of a tailings dike failure from an extreme flood or earthquake can be described only in general terms because it is impossible to determine where the released materials will be deposited over time. In the case of an extreme flood, the tailings and associated dissolved and granular contaminant materials could be carried downstream for many miles. After subsidence of the flood, particulate matter would be deposited along the stream course. The chemical and radiological characteristics of the materials that would be transported by the flood are described in Table C7.1. The geographic area that could be affected and the pattern of deposition are very difficult to predict given the many variables involved (i.e., particle size, flow volume, stream and soil characteristics, etc.). There is no distinct stream channel near the mill site. Further, an extreme flood would involve a huge amount of dilution, mixing, and sorption, and the concentrations from tailings might be well below regulatory limits. However, the U.S. NRC (1980b) estimates that tailings solids could cover a stream channel for a distance of about 6,800 feet by 425 feet at a depth of about 1.25 inches.

Historical data presented in the Final Generic Environmental Impact Statement (FGEIS) on Uranium Milling (U.S. NRC, 1980b) show that accidental tailings slurry releases occurring between 1959 and 1979

resulted in average releases of 1.4×10^7 gallons of liquids and 3.2×10^7 lb of solids. Sixty percent of the releases from embankment failure or flooding reached a watercourse. The likelihood of a release of tailings to a watercourse is calculated to be about one incident per 50 plant-years (U.S. NRC, 1980b). The Applicant considers the U.S. NRC figure meaningless unless a specific site is considered. A site near a water source might have a much greater frequency. The relatively large spill at this site in 1977 remained on the restricted area.

Such a release could result in concentrations of radioisotopes, particularly radium-226, in excess of the MPC's for unrestricted areas. In case of release, the NMEID would be notified and radioisotope concentrations downgradient from the mill would be monitored. Alternative sources of water for livestock and irrigation would have to be provided, and if radionuclide concentrations were excessive, excavation of contaminated sediments would be necessary. The flat terrain and downgradient berm at the site are factors that make escape off the restricted area unlikely except in the case of a flood far in excess of the PMP.

C7.2 NONRADIOLOGICAL MILL ACCIDENTS

Accidents not involving radioactive materials may occur at the mill which could result in release of other hazardous materials and could affect the environment. Because of proper design and stringent safety procedures, the potential for such accidents and consequences to the environment are minimal.

C7.2.1 Leaks and Ruptures in Chemical Storage Tanks and Pipelines

A number of chemical process reagents are handled and stored at locations throughout the mill site. These chemicals include sodium bicarbonate, sodium carbonate, polyacrylamide flocculent, hydrochloric acid, sodium hydroxide (caustic soda), sulfuric acid, anhydrous ammonia and ammonium sulfate. Chemicals are stored in surface storage tanks in the following amounts:

Chemical	Storage Capacity (tons)	Use (pounds/ton ore)
Soda ash	50	15.0
Caustic soda	75	22.0
Sulfuric acid	25	28.0
Hydrochloric acid	25	3.2
Anhydrous Ammonia	50	0.8
Sodium chloride	50	6.3

Conceivable accidents include pipeline or surface storage tank ruptures, solution leaks, and tank overflows. Environmental effects will be minor because spills will be confined to the mill vicinity and recovered promptly. Protective drainage curbs surround storage tanks and other structures which contain hazardous materials. Most tank overflows or ruptures will be contained within these drainage curbs and recovered to be stored, reused, or moved to the tailings pond. A secondary containment berm exists one fourth mile south (downgradient) of the mill and tailings pond. The purpose of this berm is to contain major spills or leaks, particularly from the tailings pond.

C7.2.2 Minor Fires

The plant and mill buildings are constructed of steel and concrete. Minor fires could result from faulty electrical wiring, welding or small amounts of combustible material. Chemical explosions which would release toxic materials to the air are possible but improbable because of properly designed storage systems. An adequate fire control system including 120 hand fire extinguishers, three fire hose cars, 17 fire hydrants and an overhead sprinkler system (in some buildings) is maintained at the mill. Personnel are trained in fire protection procedures and receive written copies of HMC's Mill Fire Fighting Procedures. Personnel with specific fire fighting qualifications are present at the mill site at all times. HMC employs a mill fire chief and personnel from each shift are appointed to the fire crew.

C7.2.3 Ruptures in Underground Pipelines

Steel pipelines for water supply are buried underground at the mill site. Because no toxic materials would be released by a rupture in the water supply pipeline, minimal environmental effects are expected. Other underground pipelines include small diameter diesel fuel oil and air pipelines and sewer lines. A breach in any of these pipelines would be expected to result in minimal adverse environmental impacts.

C7.2.4 Other Nonradiological Accidents

Other potential nonradiological accidents include failure of the electrical power system, ventilation system, and boilers. Electrical power failure would not result in release of toxic materials. The ventilation system is electrically connected with process equipment and failure results in an alarm sounding. The boiler system is equipped with safety release valves for over-pressure.

C7.3 TRANSPORTATION ACCIDENTS

Transportation accidents are discussed in three categories:

- Shipment of process chemicals to the mill,
- Shipment of ore from the mines to the mill, and
- Shipment of refined yellowcake from the mill to the uranium hexafluoride conversion facilities.

C7.3.1 Shipment of Chemicals to the Mill

Various chemicals are shipped to the mill for use in the uranium milling process. Impacts from accidents involving these shipments are expected to be minor in most instances. An accident involving an anhydrous ammonia spill is considered the "worst-case" condition for assessing the magnitude of environmental impacts resulting from this type of acci-accident. This analysis is based on figures reported in the FGEIS on Uranium Milling (U.S. NRC, 1980b). Based on the total annual truck shipments of anhydrous ammonia and the annual number of accidents involving these truck shipments, the estimated frequency of occurrence

of these accidents is approximately 4.3×10^{-6} accidents per mile and the average shipping distance is about 350 miles (U.S. NRC, 1980b). The U.S. NRC data indicate that about 80 percent of the reported accidents involved an average release of ammonia of about 1,700 pounds. Approximately 15 percent of the reported accidents involving an ammonia spill resulted in an injury to the general public, principally to the driver. Using these figures and average population densities, the probability of an injury to the general public as a result of an ammonia shipment by truck is about 4.8×10^{-7} injuries per mile (U.S. NRC, 1980b). Assuming that the mill will require eight ammonia shipments per year from a distance of approximately 300 miles, the probability of an injury to the general public from shipments of anhydrous ammonia to the mill site is estimated to be 1.2×10^{-3} injury accidents per year or one every 868 years. Since the mill began operation, there has never been an accident or injury at the mill involving anhydrous ammonia.

C7.3.2 Shipments of Uranium Ore to the Mill

Uranium ore is shipped in 22- to 28-ton truckloads from mines located six to 18 miles from the mill. Currently 1,500 tons of ore are shipped per day with 5,000 to 10,000 tons in storage. Maximum production involves shipments of 3,400 tpd with 10,000 to 15,000 tons in storage. Truck accident probabilities are similar to those cited in Section C7.3.3, 2.6×10^{-6} per mile, however, because of the low specific activity of the ore and the ease of cleanup operations, the radiological impacts are insignificant. Therefore, no accident scenarios are evaluated for ore shipments to the mill.

C7.3.3 Shipments of Yellowcake from the Mill

Yellowcake is shipped from the HMC mill to Allied Chemical Company in Metropolis, Illinois and Kerr-McGee Nuclear Corporation in Gore, Oklahoma for conversion to uranium hexafluoride. During 1980, approximately 1,200 tons of yellowcake were shipped in 26 shipments to Gore and shipments to Metropolis. Metropolis is located approximately 1,200 miles from the mill and Gore is 800 miles from the mill. The yellowcake is packaged in

55-gallon open head steel drums which are considered Type A containers. A normal lot or shipment packaging consists of about 40 drums containing 36,000 pounds or 18 tons of U_3O_8. The shipping routes are primarily along Interstate 40 and U.S. Highway 60. The probability and environmental effects of a transportation accident resulting in the release of yellowcake are evaluated below.

The worst-case accident for yellowcake transportation would involve a truck accident in which the drums rupture, releasing yellowcake. The analysis of this type of accident is based upon the evaluation of yellowcake transportation accidents in the FGEIS on Uranium Milling (U.S. NRC, 1980b). The U.S. NRC estimates that the overall probability of a truck accident ranges from 1.6×10^{-6} to 2.6×10^{-6} accidents per mile. The probability of a truck accident occurring during yellowcake shipment is based on the number of shipments per year, miles traveled, and truck accident probability. Using an accident probability of 2.6×10^{-6} per mile, 0.13 accidents per year could be expected to occur during shipment to Metropolis and 0.05 per year to Gore. Therefore, one accident could be expected every 7.7 years during shipment to Metropolis and one every 20 years to Gore.

The probability that an accident will result in the release of yellowcake is much lower. The U.S. NRC (1980b) developed an accident classification system based on the combined stress of impact, puncture, crash, and fire. Eight accident severity categories and fractional probabilities of each were developed (Table C7.2). The probability that any accident will release at least some yellowcake is 0.45 (all severity categories excluding Model I). Therefore the probability that an accident will result in yellowcake release is 0.06 for shipments to Metropolis and 0.02 for shipments to Gore.

In addition, the U.S. NRC (1980b) computes fractional releases by accident severity categories based upon two accident models (Table C7.2). Model I assumes complete loss of drum contents and Model II, which is

based upon actual tests, assumes partial loss of contents. The expected fractional release in any given accident under Model I is 0.45 and 0.03 under Model II. Because HMC shipments average 18 tons (36,000 pounds), the quantity of yellowcake release for any accident is estimated to be 8.0 tons under Model I and 0.05 tons under Model II.

In an accident, most of the released yellowcake will be deposited on the ground. A minor amount will become airborne immediately upon container failure and some could be transported a substantial distance by wind. Yellowcake could also be released into surface water systems if the accident occurred near a stream. However, because of its insolubility and high density, the yellowcake would tend to settle in a stream. The major exposure pathway to humans and other living organisms would be inhalation of airborne particles.

Battelle Northwest Laboratories developed expressions for calculation of the dispersal of plutonium oxide as reported by the U.S. NRC (1980b). For an average yellowcake truck accident, assuming a wind speed of 10 miles per hour, 24-hour period of release, and a population density of 7.5 persons per square mile, the environmental consequences would be 50-year dose commitments of 9.0 (Model I) and 0.7 (Model II) man-rem to the lungs of the general public. Using a greater population density of 160 persons per square mile, which is more typical of the areas of the conversion facilities, 50-year possible exposure would be 200 (Model I) and 14 (Model II) man-rem to the lungs of the general public.

The chances of an accident occurring in New Mexico involving a yellowcake release is lower than the 0.06 per year to Metropolis and 0.02 per year to Gore. Further, the population density per square mile in New Mexico is far less than 160 persons per square mile (about 10 per square mile in Valencia and McKinley Counties). The probability of direct yellowcake spill into a lake or stream for yellowcake transportation to either Metropolis or Gore is extremely low because of the low proportion of flowing streams or standing water bodies intersecting with

transportation routes. The probability is even lower in New Mexico where flowing streams and lakes are particularly rare. In September 1977, a truck from another mill overturned and released an estimated 7,000 pounds of yellowcake to the truck trailer and ground. This accident was calculated to result in a release of 53 pounds of U_3O_8, and an estimated consequence of 1.2 person-rem in an area where the population density was 2.5 persons per square mile.

C7.3.4 Accident Response

In conjunction with several other uranium milling firms in New Mexico, HMC has developed a Transportation Accident Response Guide for Yellowcake. The guide provides instructions to the truck driver and the first persons to arrive at the accident scene. The purpose is to expedite the most effective cleanup by providing guidance for persons responding. This guide is included as Appendix E.

C8.0 MONITORING AND SURVEILLANCE PROGRAMS

The radiological monitoring and surveillance programs discussed in this section have been designed to ensure the operation's compliance with the Part 4 Standards of the New Mexico Radiation Protection Regulations. Also included is a discussion of HMC's program for monitoring meteorological phenomena.

C8.1 RADIOLOGICAL MONITORING

HMC's Grants uranium operations have been monitoring the occupational and environmental impacts of their milling and tailings facilities since commencement of operations in 1958. The monitoring programs are periodically reviewed to assess adequacy and determine data requirements in order to evaluate impacts. The mill and tailings embankment have been engineered and operated to minimize the release of radioactive materials into the environment of the employee and the unrestricted areas. Practicable control measures are utilized to keep radioactive releases and employee exposures to a minimum. HMC realizes that some unusual events may occur and, therefore, the monitoring programs have been designed to detect such events as soon as possible. In the event that increases in the concentration of material in the environment occur, HMC would investigate such increases. The criteria for investigating an increase in concentration is to: 1) confirm the accuracy of the analysis; 2) analyze retake samples of the material in question; 3) inspect the milling operation, meteorological conditions and other applicable variables for reasons that the confirmed concentration increase occurred; and 4) evaluate corrective alternatives for mitigating the source of elevated releases.

The monitoring programs are summarized in Tables C8.1 and C8.2 for environmental and mill/occupational monitoring, respectively. In addition, HMC's prior experience and recommendations and guidelines from the New Mexico Environmental Improvement Division (NMEID), the U. S. Nuclear Regulatory Commission (NRC), and the Mine Safety and Health Administration (MSHA) have been utilized in the preparation and

development of these current programs, which became effective on August 1, 1981.

A system is in place under HMC's Radiological Monitoring Program that provides for sample collection utilizing approved sampling equipment in approved sampling locations and utilizing accepted sampling procedures. This continuous system is complimented also with a program for insuring the analytical quality of obtained results. To achieve the acceptable quality control on the parameters as discussed above, HMC operates four individual programs within it's Quality Assurance Programs. They are listed below:

- Quarterly calibration of all sample collection pumps through a positive displacement method.

- Semi-annual calibration of all radiation monitoring equipment performed by a licensed lab.

- Semi-annual review of HMC's monitoring Standard Practice Manual to review monitoring location, equipment and procedure.

- Semi-annual collection of duplicate splits of selected effluent samples for cross-check analysis with an independent laboratory. The samples collected for the laboratory cross-check are a random assortment of a fraction of the effluent samples collected by HMC.

Quarterly, HMC will summarize the data obtained from the Environmental Monitoring and Surveillance Programs in compliance with Part 4-400 of the New Mexico Radiation Protection Regulations. This information will be made available at the mill office upon request from the NMEID Director's authorized representative for Radioactive Material License compliance. In addition, the information contained in the quarterly summaries

is submitted to the NMEID semi-annually. The submitted report will include summaries of sample variability, the range of values observed and lower limits of detection.

HMC's Environmental Monitoring Programs include:

- o Air Quality
  - Stack particulates
  - Suspended particulates
  - Ambient radon
  - Radon daughter working levels
- o Water Quality
  - Groundwater
  - Surface water
- o Biota and Soils
  - Vegetation
  - Soil
- o Direct Radiation

The Occupational Monitoring Programs include:

- o Suspended Particulates
- o Employee Alpha Inhalation Exposure
- o Nonroutine Employee Alpha Inhalation Exposure
- o Bioassay
- o Radon Daughter Working Levels
- o Direct Gamma Radiation
- o Radiation Surveys for Equipment Removal

In addition, radiation safety training is required for all mill employees.

Complete sampling and analytical methods are summarized in Appendix F.

C8.1.1 Environmental Monitoring Programs

C8.1.1.1 Air Quality Monitoring

Radiological emission of particulates or radon emissions by a uranium mill and tailings storage facility affects the dosage to any individual at the perimeter of the mill complex. For this reason, air quality is monitored at the periphery of the HMC site. Stack particulate sampling is conducted at three stack emission points

within the yellowcake precipitation circuit and one emission point in the ore crushing circuit.

Stack Sampling

Effluents from the yellowcake dryer, roaster, and packaging room stacks are isokinetically sampled quarterly and analyzed for natural uranium by HMC's analytical laboratory (Table C8.1). HMC's analytical procedures are described in Appendix F, Attachment 1. A representative grab sample is collected from each of two Crusher Building stacks semiannually and is analyzed for natural uranium, radium-226, and thorium-230 and stack flow rates. Stack locations are shown in Figure C4-2.

Sack samples are collected during periods of normal operation, as well as during periods when no throughput of ore and yellowcake is being experienced. This is intended to define actual long-term emissions, since routine operational procedures include periods of no ore crushing or yellowcake drying and packaging.

HMC personnel utilize a Research Appliance Company (RAC) Staksmplr system, or the equivalent, for conducting the isokinetic sampling program discussed above. The U.S. EPA STandards of Performance for New Stationary Sources, Title 40 CFR Part 60, Appendix A, Method 5 is the procedure used by HMC for isokinetic stack sampling.

HMC personnel have been trained in the techniques of stack sampling, including training by U.S. EPA and NMEID Air Quality Control personnel, and have taken various stack sampling courses.

Particulate Air Sampling

HMC continuously samples total suspended particulates at the five locations shown in Figure C8-1. Locations HMC-1, HMC-2, and HMC-3 are situated at the restricted area's boundary and are expected to have the highest concentrations of airborne radioactive particulates because the predominant wind direction is in a northeasterly direction. Location HMC-4 was selected with an intent to represent background conditions and is situated at the extreme southwestern corner of the restricted area.

Location HMC-5 is near the closest residence in the vicinity of the HMC mill.

HMC uses a Sierra Instruments Model No. 305-200 high volume air sampler with a flow controller, or the equivalent, to continuously sample the ambient air of the five locations shown in Figure C8-1. The samples are collected on 8-inch by 10-inch Whatman membrane filters (or the equivalent) which are changed weekly or more frequently as required by dust loading. Composites of the collected sample filters are prepared for each sampling station. The composite samples are analyzed quarterly for natural uranium, radium-226, thorium-230, and lead-210 at HMC's analytical laboratory. Analytical procedures are outlined in Appendix F, Attachments 1 through 4.

Radon Daughter Working Levels

Radon daughter working levels (WL) are determined on a quarterly basis at each of the same five locations described above (HMC-1 through HMC-5). Radon daughter concentrations are determined by the Kusnetz Method using a Bendix low volume sampling pump at 10 liters per minute (lpm), an Eberline PS2-2 scaler, and an Eberline RD-13 drawer counter, or the equivalent. The radon daughter samples are collected on Gelman 50 mm Type A/E fiberglass filters. This method is sensitive to 0.001 WL.

Ambient Radon

Radon gas concentrations are monitored on a continuous basis at the five monitoring locations. Terra-dex Corporation's Type F track-etch passive radon monitors (PRM), or the equivalent, are used to continuously monitor radon gas at each sampling location. The alpha-particle sensitive detector is replaced and analyzed on a quarterly basis by an approved independent laboratory.

The technique by which the PRM detectors measure radon gas concentrations consists of exposing an alpha-particle sensitive plastic detector, which is mounted in a plastic cup, to ambient air. A filter is placed over the container opening to inhibit any alpha-emitting dust particle from entering and, thereby, permitting only gaseous phases to reach the plastic detector. An alpha-particle generated by the decay of radon gas

imprints a track onto the alpha-sensitive detector, which can be counted at a later time. The radon gas concentration can subsequently be calculated by determining the number of tracks per unit area of the detector. HMC expects a sensitivity of 1.0 pCi/liter month from Terra-dex.

C8.1.1.2 Water Quality Monitoring

Groundwater

Well elevation measurements indicate that the groundwater in the alluvial aquifer underlying the HMC milling operation flows in a southwesterly direction. Three upgradient water quality monitoring wells (Wells P, Q, and R) were drilled by HMC and approved by the NMEID Water quality Control Bureau to substantiate background water quality. Three additional wells (Wells BC, B, and I) have been installed hydrologically downgradient to determine the effects of the operations' tailings impoundment on the regional groundwater. WEll locations are shown in Figure C8-1. The wells are sampled quarterly and analyzed for natural uranium, radium-226, thorium-230, and lead-210.

An alluvial groundwater well (Well F) has been drilled near the closest downgradient residence, just inside the restricted area (Figure C8-1). The well is sampled quarterly and analyzed for natural uranium radium-226, thorium-230, and lead-210.

All water quality wells are pumped for a minimum of 20 minute prior to sample collection. This ensures the drawing in of surrounding alluvial groundwaters and removes the likelihood of collecting waters allowed to sit inside the well casing. Water samples are immediately filtered through a 0.45 micron filter and preserved with nitric acid.
All additional sampling of groundwater, both radiological and nonradiological, is addressed in HMC's Ground Water Protection Agreements or Discharge Plans with the NMEID Water Quality Control Bureau. These programs are maintained to ensure compliance with the applicable permits and Ground Water Protection Regulations. The latest GWDP was provided NMEID in December 1981 by HMC (Hydro-Engineering, 1981).

Surface Water

HMC's milling operation has no surface water discharges. The clarified

tailings solutions are decanted and recycled back into the milling operation as process waters. No other solutions are discharged at the surface.

HMC's IX facility at Ambrosia Lake discharges approximately 550 gpm of treated mine water to the dry Arroyo del Puerto. The discharge waters are treated by ion exchange, and by barium chloride coprecipitation and settling for removal of uranium and radium-226, respectively. This discharge is sampled quarterly and analyzed for dissolved and suspended natural uranium, radium-226, thorium-230, and lead-210. A representative split of the sample is prepared. One is filtered using a 0.45 micron filter and both are preserved with nitric acid and delivered to HMC's analytical laboratory for analysis. Procedures are discussed in Appendix F, Attachments 1 through 4.

C8.1.1.3 Biota and Soils Monitoring

Vegetation

Vegetation samples are collected on an annual basis in July at each of the five locations identified in Figure C8-1. Vegetation samples are composited for each sample location and consist of species palatable to grazing animals that contribute to the human food chain. The composited vegetation samples consist of a variety of available native grasses, forbs, and shurbs which can be classified as forage for grazing animals. The sample size is approximately 500 grams. The composited samples are analyzed for radium-226 and lead-210.

Soil

Soil samples are collected annually in July at each of the five perimeter sampling locations. Representative composite samples on an area of 100 cm^2 to a depth of five centimeters are collected for each sample location and are analyzed for natural uranium, radium-226, and lead-210. The soil sample size is approximately 100 grams.

C8.1.1.4 Direct Gamma Radiation

Gamma exposure rates are continuously monitored through the use of

thermoluminiscent dosimeters (TLD's) at each of the five sample station locations. Each TLD badge consists of five Type 100 LiF chips, selected for uniform response, in a plastic holder. The plastic provides adequate protection from weather in order for this badge to be used outdoors. The TLD's are exchanged on a quarterly basis and analyzed by an approved, independent laboratory (currently Eberline Instrument Corporation). The integrated levels of direct external radiation are recorded for each of the five locations. The TLD's are sensitive to 1.0 mrem gamma radiation.

C8.1.2 Occupational Monitoring Programs

Employee radiation exposure control at HMC's Grants milling operation is of major concern to the company. Occupational exposure control in the restricted area is kept as low as reasonably achievable (ALARA) through design engineering for prevention and control of releases, and respiratory protection programs.

Plant design and engineering controls are the primary means of controlling dust emissions and employee exposures to radiation to ALARA. The use of respiratory protection equipment is required in areas where maximum permissible levels could potentially be exceeded. Use of this equipment and restrictions on time spent in the hazardous areas ensures that employee exposures are kept below the maximum allowable dose. Respiratory protection equipment is required for all employees in the following instances:

- While working in the yellowcake packaging area;
- During yellowcake sample preparation;
- Whenever it is necessary to conduct any kind of work with either the roaster or dryer hearth doors open;
- During nonroutine precipitation building maintenance (unless otherwise directed by the Radiation Protection Administrator);
- During performance of any work in conditions requiring respiratory protection equipment as determined by a supervisor or the Radiation Protection Administrator.

HMC's Mill Respiratory Protection Program is described in Appendix F, Attachment 5.

It is recognized that prevention and control devices are not failsafe; therefore, routine occupational monitoring programs are enforced and maintained by trained and experienced personnel to keep occupational exposures to a minimum.

The routine radioactive dust monitoring and the nonroutine employee exposure monitoring programs are the primary means of evaluating each employee's exposure to airborne radioactive particulates. HMC has established a back-up monitoring program to confirm the reliability of the air monitoring programs, to ensure that the fit of respiratory protection equipment is proper, and to ensure the overall protection of the employee's health.

C8.1.2.1 Suspended Particulates

Routine monitoring of radioactive particulate dust concentration is accomplished at 17 permanent locations in the Ore Crushing and Yellowcake Precipitation Buildings. A medium volume (90 lpm), 24-hour area sample is collected at each location (Appendix F, Attachment 6) and analyzed for total alpha. In addition to the 24-hour area samples, a breathing zone sample is collected for work performed in the Yellowcake Packaging room during barrelling operations. With HMC's present milling schedule, yellowcake barrelling is performed for 5-8 hours during an operating day. The sample is collected during that time in the breathing zone of the position required to operate the barrelling apparatus. The gross alpha value determined for the breathing zone sample is reported in the space labeled "Y.C. Package Room (Barrelling and Sampling)" on HMC's Area Exposure Evaluation Report. The time remaining to collect a general area suspended particulate sample in the Yellowcake Packaging Room is 16-19 hours. This is the "Y.C. Package Room (General Duties)" sample referred to in Attachment 6, Appendix F. Samples are collected with an Eberline RAS-1 regulation air sampler, or an equivalent air sampler. The samples are counted for total alpha using an Eberline SAC-4 scintillation alpha counter, or similar piece of equipment.

C8.1.2.2 Employees' Alpha Exposure

Those operators scheduled to work in the Yellowcake Precipitation Building are required to fill out a weekly time study report identifying the amount of time spent in individual work areas. Weekly employee exposures are calculated as a percent of MPC from the area alpha concentrations (Section C8.1.2.1) and the time spent in the area. The MPC is 1×10^{-10} micro curies per milliliter (U. S. NRC, 1981, 10 CFR 20, Appendix B).

C8.1.2.3 Nonroutine Employee Exposure

Employees engaged in nonroutine maintenance activities in areas of potential acute radiation exposure are monitored by trained personnel to ensure that exposures are kept to a minimum. A ten-minute breathing zone sample, collected during those nonroutine jobs, is analyzed for total alpha. The sample is collected by an Eberline RAS-1 regulated (or equivalent) air sampler, and the filter is counted with an Eberline SAC-4 scintillation alpha counter, or similar piece of equipment. The employee fills out a time study report for the work completed. The employee exposure for the particular job is calculated as a percent of MPC from the alpha concentration and the time spent on the job.

C8.1.2.4 Bioassay

Appendix F, Attachment 7 describes HMC's Uranium Mill Bioassay Program. Bioassay analyses are performed on all mill employees routinely exposed to airborne yellowcake dust and those employees involved in maintenance tasks in which yellowcake dust may be inhaled (assuming no respiratory control), causing exposures in excess of MPC. In addition, all other Milling Division employees will have bioassay analyses performed at least annually. Urine samples are analyzed fluorometrically for Uranium content by HMC's analytical laboratory. Routine diagnostic checks for protien content and pH are also performed. All newly hired employees are required to provide a baseline control for each individual. Corrective actions based on urinary uranium results are outlined in Appendix F, Attachment 7, Table 1.

C8.1.2.5 Quarterly Radon Daughter Working Levels

On a quarterly basis HMC monitors radon daughter working levels in the

nine areas most frequently occupied or having the highest potential for elevated concentrations throughout the Crusher Building, the Fine Ore Bins, and the Metallurgical Lab. Working levels re determined either by the Kusnetz Method using a low-volume pump, an Eberline PS2-2 portable scaler, and an SPA-1 alpha counter, or by an MDA Scientific, Inc. Instant Working Level Meter (IWLM). The IWLM is sensitive to 0.01 WL.

C8.1.2.6 External Gamma Radiation

External beta-gamma radiation surveys are conducted monthly in various locations throughout the HMC mill operating area, as well as the area in which the yellowcake product is stored while awaiting shipment. External beta-gamma radiation surveys are conducted with an Eberline PRS-2 portable ratemeter-scaler and HP-270 beta-gamma probe, or similar equipment. These instruments permit a sensitivity of 0.01 millirem gamma per hour (mrem gamma/hr.). The locations surveyed on a monthly basis include:

Crusher Building
Yellowcake Dryer
Yellowcake Drum Storage Area
Yellowcake Packaging Room
Yellowcake Sample Preparation Room
Filter Building
Digester Building

The purpose of the external radiation survey program is to detect any significant changes in radiation levels that might have occurred in these locations and to delineate any areas of potentially high external radiation exposure.

HMC mill operating personnel assigned to work exclusively in the Yellowcake Precipitation Building are monitored for direct gamma radiation exposure with personnel TLD's. The TLD's are Type 100 LiF chips, sensitive to 1.0 mrem gamma. The TLD's are replaced monthly and analyzed for direct gamma radiation exposure on a monthly basis. The TLD service and analysis is provided by Eberline Instrument Corporation.

C8.1.2.7 Radiation Surveys for Equipment Removal

All contaminated milling equipment and building materials are stored in isolated areas within the restricted area of the mill. Radioactivity surveys are conducted prior to the sale or transfer of uranium milling equipment and building materials to persons not licensed by the NRC or a state agency. The radioactivity surveys conducted include the following:

Removable Alpha
Fixed Alpha
Beta-Gamma

As a practical matter, contaminated milling equipment or building materials are not now removed from the restricted area. The limitations below must be met prior to releasing any material or equipment from the restricted area to persons not having a materials license:

(1) The maximum amount of removable alpha radioactivity, in disintegrations per minute (dpm) per 100 square centimeters (cm^2), shall not exceed 1,000. (Removable is defined as capable of being removed by wiping the surface with a filter paper or soft absorbent paper.)
(2) The maximum amount of fixed alpha radioactivity, in dpm per 100 cm^2, shall not exceed 15,000.

(3) The average amount of fixed alpha radioactivity, in dpm per 100 cm^2, shall not exceed 5,000.

(4)a. The maximum radiation level at 1.0 centimeter (cm) from the most highly contaminated surface, measured with an open-window beta-gamma survey meter through a tissue equivalent absorber of not more than 7.0 milligrams per square centimeter (mg/cm^2), shall not exceed 1.0 millirad per hour (mrad/hr); and

b. The average radiation level at one centimeter from the most highly contaminated surface measured in the same manner as in (4)a. shall not exceed 0.2 mrad/hr.

Records are maintained of each transfer of milling equipment and

building materials including results of surveys to determine contamination levels, type of equipment and building materials transferred, and the name and address of the person or firm to whom the transfer was made.

The alpha activity survey is conducted with an Eberline RM-19 radiation monitor with an AC-3 alpha scintillation probe, or similar equipment. The scintillometer is sensitive to 2×10^7 cpm per uCi/cm^2. Wipe samples are collected only in the event the alpha scanner indicates a total contamination level (fixed plus removable) in excess of the removable alpha limit (1,000 dpm per 100 cm^2). The scanner is placed directly on the surveyed material. A sufficient number of readings are made to clearly indicate the average and maximum amounts of alpha radioactivity present.
The gamma radiation measurements are taken with an Eberline PRS-1 portable ratemeter-scaler and HP-270 beta-gamma probe, or similar equipment. The instruments are sensitive to 0.01 mrem/hr. A sufficient number of readings are made to clearly indicate the average and maximum levels of gamma radiation present.

C8.1.2.8 Radiation Safety Training

The HMC milling operation has an established employee training program to assist the new and present employees in the safe and efficient performance of their work assignments. The program consists of an initial employee orientation that utilized formal classroom instruction and a continual skills training process for each employee's specific job function.

New employees are given an initial indoctrination in subjects which relate to his or her new occupation, including instruction in the health protection aspects associated with exposure to radioactive materials or radiation, the different forms of radiation prevalent in the milling operation, and means by which the employee can keep his exposure as low as reasonably possible. Periodically (at least annually), all mill employees are given refresher training by qualified personnel knowledgeable in radiation protection.

All new employees are issued a copy of HMC's Mill Safety Handbook, which contains a card that the employee must sign within 30 days of his hire date, stating that he has read and understands the required operating procedures. Part VI of the handbook relates to radiation protection and is titled "Rules for Radiation Protection". A portion of these HMC radiation protection rules, which has recently undergone review and modification, has been included in Appendix F, Attachment 8 for the Precipitation Building, Metallurgical Lab and Crushing Section.

C.8.2 Meteorological Monitoring

HMC commenced the continuous monitoring of the weather at their mill in 1977. HMC's weather station is located approximately one-half the distance between the active tailing pile and the southern border of the restricted area; 1000 feet south west of the inactive tailing pile; and one-half mile west of North Highway 53. The weather station sits on top of a 10 meter tower and is protected from lightening by lightening rods. The location and height of the weather station was arrived at after consultation with personnel of the NMEID-Air Quality Control Bureau.

C8.2.1 Meteorological Monitoring Program

HMC continuously monitors meteorological phenomena with an automatic weather station. The instrumentation utilized by HMC for this purpose was upgraded in 1982 in order to make the system compatible with their Data Processing system. The continuous monitoring station surveys the following parameters: wind speed, wind direction, air temperature, barometric pressure, relative humidity and precipitation.

The automatic weather station consists of an analog data processor, meteorological sensors and a magnetic tape data recording unit. Data is processed according to user-selectable engineering unit conversion programs and output programs. The output programs that are operated for HMC's Meteorological Monitoring Program are listed as follows:

- Wind Vector
  1. Mean windspeed (units are speed)
  2. Mean windvector magnitude (units are speed)
  3. Mean windvector direction (units are degrees)
  4. Standard deviation of direction (units are degrees)

- Average Temperature
- Average Barometric Pressure
- Average Relative Humidity
- Total Precipitation

Processed data is output at chosen time intervals to an on-site cassette tape recorder. HMC selected 60 minute time intervals for data recording.

The data processed and recorded by the weather station can be interfaced with HMC's main Data Processing system for data reporting and storage.

C9.0 LONG-TERM IMPACTS

The following sections describe the stabilization plans for the tailings area after final cessation of operations. The estimated cost of stabilization for purpose of surety arrangements is also included, as are the results of calculations on wind and water erosion rates, duration of stabilization cover material, and radon concentrations. Interim stabilization measures by use of chemical binder to reduce wind blown tailings are also discussed.

C9.1 INTERIM STABILIZATION

C9.1.1 Ongoing Programs

HMC's interim stabilization program consists of the use of a chemical binder to cover the west end of the tailings pile, which is of greater importance since the prevailing wind direction in this area is from the southwest. Approximately 20 percent of the dry surface area is covered per application and this is repeated on a yearly basis due to the breakdown of the chemical binder and the deposition of new tailings over the treated area.

Although other chemicals are being tested, the major chemical presently used is a Wedco V-4100 tailings binder, from Western Chemical Company. Wedco V-4100 tailings binder is a waterbased polyvinyl latex copolymer formulated especially for thin, penetrating consistency. The product is formulated specifically to penetrate dirt and dust to inhibit erosion and dust pollution. When cured, the Wedco V-4100 forms a nonremovable binder which remains flexible and firm and has the capability of remaining stable in freeze-and-thaw climates. The Wedco V-4100 is a nontoxic biodegradable stable compound.

Prior to application of the chemical binder, some surface preparation is required in order to achieve optimum protection from wind erosion. To prepare the surface, the area must be made smooth so that a uniform

application of binder can be achieved. If a uniform application is not achieved, erosion of the soft sands beneath the surface crust eventually causes a breaking and slumping of the outer crust, allowing the deterioration to work its way up the embankment.

The Wedco V-4100 is applied by spraying on the surface using a 1,500-gallon tank trailer and a Reinco Power mulcher. The chemical is diluted with 15 to 20 parts water per one part chemical. Due to the solubility of the Wedco V-4100, the dilution with water takes place in the tank trailer without any special mixing. The Wedco V-4100 is a clear glue type chemical; therefore, to assist in applying a uniform thickness when spraying, a fugitive dye is added to the diluted chemical. When applying the chemical stabilizer, the area is sprayed until saturated to the point of runoff, allowing for maximum penetration which is the main determining factor of a successful application. Different chemical binders are being tested. The ability of Wedco V-4100 to disintegrate with time is an important characteristic, as this feature allows liquid to penetrate an old treated area. As fresh tailings are deposited over a treated area, water penetration is necessary so that no near-surface satuation and resultant sloughing will occur. The chemical stabilization has been effective in reduction of blowing tailings and suppression of gulley formation on the treated embankment.

C9.1.2 Prestabilization Procedures

Depending on the long-term behavior and condition of the areas which are disturbed or exposed during the milling operation, HMC will evaluate the need for continuing or modifying the procedures discussed above. A description of any additional interim activities will be provided to NMEID upon implementation.

C9.2 DECOMMISSIONING AND DECONTAMINATION

The Applicant will give NMEID 30 days notice prior to mill closure and starting decommissioning activities. A general approach to decommissioning of the mill facility property is set forth below on a preliminary basis.

Material and equipment that can be economically decontaminated will be salvaged for resale. The determination of the material or equipment that will be considered for salvage will be made at the time of cessation. Buildings, concrete structures, and other ancillary facilities and equipment that cannot be economically salvaged will be removed, where appropriate, from the facilities area and deposited in the tailings disposal area. Concrete and other material suitable for use as riprap will be placed on the embankment for protection against flood events.

Near the end of the useful life of the mill, HMC will submit data from radiation surveys taken at the site and plans for any mitigating measures identified by the survey.

C9.3 FINAL STABILIZATION

HMC's long-term stabilization plan provides for the reestablishment of a vegetation community over the areas that have been disturbed by the milling operations, except the tailings disposal area where a rock cover will be used for long-term stability. The plan outlines the procedures to be used for surface stabilization and vegetation for the 509 acres that will have been disturbed. The areas to be stabilized include the tailings embankment, facilities area, IX plant, and borrow area(s) as shown on Figure C9-1 through C9-3. Estimated costs for stabilization of the tailings embankment are also included for surety arrangements.

HMC has developed the stabilization plan in accordance with NMEIB's adopted rules and regulations to show the procedures that will be used during the final stabilization.

Information concerning the above mentioned plan is contained in the following subsections:

- Affected area
- Contouring plan for affected areas

- Cover material placement
- Stabilization plan
- Revegetation and fertilization
- Peak discharge for the 200-year flood event
- Erosion control
- Transport of radionuclides
- Monitoring program
- Estimated cost
- Financial surety arrangements

C9.3.1 Affected Areas

The affected area (approximately 509 acres) is comprised of the two-cell tailings embankment, the mill facilities area, mine IX plant and cover material borrow area(s) as shown on Figures C9-1 through C9-3. The area in which tailings may be deposited to the year 2000 occupies about 274 acres. This embankment area comprises 54 percent (274 acres) of the affected area. The facilities area comprises 10 percent (49 acres), the IX plant comprises one percent (five acres) and the cover material borrow area(s) 35 percent (181 acres). With the exception of the tailings embankment, the affected areas contain relatively flat topography.

C9.3.2 Contouring Plans for Affected Areas

Prior to stabilization, the tailings must be in a dry stable condition. The drying process involves the removal of free ponded water and drainage of porewater in the tailings. The first step of drying will be achieved by evaporation and infiltration. The second step is more complex and involves evaporation and downward percolation to drain the tailings. The critical part of drainage occurs near the surface where the fine-grained or slime fractions of the tailings must gain sufficient strength by desiccation to form a crust which will support the load of heavy equipment. The time involved in this desiccation, which must occur prior to final grading and cover material placement, is anticipated to be on the order of several years.

Figure C9-1 shows the existing contours of the tailings embankment. Figures C9-4 and C9-5 provide a north-south cross sectional view of the

ultimate buildout and Figure C9-6 provides an east-west cross sectional view of the ultimate tailings embankment at complete buildout. Figure C9-7 shows the postmilling stabilized tailings embankment and facilities area. The Mine IX plant recontoured area is not shown; however, it will remain essentially in the same condition as currently exists. The borrow area(s), shown on Figure C9-2, will be recontoured to tie into existing contours. The affected areas will be graded to provide natural drainage and to protect against the development of depressions.

In the event HMC decides to select an alternative tailings disposal system that includes construction of an evaporation pond, the east borrow area as shown on Figure C9-2 may be reconfigures to accommodate the construction of the pond. If the pond is constructed, the soil material removed will be stockpiled for use in stabilization of the evaporation pond area and tailings embankment. A determination will be made at the time of pond construction if adequate soil material is available in the stockpile for final stabilization. If additional borrow material is required, a new borrow area will be designated.

As shown on Figures C9-4 through C9-7, the tailings embankment will be graded to provide side slopes that are no greater than 4H:1V. The top 157 acres of the tailings embankment will have very gentle slopes, in the range of 50 to 150H:1V.

C9.3.3 Cover Material Placement

Upon completion of the tailings embankment buildout to 4H:1V slopes and recontouring of the tailings embankment top, cover material will be placed over the tailings area. It is estimated that 1,120,000 cubic yards of tailings material will have to be moved in order to obtain the configuration as shown on Figures C9-4 through C9-6. In addition, approximately 484,000 cubic yards of cover material will be used to cover the recontoured tailings to a depth of 18 inches (see Section C9.4). The material may be obtained from the borrow area(s) as shown on Figure C9-2. Material will be placed in horizontal lifts and compacted to 80 to 85 percent standard proctor density. Following placement and compaction of the cover material, the surface will be scarified on the contour to

reduce erosion potential and increase precipitation infiltration during the time period between cover material placement and placement of rock cover.

Approximately six inches of broken rock will be placed over the tailings embankment cover material. This rock material will be obtained from a quarry that is approximately five miles from the site. Approximately 242,000 cubic yards of rock material will be used.

C9.3.4 Stabilization Plan

Stabilization of the tailings embankment will be accomplished through the use of the soil and rock covers as discussed above. The use of 18 inches of cover material and six inches of broken rock cover will provide much more protection to the tailings against wind and water erosion than is required by the NMEIB's Section 12-300.B regulation and its Radiation Protection Regulations in general. HMC has selected the use of rock rather than the use of vegetative cover because, in this instance, a rock cover provides better protection against water and wind erosion than vegetation. Rock cover provides stabilization when placed, whereas vegetation may take time to become established. Neither a rock cover nor a vegetative cover would be necessary to protect the tailings against erosion for a period of 200 years, as required by Section 12-300.B of the NMRPR (NMEID, 1981). The toe of the embankment on the north and northwest side will be rip rapped using rock and perhaps concrete and rubble from the mill decommissioning. This will provide added protection from any potential 200-year flood events.

C9.3.5 Revegetation and Fertilization

C9.3.5.1 Revegetation

Areas upon which revegetation will be encouraged include the facilities area, soil material borrow area(s) on HMC Property, as shown on Figure C9-2 and on the IX plant and road areas. The Applicant believes it is worth while to make some attempt to encourage vegetative growth; however, the stabilization plan is not dependent upon the success or failure of efforts to encourage vegetation. It is anticipated that

effective seeding of vegetation will be conducted between mid-June and mid-September. This period of the year has the most favorable moisture and temperature conditions. If seed beds are prepared prior to optimum seeding dates, a preparatory crop may be planted.

C9.3.5.2 Fertilization

A soil investigation will be conducted prior to revegetation. Results of the soil analyses will allow determination of the amount of nutrients contained in the soil material in the disturbed areas. Because of the rock cover, fertilization will not be used on the stabilized tailings. Random samples will be taken from the three other affected areas to determine requirements for the following:

- Available nitrogen (N) for seed germination and plant development;
- Available phosphorus (P_2O_5) to stimulate root development and plant growth;
- Available potash (K_2O); and
- Trace elements.

Fertilizer will be applied prior to permanent seed mixture planting.

C9.3.5.3 Seed Bed Preparation

The areas to be revegetated will be prepared as follows:

- Facilities Area -- The facilities area will be the first area where revegetation efforts will be made. If appropriate, after removal of the administrative buildings, ancillary buildings, concrete, rubble, and certain soils, the area will be ripped with a bulldozer or equivalent equipment with ripper shanks which will make parallel cuts on the contour at a depth of approximately two feet. The area will then be disced or harrowed to provide a surface for drill or broadcast seeding.
- Cover Material Borrow Area -- Soil in the proposed borrow area, as shown on Figure C9-2, is the Penistaja-Prewitt-Moriarty association. This soil association is rated good to poor, depending on depth (Maker, et al., 1974). The soil depth of the association is approximately 60 inches; therefore, when the soil is removed from the borrow area for cover material (1.5 feet), an adequate plant growth medium should remain in the borrow area for revegetation. For

this reason, after soil removal, the area will be graded and then disced or harrowed to provide a surface for drill or broadcast seeding.

- IX Plant -- The IX plant area will be treated in the same manner as the facilities area.

C9.3.5.4 Postmilling Seed Mixtures

The postmilling seed mixture is based on species adapted to the site vicinity and for erosion controlling capabilities. Both sod and bunchgrass species are preferable to help provide soil stability and reduce erosion. Table C9.1 provides the permanent species mixture selected and seeding rates. Table C9.2 provides suggested seeding rates and types for establishment of a rapid growing preparatory crop, if appropriate. These seeding rates and numbers of seeds vary with local conditions at different sites. The rates and numbers on Table C9-1 reflect the local site characteristics.

C9.3.5.5 Mulch

Mulch will be applied to all seeded areas to conserve soil moisture and reduce erosion. Application will immediately follow seeding unless soil or climatic conditions (wet soil or inclement weather) prohibit the operation. Areas that have been seeded with a preparatory crop may not require mulching. The permanent seed mixture may be planted in the stubble. Mulching requirements for areas with preparatory crops will be determined on an area-by-area basis.

An appropriate mulch will be applied at a suggested rate of 2.0 to 2.5 tons per acre. The type of mulch will be determined during the postmilling stabilization program. When hay or straw mulch are used, they will be anchored with a straw crimper.

C9.3.5.6 Fencing

Fencing will be used to control access into the restricted area. The fencing will serve to control livestock grazing on revegetated areas. The area will be posted as a restricted area. Signs will be placed every 100 feet along the fence.

C9.3.6 Peak Discharge for the 200-Year Flood Event

The peak discharge and floodplain extent of the 200-year flood event were determined with the methods used for determination of the 100-year event as described in Sections B3.1.4 and B3.1.5. The rainfall amounts of the six- and 24-hour, 200-year rainfall events were extrapolated from a graph of the two-, five-, 10-, 25-, 50- and 100-year events of these same durations using data extracted from the NOAA precipitation-frequency atlas for New Mexico (NOAA, 1973). These rainfall amounts were 2.0 and 2.9 inches for the six- and 24-hour, 200-year storms, respectively, after adjustment for areal corrections. These rainfall amounts and durations were entered into the computerized version of the U. S. SCS synthetic triangular unit hydrograph method along with the San Mateo drainage basin characteristics used previously (Section B3.1.5). The resulting 200-year peak discharges were 8,456 and 8,536 cfs for the six- and 24-hour, 200-year storms, respectively. As with the 100-year event, the shorter duration storm produced the higher peak discharge because of the greater rainfall intensity used in the calculation.

The peak discharge of 8,456 cfs was used in the HEC-2 water surface profile computer program. Cross-sections B-B', C-C', and D-D' did not change from those that were used for the 100-year flood (Section B3.1.5 and Figure B3-4). Cross section A-A' was modified to reflect the tailings embankment buildout to the year 2000 and the post milling retaining berm at the west side of the embankment. Figure C9-8 provides the calculated water surface elevation and top width of the 200-year flood at each cross section. It can be seen that the 200-year will reach the new flood protection berm that will protect the west slope of the tailings embankment. The top of this berm will be at elevation 6,585 feet and will not be overtopped by the flood waters. It will, however, effectively direct the flood out and away from the embankment toe.

C9.4 EROSION CONTROL

C9.4.1 Soil Erosion Rate

C9.4.1.1 Water-Induced Erosion

Due to the gently sloping topography of the top of the stabilized

tailings embankment, HMC has determined that with 18 inches of compacted cover material and a six-inch layer of rock over the entire embankment, sheet and rill erosion caused by runoff is not anticipated to be much of a problem. This has been determined by the use of the U.S. EPA (1977) Universal Soil Loss Equation (USLE). The USLE is an empirically developed equation dependent on several parameters that affect the amount of erosion for a given slope. Each parameter and its value as selected for the HMC site is discussed below.

R Factor Rainfall factor R is a measurement of the kinetic energy, and hence the erosive force, of the expected rain storms for a specific geographic area. The R factors presented in Figure 1, US SCS, 1977, are representative of a long-term average condition based on relatively accurate data. For the Homestake site, the average annual R value is 20.

P Factor. Support practice factor P relates to erosion control on cropland fields such as contour tillage and terraced slopes. Typically, if erosion is being calculated on land used for purposes other than crop production, e.g., construction sites, the P factor would be one. Accordingly, the Homestake P factor was set equal to 1.0.

C Factor. The cover or crop management factor C accounts for the effects that various ground covers have on erosion as opposed to a continuously clean tilled field. Although limited C factor data are available for construction sites mulched with crushed stone (values present in U.S. Department of Agriculture, Agriculture Handbook #537; 1978), the data provide an empirical basis for estimating C factors for similar crushed stone covers. The data are based on a mulch rate of up to 240 tons/acre of crushed stone, whereas at the Homestake site this rate is more than three times as great, approximately 900 tons/acre (assume the 0.5 ft. cover rock to have a density of 80 lbs/ft^3 or solids with 140 lbs/ft^3 density and 40% voids). Therefore, the six-inch-thick total rock cover required by the Homestake reclamation plan was considered to provide a cover factor at least as good as a 100% cover permanent pasture or permanent mulch and probably equivalent to forest

land with nearly full canopy and duff at least two inches thick. Assuming the rock cover retards erosion and the runoff as effectively as the forest land with duff cover, the C value is probably between 0.001 and 0.003 (USDA, 1978, Table 11).

K Factor. The soil erodibility factor K is dependent on several soil parameters and can be calculated from a nomograph (US SCS, 1977). This nomograph, developed for agriculture and construction areas, should only be used as a guide since it is based on a limited number of different soils. All known soil series for the interior western U.S. have been assigned K factors (Appendix A, US SCS, 1977). Where horizons or textural phases differ greatly in erosion potential, more than one K factor is assigned. The highest known K factors for the three potential soil cover materials are: the Penistaja, K = 0.32; the Prewitt, K = 0.32; and the Moriarty, K = 0.37. Use of soil values alone for the Homestake site is not appropriate since the six-inch crushed rock cover prevents direct soil erosion by rainfall. To account for this added protection, a K value for a 90% sand material was developed to represent the crushed rock since known K values for crushed rock were not available.

Using Wishmeier's Nomograph for a soil with 5% silt, 90% sand, 0% organics, having a blocky structure with a rapid to moderate permeability, the highest K value was considered to be 0.05. Averaging this value with the other K values for the three possible soil cover materials, a K value of 0.265 was considered representative for this soil/rock cover material.

L and S Factors. The slope length factor L and the slope gradient factor S are treated as a single factor, LS, that can be obtained from available tables (U.S. SCS, 1977). However, these LS values are speculative when the slope length exceeds 400 ft. or slope gradient exceeds 24% since they are out of the data base range. Since the Homestake site consists of several slope gradients, the LS value was calculated by using an equation which accounts for variable slope lengths and gradients (Haan and Barfield, 1978):

$$LS = \frac{\sum_{j=1}^{n} S_j(\lambda_j^{1+m}) - S_j(\lambda_{j-1}^{1+m})}{\lambda_e\ (72.6)^m}$$

where: $$S_j = \frac{0.43 + 30x_j + 430x_j^2}{6.613}$$

and
- j - slope segment number
- n - total number of segments
- S_j - slope factor
- λ_j - slope length from peak elevation to base of segment j
- λ_e - overall slope length
- m - exponent factor
  - $m = 0.5$ for slopes $\geq 5\%$
  - $m = 0.3$ for slopes $\leq 3\%$
- x_j - sin θ where θ is the slope angle

For the exponent m in the denominator, a weighted average according to slope length was used to account for the variation in m values. Using the north side of the east pond, the LS value was calculated from:

j	Slope %	m	λ_j	S_j	$S_j(\lambda_j^{1+m})$	$S_j(\lambda_{j-1}^{1+m})$	Difference
1	1.111%	0.3	90	0.123	42.70	0.00	42.70
2	0.833%	0.3	930	0.107	773.41	37.14	736.27
3	25.000%	0.5	1391.8	4.99	259099.03	36068.52	223030.51

With λ_e = 1391.8 and average m = 0.37, the LS is 32.94. However, when the longest slope is considered, from mid-point on the east pond directly westward, the LS factor is calculated from:

j	Slope %	m	λ_j	S_j	$S_j(\lambda_j^{1+m})$	$S_j(\lambda_{j-1}^{1+m})$	Difference
1	1.111%	0.3	90	0.123	42.70	0.00	42.70
2	0.666%	0.3	2640.0	0.098	2749.86	34.02	2715.84
3	25.000%	0.5	3060.6	4.99	844909.91	140018.57	704891.34

With λ_e = 3060.6 and average m = 0.33, the LS is 56.22.

<u>Summary</u>. The USLE is given as:

A = RKLSCP

where A = soil loss in tons/acre/year

R = 20

K = 0.26

LS = 33 or 56

C = 0.002

P = 1.0

The soil loss is: 0.34 tons/acre/year for LS = 33

0.58 tons/acre/year for LS = 56

At this rate, the layer of rock will last approximately 2,000 years with the 18 inches of soil remaining. It is estimated that approximately 0.6 inches of rock would erode in 200 years. The reason for this slow rate of erosion is that the competent rock cobbles and pebbles will, after an initial washing away of the uppermost fine materials, form an erosion-resistant pavement. This pavement can easily withstand the energy of falling rain and the erosive force of flowing water much like the natural erosion pavements found in some desert areas.

The stabilized tailings embankment is located on very flat terrain. For this reason, there is a slight potential for arroyo headcutting. The land downgradient from the embankment does not contain arroyos. At the present, the area would seem depositional. The rock cover on the embankment should provide protection from any conceivable arroyo

headcutting. The Continued Care Fund will provide a substantial income to monitor and remedy any potential headcutting that may develop.

C9.4.1.2 Wind-Induced Erosion

Wind-induced erosion is not anticipated to be a problem for the same reasons outlined above in Section C9.4.1.1. The fine material on the surface of the six-inch layer of rock may be transported by wind during the first few years. However, following the formation of the erosion pavement, practically no material will be wind transported. The U. S. Department of Agriculture (1976) publication for determining soil loss due to wind erosion shows that soils which contain more than 80 percent of its fraction as greater than 0.84 millimeter (mm) effective diameter will not be lost due to wind erosion. All of the top layer of rock in the erosion pavement will contain particles greater than 0.84 mm.

The calculations of water-induced and wind-induced erosion assume no active maintenance. New Mexico's Continued Care Fund, to which the Applicant contributes, will provide monitoring and maintenance to control any potential erosion.

C9.5 TRANSPORT OF RADIONUCLIDES

The analyses of erosion and effects of a 200-year flood event indicate that HMC's proposed stabilization program will provide protection of the tailings in excess of 200 years. No tailings should be transported from the area during that time period or as a result of a 200-year flood event.

Another means of radionuclide transport from the tailings is by radon emanation through the cover material over the tailings. Current NMEIB Radiation Protection Standards limit concentrations of radon-222 to 30 pCi/l which is equivalent to about 100 pCi/m^2-sec (U. S. Department of Energy, 1981). Using this criterion, the required soil cover to reduce emanation to 100 pCi/m^2-sec was calculated.

D'Appolonia's computer program Radon Emanation Program (REP), was developed to predict radon emanation rates (flux) for various

combinations of soil types under steady state concentrations of radon migration through the multi-layered porous media. The program models the media by a one-dimensional, time independent equation and allows for iterations on any parameter of any particular layer for each individual run.

In the balance equation for a one-dimensional elementary control volume of dx liters (lateral surface perpendicular to the axis equal to 1 dm^2 and thickness along the x axis is equal to dx) the steady state condition requires that the net influx of radon ($F_x - F_{x+dx}$) is equal to the difference between the radon decay (Ddx) and source production rates (Sdx) in the gas phase of the same volume. The substance flux through any unitary reference surface is directly proportional to the opposite of the substance concentration gradient at the reference surface (Fick's law assumption):

$$F_{x=r} = -k \frac{dC}{dx}_{x=r}$$

where

r = Location of the reference surface along the x axis

F (flux) = Quantity of the substance crossing the unitary reference surface per unit time

C = Substance concentration at the reference surface

k = Proportionality constant called the diffusion coefficient of the substance in the medium

The substance concentration is defined on the basis of the amount present in the gas phase (interconnected channels) of the medium divided by the total volume occupied by the porous medium (gas phase + solid phase). This definition for (C), in pCi/liter of porous medium, leads to an equation free of a porosity parameter.

The source term (S), i.e., the pCi/liter liberated per second into the gas phase, is equal to (using 1 liter of porous medium as the reference volume):

$$S = [Ra] \cdot \quad \cdot \quad \cdot E \cdot 10^6 \text{ (pCi/l.s.)}$$

where

[Ra] = Radium content of the soil (g.Ra-266/1000 tons of porous medium).

= Specific weight of the porous medium (kg./l.).

= Radon-222 decay constant ($s.^{-1}$).

E = Emanation coefficient of the medium. It is the fraction of the Rn-222 atoms generated by Ra-226 decay inside the solid phase which escapes into the gas phase and becomes free to diffuse.

The decay term (D), i.e., the number of pCi/liter eliminated per second by radioactive decay from the gaseous phase of the porous medium unitary reference volume, is equal to:

$$D = C \text{ (pCi/l.s.)}$$

By defining the relaxation length, R, (dm):

$$R = \left(\frac{k}{}\right)^{1/2}$$

and manipulating several expressions, the balance equation as previously described is written as:

$$\frac{d^2C}{dx^2} - \frac{C}{R^2} + \frac{S'}{R^2} = 0 \qquad (1)$$

where

$$S' = [Ra] \cdot \quad \cdot E \cdot 10^6 \text{ (pCi/l.)} \qquad (2)$$

Equation (2) is the time independent source term while equation (1) is the form of the diffusion equation which is used in this program to calculate the flux, F, at ground surface.

The required input parameters for REP and the selected values as used for Homestake were:

Specific Weight,	1.5 kg./l.
Emanation Coefficient, E	0.2
Decay Constant,	2.1×10^{-6}/sec.

for both the cover soil and tailings. Table C9.3 lists all remaining parameters and the values as selected to address all possible soil parameter variations. D'Appolonia's program (REP) was used to compute the required soil cover to reduce radon emanation to 100 pCi/m^2-sec. This program has been accepted by NRC. Computations were based on an average ore grade of 0.15 percent and 0.20 percent, with 440 pCi/g and 590 pCi/g, respectively. Input parameters for the soil radium content, density, relaxation length and emanation coefficient are shown in Table C9.3. Three difference soil radium contents and relaxation lengths were used to provide a range of values.

According to the computer computation, there is no requirement to use any cover layer for 0.15 percent ore grade to reduce the emanation rate to 100 pCi/m^2-sec since the emanation rate for this case is 97 pCi/m^2-sec without the soil cover material (Table C9.3.a).

As shown in Table C9.3.a, approximately 0.4 to 0.84 feet of soil cover is required to reduce the emanation rate for a 0.20 percent ore grade to 100 pCi/m^2-sec. The lower value (0.4 feet) is based on a soil relaxation length of 40 cm and radium content of 1.0 pCi/g. The higher value (0.84 feet) is based on a relaxation length of 60 cm and soil radium content of 3.0 pCi/m^2-sec. A graphical presentation of the higher value is shown on Figure C9-9.

From the data presented in Table C9.3.a and Figure C9-9, the proposed 1.5 feet of soil cover material and 0.5 feet of rock cover provides conservatism and is more than adequate to meet NMEID requirements (NMEID, 1980 and 1981).

C9.6 MONITORING PROGRAM

In accordance with the recently amended Section 12-300.E of the Radiation Protection Regulations, HMC will inspect and maintain the stabilized tailings disposal area prior to any transfer of ownership of HMC's interest to the state or federal government or termination of the license. Prior to this time period, HMC will inspect the integrity of the rock and soil cover material at least annually. During this time,

maintenance required to restore the area to its original effectiveness will be performed as needed.

In addition, monitoring to determine environmental concentrations of radioactive material (as described in Section C8.0) will be performed. Upon the decommissioning of the mill and cessation of operations, only a limited number of monitoring programs, not connected with the mill operations, will be applicable.

Upon transfer or termination of the license, New Mexico's Continued Care Fund will assume costs for maintenance and monitoring and the government authority will be responsible for both.

C9.7 ESTIMATED COST FOR RESTORATION

The estimated cost to stabilize the tailings in their assumed shape at the assumed end of operations in the year 2,000 is derived from Table C9.4 for the following:

- Grading of tailings embankment area;
- Soil cover material handling; and
- Rock cover.
- Evaporation pond construction
- Reclamation

The figures are based upon 1984 dollars. The figures assume there is no purchase cost for acquiring the borrow material, and rock would be purchased and quarried locally. The figures further assume stabilization is conducted at a time when heavy machinery can be used safely for grading and placement.

C9.8 FINANCIAL SURETY ARRANGEMENTS

The Applicant has submitted, as of January 8, 1982, an Application for Approval of Surety Arrangement with necessary related instruments as required by NMEIB Radiation Protection REgulation 3-315. HMC has chosen the method of self-insurance and has submitted the necessary instruments in Section 3-315.E. Until the License Renewal application is acted

upon, an interim amount of $25,000 per acre based on the next five-year buildout and approximately 170 acres is used. Assuming that an independent contractor performs stabilization and using estimated costs summarized in Table C9.4, the stabilization costs for ultimate 2,000 year buildout embankment are estimated to be $11,001,000. This amount is the projected total cost, including the costs for the portion for which the U. S. government has assumed the obligation, which pursuant to 3-315.A are to be excluded from surety arrangements with the NMEID. Applicant intends to reduce the amount of surety equivalent to the costs for the portion for which the U. S. government has assumed the obligation.

Final stabilization costs per acre at HMC will be significantly less than the interim $25,000 per acre results because of the geometry of the tailings deposition. The ultimate embankment configuration after full buildout will be close to the final stabilization configuration. Therefore, a relatively small amount of regrading of tailings will be 13 required to develop the final grades and slopes.

Upon determination of stabilization efforts and costs in this license renewal application and upon renewal of its license, the Applicant will submit the appropriate surety arrangement to NMEID adjusted to the determined stabilization costs and reduced by amounts for which the U. S. government is obligated.

C10.0 ADMINISTRATION

The activities associated with HMC's Grants operation, described in previous sections, are conducted under the direction of the HMC administration described in this section. The organizational structure and key positions are discussed, and issues related to training, security, and safety are addressed.

C10.1 CORPORATE ORGANIZATION

HMC's Grants operation's organization chart is shown on Figure C10-1. All activities of the operation are performed under the direction of the General Manager. The General Manager reports directly to Homestake's Executive Vice-President of Operations, who is located at the company's headquarters in San Francisco, California. The Grants operation also has a Production Manager who reports directly to the General Manager and has the responsibility for managing all of the operation's production capabilities, including the Mining Division, Trucking Division and Milling Division. Each of the Division Managers reports directly to the Production Manager. The Production Manager is in charge of conducting the business affairs of the HMC operation in the absence of the General Manager.

In the Milling Division of the Grants operation, the following levels of management are responsible for development, approval and adherence to operating procedures, maintenance activities and changes in the mill circuit:

- Production Manager - Responsible for all phases of operation of the Mining, Milling and Trucking Divisions. He is responsible to the General Manager.

- Manager of Milling - Complete and full responsibility and authority for the operation of the mill and all related activities, including the development, approval and adherence to operating procedures, maintenance activities and changes in the mill circuit.

He is responsible directly to the Production Manager.

- Mill Superintendent - Complete and full responsibility for carrying on all of the mill operations, in the absence of the Manager of Milling, including responsibility and authority to require adherence to established operating procedures throughout the mill. He reports to the Manager of Milling.

- Production/Operations Foreman - Responsible to the Mill Superintendent for adherence to established operating procedures by the Shift Foremen under his supervision and who, in turn, are responsible for the individual workmen adhering to established operating procedures.

- Director of Environmental Affairs - Responsible directly to the General Manager. He has complete and full responsibility for maintaining the operation's environmental and occupational programs in compliance with all existing appropriate federal, state and company requirements.

- Radiation Protection Administrator - Responsible for carrying out all radiation safety surveys as well as for suggesting improvements in, or development of, safe operating procedures. Responsible directly to the Director of Environmental Affairs.

The relationship of the Director of Environmental Affairs and the Radiation Protection Administrator to the Manager of Milling and his staff is an advisory one.

A staff of sampling technicians support the Director of Environmental Affairs and the Radiation Protection Administrator.

Responsibility for the development of operating procedures is assigned by the Manager of Milling to staff or operating personnel. The Manager of Milling normally approves all operating procedures and changes to them. Under unusual circumstances, the General Manager approves these items.

C10.2 QUALIFICATIONS OF KEY POSITIONS

Resumes detailing qualifications, training, and previous experience of the personnel in the HMC mill organization who have the responsibility for developing, conducting, and administering the radiation safety program are included in Appendix G. Current resumes or job descriptions are included for the following positions:

- Production Manager
- Manager of Milling
- Mill Superintendent
- Production/Operations Foreman
- Director of Environmental Affairs
- Radiation Protection Administrator
- Environmental Technician

C10.3 TRAINING

The HMC milling operation has an established employee training program to assist the new and present employees in the safe and efficient performance of their work assignments. The program consists of an initial employee orientation that utilizes formal classroom instruction and a continual skills training process for each employee's specific job function.

New employees are given an initial indoctrination in subjects which relate to his or her new occupation, including instruction in the health protection aspects associated with exposure to radioactive materials or radiation, the different forms of radiation prevalent in the milling operation, and means by which the employee can keep his exposure as low as reasonably achievable (ALARA). Periodically (at least annually), all mill employees are given refresher training by qualified personnel knowledgeable in radiation protection.

C10.4 SECURITY

Unauthorized entry to the mill and tailings is prevented by a six-foot high cyclone fence with three strands of barbed wire on top, which borders the restricted area. A fence of at least four strands of barbed wire surrounds the remainder of the restricted area.

The restricted area is also conspicuously posted with signs bearing the words: "Private Property - No Trespassing - HMC". The area around the tailings pile is conspicuously posted with the signs bearing the radiation caution symbol and the words "Caution - Radioactive Material", and is also surrounded with a fence of at least four strands of barbed wire.

Entry of vehicular traffic into the restricted area is through a truck gate controlled by a uniformed security guard supplied by Burns International Security Services, Inc. Mill pedestrian traffic is accessed through the security guard house. A large three-foot by five-foot sign bearing the radiation caution symbol and the words "Caution - Any Area or Container Within This Mill May Contain Radioactive Material" is exhibited at the entrance.

Access to the restricted area can also be gained by entering the main office building through the front door and leaving by the rear doors. A receptionist is on duty at the front door during the day shift and the buildings are locked during the swing and graveyard shifts. The security guards inspect the main office building interior and any doors leading from the building during their routine patrol.

One security guard remains in the guard house at all times unless an emergency situation arises. Another security guard maintains nonroutine hours and patrols the restricted area and buildings within the plant area. The two guards can keep in contact with each other through the use of radios.

The tailings pile area is inspected several times each shift by the mill operating crew, the mill shift foreman, and the security guards.

C10.5 RADIATION SAFETY

Protection from radiation and radioactive material at the Grants uranium mill is a major concern of HMC. The radiation safety program outlined in Appendix F, Attachment 8 was prepared under the supervision of the

General Manager, Director of Environmental Affairs, and Radiation Protection Administrator. It is designed to prevent HMC employees and others from exposures to radioactive materials and levels of radiation in excess of the standards incorporated in the New Mexico Environmental Improvement Board's Radiation Protection Regulations (Parts 4-110 and 4-130) (NMEID, 1980). Exposures to radiation and radioactive material will be kept ALARA under HMC's radiation safety program. The procedures are designed to protect employees and visitors from exposure to radioactive airborne dust and surface contaminants in the Precipitation Building, Metallurgical Laboratory and the Ore Crushing Section of the processing plant. All persons working in or entering these areas are charged with the responsibility to observe the established procedures.

All new employees are issued a copy of HMC's mill safety handbook titled "Safety Rules and Regulations for Prevention of Accidents in Milling Operations." This booklet is included in Appendix H. Part VI of the handbook relates to radiation protection procedures and is titled "Rules for Radiation Protection." This section has been updated and revised and is included in Appendix F, Attachment 8.

Protection from radiation and radioactive materials is maintained at the Grants uranium mill by:

- Incorporation of radiation safety awareness into standard operating practices.
- Various radiation and occupational monitoring programs.
- Respiratory protection program.

The minimum requirements that must be followed by employees and visitors while in areas where ore or yellowcake may be present on surfaces or in the air are described in Appendix F, Attachment 8. Management may require more stringent protection practices in selected instances (i.e., for pregnant females).

C11.0 REFERENCES

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TABLE B1.1

POPULATION OF COMMUNITIES WITHIN THE 80-KILOMETER RADIUS STUDY AREA[1]

COMMUNITY	POPULATION[2]	COMMUNITY	POPULATION
Grants	11,439	Coolidge	25
Milan	3,747	Continental Divide	85
San Rafael	400	Iyanbito	1,069
Bluewater	300	Fort Wingate	1,600
Prewitt	160	Crownpoint	3,100
Ramah	500	Standing Rock	900
Thoreau	700	San Mateo	250
Rehoboth	117	Acoma Reservation	3,408
El Paso Gas Plant	219	Laguna Reservation	6,059

(1) Population totals for Grants and Milan are for 1980; all other totals are for 1978.

(2) Data for 1980 are from the University of New Mexico, 1981; data for 1978 are from Kerr-McGee, 1981.

TABLE B1.2

STUDY AREA POPULATION TRENDS[1]

AREA	POPULATION				PERCENT CHANGE		
	1950	1960	1970	1980	1950-1960	1960-1970	1970-1980
Milan	NA[2]	2,734	2,228	3,747	NA	-18.5	+68.2
Grants	2,251	10,274	8,768	11,439	+347.8	-14.6	+29.6
Valencia County	22,481	39,085	40,539	60,853	+73.9	+3.9	+50.7
McKinley County	27,603	37,209	43,208	54,950	+34.8	+16.1	+27.1
New Mexico (in thousands)	681	951	1,016	1,300	+39.6	+6.8	+30.0
United States (in thousands)	151,326	179,323	203,212	226,505	+18.5	+13.3	+11.5

(1) University of New Mexico, 1981.

(2) Not available.

TABLE B1.3

STUDY AREA POPULATION PROJECTIONS
1980 through 2000[1]

AREA	1980	1985	1990	1995	2000
Grants/Milan[2]	15,400	NA[3]	20,300	NA	25,100
Valencia County	55,200	64,100	73,100	81,700	90,300
McKinley County	61,500	72,700	83,900	94,300	104,000
New Mexico	1,270,700	1,408,700	1,546,000	1,673,200	1,790,600

(1) University of New Mexico, 1981.

(2) Projections for the Grants/Milan area include the cities and a three-mile urban fringe.

(3) Not available.

TABLE B1.4

EMPLOYMENT DATA
1980[1]

CATEGORY	NEW MEXICO	VALENCIA COUNTY AND McKINLEY COUNTY	PERCENT OF TWO-COUNTY-AREA CIVILIAN LABOR FORCE	TWO-COUNTY-AREA PERCENT OF STATE
Civilian Labor Force	542,000	45,101	100.0	8.3
Employment	502,000	41,274	91.5	8.2
Unemployment	40,000	3,827	8.5	9.6
Mining	29,500	7,886	17.5	26.7
Construction	30,200	1,917	4.3	6.3
Manufacturing	34,300	1,187	2.6	3.5
Transportation and Public Utilities	28,400	1,930	4.3	6.8
Wholesale and Retail Trade	103,100	6,592	14.6	6.4
Finance, Insurance, and Real Estate	21,000	855	1.9	4.1
Services and Miscellaneous	91,300	4,874	10.8	5.4
Government	124,500	8,036	17.8	6.5
Nonagricultural Wage and Salary Total	462,300	33,277	73.8	7.2

(1) University of New Mexico, 1981.

TABLE B1.5

PERSONAL INCOME BY INDUSTRY SOURCE
1976[1]
(Thousands of Dollars)

CATEGORY	McKINLEY COUNTY		VALENCIA COUNTY	
	Income ($)	Percent	Income ($)	Percent
Farm	263	0.1	5,742	5.0
Nonfarm Agricultural Services	135	0.1	245	0.2
Mining	66,870	31.2	33,010	28.7
Construction	13,239	6.2	7,311	6.4
Manufacturing	11,039	5.1	2,590	2.3
Transportation and Public Utilities	15,594	7.3	15,121	13.1
Wholesale and Retail Trade	35,179	16.4	16,574	14.4
Finance, Insurance, and Real Estate	3,475	1.6	4,034	3.5
Services	13,801	6.4	10,169	8.8
Government	54,867	25.6	20,193	17.6
TOTAL	214,462	100.0	114,989	100.0

(1) University of New Mexico, 1981.

TABLE B1.6

PER CAPITA PERSONAL INCOME FOR SELECTED YEARS[1]
(Dollars)

YEAR	VALENCIA COUNTY	NEW MEXICO	UNITED STATES
1959	1,377	1,914	2,161
1969	2,155	2,848	3,708
1979	6,078	7,483	8,773

(1) University of New Mexico, 1981.

Figure B2-1 Wind Rose of Wind Speeds and Directions

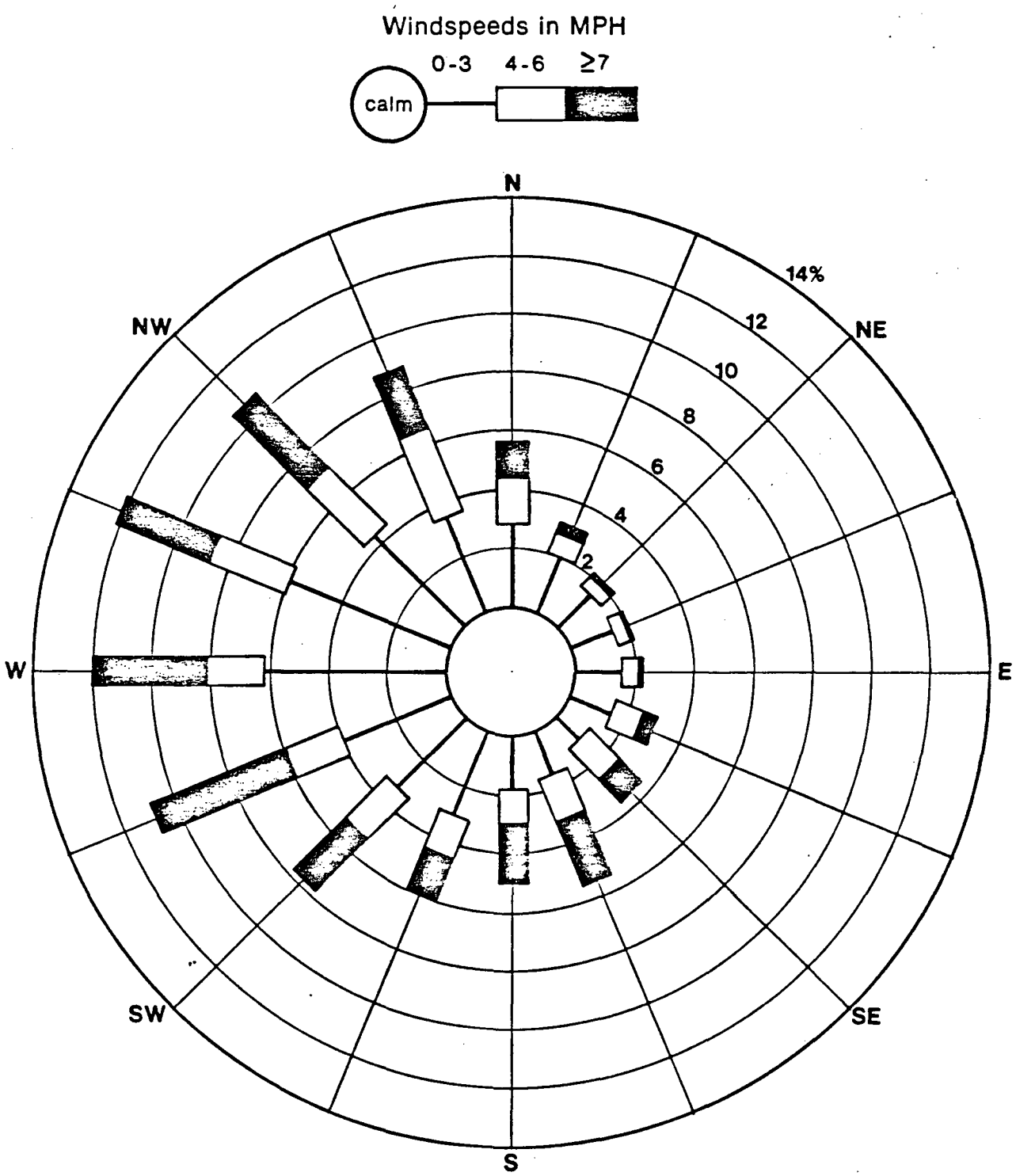

Table B2.1 Annual frequency distribution by stability class
(From NUREG/CR-1133 Appendix)

Table A2. Annual Frequency Distribution, Stability Class A

	Windspeed (mph)						
Direction	*0-3*	*4-6*	*7-11*	*12-16*	*17-25*	*> 25*	*Total*
N	24	9	1	0	0	0	34
NNE	11	5	1	0	0	0	17
NE	8	8	2	0	0	0	18
ENE	12	5	1	0	0	0	18
E	7	2	1	0	0	0	10
ESE	5	2	1	0	0	0	8
SE	0	0	0	0	0	0	0
SSE	0	0	0	0	0	0	0
S	1	0	0	0	0	0	1
SSW	3	1	0	0	0	0	4
SW	7	0	0	0	0	0	7
WSW	7	3	1	0	0	0	11
W	10	2	1	0	0	0	13
WNW	12	7	2	0	0	0	21
NW	20	7	0	0	0	0	27
NNW	19	7	0	0	0	0	26

Table A3. Annual Frequency Distribution, Stability Class B

	Windspeed (mph)						
Direction	*0-3*	*4-6*	*7-11*	*12-16*	*17-25*	*> 25*	*Total*
N	25	8	1	0	0	0	34
NNE	17	7	2	0	0	0	26
NE	17	3	0	0	0	0	20
ENE	16	3	0	0	0	0	19
E	14	4	1	0	0	0	19
ESE	7	2	1	0	0	0	10
SE	4	0	0	0	0	0	4
SSE	6	1	1	0	0	0	8
S	9	0	0	0	0	0	9
SSW	12	6	2	0	0	0	20
SW	14	2	1	0	0	0	17
WSW	14	5	1	1	0	0	21
W	29	7	2	0	0	0	38
WNW	26	8	3	0	0	0	37
NW	33	8	3	0	1	0	45
NNW	27	9	3	2	0	0	41

Table B2.1 continued

Table A4. Annual Frequency Distribution, Stability Class C

Direction	Windspeed (mph) 0-3	4-6	7-11	12-16	17-25	> 25	Total
N	44	32	8	1	0	0	85
NNE	39	10	5	0	0	0	54
NE	26	6	2	0	0	0	34
ENE	17	4	1	0	0	0	22
E	27	6	0	0	0	0	33
ESE	21	16	2	0	0	0	39
SE	10	17	2	0	0	0	29
SSE	20	12	1	1	0	0	34
S	20	11	10	4	1	0	46
SSW	32	15	4	0	0	0	51
SW	34	15	9	0	0	0	58
WSW	62	17	12	0	0	0	91
W	60	17	9	0	0	0	86
WNW	52	24	8	1	0	0	85
NW	49	26	8	1	0	0	84
NNW	35	21	5	0	1	0	62

Table A5. Annual Frequency Distribution, Stability Class D

Direction	Windspeed (mph) 0-3	4-6	7-11	12-16	17-25	> 25	Total
N	72	40	40	1	0	0	153
NNE	62	19	10	2	0	0	93
NE	40	8	5	0	0	0	53
ENE	49	16	3	1	0	0	69
E	46	22	1	0	0	1	70
ESE	67	33	22	0	0	0	122
SE	46	58	46	2	0	0	152
SSE	51	43	36	6	1	0	137
S	37	33	15	5	3	0	93
SSW	83	44	25	7	1	0	160
SW	91	38	44	20	8	0	201
WSW	99	53	64	40	8	0	264
W	164	47	68	24	2	0	305
WNW	151	54	63	22	1	0	291
NW	114	56	53	5	2	0	230
NNW	110	59	54	5	0	0	228

Table A6. Annual Frequency Distribution, Stability Class E

Direction	Windspeed (mph) 0-3	4-6	7-11	12-16	17-25	> 25	Total
N	47	30	28	4	1	0	110
NNE	21	11	10	2	0	0	44
NE	18	5	5	1	0	1	30
ENE	14	6	2	2	0	0	24
E	18	7	4	1	0	0	30
ESE	11	21	13	0	0	0	45
SE	17	33	27	1	0	0	78
SSE	35	59	89	17	7	1	208
S	57	28	52	16	8	6	167
SSW	79	33	32	9	15	4	172
SW	76	78	39	25	17	0	235
WSW	96	48	79	77	46	6	352
W	178	65	89	66	24	0	422
WNW	170	100	74	31	25	1	401
NW	98	101	77	46	20	0	342
NNW	69	114	67	6	4	0	260

Table A7. Annual Frequency Distribution, Stability Class F

Direction	Windspeed (mph) 0-3	4-6	7-11	12-16	17-25	> 25	Total
N	2	4	4	0	0	0	10
NNE	1	2	0	0	0	0	3
NE	1	1	0	1	0	0	3
ENE	0	1	0	0	0	0	1
E	0	0	1	0	0	0	1
ESE	0	1	0	0	0	0	1
SE	0	2	3	0	0	0	5
SSE	1	2	16	1	0	0	20
S	8	12	24	4	2	1	51
SSW	16	8	8	6	0	1	39
SW	16	12	17	5	2	1	53
WSW	7	9	21	8	4	7	56
W	21	5	4	3	1	1	35
WNW	33	10	14	9	6	0	72
NW	12	11	25	9	5	0	62
NNW	3	19	23	0	0	0	45

Table B2.1 continued

Table A8. Annual Frequency Distribution, Stability Class G

Direction	Windspeed (mph) 0-3	4-6	7-11	12-16	17-25	> 25	Total
N	0	1	0	0	0	0	1
NNE	0	0	0	0	0	0	0
NE	1	0	0	0	0	0	1
ENE	1	0	0	0	0	0	1
E	3	0	0	0	0	0	3
ESE	0	0	0	0	0	0	0
SE	0	0	0	0	0	0	0
SSE	0	0	0	1	0	0	1
S	0	1	5	0	0	0	6
SSW	0	1	1	1	2	0	5
SW	5	5	3	0	0	0	13
WSW	12	3	4	1	0	0	20
W	1	2	2	0	0	0	5
WNW	1	0	1	1	1	0	4
NW	1	1	3	0	0	0	5
NNW	0	1	0	0	0	0	1

Table A9. Annual Frequency Distribution, All Stability Classes

Direction	Windspeed (mph) 0-3	4-6	7-11	12-16	17-25	> 25	Total
N	214	124	82	6	1	0	427
NNE	151	54	28	4	0	0	237
NE	111	31	14	2	0	1	159
ENE	109	35	7	3	0	0	154
E	115	41	8	1	0	1	166
ESE	111	75	39	0	0	0	225
SE	77	110	78	3	0	0	268
SSE	113	117	143	26	8	1	408
S	132	85	106	29	14	7	373
SSW	225	108	72	23	18	5	451
SW	243	150	113	50	27	1	584
WSW	297	138	182	127	58	13	815
W	463	145	175	93	27	1	904
WNW	445	203	165	64	33	1	911
NW	327	210	169	61	28	0	795
NNW	263	230	152	13	5	0	663

TABLE B2.1

(CONTINUED)

WIND DIRECTION	UNSTABLE CONDITIONS (CLASS B STABILITY) WIND SPEED (miles per hour)						ANNUAL TOTAL
	0 - 3	4 - 7	8 - 12	13 - 18	19 - 24	≥ 25	
N	0.0016	0.0016	0.0000	0.0000	0.0000	0.0000	0.0032
NNE	0.0012	0.0012	0.0001	0.0000	0.0000	0.0000	0.0025
NE	0.0020	0.0018	0.0003	0.0000	0.0000	0.0000	0.0041
ENE	0.0019	0.0021	0.0001	0.0000	0.0000	0.0000	0.0041
E	0.0020	0.0020	0.0000	0.0000	0.0000	0.0000	0.0040
ESE	0.0025	0.0028	0.0001	0.0000	0.0000	0.0000	0.0054
SE	0.0030	0.0029	0.0005	0.0000	0.0000	0.0000	0.0064
SSE	0.0024	0.0026	0.0002	0.0000	0.0000	0.0000	0.0052
S	0.0025	0.0028	0.0004	0.0000	0.0000	0.0000	0.0057
SSW	0.0026	0.0029	0.0002	0.0000	0.0000	0.0000	0.0057
SW	0.0040	0.0047	0.0005	0.0000	0.0000	0.0000	0.0092
WSW	0.0025	0.0027	0.0001	0.0000	0.0000	0.0000	0.0053
W	0.0025	0.0026	0.0002	0.0000	0.0000	0.0000	0.0053
WNW	0.0026	0.0026	0.0000	0.0000	0.0000	0.0000	0.0052
NW	0.0021	0.0031	0.0001	0.0000	0.0000	0.0000	0.0053
NNW	0.0014	0.0015	0.0000	0.0000	0.0000	0.0000	0.0029
TOTAL	0.0368	0.0399	0.0028	0.0000	0.0000	0.0000	0.0795

TABLE B2.1

(CONTINUED)

WIND DIRECTION	SLIGHTLY UNSTABLE CONDITIONS (CLASS C STABILITY) WIND SPEED (miles per hour)						ANNUAL TOTAL
	0 - 3	4 - 7	8 - 12	13 - 18	19 - 24	≥ 25	
N	0.0020	0.0020	0.0010	0.0000	0.0000	0.0000	0.0050
NNE	0.0018	0.0017	0.0004	0.0000	0.0000	0.0000	0.0039
NE	0.0025	0.0028	0.0008	0.0002	0.0001	0.0000	0.0064
ENE	0.0026	0.0027	0.0008	0.0002	0.0001	0.0000	0.0064
E	0.0026	0.0027	0.0009	0.0001	0.0001	0.0000	0.0064
ESE	0.0035	0.0035	0.0007	0.0005	0.0003	0.0000	0.0085
SE	0.0043	0.0047	0.0006	0.0003	0.0001	0.0000	0.0100
SSE	0.0035	0.0035	0.0007	0.0005	0.0001	0.0000	0.0083
S	0.0041	0.0040	0.0005	0.0003	0.0000	0.0000	0.0089
SSW	0.0040	0.0041	0.0006	0.0002	0.0000	0.0000	0.0089
SW	0.0060	0.0063	0.0015	0.0004	0.0002	0.0000	0.0144
WSW	0.0040	0.0039	0.0008	0.0001	0.0000	0.0000	0.0088
W	0.0041	0.0039	0.0002	0.0001	0.0000	0.0000	0.0083
WNW	0.0040	0.0041	0.0002	0.0000	0.0000	0.0000	0.0083
NW	0.0041	0.0041	0.0001	0.0000	0.0000	0.0000	0.0083
NNW	0.0022	0.0023	0.0000	0.0000	0.0000	0.0000	0.0045
TOTAL	0.0553	0.0563	0.0098	0.0029	0.0010	0.0000	0.1253

TABLE B2.1

(CONTINUED)

WIND DIRECTION	NEUTRAL CONDITIONS (CLASS D STABILITY) WIND SPEED (miles per hour)						ANNUAL TOTAL
	0 - 3	4 - 7	8 - 12	13 - 18	19 - 24	≥ 25	
N	0.0050	0.0051	0.0030	0.0015	0.0006	0.0004	0.0156
NNE	0.0040	0.0040	0.0024	0.0010	0.0004	0.0003	0.0121
NE	0.0063	0.0060	0.0042	0.0020	0.0006	0.0006	0.0197
ENE	0.0064	0.0062	0.0042	0.0020	0.0004	0.0004	0.0196
E	0.0061	0.0063	0.0044	0.0021	0.0004	0.0005	0.0198
ESE	0.0085	0.0087	0.0058	0.0026	0.0004	0.0004	0.0264
SE	0.0100	0.0114	0.0066	0.0022	0.0004	0.0004	0.0310
SSE	0.0084	0.0081	0.0052	0.0025	0.0006	0.0005	0.0253
S	0.0089	0.0092	0.0055	0.0028	0.0006	0.0006	0.0276
SSW	0.0091	0.0090	0.0053	0.0029	0.0006	0.0006	0.0275
SW	0.0149	0.0150	0.0093	0.0045	0.0005	0.0004	0.0446
WSW	0.0094	0.0093	0.0054	0.0027	0.0003	0.0002	0.0273
W	0.0082	0.0084	0.0051	0.0026	0.0008	0.0005	0.0256
WNW	0.0083	0.0083	0.0050	0.0026	0.0007	0.0006	0.0255
NW	0.0080	0.0085	0.0051	0.0026	0.0007	0.0006	0.0255
NNW	0.0041	0.0042	0.0034	0.0014	0.0004	0.0004	0.0139
TOTAL	0.1256	0.1277	0.0799	0.0386	0.0084	0.0074	0.3870

TABLE B2.1

(CONTINUED)

WIND DIRECTION	SLIGHTLY STABLE CONDITIONS (CLASS E STABILITY) WIND SPEED (miles per hour)						ANNUAL TOTAL
	0 - 3	4 - 7	8 - 12	13 - 18	19 - 24	≥ 25	
N	0.0045	0.0047	0.0011	0.0000	0.0000	0.0000	0.0103
NNE	0.0037	0.0033	0.0010	0.0000	0.0000	0.0000	0.0080
NE	0.0062	0.0060	0.0010	0.0000	0.0000	0.0000	0.0132
ENE	0.0061	0.0060	0.0011	0.0000	0.0000	0.0000	0.0132
E	0.0060	0.0062	0.0009	0.0000	0.0000	0.0000	0.0131
ESE	0.0078	0.0075	0.0022	0.0000	0.0000	0.0000	0.0175
SE	0.0095	0.0097	0.0014	0.0000	0.0000	0.0000	0.0206
SSE	0.0079	0.0077	0.0012	0.0000	0.0000	0.0000	0.0168
S	0.0079	0.0087	0.0017	0.0000	0.0000	0.0000	0.0183
SSW	0.0082	0.0086	0.0015	0.0000	0.0000	0.0000	0.0183
SW	0.0151	0.0131	0.0015	0.0000	0.0000	0.0000	0.0297
WSW	0.0101	0.0072	0.0008	0.0000	0.0000	0.0000	0.0181
W	0.0085	0.0079	0.0006	0.0000	0.0000	0.0000	0.0170
WNW	0.0083	0.0080	0.0009	0.0000	0.0000	0.0000	0.0173
NW	0.0081	0.0082	0.0010	0.0000	0.0000	0.0000	0.0173
NNW	0.0045	0.0039	0.0009	0.0000	0.0000	0.0000	0.0093
TOTAL	0.1224	0.1168	0.0188	0.0000	0.0000	0.0000	0.2580

TABLE B2.1

(CONTINUED)

WIND DIRECTION	STABLE TO EXTREMELY STABLE CONDITIONS (CLASSES F AND G STABILITY) WIND SPEED (miles per hour)						ANNUAL TOTAL
	0 - 3	4 - 7	8 - 12	13 - 18	19 - 24	≥ 25	
N	0.0032	0.0020	0.0000	0.0000	0.0000	0.0000	0.0052
NNE	0.0027	0.0022	0.0000	0.0000	0.0000	0.0000	0.0049
NE	0.0035	0.0030	0.0000	0.0000	0.0000	0.0000	0.0065
ENE	0.0032	0.0032	0.0000	0.0000	0.0000	0.0000	0.0064
E	0.0032	0.0032	0.0000	0.0000	0.0000	0.0000	0.0064
ESE	0.0045	0.0042	0.0000	0.0000	0.0000	0.0000	0.0087
SE	0.0053	0.0050	0.0000	0.0000	0.0000	0.0000	0.0103
SSE	0.0043	0.0040	0.0000	0.0000	0.0000	0.0000	0.0083
S	0.0048	0.0044	0.0000	0.0000	0.0000	0.0000	0.0092
SSW	0.0052	0.0040	0.0000	0.0000	0.0000	0.0000	0.0092
SW	0.0077	0.0070	0.0000	0.0000	0.0000	0.0000	0.0147
WSW	0.0047	0.0042	0.0000	0.0000	0.0000	0.0000	0.0089
W	0.0045	0.0040	0.0000	0.0000	0.0000	0.0000	0.0085
WNW	0.0044	0.0041	0.0000	0.0000	0.0000	0.0000	0.0085
NW	0.0043	0.0042	0.0000	0.0000	0.0000	0.0000	0.0085
NNW	0.0026	0.0020	0.0000	0.0000	0.0000	0.0000	0.0046
TOTAL	0.0681	0.0607	0.0000	0.0000	0.0000	0.0000	0.1288

TABLE B2.1

(CONTINUED)

WIND DIRECTION	ALL STABILITY CONDITIONS WIND SPEED (miles per hour)						ANNUAL TOTAL
	0 - 3	4 - 7	8 - 12	13 - 18	19 - 24	≥ 25	
N	0.0169	0.0156	0.0051	0.0015	0.0006	0.0004	0.0401
NNE	0.0139	0.0126	0.0039	0.0010	0.0004	0.0003	0.0321
NE	0.0213	0.0199	0.0063	0.0022	0.0007	0.0006	0.0510
ENE	0.0210	0.0205	0.0062	0.0022	0.0005	0.0004	0.0508
E	0.0206	0.0208	0.0062	0.0022	0.0005	0.0005	0.0508
ESE	0.0278	0.0271	0.0088	0.0031	0.0007	0.0004	0.0679
SE	0.0332	0.0343	0.0091	0.0025	0.0005	0.0004	0.0800
SSE	0.0274	0.0264	0.0073	0.0030	0.0007	0.0005	0.0653
S	0.0291	0.0297	0.0081	0.0031	0.0006	0.0006	0.0712
SSW	0.0301	0.0291	0.0076	0.0031	0.0006	0.0006	0.0711
SW	0.0495	0.0467	0.0128	0.0049	0.0007	0.0004	0.1150
WSW	0.0315	0.0279	0.0071	0.0028	0.0003	0.0002	0.0698
W	0.0286	0.0274	0.0061	0.0027	0.0008	0.0005	0.0661
WNW	0.0285	0.0277	0.0061	0.0026	0.0007	0.0006	0.0662
NW	0.0274	0.0288	0.0063	0.0026	0.0007	0.0006	0.0664
NNW	0.0154	0.0141	0.0043	0.0014	0.0004	0.0004	0.0360
TOTAL	0.4222	0.4086	0.1113	0.0409	0.0094	0.0074	0.9998

(1) Anaconda, 1981. Joint Frequency Distribution derived from data collected in 1978 by Anaconda at their Bluewater Mill, approximately 5.5 miles northwest of the HMC mill site.

TABLE B2.2

MORNING AND AFTERNOON SEASONAL MIXING DEPTH HEIGHTS[1]
1960 TO 1964

SEASON	MEAN MIXING DEPTH HEIGHT (feet)	
	MORNING	AFTERNOON
Winter	1,283	4,803
Spring	1,814	11,326
Summer	1,910	12,930
Fall	1,358	7,530
ANNUAL	1,591	9,147

[1] Anaconda, 1981.

TABLE B2.3

MONTHLY AND ANNUAL EXTREME AND AVERAGE TEMPERATURE[1]
JANUARY 1978 to DECEMBER 1980

MONTH	TEMPERATURE (°F)				MONTHLY MEAN
	EXTREME		MONTHLY AVERAGE		
	MAXIMUM	MINIMUM	MAXIMUM	MINIMUM	
January	49	-22	32	12	22
February	55	-12	37	12	24
March	67	4	43	15	29
April	70	5	54	20	37
May	79	-6	60	25	42
June	92	22	77	41	58
July	95	31	81	44	63
August	85	25	71	41	56
September	80	20	69	36	52
October	81	-2	58	23	40
November	63	-5	39	13	26
December	60	-23	35	5	20
ANNUAL	95	-23	54	24	39

[1] HMC, 1978, 1979, and 1980.

TABLE B2.4

MONTHLY AND ANNUAL AVERAGE RELATIVE HUMIDITY[1]

MONTH	AVERAGE MONTHLY PERCENT RELATIVE HUMIDITY
January	75
February	65
March	52
April	50
May	33
June	42
July	50
August	55
September	55
October	50
November	55
December	70
ANNUAL	54

[1] NOAA, 1968.

TABLE B2.5

MONTHLY AND ANNUAL AVERAGE PRECIPITATION
JANUARY 1978 to DECEMBER 1980

MONTH	PRECIPITATION[1] (inches)	SNOW[2] (inches)	DAYS WITH 0.01 INCHES OR MORE PRECIPITATION[2]
January	0.89	NA[3]	6
February	0.69	NA	6
March	0.30	NA	6
April	0.55	NA	6
May	1.18	NA	5
June	0.50	NA	4
July	1.06	NA	10
August	1.73	NA	12
September	1.24	NA	6
October	0.63	NA	5
November	1.05	NA	4
December	0.55	NA	5
ANNUAL	10.37	24	75

[1] NWS, 1978, 1979, and 1980.
[2] NOAA, 1977.
[3] Not available.

TABLE B3.1

SUMMARY OF U.S. GEOLOGICAL SURVEY GAGING STATIONS
IN WEST CENTRAL NEW MEXICO[1]

GAGE NAME[2]	GAGE NUMBER	DRAINAGE AREA (sq. mi.)	PERIOD OF RECORD	STREAM FLOWS (cfs)		
				MINIMUM	MEAN	MAXIMUM
Rio Puerco above Arroyo Chico near Guadalupe	08334000	420	7/51 to Present	0.0[3]	13.4	6,940
Arroyo Chico near Guadalupe	08340500	1,390	11/43 to Present	0.0[3]	21.3	15,200
San Mateo Drainage near San Mateo	08342600	75.6	5/77 to Present	0.0[3]	Not Available	628
Rio San Jose at Grants	08343000	1,020	5/49 to Present	0.0[3]	3.30	1,760
Grants Canyon at Grants	08343100	13.0	12/61 to Present	0.0[3]	0.150	1,550
Rio San Jose near Grants	08343500	2,300[4]	6/36 to Present	1.9	6.69	1,400
Rio San Jose at Correo	08351500	3,600[4]	4/43 to Present	0.0[3]	11.3	7,150
Rio Puerco near Bernardo	08353000	7,350[4]	11/39 to Present	0.0[3]	46.7	18,800

(1) U.S. Geological Survey, 1980.

(2) See Figure B3-1 for gage locations.

(3) No flow for many days each year.

(4) A 1,130 square mile area does not contribute directly to surface runoff.

TABLE B3.2

PEAK DISCHARGES PRODUCED
100-YEAR STORM OF VARIOUS DURATIONS

DURATION OF STORM (hours)	AMOUNT OF PRECIPITATION[1] (inches)	PEAK DISCHARGE (cfs)
1	1.10	629
6	1.76	5,981
24	2.56	5,749

[1] Precipitation amounts were determined through use of the NOAA Precipitation Frequency Atlas for New Mexico - NOAA, 1973.

TABLE B3.3

RADIONUCLIDE CONCENTRATIONS OF THE IX PLANT DISCHARGE WATER[1]

PARAMETER	CONCENTRATION[2]	
	7/8/81	9/17/81
Natural Uranium	NA	7.0×10^{-7}
Radium-226	5.5×10^{-9}	1.3×10^{-9}
Thorium-230	NA[3]	4.5×10^{-12}
Lead-210	1.0×10^{-9} $\pm 1.0 \times 10^{-9}$	NA

[1] See Figure A2-1 for location of IX plant.

[2] All radionuclide concentrations in mCi/ml.

[3] Not available.

TABLE B3.4

RADIONUCLIDE STANDARDS IN NEW MEXICO WATERS[1]

PARAMETERS	MAXIMUM PERMISSIBLE CONCENTRATION IN WATER IN UNRESTRICTED AREAS (Dissolved)
Natural Uranium	3×10^{-5} mCi/ml
Radium-226	3×10^{-8} mCi/ml
Thorium-230	2×10^{-6} mCi/ml
Lead-210	1×10^{-7} mCi/ml

[1] NMEID, 1980.

TABLE B3.5

RADIOLOGICAL WATER QUALITY DATA[1]

WELL[2]	DATE	LEAD-210 (mCi/ml)[3]	RADIUM-226 (mCi/ml)	THORIUM-230 (mCi/ml)	NATURAL URANIUM (mCi/ml)[4]
R	7/7/81	0	1.1×10^{-9}	4.5×10^{-12}	$<6.8 \times 10^{-9}$
	9/15/81	-[5]	0.8×10^{-9}	4.5×10^{-12}	$<6.8 \times 10^{-9}$
Q	7/7/81	0	1.6×10^{-9}	1.4×10^{-11}	$<6.8 \times 10^{-9}$
	9/15/81	-	0.8×10^{-9}	9.0×10^{-12}	$<6.8 \times 10^{-9}$
P	7/7/81	0	1.9×10^{-9}	4.5×10^{-12}	6.8×10^{-9}
	9/15/81	-	0.8×10^{-9}	4.5×10^{-12}	$<6.8 \times 10^{-9}$
I	7/8/81	0	2.9×10^{-9}	1.35×10^{-11}	$<6.8 \times 10^{-9}$
F	7/8/81	0	2.1×10^{-9}	9.0×10^{-12}	$<6.8 \times 10^{-9}$
	9/22/81	-	1.3×10^{-9}	-	$<6.8 \times 10^{-9}$
BC	7/8/81	0	1.3×10^{-9}	1.35×10^{-11}	9.1×10^{-7}
	9/17/81	-	1.3×10^{-9}	-	1.93×10^{-6}
B	7/8/81	0	1.3×10^{-9}	4.5×10^{-12}	$<6.8 \times 10^{-9}$
	9/17/81	-	3.0×10^{-9}	-	0.1×10^{-6}

(1) HMC's monitoring program began in July 1981, with sampling conducted quarterly.

(2) See Figure B3-8 for well locations.

(3) Analytical precision is $\pm 1 \times 10^{-10}$ mCi/ml

(4) Detection limit is 6.8×10^{-9} mCi/ml

(5) No analysis done.

TABLE B3.6

HMC GROUNDWATER MONITORING PROGRAM
GROUNDWATER DISCHARGE PLAN[1]

WELL NO.	PARAMETERS TO BE MONITORED	FREQUENCY OF MONITORING
MILL MONITORING WELLS		
P, Q, R, DD, BB2, BC, W2, B, FB, F, I	W.L.[2], pH, TDS, SO_4, Cl, U, Se, Mo, NO_3	Quarterly
	W.L., pH, TDS, SO_4, Cl, HCO_3, CO_3, Na, Ca, Mg, K, NO_3, U, Se, Mo, Ra-226	Annually
SECONDARY MILL MONITORING WELLS		
A1, B1, C, D, DC, DM, DP, DZ, E, J, K2, KM, KZ, M1, M4, M, O, PM, S, SM, SO, T, W, WR11, WR9, WR7, WR5, X, Y, Z	W.L., pH, TDS, SO_4, Cl, U, Se, Mo, NO_3,	Semi-Annually
	W.L., pH, TDS, SO_4, Cl HCO_3, CO_3, Na, Ca, Mg, K, NO_3, U, Se, Mo, Ra-226	Annually
COLLECTION WELLS		
All Active Collection Wells	W.L., SO_4, U	Monthly
	W.L., pH, SO_4, Cl, HCO_3, CO_3, Na, Ca, Mg, K, NO_3, U, Se, Mo, Ra-226	Semi-Annually
	Discharge and Discharge Totalizer	Weekly
DM, DN, D, DP, DQ, DZ, M1, SO, SP, S, BC	W.L.	Weekly
Deep Well No. 2	Groundwater Reg. List plus HCO_3, CO_3, Na, Ca, Mg, K	Semi-Annually

See footnotes at end of table.

TABLE B3.6
(continued)

WELL NO.	PARAMETERS TO BE MONITORED	FREQUENCY OF MONITORING
BROADVIEW ACRES		
Sub-2, Sub-3, Sub-5, Sub-6, Sub-7, Sub-8, 410, 411, 412	pH, TDS, SO_4, Cl, U, Se, Mo, (W.L. in Wells EH, H, Sub-2 and Sub-3)	Quarterly
Sub-2, Sub-3, Sub-4, Sub-5 Sub-6, Sub-7, Sub-8, 410, 411, 412, 423, GH, H	pH, TDS, SO_4, Cl, HCO_3, CO_3, Na, Ca, Mg, K, NO_3, U, Se, Mo, Ra-226	Annually
FELICE ACRES		
490, 492, 484, 487, 953	pH, TDS, SO_4, Cl, U, Se, Mo, NO_3	Quarterly
490, 492, 484, 487, 953	pH, TDS, SO_4, Cl, HCO_3, CO_3, Na, Ca, Mg, K, NO_3, U, Se, Mo, Ra-226	Annually
MURRAY ACRES		
WR1, AW, HW, 802, 811, 815, WCW, HCW, ACW, 820	pH, TDS, SO_4, Cl, U, Se, Mo, NO_3, (W.L. in Wells WR1, AW, HW, 802, 815)	Quarterly
WR1, AW, HW, 802, 804, 811, 815, WCW, HCW, ACW, 820	pH, TDS, SO_4, Cl, HCO_3, CO_3, Na, Ca, Mg, K, NO_3, U, Se, Mo, Ra-226	Annually
PLEASANT VALLEY		
832, 835, 840, 843	pH, TDS, SO_4, Cl, U, Se, Mo, NO_3	Quarterly
832, 835, 840, 843	pH, TDS, SO_4, Cl, HCO_3, CO_3, Na, Ca, Mg, K, NO_3, U, Se, Mo, Ra-226	Annually
REGIONAL		
920, 942, 905, 910	pH, TDS, SO_4, Cl, HCO_3, CO_3, Na, Ca, Mg, K, NO_3, U, Se, Mo, Ra-226	Annually

(1) Hydro-Engineering, 1981.
(2) Water Level.

TABLE B3.7

NEW MEXICO GROUNDWATER QUALITY STANDARDS

A. Human Health Standards - Groundwater shall meet the standards of Section A and B unless otherwise provided.

Arsenic (As)	0.1 mg/l
Barium (Ba)	1.0 mg/l
Cadmium (Cd)	0.01 mg/l
Chromium (Cr)	0.05 mg/l
Cyanide (CN)	0.2 mg/l
Fluoride (F)	1.6 mg/l
Lead (Pb)	0.05 mg/l
Total Mercury (Hg)	0.002 mg/l
Nitrate (NO_3 as N)	10.0 mg/l
Selenium (Se)	0.05 mg/l
Silver (Ag)	0.05 mg/l
Uranium (U)	5.0 mg/l
Radioactivity: Combined Radium-226 and Radium-228	30.0 pCi/l

B. Other Standards for Domestic Water Supply

Chloride (Cl)	250. mg/l
Copper (Cu)	1.0 mg/l
Iron (Fe)	1.0 mg/l
Manganese (Mn)	0.2 mg/l
Phenols	0.005 mg/l
Sulfate (SO_4)	600. mg/l
Total Dissolved Solids (TDS)	1000. mg/l
Zinc (Zn)	10.0 mg/l
pH	between 6 and 9

C. Standards for Irrigation Use - Groundwater shall meet the standards of Subsections A, B and C unless otherwise provided.

Aluminum (Al)	5.0 mg/l
Boron (B)	0.75 mg/l
Cobalt (Co)	0.05 mg/l
Molybdenum (Mo)	1.0 mg/l
Nickel (Ni)	0.2 mg/l

Reference: New Mexico Water Quality Control Commission Regulations, Section 3-103, Amended January 21, 1981.

TABLE B3.8

WATER QUALITY OF THE SAN ANDRES LIMESTONE INJECTION WATER (DEEP WELL No. 2)

CONSTITUENTS	MAXIMUM INJECTION CONCENTRATION
SO_4	680 mg/l
Na	250 mg/l
HCO_3	553 mg/l
NO_3 as N	2.1 mg/l
U	0.19 mg/l 0.12 mg/l[1]
Se	0.05 mg/l[1]
Mo	0.13 mg/l 0.11 mg/l[1]
Ra-226	2.9 pCi/l

[1] Second highest.

TABLE C1.1

EMISSIONS GENERATED BY THE HMC MILL

EMISSION SOURCE	EMISSION	ANNUAL RATE
Ore storage pad, crushing, grinding, transfer and drying	Ore Dust	53.24 tons(1)
Yellowcake drying and packaging	U_3O_8	1,320 pounds(1)
Tailings pile	Tailings Liquids	80,416,800 gallons(2)
Tailings pile	Tailings Dust	5,194 tons to 5,554 tons(3)
Natural gas fueled dryers and roasters	SO_2	0.28 tons(4)
Natural gas fueled dryers and roasters	NO_2	80.63 tons(5)
Washrooms, showers, etc.	Domestic Sewage	6,757,975 gallons(6)

(1) Based on calculations provided by Impact Environmental Consultants, Ltd., 1981.

(2) Hydro-Engineering, 1981.

(3) The volumes of dust emissions vary as the amount of fluids in the embankment ponds varies. These are conservative estimates because they do not account for wind erosion reductions due to the applications of Wedco V-4100 binder (see Section C9.2.1).

(4) Based on an emission factor of 0.6 $lb/10^6$ ft^3 (U.S. EPA, 1977b).

(5) Based on an emission factor of 175 $lb/10^6$ ft^3 (U.S. EPA, 1977b).

(6) Based on a domestic sewage generation rate of 35 gallons/person/day (NMEID, 1979).

TABLE C1.2

RADIOLOGICAL EMISSION RATES FROM THE HMC MILL[1,2]

SOURCE	URANIUM-238 (Ci/yr)	THORIUM-230 (Ci/yr)	RADIUM-226 (Ci/yr)	LEAD-210 (Ci/yr)	RADON-222 (Ci/yr)	EXIT VELOCITY (m/sec)
Yellowcake dryer	4.47×10^{-2}	1.47×10^{-3}	4.25×10^{-4}	4.47×10^{-5}	0	2.65
Roaster packaging	3.98×10^{-2}	1.31×10^{-3}	3.78×10^{-4}	3.98×10^{-5}	0	5.45
Ore handling storage	1.95×10^{-2}	1.95×10^{-2}	1.95×10^{-2}	1.95×10^{-2}	166	0
Grizzly	1.47×10^{-2}	1.47×10^{-2}	1.47×10^{-2}	1.47×10^{-2}	0	0
Ore conveyor crushing	1.35×10^{-2}	1.35×10^{-2}	1.35×10^{-2}	1.35×10^{-2}	88	0
Ore dryer	4.4×10^{-4}	4.4×10^{-4}	4.4×10^{-4}	4.4×10^{-4}	0	2.0

(1) Values were calculated by Impact Environmental Consultants, Ltd., 1981.

(2) Based on the maximum ore processing rate of 3,400 tons per day.

TABLE C2.1

EMBANKMENT CONFIGURATION
DURING BUILDOUT

TIME (Year)	EAST POND CREST ELEVATION (feet)	EAST POND BENCH WIDTH (feet)	WEST POND CREST ELEVATION (feet)	WEST POND BENCH WIDTH[1] (feet)
One	6,679	75	6,671	50
Two	6,686	55	6,677	40
Three	6,692	45	6,681	30
Four	6,694	35	6,685	25
Five	6,696	25	6,689	20

(1) Downstream toe of new crest to downstream edge of old crest.

TABLE C2.2

LABORATORY STRENGTH PARAMETERS FOR TAILINGS AND NATIVE SOILS

SOIL TYPE	SATURATED				
	TYPE OF TEST	MOIST UNIT WEIGHT (pcf)	UNIT WEIGHT (pcf)	FRICTION ANGLE	COHESION (psf)
Native Soil	CU(1)	110.0	125.0	29.0	0.0
Tailings Silty Sand	CU(1)	105.0	122.0	29.0	0.0
Very Silty Sand	CU(1)	114.0	118.0	29.0	180.0
	UU(2)	114.0	118.0	0.0	1,800.0

(1) Consolidated-undrained triaxial test.

(2) Unconsolidated-undrained triaxial test.

TABLE C2.3

FACTOR OF SAFETY
FOR EARTHQUAKE-INDUCED LIQUEFACTION
DURING INITIATION OF SETBACK CREST

LOCATION	SAFETY FACTOR
Front Slope Toe	0.9
Mid-Front Slope	1.9
Old Crest	2.3
Buildout Crest	2.2
Pond to Beach Contact	1.3

Table C4.1 Sources of Radioactive effluents from the Homestake Mining Company uranium mill

Yellowcake Roaster

Yellowcake Packaging, Sampling and Trash Incineration

Yellowcake Dryer

Yellowcake Roaster Discharge to Leach Tank

Ore Crushing Circuit

Ore Dryer Exhaust

Ore Handling and Storage

Grizzly

Table C4.1.A Average tons of ore processed per day by time period (time step)

Time Step	Years	Time (yrs)	Ore processed (tons/day)
1	1956.8 - 1958	2.2	570
2	1959 - 1963	5	2610
3	1964 - 1970	7	3270
4	1971 - 1977	7	1870
5	1978 - 1980	3	2935
6	1981 - 1983	3	875
7	1984 - 1986	3	550*
8	1987 - 2000	14	2000
9	Reclamation	2	0
10	Post-reclamation	3	0

*for a 190 day per year operating schedule

TABLE C4.2

HOMESTAKE MINING COMPANY
SOURCE LOCATION TABLE

SOURCE DESCRIPTION	LOCATION(1)			
	x(km)	y(km)	z(m)	Area (km^2)
Yellowcake dryer stack and roaster discharge(2)	0.00	0.00	13.90	0.000
Yellowcake packaging and yellowcake roaster(2)	0.00	0.00	13.90	0.000
Ore handling and storage(3)	0.01	0.02	0.00	0.028
Grizzly	0.01	0.01	0.00	0.000
Ore conveyor and crushing	0.10	0.00	3.10	0.000
Ore dryer	0.01	0.00	19.80	0.00

(1) A positive x value indicates east and a negative x value indicates west of the yellowcake dryer stack origin.

A positive y value indicates north and a negative y value indicates south of the yellowcake dryer stack origin.

A positive z value indicates meters above and a negative z value indicates meters below the base of the yellowcake dryer stack.

(2) Combined as one source.

(3) Ore dumping onto and storage on ore pads.

Table C4.3 Annual emission rates for yellowcake sources for the reference time period (1987 - 2000)

	Dryer and Roaster Discharge	Roaster and Packaging
U-238	2.08×10^{-1} Ci/y	1.58×10^{-1} Ci/y
Th-230	6.86×10^{-3} Ci/y	5.21×10^{-3} Ci/y
Ra-226	1.98×10^{-3} Ci/y	1.50×10^{-3} Ci/y
Pb-210	2.08×10^{-4} Ci/y	1.58×10^{-4} Ci/y

Table C4.4 Particulate source terms for effluent sources other than yellowcake stacks (All radionuclides except Rn-222 are in equilibrium

	Particulate source terms (Ci/y)		
	1987 - 2000	1981 - 1983	1984 - 1986
Ore handling and storage	1.30×10^{-2}	8.41×10^{-3}	6.12×10^{-3}
Grizzly	8.12×10^{-3}	3.55×10^{-3}	1.27×10^{-3}
Ore conveying and crushing	7.69×10^{-3}	3.36×10^{-3}	1.20×10^{-3}
Ore dryer	4.40×10^{-4}	2.64×10^{-4}	2.64×10^{-4}

TABLE C4.5

SUMMARY OF FOOD CHAIN PARAMETERS USED IN MILDOS[1]

PARAMETER DESCRIPTION	VARIABLE NAME IN MILDOS	ASSIGNED VALUE
Individual Animal Annual Feed Requirement Satisfied by Pasture Grass	FFORI	1.0
Animal Population Annual Feed Requirement Satisfied by Pasture Grass	FFORP	0.50
Individual Animal Annual Feed Requirement Satisfied by Hay	FHAYI	0.0
Animal Population Annual Feed Requirement Satisfied by Hay	FHAYP	0.50
Food Production Rate - Vegetables	FPR (1)	280.0 $kg/yr/km^2$
Food Production Rate - Meat	FPR (2)	1115.0 $kg/yr/km^2$
Food Production Rate - Milk	FPR (3)	460.0 $kg/yr/km^2$

(1) Strenge and Bander, 1981.

TABLE C4.6

HOMESTAKE MINING COMPANY
RATIO OF THE U.S. POPULATION AT TIME STEPS TO 1978 POPULATION[1]

TIME STEP	POPULATION RATIO
1956 - 1958	0.80
1959 - 1963	0.87
1964 - 1970	0.94
1971 - 1977	0.99
1978 - 1980	1.02
1981 - 1985	1.04
1986 - 2000	1.19
Stabilization Period	1.20
Poststabilization	1.22

[1] Strenge and Bander, 1981.

Table C4.7 MILDOS Receptor locations

	Name of Receptor	Location X (km)	Y (km)	Z (m)	Distance (km)
1.	Nearest NE Resident*	1.88	2.87	13.11	3.43
2.	Broadview Acres*	-0.58	-1.38	-2.44	1.50
3.	Vista Montano	0.03	-1.59	-5.18	1.59
4.	Murray Acres*	-1.50	-1.01	-5.18	1.81
5.	NW Property Line	-1.88	1.09	0.00	2.17
6.	HMC Monitor 1	-0.78	1.33	1.83	1.54
7.	HMC Monitor 2	0.48	0.93	4.57	1.05
8.	HMC Monitor 3	0.59	0.19	9.14	0.62
9.	HMC Monitor 4	-1.40	-1.38	-6.10	1.97
10.	HMC Monitor 5	-1.40	-0.71	-5.18	1.57
11.	Nearest Town - Milan,NM*	-3.31	-7.66	-18.90	8.34
12.	Grants, NM*	1.03	-10.09	-48.77	10.14
13.	Nearest SE Resident*	5.80	-6.17	18.00	8.47
14.	ESE Property Line	0.62	-0.26	9.14	0.67

*Occupied receptor locations

TABLE C4.7.a.
Time Step 5 (1978 - 1980)

ANNUAL POPULATION DOSE COMMITMENTS (PERSON-REM/YR)
TOTAL DOSES COMPUTED FOR POPULATIONS WITHIN 80 KM OF SITE

EXPOSURE PATHWAY	EXPOSED ORGAN					
	WHOLE BODY	BONE	AVERAGE LUNG	LIVER	KIDNEY	BRONCHIAL TUBES
Inhalation	8.88×10^{-2}	2.28	6.07	1.16×10^{-1}	6.45×10^{-1}	6.84
Ground	2.42×10^{-1}	2.42×10^{-1}	2.42×10^{-1}	2.42×10^{-1}	2.42×10^{-1}	2.43×10^{-1}
Cloud	9.90×10^{-2}	9.90×10^{-2}	9.90×10^{-2}	9.90×10^{-2}	9.90×10^{-2}	9.90×10^{-2}
Veg. Ingestion	9.77×10^{-2}	1.25	9.77×10^{-2}	1.25×10^{-1}	4.10×10^{-1}	9.77×10^{-2}
Meat Ingestion	9.79×10^{-3}	1.29×10^{-1}	9.79×10^{-3}	1.66×10^{-2}	5.14×10^{-2}	9.79×10^{-3}
Milk Ingestion	1.92×10^{-2}	2.08×10^{-1}	1.92×10^{-2}	6.04×10^{-3}	2.56×10^{-2}	1.92×10^{-2}
Totals	5.57×10^{-1}	4.21	6.54	6.04×10^{-1}	1.47	7.31

Table C4.8 Estimated doses (excluding radon) to individuals at occupied receptor locations

(1981 - 1983)

	Annual dose (mrem/y)					
	Whole Body	Bone	Ave. Lung	Liver	Kidney	Bronchi
Nearest NE Resident						
Infant	0.163	1.89	4.78	0.094	0.464	0.109
Child	0.194	2.36	4.81	0.122	0.559	0.140
Teenager	0.160	1.92	4.78	0.110	0.498	0.105
Adult	0.154	1.85	4.77	0.111	0.476	0.099
Broadview Acres						
Infant	0.400	4.63	11.4	0.232	1.13	0.269
Child	0.483	5.83	11.5	0.309	1.39	0.351
Teenager	0.395	4.75	11.4	0.277	1.23	0.263
Adult	0.381	4.59	11.4	0.280	1.18	0.250
Murray Acres						
Infant	0.200	2.33	5.80	0.117	0.571	0.133
Child	0.239	2.90	5.84	0.152	0.691	0.172
Teenager	0.196	2.37	5.79	0.138	0.616	0.129
Adult	0.189	2.29	5.79	0.139	0.589	0.122
Nearest Town - Milan, NM						
Infant	0.017	0.195	0.480	0.010	0.048	0.011
Child	0.020	0.244	0.484	0.013	0.058	0.015
Teenager	0.016	0.199	0.480	0.012	0.052	0.011
Adult	0.016	0.193	0.479	0.012	0.050	0.010
Grants, NM						
Infant	0.029	0.341	0.796	0.017	0.082	0.020
Child	0.036	0.438	0.803	0.024	0.105	0.027
Teenager	0.029	0.357	0.796	0.021	0.092	0.020
Adult	0.028	0.347	0.795	0.022	0.088	0.019
Nearest SE Resident (downwind)						
Infant	0.036	0.421	1.03	0.021	0.103	0.024
Child	0.043	0.528	1.04	0.028	0.126	0.031
Teenager	0.035	0.432	1.03	0.025	0.112	0.023
Adult	0.034	0.418	1.03	0.025	0.107	0.022

Table C4.9 Estimated doses (excluding radon) to individuals at occupied receptor locations

(1984 - 1986)

	Annual dose (mrem/y)					
	Whole Body	Bone	Ave. Lung	Liver	Kidney	Bronchi
Nearest NE Resident						
Infant	0.110	1.01	2.41	0.073	0.263	0.083
Child	0.131	1.30	2.43	0.092	0.325	0.104
Teenager	0.111	1.06	2.41	0.084	0.289	0.084
Adult	0.108	1.03	2.41	0.085	0.277	0.081
Broadview Acres						
Infant	0.268	2.45	5.63	0.180	0.633	0.204
Child	0.325	3.22	5.69	0.231	0.804	0.260
Teenager	0.273	2.61	5.64	0.210	0.710	0.209
Adult	0.266	2.54	5.63	0.211	0.681	0.202
Murray Acres						
Infant	0.133	1.21	2.86	0.090	0.317	0.101
Child	0.159	1.58	2.88	0.113	0.395	0.127
Teenager	0.135	1.28	2.86	0.103	0.351	0.102
Adult	0.131	1.25	2.86	0.104	0.336	0.099
Nearest Town - Milan, NM						
Infant	0.011	0.102	0.238	0.007	0.027	0.008
Child	0.013	0.134	0.240	0.009	0.033	0.010
Teenager	0.011	0.109	0.238	0.009	0.030	0.009
Adult	0.011	0.106	0.238	0.009	0.028	0.008
Grants, NM						
Infant	0.020	0.181	0.394	0.013	0.046	0.015
Child	0.024	0.244	0.399	0.018	0.061	0.020
Teenager	0.020	0.197	0.395	0.016	0.053	0.016
Adult	0.020	0.193	0.394	0.016	0.051	0.015
Nearest SE Resident (downwind)						
Infant	0.024	0.224	0.520	0.016	0.058	0.018
Child	0.029	0.291	0.525	0.021	0.073	0.023
Teenager	0.024	0.237	0.520	0.019	0.064	0.018
Adult	0.024	0.231	0.520	0.019	0.062	0.018

Table C4.10 Estimated doses (excluding radon) to individuals at occupied receptor locations

(1987 - 2000)

	Annual dose (mrem/y)					
	Whole Body	Bone	Ave. Lung	Liver	Kidney	Bronchi
Nearest NE Resident						
Infant	0.314	4.04	10.6	0.162	0.971	0.193
Child	0.369	4.92	10.7	0.213	1.14	0.248
Teenager	0.299	4.02	10.6	0.192	1.02	0.178
Adult	0.287	3.86	10.6	0.194	0.972	0.166
Broadview Acres						
Infant	0.771	9.94	25.6	0.403	2.38	0.477
Child	0.918	12.2	25.7	0.540	2.83	0.624
Teenager	0.742	9.97	25.6	0.484	2.53	0.448
Adult	0.711	9.60	25.5	0.490	2.41	0.417
Murray Acres						
Infant	0.388	5.03	13.1	0.204	1.21	0.238
Child	0.459	6.14	13.1	0.269	1.43	0.309
Teenager	0.372	5.02	13.0	0.242	1.28	0.222
Adult	0.356	4.83	13.0	0.245	1.22	0.206
Nearest Town - Milan, NM						
Infant	0.032	0.419	1.08	0.017	0.101	0.020
Child	0.038	0.512	1.08	0.023	0.119	0.026
Teenager	0.031	0.420	1.08	0.020	0.107	0.019
Adult	0.030	0.404	1.07	0.021	0.102	0.017
Grants, NM						
Infant	0.056	0.726	1.78	0.030	0.172	0.035
Child	0.069	0.907	1.79	0.042	0.212	0.048
Teenager	0.055	0.742	1.78	0.037	0.188	0.034
Adult	0.053	0.717	1.78	0.038	0.180	0.032
Nearest SE Resident (downwind)						
Infant	0.069	0.897	2.29	0.037	0.216	0.042
Child	0.082	1.10	2.30	0.049	0.256	0.055
Teenager	0.066	0.901	2.29	0.044	0.229	0.040
Adult	0.064	0.868	2.28	0.045	0.219	0.037

Table C4.11 Estimated doses (excluding radon) to individuals at occupied receptor locations

(Reclamation period - 2 years)

	Annual dose (mrem/y)					
	Whole Body	Bone	Ave. Lung	Liver	Kidney	Bronchi
Nearest NE Resident						
Infant	0.080	0.170	0.137	0.075	0.089	0.079
Child	0.093	0.321	0.150	0.084	0.121	0.092
Teenager	0.086	0.251	0.143	0.080	0.108	0.085
Adult	0.086	0.256	0.143	0.080	0.106	0.085
Broadview Acres						
Infant	0.195	0.429	0.332	0.182	0.218	0.193
Child	0.228	0.823	0.366	0.205	0.303	0.226
Teenager	0.210	0.643	0.348	0.194	0.269	0.209
Adult	0.211	0.658	0.349	0.195	0.262	0.209
Murray Acres						
Infant	0.098	0.211	0.168	0.092	0.110	0.097
Child	0.114	0.401	0.184	0.103	0.150	0.113
Teenager	0.105	0.313	0.176	0.098	0.133	0.105
Adult	0.106	0.320	0.176	0.098	0.130	0.105
Nearest Town - Milan, NM						
Infant	0.008	0.018	0.014	0.008	0.009	0.008
Child	0.009	0.034	0.015	0.008	0.013	0.009
Teenager	0.009	0.026	0.015	0.008	0.011	0.009
Adult	0.009	0.027	0.015	0.008	0.011	0.009
Grants, NM						
Infant	0.014	0.033	0.024	0.013	0.016	0.014
Child	0.017	0.065	0.026	0.015	0.023	0.017
Teenager	0.015	0.051	0.025	0.014	0.020	0.015
Adult	0.015	0.052	0.025	0.014	0.019	0.015
Nearest SE Resident (downwind)						
Infant	0.017	0.038	0.029	0.016	0.019	0.017
Child	0.020	0.072	0.032	0.018	0.027	0.020
Teenager	0.019	0.057	0.031	0.017	0.024	0.018
Adult	0.019	0.058	0.031	0.017	0.023	0.018

Table C4.12 Estimated doses (excluding radon) to individuals at occupied receptor locations

(Post-reclamation period - 3 years)

	Annual dose (mrem/y)					
	Whole Body	Bone	Ave. Lung	Liver	Kidney	Bronchi
Nearest NE Resident						
Infant	0.072	0.163	0.131	0.072	0.086	0.076
Child	0.089	0.308	0.144	0.080	0.116	0.088
Teenager	0.082	0.241	0.137	0.076	0.104	0.082
Adult	0.083	0.246	0.137	0.077	0.101	0.082
Broadview Acres						
Infant	0.187	0.411	0.319	0.175	0.209	0.185
Child	0.219	0.789	0.351	0.196	0.291	0.217
Teenager	0.202	0.617	0.334	0.186	0.258	0.200
Adult	0.202	0.630	0.334	0.187	0.251	0.201
Murray Acres						
Infant	0.094	0.202	0.161	0.088	0.105	0.093
Child	0.109	0.384	0.176	0.098	0.144	0.108
Teenager	0.101	0.300	0.168	0.094	0.128	0.100
Adult	0.101	0.307	0.169	0.094	0.125	0.100
Nearest Town - Milan, NM						
Infant	0.008	0.017	0.013	0.007	0.009	0.008
Child	0.009	0.032	0.015	0.008	0.012	0.009
Teenager	0.008	0.025	0.014	0.008	0.011	0.008
Adult	0.008	0.026	0.014	0.008	0.010	0.008
Grants, NM						
Infant	0.013	0.031	0.023	0.012	0.015	0.013
Child	0.016	0.063	0.025	0.014	0.022	0.016
Teenager	0.015	0.049	0.024	0.013	0.019	0.015
Adult	0.015	0.050	0.024	0.013	0.019	0.015
Nearest SE Resident (downwind)						
Infant	0.016	0.036	0.028	0.015	0.018	0.016
Child	0.019	0.069	0.031	0.017	0.026	0.019
Teenager	0.018	0.054	0.030	0.016	0.023	0.018
Adult	0.018	0.056	0.030	0.017	0.022	0.018

Table C4.13 Estimated doses (excluding radon) to individuals at Vista Montano (unoccupied receptor)

	Annual dose (mrem/y)					
	Whole Body	Bone	Ave. Lung	Liver	Kidney	Bronchi
1981 - 1983						
Infant	0.612	7.07	16.5	0.358	1.70	0.420
Child	0.761	9.15	16.6	0.503	2.18	0.569
Teenager	0.616	7.44	16.5	0.444	1.92	0.424
Adult	0.595	7.22	16.4	0.449	1.83	0.403
1984 - 1986						
Infant	0.411	3.78	8.14	0.275	0.957	0.317
Child	0.514	5.14	8.24	0.371	1.28	0.419
Teenager	0.427	4.15	8.16	0.331	1.11	0.332
Adult	0.416	4.05	8.14	0.335	1.07	0.322
1987 - 2000						
Infant	1.17	15.0	36.9	0.623	3.56	0.741
Child	1.43	18.9	37.2	0.878	4.39	1.00
Teenager	1.15	15.4	36.9	0.774	3.89	0.718
Adult	1.10	14.9	36.9	0.784	3.71	0.672
Reclamation						
Infant	0.291	0.698	0.491	0.269	0.330	0.289
Child	0.351	1.39	0.551	0.311	0.482	0.348
Teenager	0.320	1.08	0.520	0.292	0.420	0.317
Adult	0.321	1.11	0.521	0.293	0.409	0.318
Post-reclamtation						
Infant	0.279	0.669	0.471	0.258	0.317	0.277
Child	0.336	1.33	0.528	0.299	0.462	0.334
Teenager	0.307	1.04	0.499	0.280	0.403	0.304
Adult	0.308	1.07	0.500	0.281	0.392	0.305

Table C4.14 Estimated total doses to a child at occupied or potentially occupied receptor locations

	Annual dose (mrem/y)					
	Whole Body	Bone	Ave. Lung	Liver	Kidney	Bronchi
1981 - 1983						
Nearest NE Resident	0.353	2.52	4.97	0.281	0.718	0.941
Broadview Acres	0.894	6.24	11.9	0.720	1.80	1.78
Vista Montano*	1.51	9.90	17.3	1.25	2.92	2.81
Murray Acres	0.437	3.10	6.03	0.350	0.889	0.843
Milan, NM	0.038	0.262	0.501	0.031	0.076	0.090
Grants, NM	0.073	0.475	0.839	0.061	0.141	0.143
Nearest SE Resident	0.083	0.569	1.08	0.068	0.166	0.279
1984 - 1986						
Nearest NE Resident	0.285	1.46	2.58	0.245	0.479	0.487
Broadview Acres	0.730	3.63	6.09	0.636	1.21	1.03
Vista Montano*	1.25	5.87	8.98	1.11	2.01	1.69
Murray Acres	0.354	1.77	3.08	0.307	0.589	0.490
Milan, NM	0.030	0.151	0.257	0.027	0.051	0.048
Grants, NM	0.059	0.279	0.434	0.053	0.096	0.083
Nearest SE Resident	0.066	0.329	0.562	0.058	0.110	0.134
1987 - 2000						
Nearest NE Resident	0.590	5.14	10.9	0.434	1.36	1.94
Broadview Acres	1.48	12.8	26.3	1.10	3.39	3.50
Vista Montano*	2.44	19.9	38.2	1.89	5.40	5.42
Murray Acres	0.727	6.40	13.4	0.538	1.70	1.66
Milan, NM	0.063	0.538	1.11	0.048	0.145	0.182
Grants, NM	0.118	0.959	1.84	0.092	0.263	0.280
Nearest SE Resident	0.138	1.16	2.36	0.106	0.315	0.587
Reclamation						
Nearest NE Resident	0.292	0.521	0.349	0.283	0.321	0.291
Broadview Acres	0.760	1.36	0.897	0.736	0.835	0.758
Vista Montano*	1.31	2.35	1.51	1.27	1.45	1.31
Murray Acres	0.368	0.655	0.439	0.357	0.405	0.368
Milan, NM	0.031	0.056	0.037	0.030	0.035	0.031
Grants, NM	0.062	0.111	0.072	0.060	0.069	0.062
Nearest SE Resident	0.068	0.120	0.080	0.066	0.074	0.068

*unoccupied receptor

Table C4.14 continued

	Annual dose (mrem/y)					
	Whole Body	Bone	Ave. Lung	Liver	Kidney	Bronchi
Post-reclamation						
Nearest NE Resident	0.280	0.499	0.335	0.271	0.308	0.279
Broadview Acres	0.728	1.30	0.860	0.706	0.800	0.726
Vista Montano*	1.26	2.25	1.45	1.22	1.39	1.26
Murray Acres	0.353	0.628	0.420	0.342	0.388	0.352
Milan, NM	0.030	0.054	0.036	0.029	0.033	0.030
Grants, NM	0.060	0.106	0.069	0.058	0.066	0.060
Nearest SE Resident	0.065	0.115	0.077	0.063	0.071	0.065

*unoccupied receptor

Table C4.15 Estimated annual population doses from operation of the HMC mill

	Population dose (person-rem/year)					
	Whole Body	Bone	Ave. Lung	Liver	Kidney	Bronchi
1981 - 1983						
Within 80 km	0.536	3.51	8.45	0.474	1.14	2.00
Beyond 80 km	0.557	7.46	0.139	0.561	0.622	3.42
Entire population	1.09	11.0	8.59	1.04	1.76	5.42
1984 - 1986						
Within 80 km	0.437	2.01	4.32	0.400	0.739	0.947
Beyond 80 km	0.206	2.75	0.057	0.208	0.248	1.23
Entire population	0.643	4.76	4.38	0.608	0.987	2.17
1987 - 2000						
Within 80 km	0.888	7.23	18.7	0.753	2.19	4.25
Beyond 80 km	1.44	19.3	0.347	1.45	1.56	8.93
Entire population	2.33	26.5	19.1	2.20	3.75	13.2
Reclamation period						
Within 80 km	0.470	0.764	0.569	0.457	0.497	0.469
Beyond 80 km	0.010	0.123	0.010	0.012	.036	0.010
Entire population	0.481	0.887	0.579	0.468	0.533	0.479
Post-reclamation period						
Within 80 km	0.451	0.731	0.545	0.437	0.476	0.450
Beyond 80 km	0.010	0.117	0.010	0.011	0.034	0.010
Entire population	0.461	0.849	0.555	0.448	0.509	0.459

Table C4.15A Estimated total dose to child and adult at Broadview Acres for 1987 - 2000 time period by pathway

	Annual dose (mrem/y)					
	Whole Body	Bone	Ave. Lung	Liver	Kidney	Bronchi
Child						
Inhalation	0.294	6.35	25.1	0.180	1.61	2.32
Ground	0.724	0.724	0.724	0.724	0.724	0.724
Cloud	0.011	0.011	0.011	0.011	0.011	0.011
Vegetable Ingestion	0.201	2.60	0.201	0.123	0.581	0.201
Meat Ingestion	0.026	0.331	0.026	0.027	0.101	0.026
Milk Ingestion	0.222	2.75	0.222	0.034	0.363	0.222
Total	1.48	12.8	26.3	1.10	3.39	3.50
Adult						
Inhalation	0.294	6.35	25.1	0.180	1.61	2.32
Ground	0.724	0.724	0.724	0.724	0.724	0.724
Cloud	0.011	0.011	0.011	0.011	0.011	0.011
Vegetable Ingestion	0.164	2.12	0.164	0.100	0.451	0.164
Meat Ingestion	0.027	0.347	0.027	0.027	0.096	0.027
Milk Ingestion	0.050	0.606	0.050	0.008	0.076	0.050
Total	1.27	10.2	26.1	1.05	2.97	3.30

Table C4.15B Airborne radionuclide concentrations at unoccupied receptors (boundary locations and HMC monitors) for three operating time periods

	Concentration (pCi/m^3)				Fraction
	U-238	Th-230	Ra-226	Rn-222 (WL)	MPC*
1981 - 1983					
NW Prop. Line	2.06E-3	1.32E-4	8.54E-5	3.65E-6	2.76E-3
HMC 1	5.39E-3	3.51E-4	2.29E-4	6.14E-6	7.18E-3
HMC 2	1.79E-2	1.13E-3	7.28E-4	2.19E-5	2.35E-2
HMC 3	6.85E-2	4.86E-3	3.32E-3	5.32E-5	9.60E-2
HMC 4	1.78E-3	1.23E-4	8.27E-5	3.96E-6	2.53E-3
HMC 5	2.66E-3	1.80E-4	1.20E-4	4.38E-6	3.68E-3
SE Prop. Line	7.76E-2	5.14E-3	3.39E-3	6.54E-5	1.04E-1
1984 - 1986					
NW Prop. Line	1.01E-3	6.71E-5	4.43E-5	1.30E-6	1.37E-3
HMC 1	2.63E-3	1.78E-4	1.19E-4	2.19E-6	3.58E-3
HMC 2	8.68E-3	5.80E-4	3.83E-4	7.82E-6	1.17E-2
HMC 3	3.31E-2	2.49E-3	1.75E-3	1.90E-5	4.80E-2
HMC 4	8.71E-4	6.28E-5	4.32E-5	1.42E-6	1.25E-3
HMC 5	1.30E-3	9.05E-5	6.13E-5	1.56E-6	1.81E-3
SE Prop. Line	3.75E-2	2.63E-3	1.78E-3	2.34E-5	5.19E-2
1987 - 2000					
NW Prop. Line	4.69E-3	2.82E-4	1.75E-4	8.36E-6	6.03E-3
HMC 1	1.23E-2	7.47E-4	4.68E-4	1.40E-5	1.57E-2
HMC 2	4.10E-2	2.42E-3	1.48E-3	5.01E-5	5.14E-2
HMC 3	1.57E-1	1.03E-2	6.72E-3	1.22E-4	2.09E-1
HMC 4	4.07E-3	2.61E-4	1.68E-4	9.07E-6	5.05E-3
HMC 5	6.08E-3	3.86E-4	2.47E-4	1.00E-5	8.06E-3
SE Prop. Line	1.78E-1	1.09E-2	6.88E-3	1.50E-4	2.27E-1

TABLE C4.16

HOMESTAKE MINING COMPANY
ANNUAL STATISTICS FOR PERIMETER AIR
NATURAL URANIUM CONCENTRATION (μCi/ml)

PARAMETER	HMC ENVIRONMENTAL LABORATORY	HMC EMPLOYMENT OFFICE	BROADVIEW ACRES PARK	NORTHWEST PERIMETER CORNER	HMC TRUCKING 1 HOUR	YELLOWCAKE DRYER STACK	HMC TRUCKING 24 HOURS	TAYLOR VIEW PARK
1980								
Mean	5.47×10^{-14}	7.16×10^{-14}	2.27×10^{-14}	3.86×10^{-14}	10.59×10^{-14}	4.90×10^{-14}	14.81×10^{-14}	8.4×10^{-14}
σ	4.15×10^{-14}	7.59×10^{-14}	2.87×10^{-14}	6.06×10^{-14}	16.54×10^{-14}	7.04×10^{-14}	11.03×10^{-14}	8.87×10^{-14}
n	3	12	12	12	12	12	11	9
Net Conc.	2.51×10^{-14}	4.20×10^{-14}	0	0.9×10^{-14}	7.63×10^{-14}	1.94×10^{-14}	11.85×10^{-14}	5.44×10^{-14}
% MPC	0.025(1)	0.042(1)	0(2)	0.01(1)	0.08(1)	0.02(1)	0.12(1)	1.09(2)
1981								
Mean	11.53×10^{-14}	5.70×10^{-14}	3.60×10^{-14}	1.88×10^{-14}	20.43×10^{-14}	11.50×10^{-14}	17.97×10^{-14}	---
σ	10.10×10^{-14}	5.87×10^{-14}	2.23×10^{-14}	1.06×10^{-14}	35.49×10^{-14}	16.76×10^{-14}	9.90×10^{-14}	---
n	6	6	6	6	6	6	6	---
Net Conc.	8.57×10^{-14}	2.74×10^{-14}	0.64×10^{-14}	0	17.47×10^{-14}	8.54×10^{-14}	15.01×10^{-14}	---
% MPC	0.086(1)	0.027(1)	0.13(2)	0(1)	0.18(1)		0.09(1)	0.15(1)

(1) MPC (restricted area) = 1×10^{-10} (= $10{,}000 \times 10^{-14}$) μCi/ml.

(2) PC (unrestricted area) = 5×10^{-12} (= 500×10^{-14}) μCi/ml.

TABLE C4.17

HOMESTAKE MINING COMPANY
ANNUAL STATISTICS FOR PERIMETER AIR
THORIUM-230 CONCENTRATION (μCi/ml)

PARAMETER	HMC ENVIRONMENTAL LABORATORY	HMC EMPLOYMENT OFFICE	BROADVIEW ACRES PARK	NORTHWEST PERIMETER CORNER	HMC TRUCKING 1 HOUR	YELLOWCAKE DRYER STACK	HMC TRUCKING 24 HOURS	TAYLOR VIEW PARK
1980								
Mean	3.67×10^{-17}	3.83×10^{-17}	3.83×10^{-17}	3.36×10^{-17}	5.17×10^{-17}	2.61×10^{-17}	1.47×10^{-17}	3.67×10^{-17}
σ	0.58×10^{-17}	2.04×10^{-17}	2.92×10^{-17}	1.50×10^{-17}	3.79×10^{-17}	1.46×10^{-17}	1.08×10^{-17}	1.12×10^{-17}
n	3	12	12	11	12	12	11	9
Net Conc.	0	0	0	0	1.05×10^{-17}	0	0	0
% MPC	0(1)	0(1)	0(2)	0(1)	<0.01(1)	0(1)	0(1)	0(2)
1981								
Mean	11.33×10^{-17}	8.00×10^{-17}	2.50×10^{-17}	2.33×10^{-17}	12.83×10^{-17}	10.83×10^{-17}	1.88×10^{-17}	---
σ	20.94×10^{-17}	10.39×10^{-17}	0.55×10^{-17}	0.52×10^{-17}	15.37×10^{-17}	17.76×10^{-17}	2.18×10^{-17}	---
n	6	6	6	6	6	6	6	---
Net Conc.	7.21×10^{-17}	3.88×10^{-17}	0	0	8.71×10^{-17}	6.71×10^{-17}	0	---
% MPC	<0.01(1)	<0.01(1)	<0(1)	<0(1)	<0.01(1)	<0.01(1)	0(1)	---

(1) MPC (restricted area) = 1×10^{-11} (= $1{,}000{,}000 \times 10^{-17}$) μCi/ml.
(2) PC (unrestricted area) = 3×10^{-13} (= $10{,}000 \times 10^{-17}$) μCi/ml.

TABLE C4.18

HOMESTAKE MINING COMPANY
ANNUAL STATISTICS FOR PERIMETER AIR
RADIUM-226 CONCENTRATIONS (μCi/ml)

PARAMETER	HMC ENVIRONMENTAL LABORATORY	HMC EMPLOYMENT OFFICE	BROADVIEW ACRES PARK	NORTHWEST PERIMETER CORNER	HMC TRUCKING 1 HOUR	YELLOWCAKE DRYER STACK	HMC TRUCKING 24 HOURS	TAYLOR VIEW PARK
1980								
Mean	9.23×10^{-14}	7.42×10^{-14}	12.95×10^{-14}	5.70×10^{-14}	15.86×10^{-14}	8.67×10^{-14}	4.67×10^{-14}	17.53×10^{-14}
σ	7.72×10^{-14}	5.19×10^{-14}	12.56×10^{-14}	5.71×10^{-14}	17.50×10^{-14}	7.83×10^{-14}	3.76×10^{-14}	10.15×10^{-14}
n	3	12	11	12	12	12	11	9
Net Conc.	2.26×10^{-14}	0.45×10^{-14}	5.98×10^{-14}	0	8.89×10^{-14}	1.70×10^{-14}	0	10.56×10^{-14}
% MPC	0.05(1)	0.01(1)	2.99(2)	0(1)	0.18(1)	0.03(1)	0(1)	5.28(2)
1981								
Mean	15.62×10^{-14}	4.77×10^{-14}	12.48×10^{-14}	5.27×10^{-14}	7.38×10^{-14}	26.05×10^{-14}	1.52×10^{-14}	---
σ	15.13×10^{-14}	3.42×10^{-14}	10.85×10^{-14}	3.63×10^{-14}	6.58×10^{-14}	43.94×10^{-14}	1.55×10^{-14}	---
n	6	6	6	6	6	6	6	---
Net Conc.	8.65×10^{-14}	0	5.51×10^{-14}	0	0.41×10^{-14}	19.08×10^{-14}	0	---
% MPC	0.17(1)	0(1)	2.76(2)	0(1)	0.01(1)	0.38(1)	0(1)	---

(1) MPC (restricted area) = 5×10^{-11} (= $5{,}000 \times 10^{-14}$) μCi/ml.
(2) PC (unrestricted area) = 2×10^{-12} (= 200×10^{-14}) μCi/ml.

TABLE C5.1

TAXES GENERATED BY HMC
MINING AND MILLING
1980[1]

TAX	AMOUNT PAID TO THE FEDERAL GOVERNMENT	AMOUNT PAID TO THE STATE GOVERNMENT
Paid by HMC		
Severance Tax	$ --	$ 1,727,000
Processors Tax	--	222,000
Conservation Tax	--	11,000
Continued Care Tax	--	175,000
Property Tax	--	420,000
Unemployment	37,000	93,000
FICA	1,000,000	--
Sales Tax	--	1,510,000
Gross Receipts Tax (trucking)	--	5,500
Highway and Fuel Taxes	5,700	--
Total Paid by HMC	$1,042,700	$ 4,163,500
Withheld From Employees		
Income Tax	$2,335,000	$ 156,000
FICA	1,000,000	--
Total Withheld	$3,335,000	$ 156,000
GRAND TOTAL	$4,377,700	$ 4,319,500

(1) HMC, 1981a.

TABLE C5.2

GOVERNMENT EXPENDITURES FOR DIRECT AND INDIRECT POPULATION IN VALENCIA COUNTY AND GRANTS 1981[1]

CATEGORY	VALENCIA COUNTY				GRANTS				TOTAL CITY-COUNTY EXPENDITURES	
	PER CAPITA EXPENDITURES (dollars)	DIRECT POPULATION (2) (thousands of dollars)	INDIRECT POPULATION (3) (thousands of dollars)	TOTAL (thousands of dollars)	PER CAPITA EXPENDITURES (dollars)	DIRECT POPULATION (4) (thousands of dollars)	INDIRECT POPULATION (5) (thousands of dollars)	TOTAL (thousands of dollars)	DIRECT POPULATION (thousands of dollars)	INDIRECT POPULATION (thousands of dollars)
Administration	24.25	43.87	45.91	89.78	62.30	103.98	108.84	212.82	147.85	154.75
Public Safety	18.27	33.05	34.59	67.64	107.09	178.73	187.09	365.82	211.78	221.68
Health/Welfare	5.60	10.13	10.60	20.73	12.13	20.24	21.19	41.43	30.37	31.79
Transportation	13.01	23.54	24.63	48.17	122.27	204.07	213.61	417.68	227.61	238.24
Utilities	1.97	3.56	3.73	7.29	192.73	321.67	336.70	658.37	325.23	340.43
Public Works Planning	0.47	0.85	0.89	1.74	12.90	21.53	22.54	44.07	22.38	23.43
Recreation	1.92	3.47	3.63	7.10	44.05	73.52	76.96	150.48	76.99	80.59
Education	--	--	--	--	6.09	10.16	10.64	20.80	10.16	10.64
Miscellaneous	7.74	14.00	14.65	28.65	68.98	115.13	120.51	235.64	129.13	135.16
Debt Service	--	--	--	--	34.74	57.98	60.69	118.67	57.98	60.69
TOTAL	73.23	132.47	138.63	271.10	663.28	1,107.01	1,158.75	2,265.75	1,239.47	1,297.38

(1) Based on FY80-81 budgets for Grants and Valencia County (Kerr-McGee, 1981).

(2) Based on an estimated direct population (1,809 persons) residing in Valencia County.

(3) Based on an estimated indirect population (1,893 persons) residing in Valencia County.

(4) Based on an estimated direct population (1,670 persons) residing in Grants.

(5) Based on an estimated indirect population (1,747 persons) residing in Grants.

TABLE C7.1

CHEMICAL AND RADIOLOGICAL CHARACTERISTICS OF HMC TAILINGS SOLUTION[1,2]

CHEMICAL	CONCENTRATION (mg/l)
Ca	135
Mg	30.0
Na	9,800
HCO_3	1,850
CO_3	6,450
SO_4	15,700
Cl	2,340
NO_3	8.2
Al	<1.0
As	0.07
Ba	<1.0
Cd	<0.01
Pb	<0.01
Mo	105
Se	35.5
U_3O_8	248
V	9.23
Zn	6.62
RADIONUCLIDE	**ACTIVITY (pCi/l)**
Ra-226	88.4
Th-230	0.151
OTHER PARAMETERS	
pH	10.3
TDS[3]	43,300 mg/l

[1] Hydro-Engineering, 1981.

[2] Sample taken on September 23, 1981.

[3] Total dissolved solids.

TABLE C7.2

FRACTIONAL PROBABILITIES OF OCCURRENCE AND CORRESPONDING PACKAGE RELEASE FRACTIONS FOR EACH OF THE RELEASE MODELS FOR LOW SPECIFIC ACTIVITY (LSA) AND TYPE A CONTAINERS INVOLVED IN TRUCK ACCIDENTS[1]

ACCIDENT SEVERITY CATEGORY	FRACTIONAL OCCURRENCE OF ACCIDENT	RELEASE FRACTIONS	
		MODEL I LSA & TYPE A	MODEL II LSA & TYPE A
I	0.55	0	0
II	0.36	1.0	0.01
III	0.07	1.0	0.1
IV	0.016	1.0	1.0
V	0.0028	1.0	1.0
VI	0.0011	1.0	1.0
VII	8.5×10^{-5}	1.0	1.0
VIII	1.5×10^{-5}	1.0	1.0

[1] U.S. NRC, 1980b.

TABLE C8.1

ENVIRONMENTAL RADIOLOGICAL MONITORING PROGRAM

TYPE OF SAMPLE	NUMBER	LOCATIONS	METHOD	FREQUENCY	ANALYTICAL PARAMETERS
STACKS					
Particulates	3	Yellowcake dryer stack, vanadium roaster stack, yellowcake packaging room area stack	Isokinetic	Quarterly	Unat
Particulates	2	Crushing circuit stack	Representative Grab	Semi-annually	Unat, Ra-226, Th-230, Stack Flow
AIR					
Particulates	3	Locations at or near the site boundary and in different sectors that have the highest predicted concentrations of radioactive airborne particulates	Continuous (High Vol.)	Weekly filter change, or more frequently as required - Samples composited and analyzed quarterly	Unat, Ra-226, Th-230, Pb-210
	1	Nearest occupied residence	Continuous (High Vol.)	Weekly filter change, or more frequently as required - Samples composited and analyzed quarterly	Unat, Ra-226, Th-230, Pb-210
	1	Control location	Continuous (High Vol.)	Weekly filter change, or more frequently as required - Samples composited and analyzed quarterly	Unat, Ra-226, Th-230, Pb-210
Radon daughter working levels	5	Locations described in AIR - Particulates	Grab - Kusnetz	Quarterly	Working levels
Radon gas	5	Locations described in AIR - Particulates	Continuous-Track-etch	Quarterly	Rn-222
WATER					
Groundwater	3	Hydrologically upgradient of tailing impoundment (background)	Pumped-Grab	Quarterly	Unat, Ra-226, Th-230, Pb-210
	3	Hydrologically downgradient and relatively close to the tailings impoundment	Pumped-Grab	Quarterly	Unat, Ra-226, Th-230, Pb-210
	1	Downgradient near the closest resident	Pumped-Grab	Quarterly	Unat, Ra-226, Th-230, Pb-210
Surface water	1	Mine ion exchange discharge	Grab	Quarterly	Dissolved and suspended Unat, Ra-226, Th-230, Pb-210
VEGETATION	5	Locations described in AIR - Particulates	Grab	Annually	Ra-226, Pb-210
SOIL	5	Locations described in AIR - Particulates	Grab	Annually	Unat, Ra-226, Pb-210
DIRECT RADIATION	5	Locations described in AIR - Particulates	Continuous	Quarterly	Gamma exposure rate

TABLE C8.2
MILL/OCCUPATIONAL RADIOLOGICAL MONITORING PROGRAM

TYPE OF SAMPLE	NUMBER	LOCATION	METHOD	FREQUENCY	ANALYTICAL PARAMETERS
Routine Suspended Particulates	17	17	Medium Volume 24 Hours	Monthly	Total Alpha
Non-Routine Suspended Particulates	Varies	Varies	Medium Volume Grab	When Required by non-routine maintenance work	Total Alpha
Employee's alpha inhalation exposure	Approximately 6	Employees	Calculated	Weekly	Precent MPC
Nonroutine employee alpha exposure	Varies with need	Employees	Calculated	Weekly	Precent MPC
Bioassay	Varies	Employees	Fluorometric	Annually, or more frequently	Concentration of Unat in urine
Radon daughter working levels	9	Crusher Bldg. fine ore bins metallurgical lab	Kusnetz or IWLM (1)	Quarterly	Working levels
Direct gamma radiation	?	Crusher bldg. yellowcake dryer, yellowcake drum storage area, yellowcake packaging room, yellowcake sample prep. room, filter bldg., digester bldg.	Scintillometer	Monthly	Gamma radiation, exposure mrem
Personnel exposure	Varies	Employees	Continuous TLD	Monthly	Gamma radiation, exposure mrem
Radiation survey equipment removal	As needed	As needed	Scintillometer	As needed	Removable alpha, fixed alpha, beta-gamma

(1) IWLM = Instant Working Level Meter

TABLE C9.1

STABILIZATION SEED MIXTURE

SCIENTIFIC NAME	COMMON NAME	SEEDING RATE		
		GROWTH[1] HABIT	LBS PURE LIVE SEED/ACRE	NUMBER OF SEEDS/FT^2
Grasses				
Agropyron smithii	Western wheatgrass	NS	4.0	10.1
Bouteloua gracilis	Blue grama	NB	2.0	37.9
Sporobolus cryptandrus	Sand dropseed	NB	0.5	60.8
Oryzopsis hymenoides	Indian ricegrass	NB	3.0	9.7
Sporobolus airoides	Alkali sacaton	NB	0.5	20.2
Shrubs				
Atriplex canescens	Four-wing saltbush	--	0.5	0.6

[1] NB - Native Bunchgrass.
NS - Native Sod.

TABLE C9.2
PREPARATORY CROP SEEDING RATES

SCIENTIFIC NAME	COMMON NAME	SEEDING RATE[1] LBS PURE LIVE SEED/ACRE
Hordium vulgare	Barley	25.0
or	or	
Triticum aestivum	Wheat	25.0
or	or	
Avena sativa	Oats	25.0

[1] Seeding rate is for drill seeding. If broadcast seeding is used the rate will be doubled.

TABLE C9.3

Soil Parameter Variations For
Radon Emanation Calculations

TAILINGS (1) RADIUM CONTENT [Ra] (pCi/g)	TAILINGS DIFFUSION COEFFICIENT k (cm^2/sec)	COVER SOIL (1) RADIUM CONTENT [Ra] (pCi/g)	COVER SOIL DIFFUSION COEFFICIENT k (cm^2/sec)	COVER SOIL RELAXATION LENGTH R (cm)
440	2.57×10^{-3}	1 2 3	3.36×10^{-3}	40.0
		1 2 3	5.25×1^{-3}	50.0
		1 2 3	7.56×10^{-3}	60.0
590	2.57×10^{-3}	1 2 3	3.36×10^{-3}	40.0
		1 2 3	5.25×10^{-3}	50.0
		1 2 3	7.56×10^{-3}	60.0

(1) $1 \frac{pCi}{g}$ [Ra] = 0.001 g [Ra]/1000 metric tons

TABLE C9.3a

SUMMARY OF COMPUTER RESULTS
FOR 0.15 PERCENT AND 0.2 PERCENT GRADE ORES

RADIUM CONTENT (pCi/g)	SOIL RELAXATION LENGTH (dm)	SOIL RADIUM CONTENT (pCi/g)	SOIL THICKNESS (feet)	REDUCE TO pCi/m^2-sec Without soil 97 pCi/m^2-sec
440	4.0	1	1.0	48.3
		2	1.0	48.4
		3	1.0	48.6
	5.0	1	1.0	59.6
		2	1.0	59.8
		3	1.0	59.9
	6.0	1	1.0	67.9
		2	1.0	68.1
		3	1.0	68.2
590	4.0	1	0.4	100.0
		2	0.42	100.0
		3	0.44	100.0
	5.0	1	0.53	100.0
		2	0.55	100.0
		3	0.57	100.0
	6.0	1	0.8	100.0
		2	0.82	100.0
		3	0.84	100.0

TABLE C9.4

STABILIZATION COSTS*

Area	Cost
Tailings Embankment	
Move embankment sand to 4.0:1 and fill center 1,120,00 yd^3 @ $0.89/$yd^3$	$ 1,000,000
Placement of soil cover material 484,000 yd^3 @ $6.50/$yd^3$	$ 3,146,000
Rip-rap cover placement 242,000 yd^3 @ $15.00	$ 3,630,000
Tailing Pile Dewatering	
Evaporation Ponds 60 acres @ $50,000/acre	$ 3,000,000
Reclamation	
Evaporation ponds and borrow pit 90 acres @ $2,500/acre	$ 225,000
Total	$11,001,000

* HMC and Applied Research Associates