United States
Department of
Agriculture

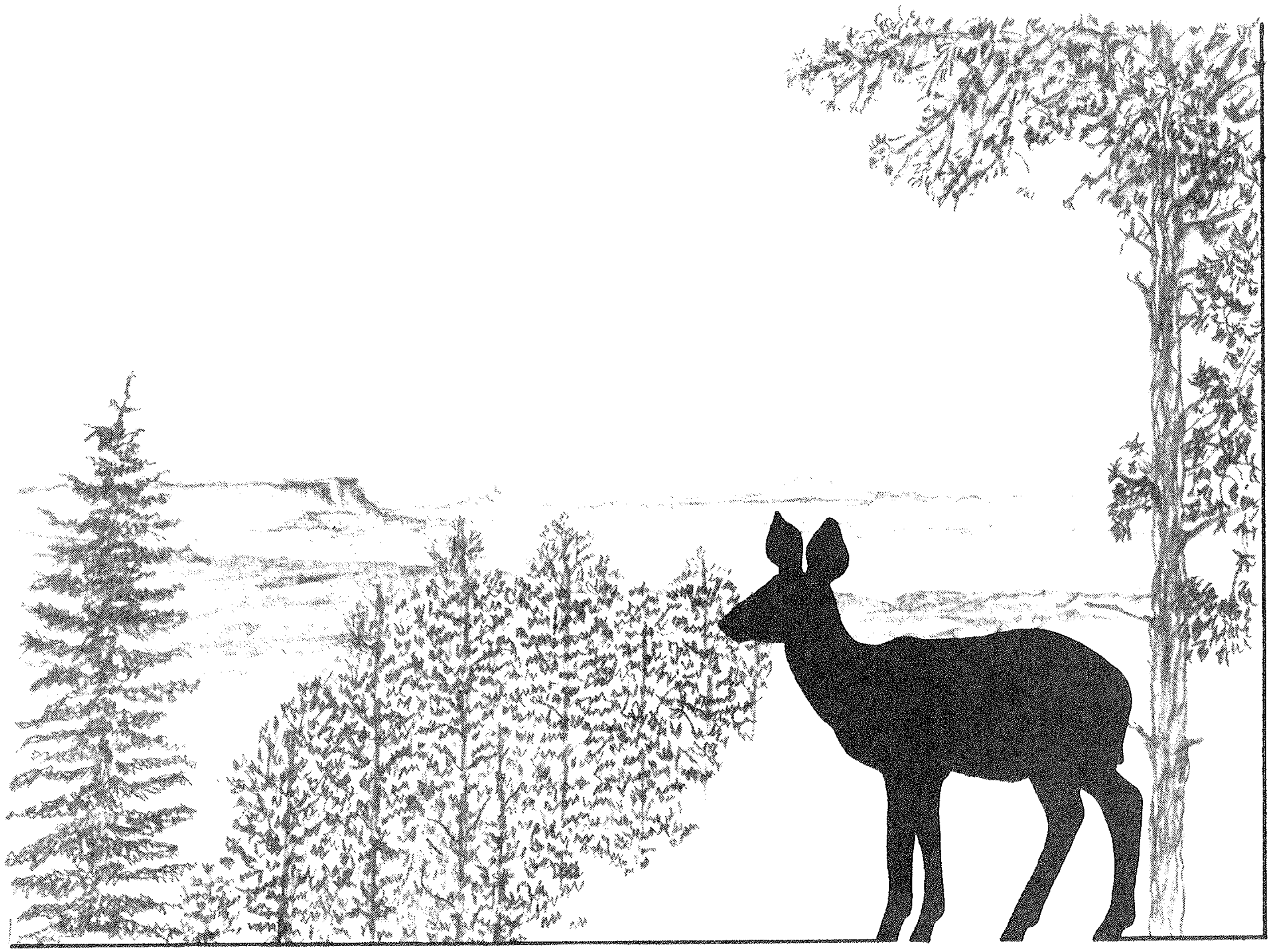
Forest Service

Southwestern
Region

Kaibab National
Forest

December 1985

Appendix Draft Environmental Impact Statement Canyon Uranium Mine



ENVIRONMENTAL IMPACT STATEMENT
CANYON URANIUM MINING PROPOSAL
COCONINO COUNTY, ARIZONA

APPENDICES

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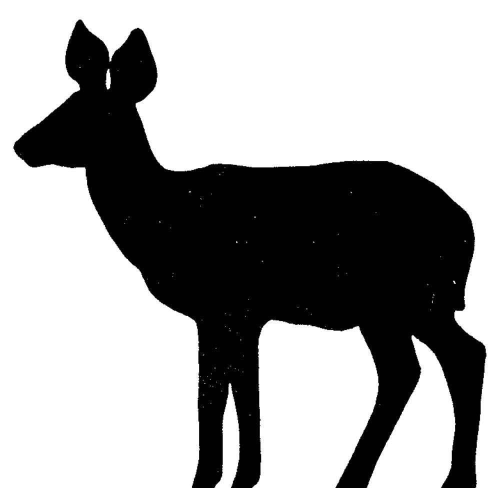
Plan of Operations



PLAN OF OPERATIONS
NOTICE OF INTENT

CANYON MINE

October, 1984

Energy Fuels Nuclear, Inc.
Executive Offices
Three Park Central
Suite 900
1515 Arapahoe
Denver, Colorado 80202

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I. INTRODUCTION

The Canyon Mine Project, for which this Plan of Operations was prepared, is located on unpatented lode mining claims located by Energy Fuels Exploration Company ("EFEX") an affiliate of the operator Energy Fuels Nuclear, Inc. ("EFN"). As shown on Plate 1, the claims are located in Section 20, Township 29 North, Range 3 East, Gila & Salt River PM, Coconino County, Arizona. The site is located approximately 6 miles southeast from Tusayan, Arizona.

EFN submits this Plan of Operations for approval pursuant to the requirements of 36 C.F.R. § 228.1, et. seq.

The name and legal mailing address of the entity for which the operation will be conducted is: Energy Fuels Nuclear, Inc., Three Park Central, Suite 900, 1515 Arapahoe Street, Denver, Colorado 80202, (303) 623-8317. The person who will be in charge of the operation is: Roger B. Smith, Manager of Mining Operations, Energy Fuels Nuclear, Inc., P. O. Box 36, Fredonia, Arizona 86022, (602) 643-5823. The name and legal mailing address of the record owner of the mining claims upon which the operation will be conducted is: Energy Fuels Exploration Company, Three Park Central, Suite 900, 1515 Arapahoe Street, Denver, Colorado 80202, (303) 623-8317.

EFN is active in the natural resource industry with holdings in uranium. The company built and is part owner of a 2,000 ton-per-day uranium ore processing mill at Blanding, Utah. As part of its activity as a uranium producer, EFN currently operates three mines in northern Arizona--the Hack Canyon Mine, the Pigeon Mine and the Kanab North Mine.

The objective of this operation is to recover, by underground mining methods, a uranium ore deposit occurring within the Project Area. The discovery of this ore deposit was made during an exploratory drilling program undertaken by EFEX pursuant to plans approved by the National Forest Service ("NFS"). The proposed mining activities will require surface facilities within the Area of Operations encompassing approximately 17.4 acres, installation of a 1.7 mile electric power line by Arizona Public Service Company to provide power to the Project Area, and utilization of roads for access and haulage.

Access to the Canyon Mine Project Area is achieved by turning east off State Highway 64 to National Forest Road 305, eight miles south of the Grand Canyon Airport. After following Forest Road 305 two miles, the north fork of Forest Road 305A is taken nearly due north for four miles past Owl Tank, where a side road is taken due west one-half mile to the Canyon Mine Project site.

The mining claims making up the Project Area consist of three unpatented lode claims, which are identified by the following Bureau of Land Management ("BLM") serial numbers and claim names:

Claim Name	BLM Number
Canyon 73-75	A MC 22642-22644

Plate 1 shows the relationship of the individual mining claims to the Project Area and the Area of Operations.

Upon approval of this Plan of Operations by the NFS, EFN intends to proceed as quickly as practicable to begin activities at the Project Area. In this regard, because the required surface facilities are minimal and because of their similarity to those at other mines operated by EFN, the final design and construction activities are expected to be achievable in a relatively short period of time. Specifically, assuming this Plan of Operations is approved by the NFS in early 1985, EFN anticipates that all surface facilities and initial shaft sinking will be in place by the end of 1985.

II. GENERAL DESCRIPTION OF PROJECT AREA

The Project Area is located in that portion of Arizona known as the Coconino Plateau. This 4,000 square mile region extends from the Little Colorado River and San Francisco Mountain northwest to the Grand Canyon. Much literature has been written on this region and on the Grand Canyon to the north.

Relief is flat-lying across the several square miles surrounding the Project Area. Elevation at the mine site is 6,500 feet above sea level with a down slope toward the south at an average rate of 100 feet per mile. Two major topographical features, some distance from the Project Area, have much greater relief and different elevations. Red Butte, a lava capped mesa, 4.5 miles south of the Project Area reaches 7,234 feet in elevation and the Colorado River, 15 miles due north, is 2,500 feet above sea level.

The drainage from the Project Area is toward the south for seven miles, where it curves west for 15 miles and then back north for 50 miles until it reaches the Colorado River. Only in the last several miles of this drainage is there any consistent flow.

Because of the high elevation of the area, annual rain fall is somewhat higher than for the region as a whole, averaging about 13 inches per year since 1931. The winters are cold enough to hold precipitation as snow, but only to freeze the soil to a few inches in depth. The annual temperatures will rarely fall outside of the 20° to 90° F range.

With the moderate temperatures and more than 12 inches of rain fall, the growth of Ponderosa, Pinyon and other species of pine are common in the area. Timber rarely exceeds 100 feet in height or 30 inches in diameter. Typically, Scrub Oak and Juniper are abundant at the edges of the dominating stands of pines. The actual Project Area is in a natural clearing of approximately one-half mile in diameter. The only vegetation in this clearing are native grasses and plants. No threatened or endangered plant species are known to occur in the Project Area.

Wildlife in the general region appears to be limited as evidenced by the fact that during the implementation of the exploration drilling program at the Project Site little, if any, wildlife was observed. No unique, threatened or endangered animal species are known to exist in the Project Area.

Very limited archeological and cultural resources have been previously identified in the examinations which were undertaken prior to commencing drilling activities at the Project Site. However, the entire Project Area is currently being surveyed by Abajo Archaeology, USDI-Antiquities Permit No. 83-AZ-212 to confirm the absence of any significant cultural resources. EFN expects Abajo Archeology to submit its report on the archeological and cultural resources within the Project Area to the NFS by mid-December, 1984.

The entire Project Area is covered by Mid-Permian Kaibab and Toroweap limestones that dip a few degrees to the south. This formation extends to approximately the 600 foot depth. Below this depth is Coconino sandstone approximately 300 feet in thickness. This is the formation exposed at the canyon rim just north of the visitor center at the Grand Canyon National Park. Minor mineralization is noted in the Coconino and some mining is expected in this formation. The next formation, from depths of 900 to 1,200 feet, is the Hermit Shale formation. This formation is the bright red unit that is viewed and takes its name from Hermit's View, eight miles west of the headquarters of the Grand Canyon National Park. Because the Hermit Shale is a dense, clay-cemented siltstone under the much coarser Coconino sandstone, some water, springs or seeps, are noted at outcrop contacts between these units. In the whole area, 35^{o}-45' to 36^{o}-00' north by 111^{o}-45' to 112^{o}-20' west only five water wells are on record by the U.S. Geological Survey, Water Resource Division, Tucson, Arizona. Average discharge from these wells is a few gallons per minute according to existing records. The next formation below the Hermit Shale is the Supai formation which extends from 1,200 to 2,300 feet below the surface. This is the deepest formation tested in the exploration program at the Project Area. The upper few hundred feet of the Supai formation is the resistant sandstone that causes the inter-gorge of the Grand Canyon to form. It is the main host to the ore deposits that are the object of this mining project. With greater depth, the Supai formation changes from a sandstone to a limestone, resting on the older limestones of the Redwall formation.

The geology of the Project Area is very similar to that of the Grand Canyon. In fact, the similarity of the Project Area to Maricopa Point located just a few miles from the Grand Canyon National Park Headquarters provided the impetus for the initial exploration of the area. At Maricopa Point, a uranium mine known as the Orphan Mine operated on a patented mining claim pre-dating the establishment of the Park. Active from 1956 to 1964, the Orphan produced significant quantities of uranium, copper, silver and gold. The headframe and surface buildings at the Orphan Mine still exist at the site, largely unnoticed by the millions of park visitors who have driven the main rim road passing near the mine.

Figure No. 1: CANYON SITE, regional view, site is in clearing at upper left, Owl Tank at bottom center, photo taken 11/4/83, Scale about 1" to 1100'

Figure No. 2: CANYON SITE, local view, Area of Operations shaded, enlargement of Figure No. 1, Scale about 1" to 300'

Uranium mineralization in the Project Area occurs in a breccia pipe structure that cuts vertically through the flat-lying sedimentary rocks. Cavities formed millions of years ago by water dissolving the deeper Redwall limestone created space into which the overlying rock collapsed. The collapsed zone worked its way up hundreds of feet in the form of a cylinder or narrow cone. This broken rock, or pipe, created a favorable environment for mineral deposition.

III. PLANNED OPERATIONS

During the next several years, EFN will develop and mine the uranium deposit located in the Project Area by underground methods.

Access to the deposit will be by a vertical shaft located northeast of the deposit in the Area of Operations as shown on Plate 2. This shaft will be sunk utilizing either a surface drill rig or by conventional sinking using drilling and blasting methods. Although each method offers EFN certain advantages and disadvantages in terms of time of completion and flexibility, the potential environmental impacts which may result from sinking the shaft utilizing conventional shaft sinking methods will be no greater than the potential environmental impacts which may result from drilling the shaft utilizing a large drill rig. Consequently, final selection of the sinking method will be made by EFN after competitive bids have been received from qualified contractors.

After the vertical shaft has been sunk to a depth of approximately 1,400 feet below the surface, at various levels off of the shaft, workings will be driven toward the deposit. The highest level of the mine is expected to be located approximately 900 feet below the surface in the Coconino formation and the lowest level is expected to be approximately 1,400 feet below the surface in the Supai Formation. At present, EFN does not expect significant economic ore reserves below the 1,400 foot. However, since surface drilling has disclosed limited mineralization to a depth of 2,100 feet, further drilling from underground stations will be undertaken after the shaft is driven to the 1,400 foot depth to further define and delineate the uranium ore deposit. If economic reserves are found at these lower depths, the shaft may be deepened or a decline from the 1,400 foot depth driven in order to permit recovery of these reserves. In any event, if mining is justified below 1,400 feet, no changes in the surface facilities described in this Plan of Operations will be necessary other than perhaps to increase the waste disposal areas by a fraction of an acre. At all times the decision to deepen the shaft or to drive a decline from the lowest shaft level will be to assure access to all economically recoverable ore with haulage drifts that do not have restrictive grades.

Once the initial underground drilling program has fully delineated the extent of the ore deposit, the lower level from the main shaft will be driven underneath the deposit due south to a point just outside of the furthest extent of the ore reserve. At this point, a vertical ventilation shaft will be drilled from the surface to connect with the workings. This shaft will be drilled utilizing a one-foot diameter pilot hole from the surface to intersect the lowest elevation level. Thereafter, an eight-foot diameter upward reaming bit will be attached to the drill pipe and the vertical ventilation shaft drilled upward to the surface. The second (ventilation) shaft is used to exhaust air, thereby creating adequate airflow throughout the mine workings and, in addition, providing a second exit or escapeway from the mine in the event of an emergency.

Raises or vertical workings within the mine will connect the various mining levels within or very near the deposit. At various elevations from these raises, sublevel workings will then be driven off to extract ore from the deposit. The broken ore will then be dropped down raises, designed for such use, to draw points on the lower level. The ore will then be hauled to the shaft. At the shaft, the material is transferred to skips in the shaft which then hoist it to the surface. Waste rock generated during shaft sinking, development and mining will be removed and disposed of on the surface in the waste disposal areas, to the extent such material cannot be utilized for road maintenance or utilized in the construction of the mine yard. Ore will be stockpiled on the surface near the shaft until shipment to a mill takes place.

After development work is completed in about three years, the mine will be operated at a 200 ton-per-day ore rate for approximately five years. It is hoped that planned underground drilling will increase the tonnage to be mined and consequently, will extend the operation's life by a number of years. The period of time required to exhaust the reserve is currently estimated to be 10 years. However, the duration of activities will ultimately be determined by the extent and mining grade of the deposit, as well as milling capacity and market conditions.

Employment at the mine during the first few years of development will range from 15 to 30 personnel. As production capacity grows, employment could reach a high of approximately 35 men at the 200 ton-per-day rate, working at least two shifts per day.

Most employees will be existing residents of the area. A few experienced miners and supervisors will be transferred from existing EFN operations, but the majority of the work force will be hired locally. Employees will be provided transportation to work with a mine van. Driving of individual vehicles to the mine site will be discouraged. Management and technical staff support will be from the Fredonia office. Air travel will be used to provide staff movement between Tusayan and Fredonia.

IV. AREAS TO BE DISTURBED

There are three specific areas that will be temporarily used or disturbed during the mine's life: (1) the mine site made up of the Area of Operations (14.7 acres) and adjacent diversion drainage channels (2.7 acres); (2) 1.7 miles of electric powerline tying the mine to public power; and (3) the use of various federal, state and NFS roads for mine access and haulage.

The Area of Operations where all mining activities will take place is shown on Plates 1 and 2. This area is part of a naturally treeless area and, therefore, no significant tree cutting will be required to install the surface facilities necessary to the mining activities. In designing this Plan of Operations, EFN has minimized the size of the Area of Operations as much as practicable by clustering the various surface facilities. The design of the Area of Operations will ensure adequate working area during mining while minimizing the area disturbed. Moreover, having identified through surface drilling the precise location of the ore deposit, the Area of Operations needed for mining is less than the exploration area previously authorized under Special-Use Permit 84-14. The locations of the shafts, office, warehouse, shop, waste disposal and ore stockpiles will all be generally located in the areas shown on Plate 2. Of course, further engineering and unexpected problems encountered in the excavation of the mine yard, shafts or building foundations could cause the actual mine facility layout to differ in minor detail from that shown on Plate 2. A core hole at the proposed shaft is yet to be completed and conditions could be found that would cause the main shaft to be relocated up to 50 feet from the location noted on Plate 2. Once the mine plant is constructed, a detail plot of all structures and the yard will be forwarded to the NFS. In any event, the surface impacts from the proposed operations will be unaffected by any necessary minor relocation within the Area of Operations.

Prior to the construction of the mine yard, the six-inch topsoil layer within the Area of Operations will be removed and stored at the northern edge of the Area of Operations. The placement of the topsoil stockpile in this location will assure that it will not be disturbed during mining activities. In addition, after construction of the water diversion facilities discussed below, the topsoil stockpile will be protected from erosion from surface runoff. At the end of mining, this topsoil will be reapplied over the Area of Operations and reseeded as part of final reclamation activities.

The main building will be built to near existing grade. Minor grading to establish drainage away from the building and to the south will be done. The shaft collar will be at the same elevation as the building floor or a few feet above the pre-mining contour. Drainage will be away from the main shaft. Prior to sinking, the mine yard will be built to its production grade or contour in an area of about 3 acres. This initial yard contains and extends 100 feet beyond all buildings and the main shaft. Minor amounts of borrow will be needed to obtain these grades and will be taken from material excavated during construction of the water diversion facilities or from other areas of the Area of Operations. Waste rock from shaft sinking and mine development will extend the yard to the shape noted on Plate 2. It is estimated that 40,000 cubic yards of waste rock will be generated over the life of the mine. This volume of rock will cover five acres to an average depth of five feet. Waste rock is defined as all rock moved in mining with less than 0.03% uranium. If additional waste is produced, it will be disposed of along the south and west edge of the mine yard. Relief between the south edge of the mine yard and the prior surface will reach 10 feet by the end of the mine's life. Non-ore bearing mine waste will be available for the maintenance of the nearby roads and drainage channels outside the Area of Operations, if necessary. Gravel will be brought from outside the Area of Operations to provide an all-weather surface to the mine yard.

Located on the yard and along its north edge will be the main building. This steel structure will house most surface activity and fixed equipment. The hoist, air compressors, stand-by generator, shop, warehouse, and ambulance will all be housed in this building. It will be 160 feet by 50 feet and, in part, contain two floors.

The main shaft will be located approximately 100 feet south of the main building and just northeast of the deposit. Located over the shaft will be the tallest structure within the Project Area, a 100-foot high headframe. Its base will be about 40 feet wide and extend toward the main building about 75 feet. Both the main building and headframe will be finished in some shade of green to blend with the natural surroundings.

Just east of the main building will be the mine office and showers in a portable building approximately 25 feet by 50 feet. The unit will come to the site fully equipped, needing only to be connected to utilities. In this same general area one to three other trailers will be located to provide lodging for a watchman and overnight staff personnel. No full-time residents, other than the watchman, are planned. Along this north edge of the yard, other minor items, supplies, and equipment will be stored. Tankage for water, gasoline and diesel fuel will be located in the same area. Water storage capacity should be approximately 12,000 gallons; gasoline less than 5,000 gallons; and diesel less than 10,000 gallons.

A water source of a few gallons per minute is needed for sanitation and underground drilling. At the start of activities, water will be trucked to the site. It is hoped that shaft sinking may generate a flow of a few gallons per minute of potable water from the base of the Coconino formation at approximately the 1,000-foot depth. If this does occur, this water will be collected and used at the site. However, in the event that no water is found in the shaft, a well to the Redwall of 2,500 to 3,000 feet deep would be located and drilled north of the mine yard.

Approximately 300 feet due south of the main shaft will be the vent/escape shaft. This second shaft is required by federal mine safety law which requires at least two routes to exit any operating mine. Both a fan to exhaust air and a small hoist will be located at this point. A small headframe, about 30 feet high will be placed over the vent/escape shaft. The escape hoist will be set in a metal building with dimensions of approximately 20 feet by 20 feet. Under normal operating conditions, a larger ventilation fan will be positioned over the ventilation shaft. However, in the event this shaft is needed for access or escape, the fan will be lifted off the shaft and a mancage lowered to any level in the mine.

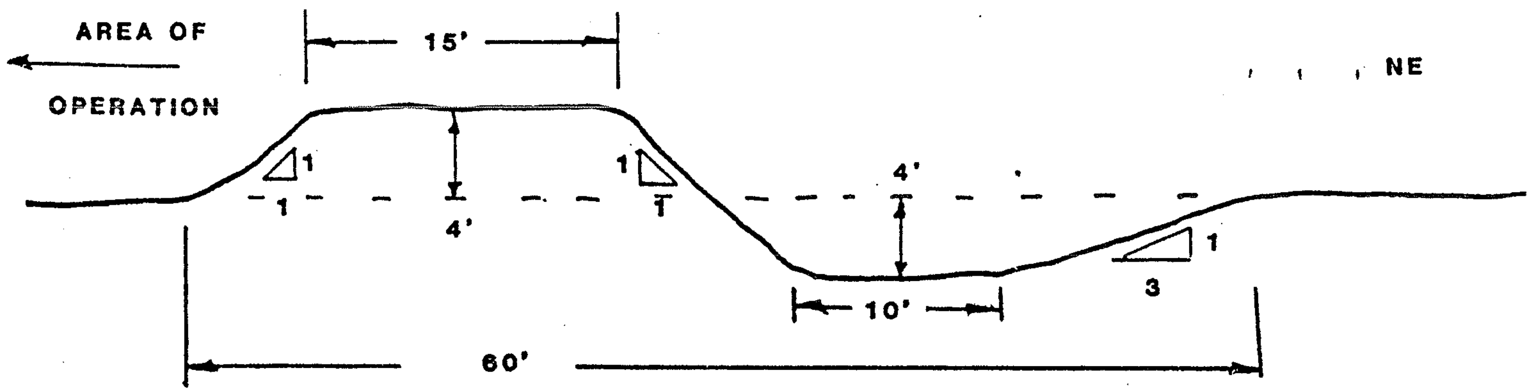
Located on the west and lower edge of the mine yard will be one or more water holding ponds. All surface drainage from the yard will flow into the pond or ponds. In addition, if excessive water is encountered in the course of mining it will be stored and treated in this area prior to discharge. In this regard, contemporaneously with the submittal of this

Plan of Operations to the NFS, a National Pollutant Discharge Elimination System (NPDES) Permit is being applied for to the Arizona Department of Health Services and the U.S. Environmental Protection Agency. No discharge is expected but this action is taken as a prudent business policy. In addition, a septic drainage field will be located just southwest of the yard in an area precisely located after soil testing.

A 6-foot chainlink security fence with lockable gates will surround the Area of Operations and "No Trespassing" signs will be posted. Gates in the fence will be closed and locked during periods of inactivity at the mine site.

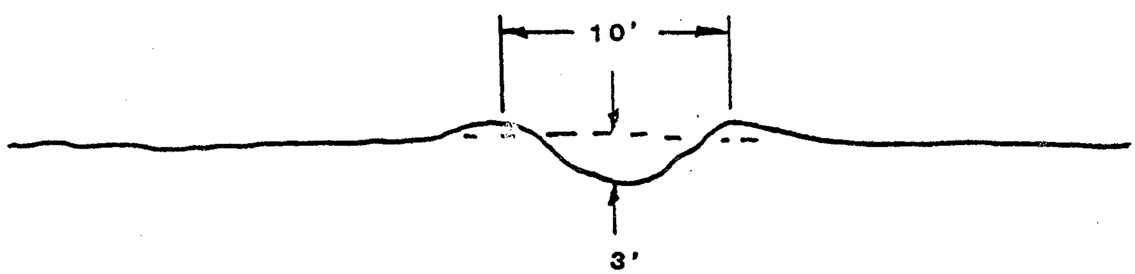
Because of the location of the Area of Operations within a portion of a half-mile wide grass-covered topographic low, one large and several small water diversion facilities will be constructed by EFN as shown on Plate 2 and Figure 3. These facilities will be maintained by EFN throughout mining activities to ensure that no surface runoff from outside of the Area of Operations is allowed to enter. The planned configuration of the Area of Operations will ensure internal drainage into the pond or ponds located along the west edge. All surface run-off within the Area of Operations and all water encountered during mining which cannot be utilized in connection with mining will be held on-site until it evaporates or until it meets the discharge standards under the NPDES permit.

Because the principal watershed is to the north or northeast, the main diversion channel will be positioned to divert all of the surface run-off to the northeast of the Area of Operations. After examining the annual rainfall of the area and the size of the watershed, EFN has designed this diversion channel to ensure it can accommodate not only normal anticipated surface run-off but also surface run-off anticipated in



MAJOR CHANNLE

northeast of Area of Operation



MINOR CHANNLES

mainly west of Area of Operation

figure 3. TYPICAL REBUILT DRAINAGE CHANNELS CROSS SECTIONS

any 10-year, 24-hour event. Specifically, EFN will build a trapezoidal channel and protective dike which is 1,600 feet in length and 60 feet in width, with a 10-foot wide channel bottom. The material generated in the excavation of the channel will be used to construct a bank or protective dike along its western edge to provide additional protection of the Area ~~of Operat~~ions in the event of a severe thunderstorm and its associated surface run-off. As shown in the idealized cross-section attached as Figure 3, the slope of the channel will be 1:1, and will be four feet deep with a 15-foot wide dike top. In construction of the channel and dike, EFN will remove the six inches of available topsoil from the area of construction until the channel is completed and then reapply it over the dike. Once the soil is spread over the dike, it will be seeded to protect it from erosion. During mining activities, the channel will be kept clean of debris to ensure proper functioning and, if necessary, portions will be rip-rapped. After mining activities are completed, the channel and dike will remain in place.

West of the Area of Operations are some minor drainages which EFN proposes to divert away from the Area of Operations with small triangular diversion ditches of up to three feet deep and 10 feet wide. A total of approximately 2,000 feet of such ditches will be required to assure no run-off from the west will enter the Area of Operations. The total area of water diversion channels will not exceed 2.7 acres.

The second area of disturbance caused by the proposed activities will be the result of the electric powerline tie connecting the mine site with the existing 69KW line that is located just east of US Highway 64. This 69KW line is owned and operated by Arizona Public Service Company. Starting at the existing line just east of US Highway 64, the proposed power line will follow the shortest access to the Area of

Operations. The line will be constructed at EFN's expense, but will be owned and operated by Arizona Public Service Company. Final alignment will be submitted by them and be subject to NFS approval.

In addition to the areas of disturbance discussed above, brief mention should be made of the roads needed for access and ore haulage. All of the roads required are in existence or are scheduled for construction. Upgrading and maintenance to insure adequate ingress and egress to the Area of Operations are needed. Nearly all employees and supplies will come from US Highway 64 southwest of the Project Area, on Forest Roads 305 and 305A. Upon approval of this Plan of Operations, and with the approval and supervision of the NFS, all road surfaces on non-paved access routes will be graveled, shoulders graded for drainage, culverts and other structures, as appropriate, installed and maintained for all-weather use by EFN.

Once ore haulage begins in approximately 2-1/2 years, Forest Road 305A will be used to Forest Road 302 in the center of Section 3, Township 29 North, Range 3 East. Haulage will then follow existing Forest Roads 302 and 307 to US Highway 64 on the east edge of the Kaibab National Forest, 19 road miles from the Area of Operations.

EFN will share in the required maintenance of the Forest roads used during ore haulage in proportion to use by EFN and other needs of the road bed.

Once ore production begins, it is anticipated that on the average, 10 ore trucks per day will enter and leave the Area of Operations.

V. MEASURES TO LIMIT DISTURBANCE

This Plan of Operations has been designed to minimize disturbances to the environment to allow reclamation after its completion to the standards required by law. The Project Area is as compact as practicable with stockpile and disposal areas clustered together where appropriate.

In the design of this Plan of Operations, EFN recognized that one of the important natural environmental issues at the site is proper handling of surface water run-off from adjacent watersheds. To address this issue, and to insure the integrity of the Area of Operations during activities, flood control measures have been built into the plant layout. As designed, surface water cannot enter the Area of Operations from any direction. In addition, rainfall within the yard will be retained within the Area of Operations because of its internal drainage. The low point in the yard will discharge into holding ponds along its west edge. The holding pond or series of holding ponds will be lined with plastic or impervious material. All water encountered during mining which cannot be utilized in connection with mining will be discharged into these holding ponds and held until it evaporates or treated until it meets the discharge standards applicable under the NPDES permit.

The central portion of the mine yard will be used to stockpile ore prior to shipment to a mill for processing. Prior to stockpiling ore grade material in the locations shown on Plate 2, EFN will construct an ore pad upon which all ore grade material will be stockpiled pending removal from the Project Area. Each ore pad will be at least one foot thick and shall be constructed utilizing an equal mixture of limestone and shale produced from the underground excavation at the Project Area. In all circumstances where ore grade material will be stockpiled on the ground, pending removal, it is the practice of EFN to construct similar ore pads. The purpose of the ore pad is to prevent leaching of mineral values contained within the ore grade material into the soil due to rainfall. Such leaching is prevented by the impermeable characteristics of the shale and by the chemical reaction which occurs when and if any dissolved uranium contacts the limestone component of the ore pad.

In the disposal area identified as High-Waste, all material containing in excess of 0.03% uranium, which is uneconomical to ship, will be temporarily stockpiled. At present, it is anticipated that approximately 10,000 to 20,000 tons of such low grade material will be produced during mining activities. In light of the volatile market prices for energy, it is expected that nearly all of this material will ultimately be shipped to a mill for processing before the close of mining activities. However, in the event any material remains in the High-Waste stockpile at the close of activities, prior to final reclamation, EFN will haul this material from the site or dispose of it underground in the mined-out workings.

Because of the location of the Area of Operations in a naturally treeless area, there is little likelihood of increased risk of forest fire because of the proposed mining activities. In addition, the relative frequency of brief summer rains in the area further reduces risk of forest fire. However, fire security will be maintained at the surface facilities as well as on all vehicles traveling to and from the Area of Operations.

Although EFN considered a route for the proposed electric powerline to the Area of Operations which would follow existing roads, the route shown on Plate 2 was chosen as preferable due to the reduced length and lack of visibility to normal vehicular traffic.

While no complete new road bed is required for this project, some realignment, up-grading and maintenance, as needed, will be undertaken by EFN in consultation with the NFS. EFN has and will continue to work with the NFS and other users of the forest during activities so that road impacts will be minimal.

Ore haulage from the Area of Operations will be by independent truck contractors, with single trailer trucks of 20-ton capacity or double-trailer trucks of 25-ton capacity that meet the Arizona Highway weight restrictions. Each load will be covered with a tarpaulin, lapping over the side about a foot and secured every few feet around the truck bed. Thus, wind erosion and uneven roads will not cause any loss of material in transit. In the event of a truck accident that causes spillage of ore, EFN will take immediate aggressive action to clean up any spilled material. All uranium ore will be removed from the site of the spill within two working days of the time of the spill, provided that the action is not prevented by conditions beyond the control of EFN.

VI. MEASURES TO RECLAIM AT THE END OF THE OPERATIONS

At the end of all mining activities, EFN will remove all structures, clean the Area of Operations, seal the mine entrances, and reclaim the disturbed areas.

After the removal of all equipment, the main shaft and vent shaft will be sealed in a manner approved by the appropriate regulatory agencies. At the shaft openings, the concrete slab used during operations will be left in place and used in the shaft sealing system. All supplies and equipment in the buildings within the Area of Operations will be removed. The headframe, buildings, and tankage will all be taken down and removed. All concrete slabs and footings other than those around shafts will be excavated, broken and buried in the mine yard or backfilled into the shafts. Minor amounts of other debris will be handled similarly.

The mine yard will be radiometrically surveyed and any material found which exceeds radiation regulations will be removed from the area, backfilled into the shaft or hauled from the Project Area. In the event treatment of water from the underground working is needed during mining operations, sediments resulting from this will be scalped from the ponds and either hauled from the Project Area or disposed of underground in the mined-out workings.

The Area of Operations which has relief only along its south and west edge will have its edge rounded and recontoured to blend with the surrounding area. All holding ponds will be filled and recontoured. Thereafter, the previously stockpiled topsoil will be spread evenly over the entire Area of Operations.

All ground surface which has been disturbed will be drill-seeded using a seed mixture as follows, or any recommended mixture approved by the NFS prior to application:

Fairway Crested Wheatgrass	5.0 lbs./acre
Intermediate or Western Wheat-grass	5.0 lbs./acre
Yellow Sweet Clover	2.0 lbs./acre
TOTAL	12.0 lbs./acre

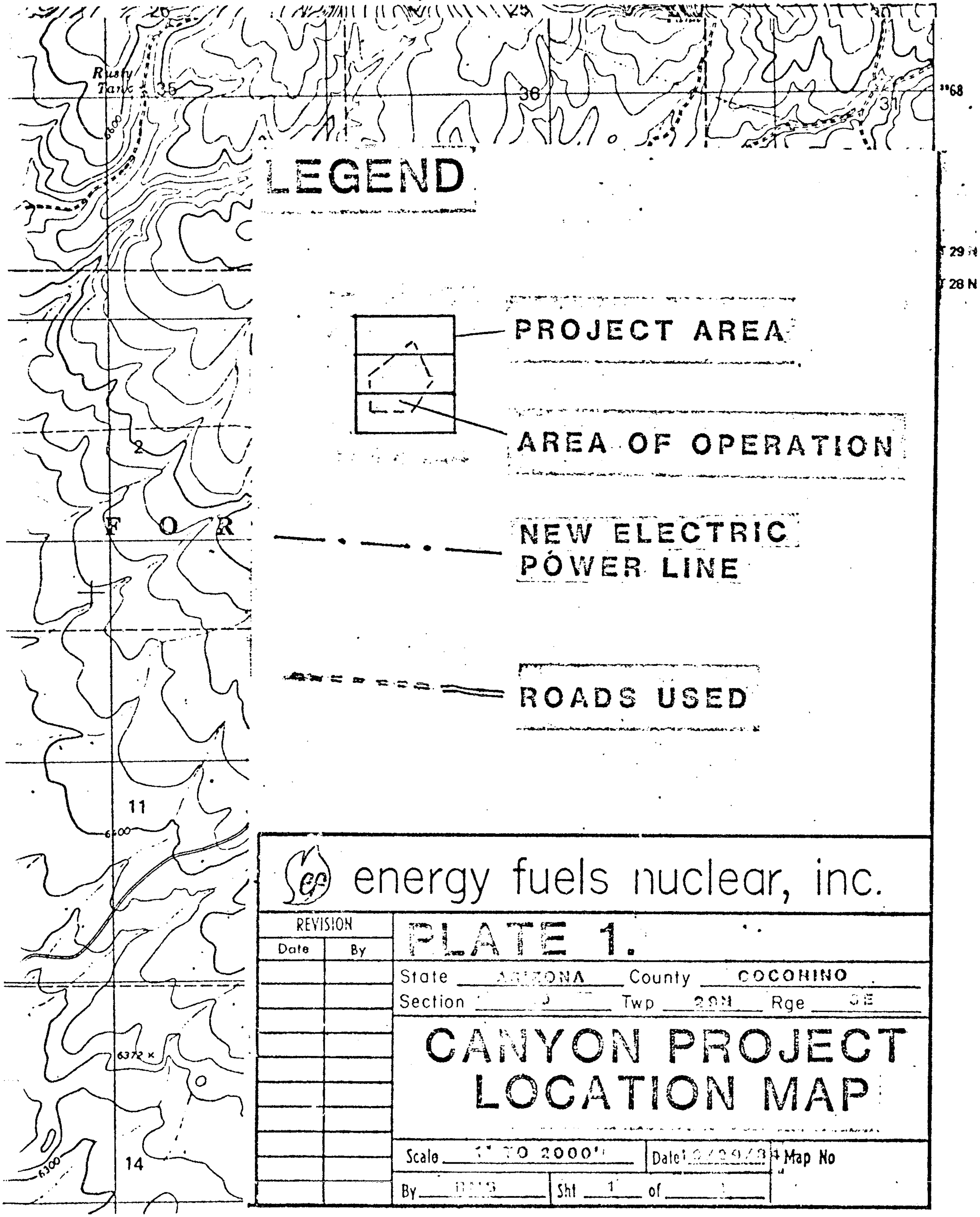
All drainage channels used during operations will be left in place, so as to direct surface runoff around the area of reseeding until revegetation has been adequately reestablished. Thereafter, if requested by the NFS, these channels will be similarly recontoured and reseeded.

The half-mile of road between the Area of Operation and Forest Road 303A will be graded back to surrounding contour, scarified and reseeded.

The powerline will be dismantled if no other uses exist, as directed by the NFS.

VII. CONCLUSION

EFN, as operator of the Canyon Mine, has prepared and submitted this Plan of Operations. The Plan was developed in accordance with guidelines contained in the published regulations, and pursuant to discussions with the NFS. EFN will provide additional information as required, and will entertain a request for further discussion or on-site meetings. EFN believes that implementation of this Plan of Operations will ensure that there is no unnecessary or undue degradation of the land associated with the Canyon Project.



Rusty Tank
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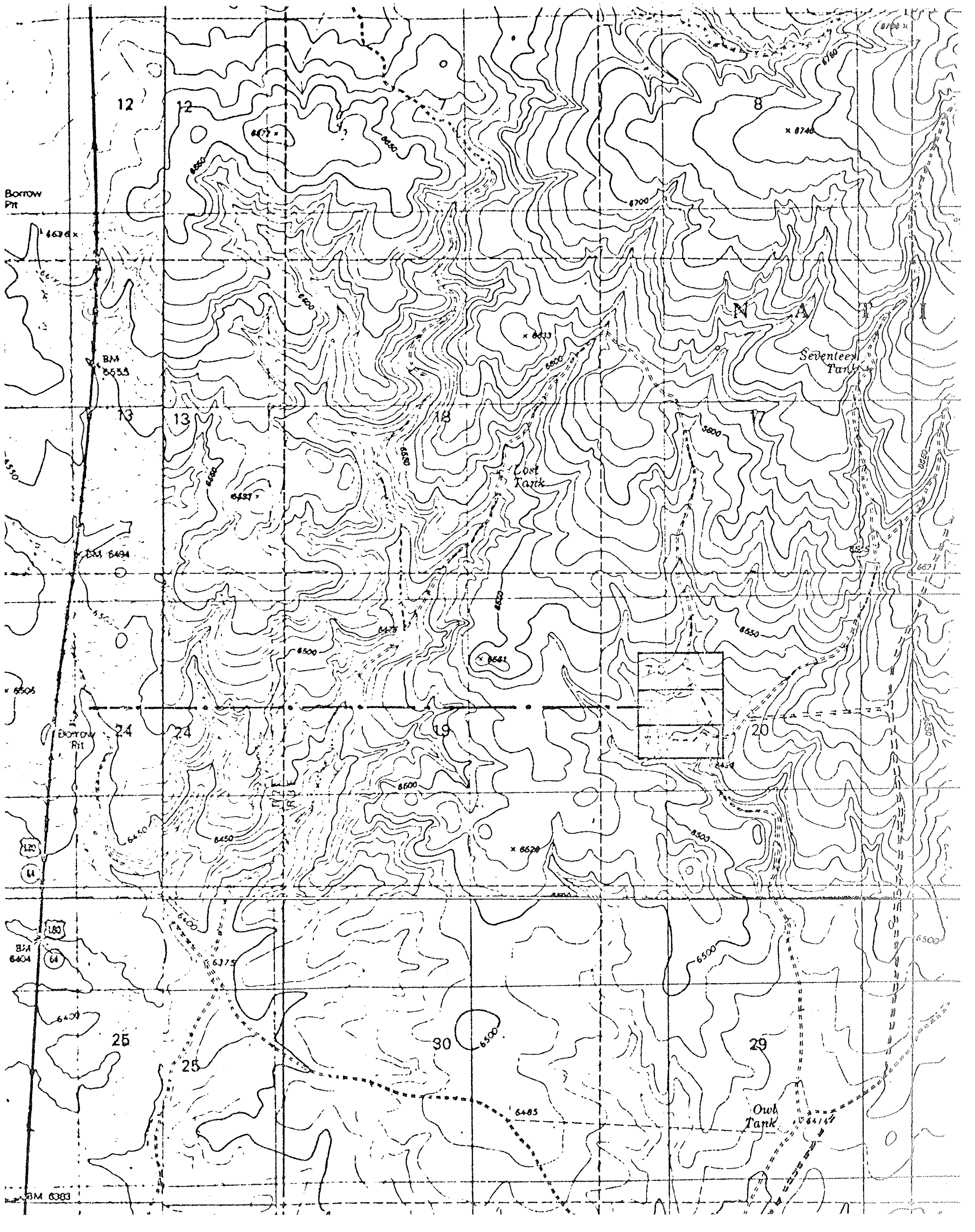
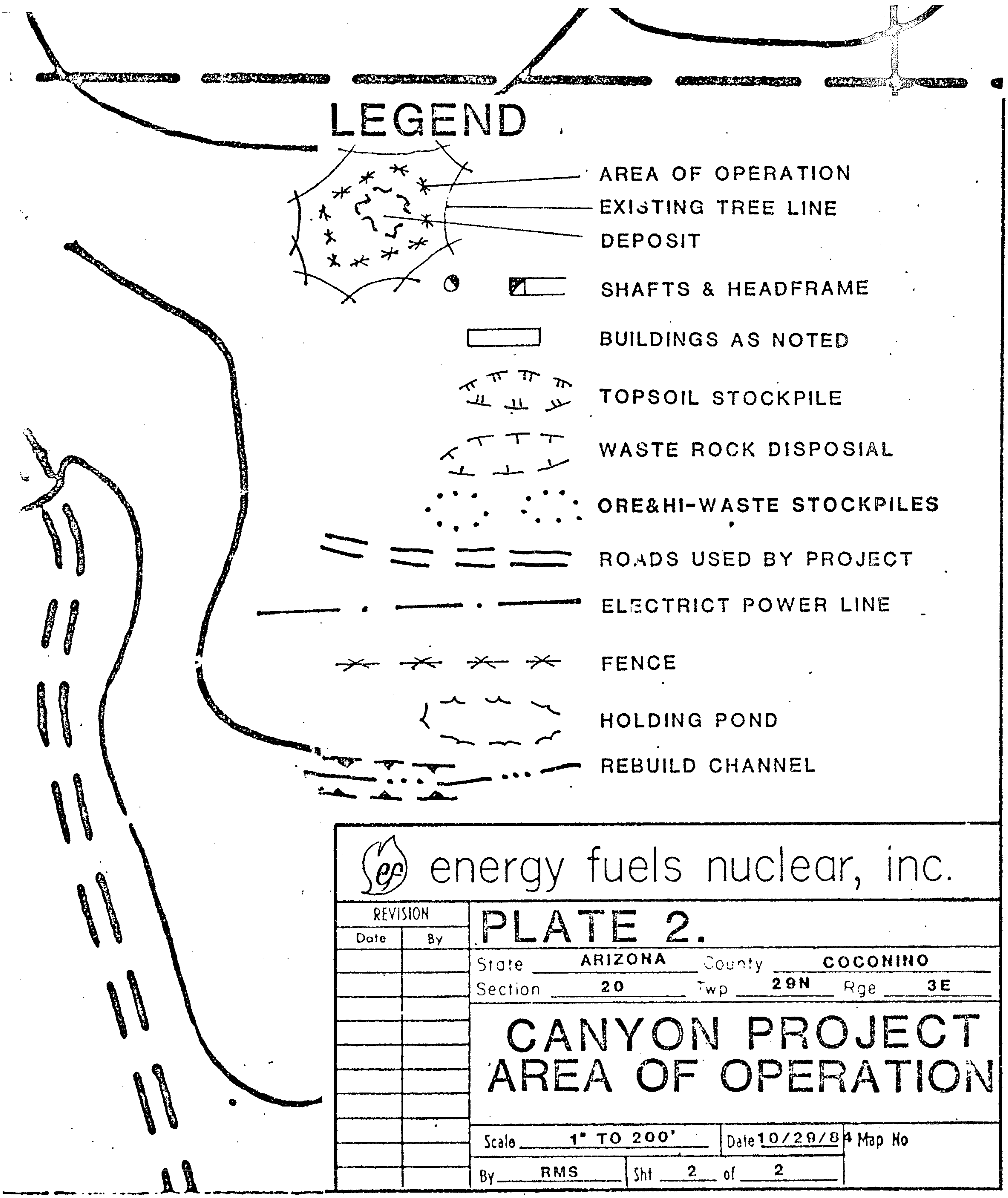
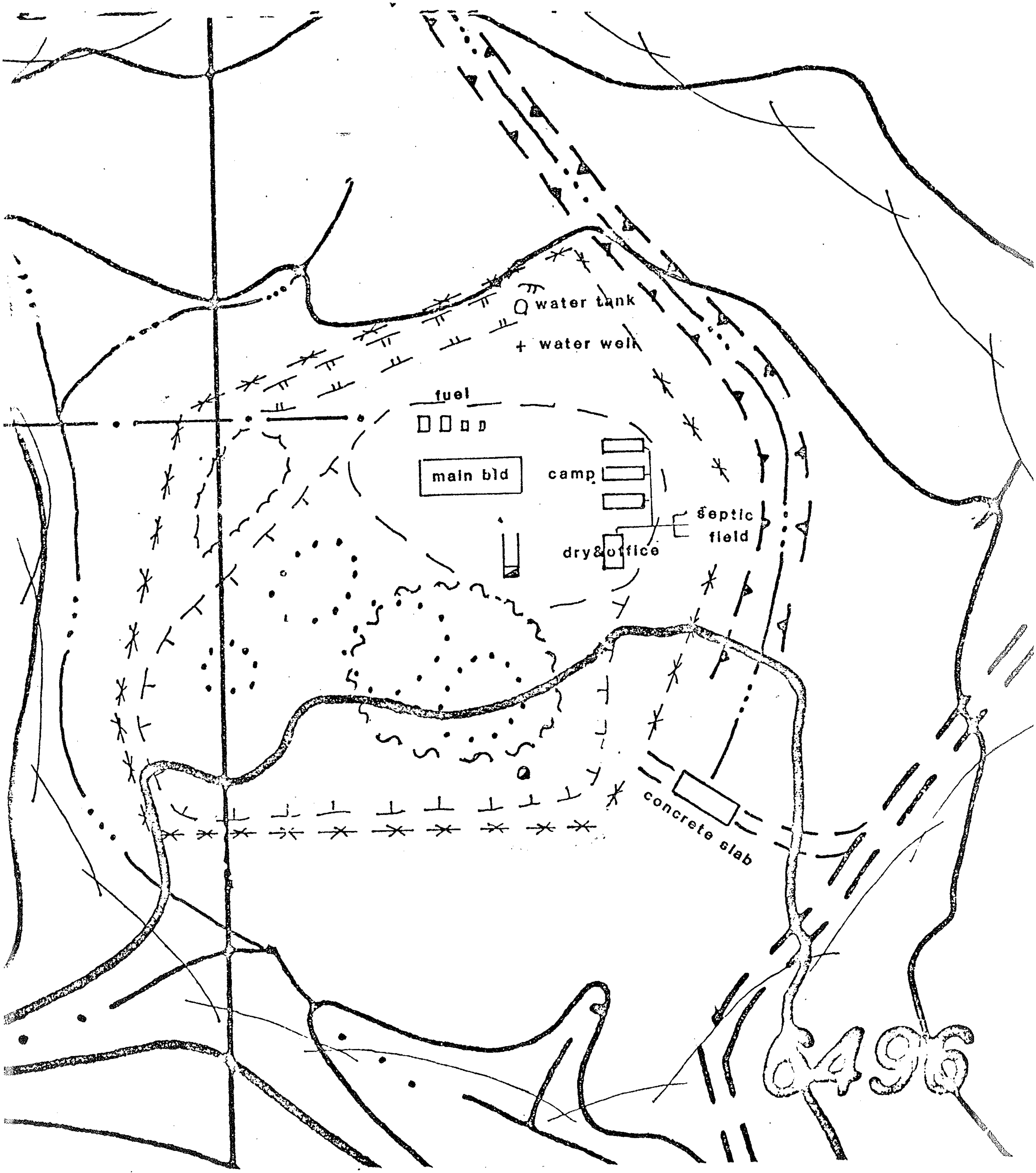
LEGEND
PROJECT AREA
AREA OF OPERATION
NEW ELECTRIC POWER LINE
ROADS USED
T 29 N
T 28 N
energy fuels nuclear, inc.
REVISION
Date
By
PLATE 1.
State
County COCONINO
Section
Twp 29N
Rge
CANYON PROJECT LOCATION MAP
Scale 1" TO 2000'
Date
Map No
By
Sht 1 of



12
12
7
8
× 6740
6700
Borrow Pit
6650
6600
× 6633
Seventeen Tank
13
13
18
17
6800
Lost Tank
BM 6555
BM 6494
6500
6550
6450
24
24
19
20
Borrow Pit
6600
× 6620
6500
BM 6404
6375
6400
25
25
30
29
6485
Owl Tank
BM 6383

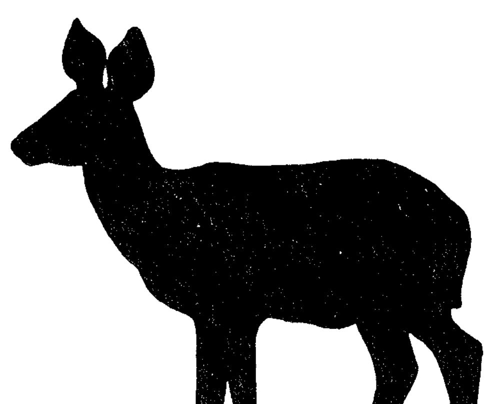

LEGEND
AREA OF OPERATION
EXISTING TREE LINE
DEPOSIT
SHAFTS & HEADFRAME
BUILDINGS AS NOTED
TOPSOIL STOCKPILE
WASTE ROCK DISPOSIAL
ORE&HI-WASTE STOCKPILES
ROADS USED BY PROJECT
ELECTRICT POWER LINE
FENCE
HOLDING POND
REBUILD CHANNEL
energy fuels nuclear, inc.
REVISION
Date
By
PLATE 2.
State ARIZONA County COCONINO
Section 20 Twp 29N Rge 3E
CANYON PROJECT
AREA OF OPERATION
Scale 1" TO 200'
Date 10/29/84
Map No
By RMS
Sht 2 of 2


water tank
+ water well
fuel
main bld
camp
septic
field
dry&office
concrete slab
6496

Appendix

B

Engineering Report



ENGINEERING REPORT

This report covers the following items:

- Transportation Routes for Ore Haul
- Evaporation Pond Needs
- Dust Control on Haul Roads
- Employee Parking
- Electrical Power
- Reclamation Plan

The purpose of this section is to review and estimate various options to provide the needed service. The estimates are for use in comparative analysis for the Canyon Mine.

The costs may not reflect the actual price of doing the work since they represent estimates based on former Government contracts and other sources which require Davis-Bacon wages and compliance with industry specifications which may or may not be used in the work. Also these estimates are preliminary, in advance of project survey and staking. The same basis was used on all work estimated so the figures are comparative.

HAUL ROUTES

General

This section analyzes haul routes from the proposed Canyon Mine on the Tusayan Ranger District of the Kaibab National Forest. A total of seven routes have been analyzed in detail. The final destination of the haul is the mill site in Blanding, Utah. To provide uniformity in comparison of the routes, the junction of SR 64-US 89 at Cameron, Arizona was selected as a common point on all haul routes from the mine.

The Tusayan District is reasonably well-roaded from past activities. The roads that exist are narrow, unsurfaced, generally have poor alignment and are considered low standard. This is due to the lack of the development of an early transportation plan, established design standards and an inexpensive surfacing material source in the area. The need for routes to the east has been low and has been met by the single road off the Coconino Rim at Hull Cabin (Forest Road #307). Because it is steep and rocky, the rim has been a natural barrier for travel routes in the past.

Road Standard

The analysis considers that the selected travelway across the Forest to haul the uranium ore will be upgraded to a single-lane (16 ft. wide) route with good grade and alignment, ditched and culverted for drainage and surfaced with 6 inches of aggregate. This same standard applies to the option (#7) across State and other land. For the options that consider a new route off of the Coconino Rim, the alignment in that portion is reduced to a fair standard. All grades are to be a maximum of 8 percent. Clearing would be restricted to a minimum width necessary to safely accommodate the traffic while allowing for snow removal and snow storage.

In the proposal for the project, EFN has noted that they will haul 200 tons of ore per day (10 vehicles). The described 16-foot standard will provide for this use except during spring snowmelt or other periods of adverse weather (heavy snows, prolonged rainy spells, etc.), during which time the haul route subgrade would not support the loads. It is estimated that the haul days lost with the proposed standard would be less than one month per year. To increase the days hauled per year would require increased surfacing depth to provide the support during the wet weather.

Forest Transportation Needs

The major uses of the transportation system on the Tusayan District are for general administrative needs, dispersed recreation (including hunting), timber hauling and range use. Recently there has been added the minerals exploration use, however, it is recent and very scattered. The future extent of this use is not known.

The major routes east of Highway 180 in the area being considered are the east-west Forest Roads No. 302, on the north side of the District, and No. 320 in the south-central part of the District. The majority of use originates from Highway 180, with these two roads serving as feeders.

Traffic counts have been taken on several roads on the District. They vary considerably along any specific road segment. The attached map (#1) shows the volumes in terms of seasonal average daily traffic (SADT). This term accounts for lack of winter access. The counts taken to date fluctuate considerably due to various resource activities in a specific area, e.g., timber haul, range projects, etc., but do point out that the traffic volume is low. Excluding private land, there are no major attractions within the Forest to create a continuous and higher level of travel, nor is any planned.

Past studies have shown that when roads of a similar nature are improved, the volume of traffic will increase approximately 20 percent, in addition to expected annual increases, which for the current low level of use is a minor impact on the roadway. This increased use is a combination of traffic from other roads and new users taking advantage of the improved access.

The breakdown of the transportation system on the Tusayan Ranger District shown below best describes the condition of roads.

A) Paved roads	3 miles	- Bituminous surfaced roads at 10-X Campground and at the Tusayan Administrative Site
B) Gravel surfaced (Routine annual maintenance)	8 miles	- Road 302
C) Unsurfaced (Routine annual maintenance)	190 miles	- Accessible by sedan in dry weather.

D) Unsurfaced (Not maintained annually)	1,124 miles	- Accessible by pickup truck or other high clearance vehicle. Most of these roads were either never built to an acceptable standard or have deteriorated to a low standard.

One of the major problems with the transportation system on the Tusayan District is the lack of surfacing. Accessibility and the road standard have been poor as a result. The sources of material to overcome this problem are quarry pits. No known natural aggregate sources such as alluvial deposits, have been located in the area. Based on this assumption, the costs of placing gravel on the haul road is expected to be a major factor in the development of the mine. An alternative to using crushed rock would be to import a less expensive material such as cinders, from the Flagstaff-Williams area. Cinders have a shorter life than crushed aggregate, however this is not a major factor for the short term (5 years) and low haul rate (200 tons/day).

Description of Haul Route Options

The following described options are shown on Maps #2 & #3. Construction requirements and operation and maintenance costs are on Table 1.

Option 1

This is the EFN proposal. The route has the benefit of being the better existing route from the mine to the east side of the District. The short section of new construction are to connect the mine to Road 302 and for an improved access off the Coconino Rim near Hull Cabin. Reconstruction of existing routes will be minor consisting of surfacing and minor widening, both of the travelway and corridor clearing. The roads (No. 302 and 307) are existing Forest arterial roads; improvement to these would enhance the system by bettering access within the timbered area.

Road #	Length	Width	Alignment	Surfacing	Needs
305A	1.7	8	Very Poor	None	Major reconst.
New	2.3	N/A			New Constr.
302 (1)	4.0	12	Good	Gravel	Minor Widening
302 (2)	5.2	12	Fair	None	Minor reconstr.
New	1.3	N/A			New Constr.
307	13.0	12	Good	None	Minor widening
	27.5				

Option 2

This is the EFN proposal modified to improve the haul by shortening the distance and improving the haul route (new) off the Coconino Rim. The first modification is obvious when reviewing the map since it shortens haul length. The second modification would improve the existing grade at Hull Cabin. These modifications would increase initial cost but shorten the haul distance by 2.1 miles.

Road #	Length	Width	Alignment	Surfacing	Needs
305A	1.7	8	Very Poor	None	Major reconstr.
New	2.3	N/A			New constr.
302	1.2	12	Good	Gravel	Minor widening
2719,2720, 2723	3.9	8	Poor	None	Reconstr.
New	0.5	N/A			New constr.
302	1.5	12	Fair	None	Minor reconstr.
New	1.3	N/A			New constr.
307	13.0	12	Good	None	Minor widening
	25.4				

Option 3

This option was proposed to describe the shortest route from the mine to Cameron and in so doing reduce the surfacing costs and haul costs. A proposed new location off the Coconino Rim near Newt Lewis Tank is included. The route includes lower standard roads that are of secondary status in the forest transportation system. This upgrading would in all probability draw traffic from the other routes and replace Road 302 as the Forest arterial road on the north end of the District.

Road #	Length	Width	Alignment	Surfacing	Needs
305A	1.2	8	Very poor	None	Major reconst
343	5.6	10	Poor	None	Major reconst.
2732/304	3.4	10	Fair	None	Reconstr.
301A/317	3.9	10	Fair	None	Reconstr.
New	4.4	N/A			New constr.
307	5.5	12	Good	None	Minor widening
	24.0				

Option 4

This option was proposed to reduce the effect on wildlife and would utilize the proposed location at Newt Lewis Tank off the Coconino Rim The southern Forest arterial road No. 320 is used as a portion of the haul route to both reduce initial road reconstruction costs and to get further removed from the priority identified wildlife habitat areas.

This route is longer than the previous options, thus adversely affecting surfacing and haul costs.

Road #	Length	Width	Alignment	Surfacing	Needs
305A	2.8	8	Very poor	None	Major reconst.
305	3.8	12	Good	None	Minor reconst.
320	13	12	Good	None	Minor reconst.
311/320	4.9	10	Good	None	Minor reconst.
New	4.4	N/A			New constr.
307	5.5	12	Good	None	Minor widening
	34.4				

Option 5

This modification to option #4 was proposed to further mitigate wildlife concerns. The route uses Road 320 and an alternate location off the Coconino Rim near Upper Cabin Tank. This would be a very desirable and cost-effective location if future mines are developed in the southeast quadrant of the Tusayan Ranger District. By comparison, this proposed location is the most costly of the 7 options because of the steep terrain off the Coconino Rim.

Road #	Length	Width	Alignment	Surfacing	Needs
305A	2.8	8	Very poor	None	Major reconst.
305	3.8	12	Good	None	Minor reconst.
320	18.3	12	Good	None	Minor reconst.
316	2.0	12	Good	None	Minor reconst.
310	2.3	10	Fair	None	Major reconst.
New	2.9	N/A			New Const.
307	1.4	12	Good	None	Minor widening
	33.5				

Option 6

This route is proposed to minimize initial development and maintenance cost. It uses highway haul as the means to get to the mill site via Cameron. The route would virtually eliminate haul route maintenance. Its drawback is the increased haul distance to Cameron by a factor of two and one-half over the EFN proposal with a corresponding increase in haul cost.

Road #	Length	Width	Alignment	Surfacing	Needs
305A	2.8	8	Very Poor	None	Major reconst.
305	2.0	12	Good	None	Minor reconst.
	4.8				

Option 7

This option uses State Route 64 to Valle, US 180 to Coconino Forest Road 417, then the 417 road and an extension across State and private property to Highway 89.

The advantages of this route are:

- Haul costs are lower than Option #6 but higher than on-Forest options.

- First costs for construction are low because the 417 road (with extension) can utilize a cinder surfacing to reduce costs.

- The road is lower in elevation reducing the effects of winter snows.

The disadvantages are:

- A right-of-way is needed across private and State lands.

- Haul costs are comparatively high.

Road #	Length	Width	Alignment	Surfacing	Needs
305A	2.8	8	Very poor	None	Major reconst
305	2.0	12	Good	None	Minor reconst.
County Rd (#417)	4.0	24	Very good	Cinders	Surface repl. only
State/ other	21.0	12	Good	None	Minor reconst/ widening

Other routes considered but eliminated from further review:

A) Use of SR 64 through the National Park. This route is closed to commercial haul.

B) Use of the railroad at Anita to haul the ore. The future of the railroad from Williams to Anita is too uncertain to include this as an alternative.

C) Use of US 180 through Flagstaff (via Kendrick Park). This route is a reduction of only 8 miles over the haul through Williams. Furthermore, the road is closed at times during winter and the alignment, grades, and width would increase haul costs to more than offset the reduction in miles.

D) Haul across the Navajo reservation. These routes were eliminated because of greatly increased costs due to irregular terrain and poor access off the Coconino Rim.

Unit Cost Summary

The following is a summary of the costs used in generating the figures in Table 1.

A - New Construction Costs at Proposed Rim Locations (Without Surfacing)

Haul Route Option #1

1) Lockett to Basin. Length 1.4 miles — $ 86,250
Basin to Belknap (Rd. 307). Length 0.4 miles — $ 34,850

Haul Route Options #3 and #4

2) Newt Lewis to Basin. Length 2.2 miles — $213,000
Basin to Sand Tank (Rd. 307). Length 2.2 miles — $112,000

Haul Route Option #5

3) Upper Cabin to Basin. Length 1.4 miles $376,000
Basin to Bull Tank (Rd. 307). Length 1.4 miles $ 83,000

B - <u>New Construction Costs - Across Forest</u> - (Surfacing not Included)

1) New Construction $ 16,790/mile

C - <u>Reconstruction Costs - Across Forest</u> - (Surfacing not Included)

1) Existing Road, Good Condition, Minor Work $ 3,200/mile

2) Existing Road, Poor Condition, Major Work $ 11,250/mile

D - <u>Surfacing Cost</u> (16' wide x 6" deep x 1 mi.)

1) Crushed Rock ($20/C.Y.) $ 39,360/mile

2) Cinders (Option #7 only) ($7/C.Y.) $ 13,800/mile

E - <u>Haul Costs</u>

1) Highway = $0.10/Ton Mile $ 7,300/mile year

2) Forest Rd., Gravel, Good Grade and Alignment = $0.195/Ton Mile $ 14,200/mile year

3) Forest Rd., Gravel, (Rim) Poor Grade and Alignment = $0.389/Ton Mile $ 28,400/mile year

F - <u>Maintenance Costs</u>

1) $0.013/Ton Mile $ 1,000/mile year

POND NEEDS

Three sources of water will be stored in ponds at the mine site. These are 1) mine pumping water, 2) runoff contaminated by ore and other work areas which could be in contact with ore, and 3) runoff from non-contaminated area. Separating contaminated water will permit release of other water. Contaminated ponds are to be lined.

The design criteria utilized for the site is:

A) Evaporation, gross 52 inches annually = 4.33 feet. (Source USGS measured at Kaibab Reservoir, Williams, AZ).

B) Rainfall, 14.5 inches annually.

C) 100-year flood = 3.0 inches in 24 hours.

D) Total area - 15.0 acres.

1 - Mine pumping Water, pond lined.

Volume EST = 1 x 10^6 gal/year = 3 ac. ft.
Pond Volume needs = 3 ac. ft + rainfall
Area = $[3 \text{ ac} + (\frac{14.5 + 3}{12}) \times \text{area}] / 4.33$ = 1.1 acres (4.3' deep)

2 - Ore and other contaminated runoff, pond lined.

Estimated area - ore pile = (2 acres) + bldgs. roads, etc. = (2 acres)
Estimated runoff rate = 50%.
Volume est. = 4 acres x 0.5 x $\frac{14.5 + 3}{12}$ + rainfall

Pond vol. need = 2.92 ac. ft + rainfall
Area (same as 1) = 1.1 acres (4.3 ft. deep)

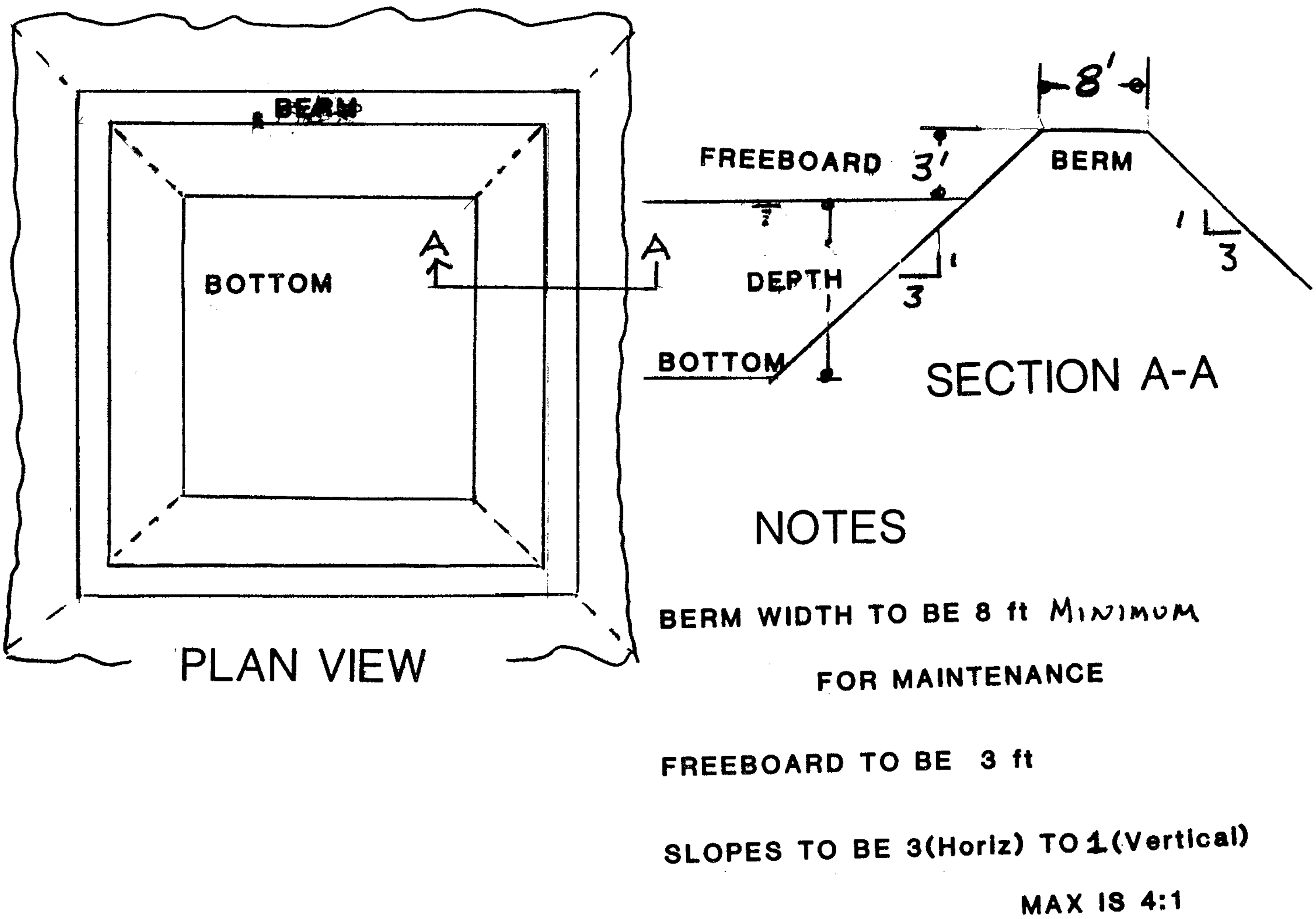
3 - Non-contaminated runoff (can be settled and discharged), pond unlined.

Estimated area = 8.8 ac = 15.0 acres - (less ponds and area in #2)
Estimated runoff rate = 10%, pond depth to be 6 feet.
Volume est = 8.8 ac x 0.1 x $\frac{14.5+3}{12}$ x + rainfall

Area needs = 1.65 + rainfall = 0.5 ac (6 feet deep)

There are combinations of ponds that could be utilized. The most economical would be to combine the mine-pumping water and contaminated runoff into one lined pond with a separate unlined pond for the noncontaminated water. This combination would minimize the number of ponds and allow for the release of the water from the non-contaminated pond quickly after a storm.

Pond Design Criteria from Arizona DHS Engineering Bulletin No. 11



DUST CONTROL

Several sections of haul road have been identified as requiring dust control. These roads are in the vicinity of Hull Cabin on Road 302 and 307.

The method of dust control which has been utilized on other forest roads is with magnesium chloride. Two applications per season of this material, in liquid form, has been an economical solution to the dust problem.

Cost Estimate:

Application Rate = 0.5 gal/sq. yd., twice per year.
Material Cost = $75/ton, 25 tons per mile.
Road Preparation Costs = $450/mile (watering and shaping).

Cost = $2,330/mile per application.

EMPLOYEE PARKING

Employment at the mine is described in the Plan of Operation as being in the range of 15 to 30 employees and could reach a high of 35 persons with the potential for multiple shifts to achieve the desired production rates. The plan further notes the transportation of workers to the job site could be by company-owned vans (preferred in Plan of Operation) or by individually owned worker vehicles.

The costs associated with these two methods are shown below:

A) Company-Owned Vans

Two or three vans to transport the employees to the job site would require a maximum of three spaces, each space to be 10 feet x 24 feet. These parking spaces would be provided adjacent to the entrance roadway.

Area = 3 ea. x 10' x 24' = 720 S.F. or 0.017 acres.
Costs: Vans - 3 ea. x 17,000 ea = 51,000
Parking Surfacing = 720 S.F. x 6 " x 20/c.y. = 300
TOTAL $51,300

B) Individually Owned Vehicle

Thirty-five (35) vehicles, privately owned and driven by each worker would require a maximum of 35 spaces. Each space would be 10 feet x 24 feet and would be located adjacent to the entrance road on the outside of the security fence.

Area = 35 ea x 10' x 24' = 8,400 S.F. or 0.193 acres.
Costs: Shaping = 1/2 day with grader @ $100/hr = $400
Gravel = 8,400 S.F. x 6" x 20/c.y. = 3,200
TOTAL + $3,600

ELECTRICAL POWER

The electrical power at the site would be obtained by a line to the mine site. Three options are considered in this section. These are described in the following. Costs of the line were estimated from N.P.S. cost summaries.

A - An Overhead Line from the 69 K.V. line to mine.
(Shortest Route)
This is the proposal by EFN. The distance is 1.7 miles. Minor alignment changes to prevent the corridor effect would be required. Since the line is intended to last only 5 years, an improved work road for installation or maintenance is not required. Clearing would be to the minimum requirements of the power company, APS. Within the clearing, the stumps, small trees, and shrubs could remain.

Cost Estimate: Clearing, width = 50', area = 10.3 acres
Clearing, Unit Cost $1,000/acres; $ 10,300
Line Cost @ $47,000 mile = 79,900
Total Cost $ 90,200

B - An Overhead line from the 69 K.V. Line to mine, following Forest Roads 305 and 305A

This route is a distance of 4.8 miles. Access for installation and maintenance would be along the roads. Some additional clearing would be required to accommodate the powerline. Stumps, small trees, and shrubs could remain in the cleared area.

Cost Est.; Clearing = Additional width = 18', Area = 10.5 ac.
Clearing - Unit Cost = $1,000/ac; $ 10,500
Line Cost @ 47,000/mile = 225,600
Total Cost = $236,100

C - An Underground Line from the 6.9 K.V. line to the mine following Forest Road 305 and 305A

This proposal is the same as "B" above except that it is underground. The use of an underground line would result in further clearing reducitons. The depth of bury is three feet minimum and would be in accordance with Arizona Public Service requirements. Some rock would be encountered in the excavation.

Cost Estimate: Clearing: width = 10', Area = 5.5 acres
Clearing Unit Cost = $1,000/acres, $ 5,500
Line Cost = $12/lin. ft. 304,100
Total Cost = $ 309,600

RECLAMATION PLAN

At the end of mining activities, Energy Fuels will remove all structures, clean the Area of Operations, safely dispose of contaminated material, seal the mine entrances and reclaim the disturbed areas.

After the removal of all equipment, the main shaft and vent shaft will be sealed in a manner approved by the appropriate regulatory agencies. At the shaft openings, the concrete slab used during operations will be used in the shaft sealing system. All supplies and equipment in the buildings within the Area of Operations will be removed. The headframe, buildings, and tankage will all be taken down and removed. All concrete slabs and footings other than those around shafts will be excavated, broken and buried in the mine yard or backfilled into the shafts. Minor amounts of other debris will be handled similarly.

The following is a list of items to be accomplished during the reclamation process, along with an estimate of costs involved:

1 - Remove:	a) Head Frame (salvage	
	4 men x $150/day x 10 days	$ 6,000.00
	Crane @ $60/hr. x 10 days	6,000.00
	b) Big Building (2 story)	
	4 men x $150/day x 10 days	6,000,00
	c) Water Tank (12,000 gal)	
	1 man-day x $150/day	150.00
	d) Gasoline Tank (5,000 gal)	
	1 man-day x $150/day	150.00
	e) 5 Small Buildings	
	4 men x $150/day x 10 days	6,000.00
	f) Chain-link fence (D-8 Cat)	1,200.00
	g) Rip-rap (D-8 Cat).	1,200.00
	H) Dike (D-8 Cat)	4,800.00
	i) Waste Ore (Push into Shaft)	
	40,000 CY w/D-8 Cat = 14 days	16,800.00
2 - Cap Water Well		100.00
3 - Break and Bury Septic Tank		150.00
4 - Break and Bury Concrete Slabs		1,200.00
5 - Dismantle Utilities		1,200.00

6 - Powerline Cleanup and Seeding (3.4 ac.)	$	680.00
7 - Obliterate Entrance Road (including concrete slab) 12 hrs. D-8 Cat @ $150/hr.		1,800.00
8 - Seal Shafts (w/slabs) 8-hrs. D-8 Cat @ $150/hr.		1,200.00
9 - Rip and Seed (Yard and Road)		1,000.00
Sub Total . . .		$55,630.00
10 - Supervision and Overhead (30%)		16,689.00
TOTAL . . .		$72,319.00

The mine yard will be radiometrically surveyed and any material found which exceeds radiation regulations will be removed from the area, back-filled into the shaft or hauled from the Project Area. In the event treatment of water from the underground working is needed during mining operations, sediments resulting from this will be scalped from the ponds and either hauled from the Project Area or disposed of underground in the mined-out workings. All holding ponds will be filled and recontoured.

The riprap will be removed from the dike surrounding the area of operations, and disposed of in the mine shafts. The previously stockpiled topsoil will be spread evenly over the entire area of operations.

All ground surface which has been disturbed (power corridor, entrance road and area of operations) will be drilled or broadcast seeded.

The following species and application rates are recommended for the areas to be reseeded:

Species	Percent in Mix		Lbs./Acre for 25 Seeds per Sq. Ft.		Pounds Needed In Mixture
Crested Wheat	30	X	5.4	=	2
Pubescent Wheatgrass	30	X	12.5	=	4
Smooth Brome	25	X	8.0	=	2
Yellow Sweet Clover	15	X	4.2	=	1
Pounds of mixture for 25 seeds/sq. ft. (pure live seed)				=	9 lbs/ac.*

* Application rate is for drilling; for broadcasting, double this rate.

Drill the following browse species <u>separately</u>:

Four-wing saltbush - 15.0 #/ac.
Winterfat - 7.5 #/ac.

All drainage channels used during operations will be left in place, so as to direct surface runoff around the area of reseeding until revegetation has been adequately reestablished. Thereafter, if requested by the NFS, these channels will be similarly recontoured and reseeded.

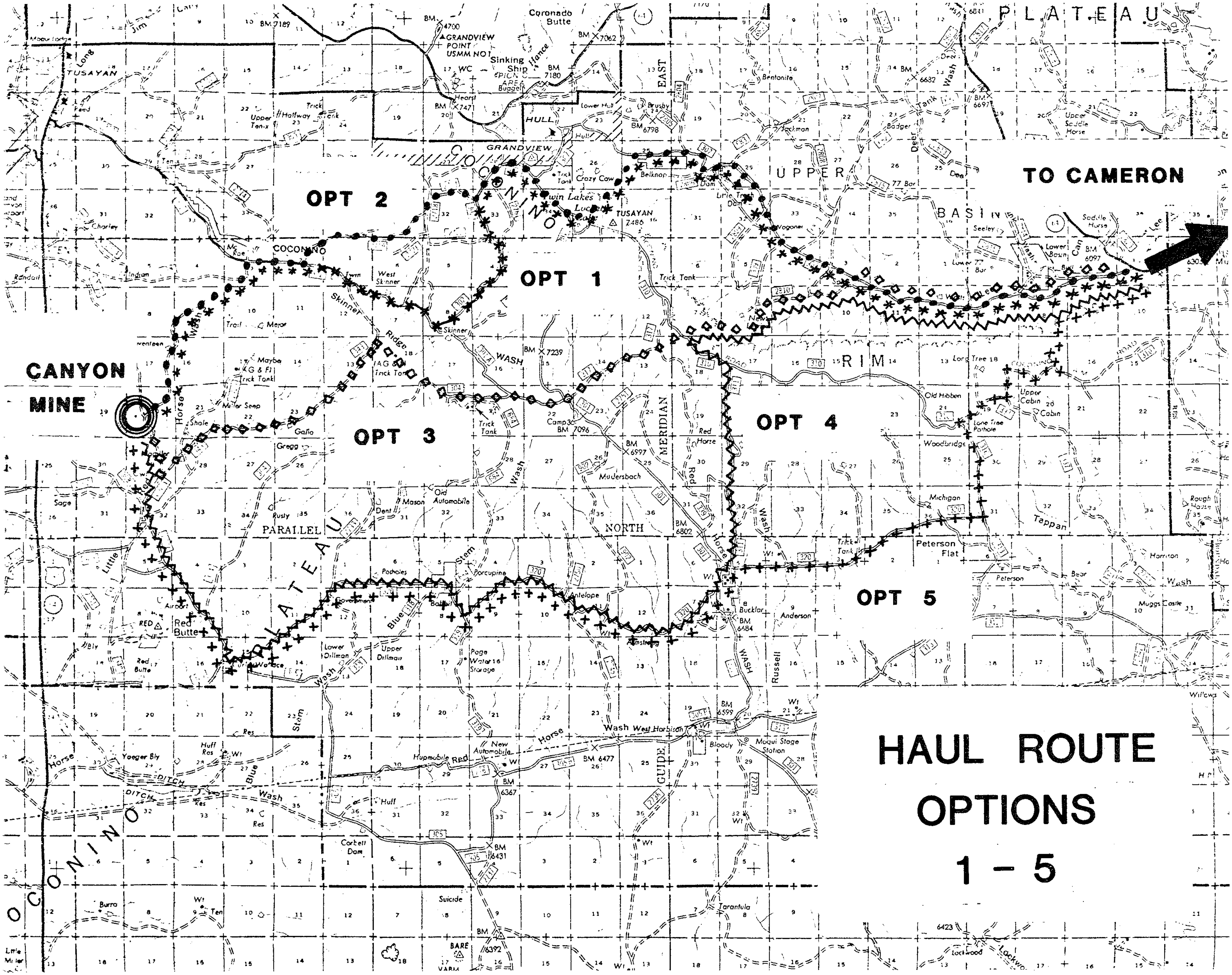
The half-mile of road between the Area of Operation and Forest Road 305A will be graded back to natural contours, scarified and reseeded.

The powerline will be dismantled if no other uses exist, as directed by the Kaibab National Forest and the Arizona Public Service Company.

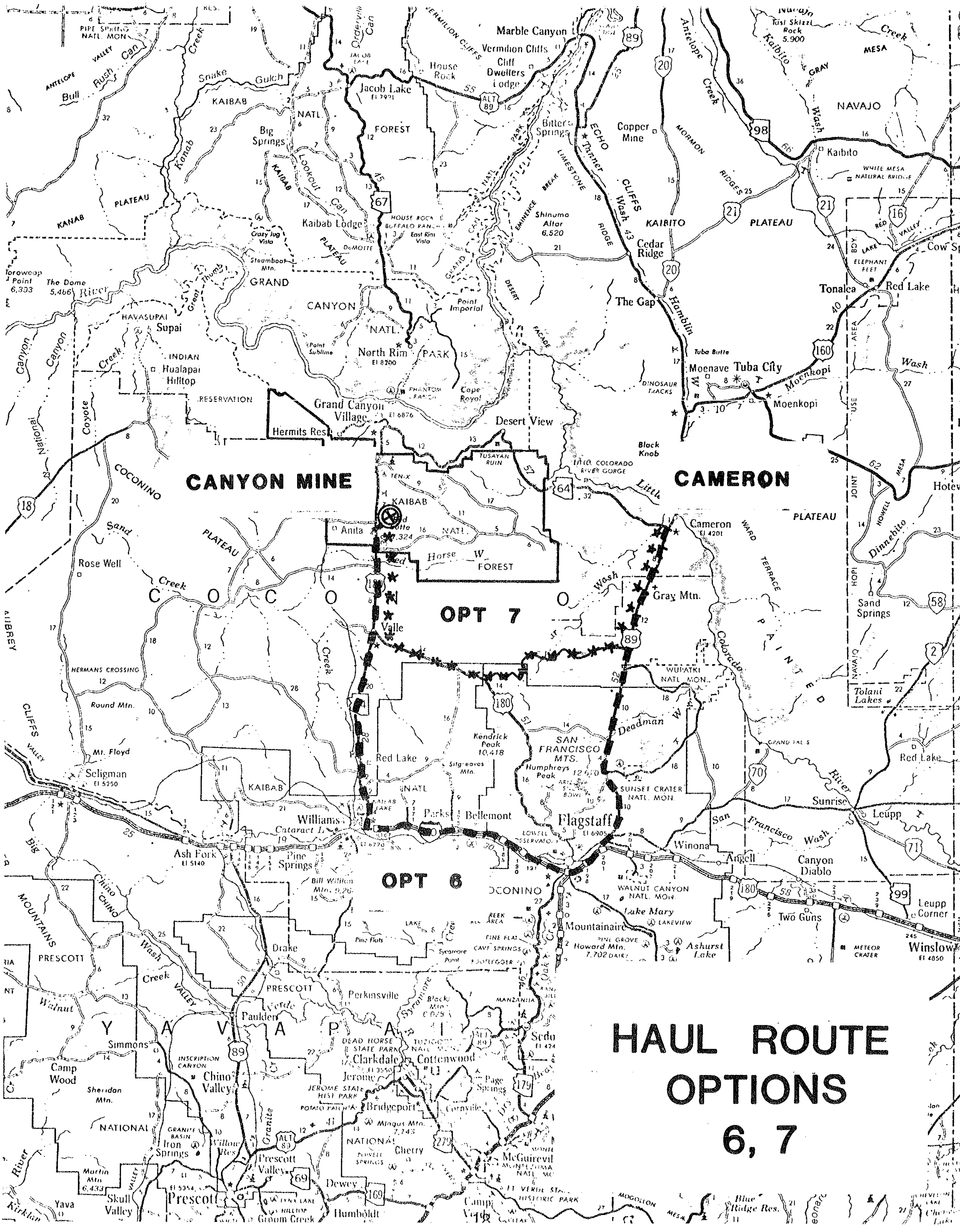
TABLE 1. -- SUMMARY OF HAUL ROUTE COSTS.

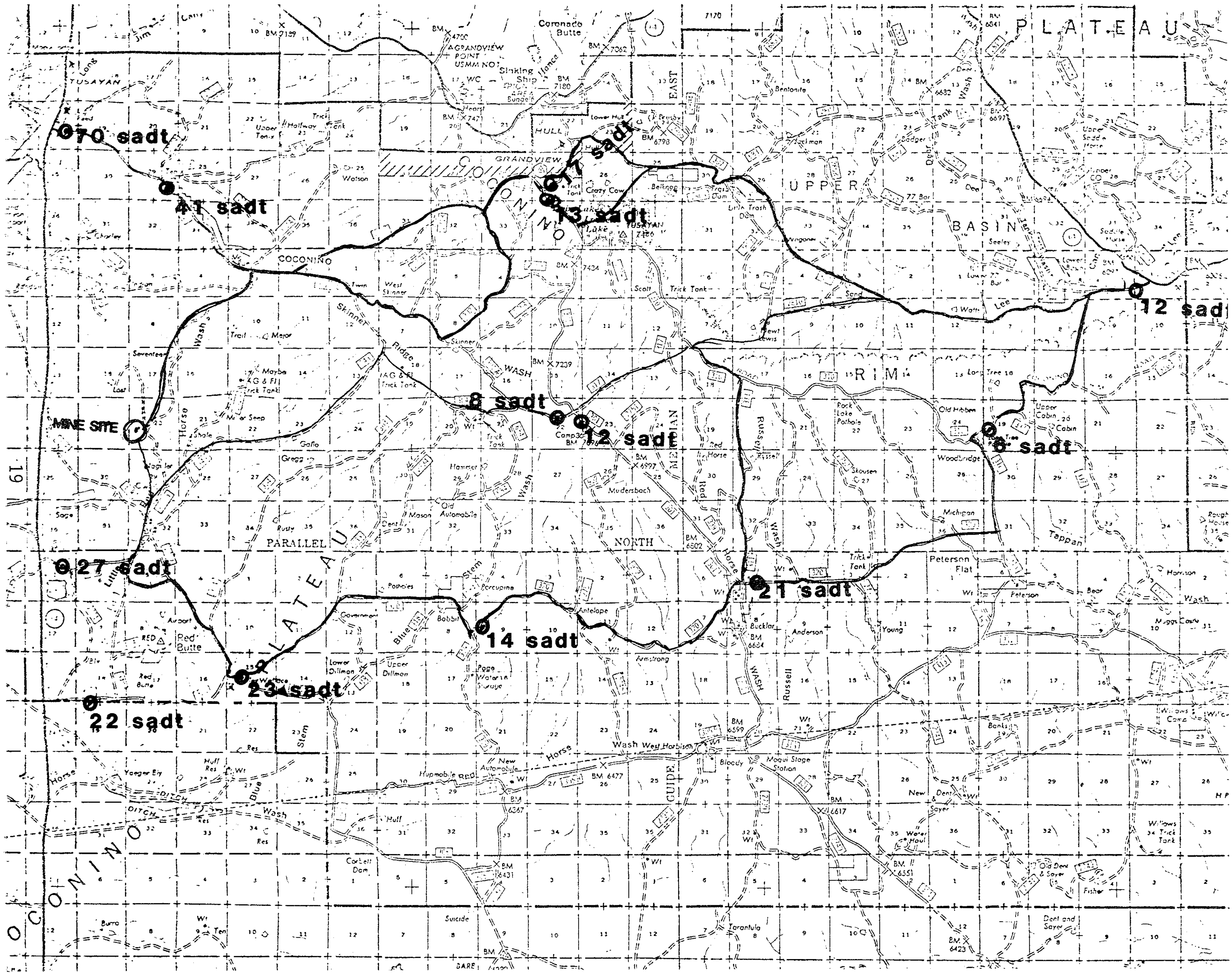
	Length [3]		First Cost [1]					Annual Cost				
Haul Route Options	On Forest	Total	New Const. Cost($)	Mi.	Reconst. Cost($)	Mi.	Surfacing Cost($)	Maint. Cost($)	Haul Cost($)	Total First Cost($)	Total Annual Cost($)	Net Present Value($) [2]
#1 E.F.N. Proposal (Incl. Relocation of 307 at Hull Cabin)	27.5	48.5	206,000	3.6 [4]	90,200	23.9	1,075,200	27,500	558,000	1,371,400	585,500	3,591,030
#2 E.F.N Proposal with Modifications	25.4	46.4	208,900	4.1 [5]	126,800	21.3	993,000	25,400	538,640	1,328,700	564,040	3,466,975
#3 Shortest Route with Newt Lewis	24.0	45.0	325,000	4.4	171,800	19.6	878,500	24,000	529,600	1,375,300	553,600	3,473,997
#4 South Route with Newt Lewis	34.4	55.4	325,000	4.4	158,100	30.0	1,356,800	34,400	671,600	1,839,900	706,000	4,516,346
#5 South Route with Upper Cabin	33.5	54.5	459,000	2.9	152,200	30.6	1,309,300	33,500	670,180	1,920,300	703,680	4,587,950
#6 Highway Haul via Williams & Flagstaff	4.8	128.8	---	---	37,900	4.8	187,700	4,800	973,360	225,600	978,160	3,933,804
#7 Highway Haul via Valle & S.P. Crater	4.8 25.0	79.8 [6]	---	--	153,100	29.8	490,800	29,800	788,160	643,900	817,960	3,744,786

1/ Right-of-way acquisition costs are not included.
2/ N.P.V. calculated at 10% rate of interest for 5 years.
3/ Total length shown is from the mine to Cameron, Arizona.
4/ Includes 2.3 miles of new construction near old 305A alignment.
5/ Includes 2.3 miles of new construction near old 305A and 2723 alignment.
6/ Shown length on Kaibab Forest and off-highway haul from US 180 to US 89.



HAUL ROUTE OPTIONS 1 – 5


CANYON MINE
CAMERON
OPT 7
OPT 6
HAUL ROUTE OPTIONS 6, 7
Marble Canyon
Jacob Lake
Grand Canyon Village
Desert View
Tuba City
Moenkopi
Cameron
Gray Mtn.
Valle
Williams
Flagstaff
Parks
Bellemont
Seligman
Ash Fork
Winona
Leupp
Winslow
Prescott
Sedona
Cottonwood
Clarkdale
Chino Valley
Tonalea
Red Lake
Kaibito
Cedar Ridge
The Gap
Supai
North Rim
Anita
Red Butte



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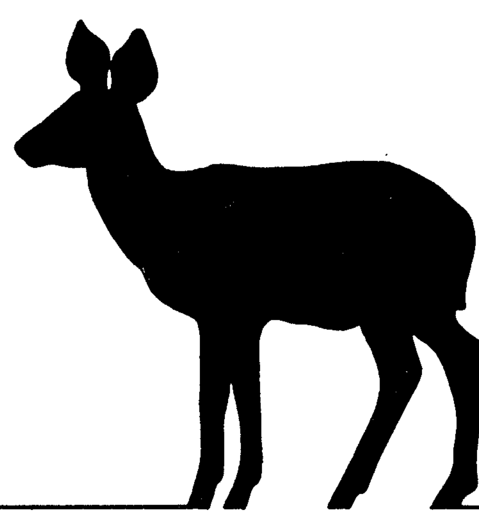
PLATEAU
GUIDE
GRANDVIEW
EAST
HULL
TUSAYAN
Coronado Butte
GRANDVIEW POINT
Sinking Ship
Red Butte
Peterson Flat
Skinner Ridge

Appendix

C

Wildlife Evaluation & Recommendations



Region 3
USDA - Forest Service

Wildlife Evaluation and Recommendations

PROPOSED CANYON URANIUM MINE

Kaibab National Forest
Supervisor's Office
800 South Sixth Street
Williams, Arizona 86046

Prepared by: Katherine A. Peckham Date: Dec. 5, 1985
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WILDLIFE BIOLOGIST

I. Purpose

The purpose of this evaluation is to assess the impacts of the proposed Canyon Mine on wildlife populations and their habitats, as required by the National Environmental Policy Act (NEPA) of 1969.

Almost any ground-disturbing activity will adversely affect habitat for some wildlife species while it improves it for others. This evaluation will not attempt to discuss in detail the positive and negative impacts of mining on every wildlife species in the project area. Instead, emphasis will be placed on 1) species whose population viability may be affected (e.g. threatened, endangered, and sensitive species); 2) species that have special habitat needs (e.g. raptors); and 3) species that are given management emphasis in response to public demand (e.g. game species).

A glossary and a list of the scientific names for all plant species mentioned in this report can be found in Appendix A.

II. Affected Area

The eastern half of the Tusayan Ranger District (east of Highway 64) will be considered the "affected area" in this evaluation.

A. Habitat

The Tusayan District is located in the northern half of Game Management Unit 9. The overall carrying capacity (see glossary) of the habitat in Unit 9 is low relative to other units in northern Arizona. This is partly due to the severe lack of water in the area. Scarcity of reliable water sources in the unit affects the distribution, size, and behavior of resident wildlife populations.

The fact that the habitat is relatively marginal points out the need to manage it intensively. Project impacts that would have little or no effect under optimum habitat conditions may have a significant effect under less favorable conditions.

Wildlife habitat on the Tusayan District can be categorized into five vegetation types: Conifer, Pinyon-Juniper, Sagebrush, Browse, and Grassland. Acreage figures below represent the total acres of each vegetation type for the entire District.

1. Conifer (96,182 acres)

Ponderosa pine forest covers approximately 96,182 acres of the Tusayan Ranger District. Understory species are typically gambel oak, pinyon pine, and/or juniper. This vegetation type serves as summer habitat for antelope, mule deer, elk, and turkey. The northern goshawk, Cooper's hawk, red-tailed hawk, acorn woodpecker, and pygmy nuthatch are among the more than twenty-five bird species that nest in the area. The Abert squirrel, golden-mantled squirrel, and valley pocket gopher are yearlong residents in this type.

Bear habitat can be found along the Coconino Rim in the northeast portion of the District. The Rim marks a transition between the conifer and pinyon-juniper vegetation types. Quality cover conditions within this relatively undisturbed area make this a suitable habitat for the District's small bear population.

Five elk calving areas, totaling approximately 2,000 acres, have been delineated within the conifer type (Map 5). Water is an important component in elk calving habitat. Calving in the affected area occurs during the dry months of May and June when water becomes limited. This makes the habitat adjacent to reliable waters particularly critical. Each of the known calving areas is within the proximity of a reliable water source.

Approximately 9,900 acres of deer fawning habitat have been identified within the affected area (Map 4). Quality forage and available water are essential components in optimum fawning habitat. "Optimum fawning habitat for deer includes low shrubs or small trees from 0.6 to 1.8 meters (2 to 6 feet) tall under a tree overstory of approximately 50 percent crown closure" (Thomas 1979).

Antelope fawning occurs primarily in open grassland habitats which provide high visibility as well as adequate grass cover for concealing young fawns. Three fawning areas, totaling roughly 2,300 acres have been identified to date (Map 5).

Turkey typically select nest sites on slopes in or adjacent to ground cover. Nesting cover is often provided by dense oak thickets, logging slash, logs, or shrubs (Phillips 1982, Jones 1981). Approximately 1,600 acres of turkey nesting habitat have been delineated within the affected area (Map 6).

2. Pinyon-Juniper (175,770 acres)

   Pinyon pine-juniper woodland is the most extensive vegetation type on the District, covering 175, 770 acres. Sagebrush and rabbitbrush are the most common understory species. This vegetation type serves as winter habitat for antelope, mule deer, and elk. Other mammals in this type include the grey fox, bobcat, rock squirrel, and blacktailed jackrabbit. Pinyon pine and juniper trees provide nest sites for the plain titmouse, pinyon jay, and great horned owl.

3. Sagebrush (27,759 acres)

   This vegetation type is dominated by sagebrush, rabbitbrush or a mixture of both. Grasses and forbs are generally very sparse in the understory. Blue grama is typically the most common forage species found in this type. The black-throated sparrow and Brewer's sparrow potentially inhabit the sagebrush type.

4. Browse (1,731 acres)

Winterfat, cliffrose, and four-wing saltbush are the primary species found in the browse vegetation type. The understory forb and grass composition varies depending upon browse stand density and location. Elk, deer, and antelope depend more heavily on browse plants for forage during the winter months when palatable grasses and forbs are unavailable. The relatively large seeds from the four-wing saltbush provide a food source for small birds and mammals.

5. Grassland (23,591)

Grassland openings are dominated by perennial grasses with low densities of forbs and/or sedges. Primary forage species within the affected area are mutton bluegrass, western wheatgrass, squirreltail, and blue grama. Crested wheatgrass, an introduced species, is abundant in areas that have been disturbed and reseeded. Grassland openings on the Tusayan District provide foraging habitat for elk, and to a lesser extent, deer and antelope. Ground-nesting birds, such as the western meadowlark, commonly nest in the grassland type.

6. Water

Lack of dependable water is the primary factor affecting wildlife distribution in the area. Twenty-three stock tanks have been identified as important water sources because they are known to consistently receive wildlife use on a seasonal basis.

McCrae Tank
Skinner Tank
Lockett Lake
Hull Tank
Russell Tank
Camp 36 Tank
New Automobile Tank
Bly Tank
Sand Tank
Trash Dam
Antelope Tank
Twin Tanks
Owl Tank
Red Horse Tank
Skousen Tank
Lower Hull Tank
Michigan Tank
Woodbridge Tank
Bucklar Tank
Young Tank
Lower Cabin Tank
Charley Tank
Mudersbach Tank

Russell and Bucklar Tanks are the only tanks that are stocked with fish. The Arizona Game and Fish Department stocks Russell Tank with trout on a seasonal basis. Bucklar Tank, on private land, is also occasionally stocked with fish by the landowners.

The Arizona tiger salamander breeds in several stock tanks on the District. Breeding typically occurs in July and August during the summer rains. Adults spend much of the non-breeding season in the underground burrows of small mammals.

B. Wildlife Populations

1. Nongame

Nongame animals include all wildlife species that are protected from being hunted, trapped or otherwise "taken" as defined by state and federal laws. Species lists for game and nongame species on the Tusayan District can be found in Appendix A. These lists were compiled to give the reader a general idea of the diversity of species that either currently or potentially exist on the District according to Forest records and/or published field guides. No intensive field surveys have been conducted to confirm the existence of many of these species within the affected area.

2. Game

Game animals include all wildlife species that can be legally "taken" under Arizona State law (Arizona Hunting Regulations 1985). The following discussion will focus on game species that may be significantly impacted by mining activities, including: antelope, elk, mule deer, turkey, and black bear.

Big game population estimates for the Tusayan Ranger District are as follows (Kaibab National Forest Annual Wildlife and Fisheries Report 1983):

Species	Population Estimate
Black Bear	15
Antelope	100
Elk*	325
Turkey	365
Mule Deer	1,200

(*Revised 1985 estimate)

Bear and antelope populations are currently static. Deer and turkey populations are on a slight upward trend while the elk population is increasing at a rate of roughly 20 percent per year (Tim Baumgarten, pers. comm.).

The elk herd deserves special note due to its unique history, rapid expansion, and developing importance to elk hunters statewide.

Elk were not present on the Tusayan District until the 1950's. The first documented elk sighting was made in 1959, though several unverified sightings were made prior to that date. The first animals to appear on the District apparently originated from the elk population in the Williams-Flagstaff area (Game Management Unit 7). The emigration was likely a result of increasing competition for resources within the growing Unit 7 herd combined with human enroachment in elk habitat.

An unusually high percentage of bulls in this population are in the older age classes. This is due to the fact that, until recently, the herd had virtually been unhunted. Consequently, the herd is gaining popularity statewide among trophy elk hunters.

III. Predicted Impacts

There are three areas that will be disturbed during the life of the mine: 1) the utility corridor; 2) the Area of Operation (mine site); and 3) the haul route.

A. Utility Corridor

Four alternatives for providing electrical power to the mine site were evaluated:

Alternative 1 - Overhead powerline starting at the existing 69 kV line just east of Highway 64 and following the shortest access to the mine site.

Alternative 2 - Overhead powerline from Highway 64 along Forest Roads 305 and 305A to the mine site.

Alternative 3 - Buried cable from Highway 64 along Forest Roads 305 and 305A to the mine site.

Alternative 4 - Electrical generators at the mine site.

1. Alternative 1 - Overhead powerline using shortest route.

This alternative was proposed by EFN in its Plan of Operation. The operating plan does not specify what voltage of powerline design would be used. Don Smith, Arizona Public Service Company (APS), believes it would be a 12.5 KV line.

The operating plan does not specify the width or extent of vegetation clearing to be done in the corridor. For purposes of this report, it will be assumed that a standard 20-foot corridor will be cleared of all vegetation.

Direct impacts resulting from corridor construction and clearing include 1) temporary disturbance of wildlife during construction activities; and 2) long-term loss (more than 10 years) of tree cover within a narrow strip.

a. Construction Activities

The proposed powerline travels primarily through pinyonjuniper woodland, and crosses several pine stringers and sagebrush openings. Construction activities would potentially have the greatest effect on any raptors (birds-of-prey) nesting in the area.

Human disturbance of nesting raptors increases the probability of nest abandonment, egg breakage or trampling of young by adult birds, and overheating, cooling, loss of humidity, and avian predation of eggs (Fyfe and Olendorff 1976, cited by Olendorff et al. 1981). Desertion of nests after eggs are laid is the most serious concern during construction, although the result (loss of one year's productivity) may be only short term (Olendorff et al. 1981).

The nesting season for the area's raptors spans approximately April through July. It is recommended that a nest survey be conducted along the proposed line corridor during the nesting season if this alternative is chosen. There are several ways to mitigate nest disturbance if an active nest is found.

b. Vegetation Removal

Complete overstory clearing in the corridor would eliminate a long, linear strip of vegetation totaling approximately 4.1 acres. Tree removal and the subsequent reseeding of the disturbed area would improve grass production there. The resulting four acres of improved foraging habitat would only be a slight benefit to big game because of the narrow configuration of the clearing.

Tree removal would eliminate small mammal and bird den/nest sites. Habitat loss would be very localized and would not cause a significant reduction in affected populations on a region-wide basis.

Overstory removal would adversely affect any raptors nesting in the corridor. Raptors are mentioned because, as a group, they generally have narrow nesting requirements and show high nest site fidelity. Many return to the same nest site annually. Raptors may abandon or not return to a nest site that has been altered by tree removal.

c. Powerline Impacts

Depending on its design, the proposed powerline has the potential to: 1) improve raptor habitat by providing additional perches for hunting and roosting, and/or 2) increase the risk of raptor electrocution in the area.

1. Perch Sites

The use of powerpoles for hunting perches varies according to the topography, season, and abundance of prey. Raptors prefer to hunt from elevated sites where prey might be observed over a wide radius and where air currents are more favorable for flight (Olendorff et al. 1981). Powerpole installation can be expected to slightly enhance raptor habitat within foraging areas.

2. Raptor Electrocution

It has been well-documented that certain powerpole designs present an electrocution risk to large raptors. The Plan of Operation (1984) does not state what powerpole design is to be used.

It is recommended that the powerline is specifically designed to be raptor-safe. The following discussion provides background information on raptor electrocution and evaluates the potential for problems in the affected area. Information was taken from the Raptor Research Report "Suggested Practices for Raptor Protection on Power Lines: the State of the Art in 1981" (Olendorff et al. 1981) unless otherwise cited.

Raptor electrocution on powerlines was recognized as a serious problem in the early 1970's. Boeker and Nickerson (1975) documented 37 golden eagle deaths along a powerline of 88 poles in Moffat County, Colorado in 1971. Five golden eagles and four bald eagles were located under a powerline in Tooele County, Utah, and another 47 eagles died along a line in Beaver County, Utah, (Smith and Murphy 1972, Richardson 1972). In recent years, APS has redesigned a stretch of powerline near Seligman, Arizona, where golden eagles were being electrocuted (John Vitt, pers. comm.).

Raptors are electrocuted on powerlines because of two major factors: 1) their distribution, size, and behavior; and 2) the design of some powerlines which place phase and ground wires close enough together that raptors simultaneously touch them with their wings or other parts of their bodies.

At least 11 raptor species are known to inhabit the District as part- or full-time residents (Appendix A). Susceptibility to electrocution varies with each species. The District's forest-dwelling species, such as the Cooper's Hawk and Northern Goshawk, rarely perch on powerlines, preferring the shelter and seclusion that trees provide. Large size is the most important factor that predisposes certain raptors to electrocution. Small species on the district such as the American Kestrel, Flammulated Owl, Screech Owl, Northern Pygmy Owl, and the Northern Saw-Whet Owl can rarely span the distance between two wires.

The majority of lines that electrocute raptors carry between 12 and 69 kV. Higher voltage lines pose little electrocution hazard because wire separation is adequate. The proposed powerline will probably be a 12.5 kV line (Don Smith, pers. comm.).

Between 70 and 90 percent of all raptor mortalities along distribution lines are eagles (Boeker and Nickerson 1975, Peacock 1980, Ansell and Smith 1980). Existing information shows that the overwhelming majority of eagles killed by electrocution are golden eagles.

The probability of any one raptor being electrocuted on a powerline is low. Weather conditions and hunting/flight experience ultimately determine whether a bird runs the risk of electrocution. Rain, snow, and wind increase the susceptibility of raptors to electrocution because of feather wetting (increased conductivity) and ineptness of immatures and subadults in landing on powerpoles in the wind (Nelson and Nelson 1976, 1977).

Though the risk of raptor electrocution on a standard powerline is low, it is a significant concern due to the possibility of two endangered species, the Bald Eagle and the Peregrine Falcon, using the affected area. (See Threatened and Endangered Species section).

Efforts to minimize electrocution of golden eagles will also benefit bald eagles and most other raptors (Olendorff et al. 1981). Adequate separation of phase wires, ground wires, and other metal hardware is the most important factor in preventing electrocutions. Olendorff et al. (1981) recommends a 60-inch minimum separation of phase wires which will prevent golden eagles from making skin-to-skin contact. Wing-tip to wing-tip contact with the wires is still possible with this separation but the likelihood of it being fatal is minimal.

2. Alternative 2 - Overhead powerline along Forest Roads 305 and 305A.

   Forest Roads 305 and 305A are access roads that will be widened and surfaced in preparation for all-weather use. The powerline would be installed within the cleared road corridor resulting in no additional loss of habitat. Intermittent vehicle traffic on FR 305/305A already poses some disturbance to wildlife in the area. As a consequence, the additional temporary disturbance from powerline installation would be relatively insignificant.

   The powerline itself has the same potential to enhance and/or adversely affect raptor habitat, as discussed under alternative 1.

3. Alternative 3 - Buried cable along Forest Roads 305 and 305A.

   Impacts from this alternative would be similar to those in alternative 2. There would be no additional loss of habitat and construction disturbance would be minimal.

This alternative avoids the potential raptor electrocution problems found in alternatives 1 and 2.

4. Alternative 4 - Electrical generators at the mine site.

   Noise from on-site generators would contribute to the larger noise disturbance created by vehicles, equipment, and people at the mine site. Noise from mining activities can have a disturbing effect on wildlife, as discussed later in this report.

   This alternative, like alternative 3, would not result in any additional habitat loss or pose any electrocution risk to area raptors.

B. Area of Operation

The 17.4-acre Area of Operation (AO) is located within a 32-acre "grassland" opening. The opening is dominated by blue grama (Bouteloua gracilis) and western wheatgrass (Agropyron smithii). Rubber rabbitbrush (Chrysothamnus nauseosus) is present in low-moderate densities throughout the opening. Big sagebrush (Artemisia tridentata) dominates a small area in the northwest portion of the AO.

Three 100-foot range transects were established in a representative portion of the AO on May 2, 1985, to evaluate vegetation and soil condition. The transects were established and read according to the Three-Step Method described in the Region 3 Range Analysis Handbook (FSH 2209.21). Vegetation condition was determined by rating forage density, composition, and vigor. The extent of bare soil and soil disturbance present determined the soil condition class. Possible condition classes were Excellent, Good, Fair, Poor, or Very Poor. Transect results indicated that both vegetation and soil condition in the AO are Fair.

The opening is used as a foraging area by elk, antelope, and deer. It also contains suitable hunting habitat for raptors due to the availability of surrounding pine trees/snags for perches, high visibility within the opening, and abundance of small mammals for prey (e.g. desert cottontail, pocket gopher). The western meadowlark is one of several ground-nesting birds that may potentially nest within the opening.

1. Impacts from Topsoil Removal

   The proposed removal of the 6-inch topsoil layer in the AO would result in a short-term (less than 10 year) loss of approximately 17 acres of wildlife habitat. This disturbance would eliminate small mammals and reptiles whose home ranges are mostly or entirely within the opening. It cannot be assumed that these animals will disperse successfully to adjacent habitats. Adjacent habitats may not be suitable or may already be occupied (Kroodsma 1985). The expected loss of nongame species and their habitats within the AO should not threaten the viability of affected populations.

2. Exposure to Radioactive Materials

Numerous studies have been conducted on the effects of human exposure to radioactive materials. In contrast, very little comparable research has been done on wildlife populations. Due to obvious differences in size and physiology, some wildlife species may respond differently to radioactive exposure than humans do. However, until conclusive data becomes available, the exposure levels considered safe for humans will be considered safe for the majority of wildlife species.

a. Water Contamination

EFN proposes to construct water diversion channels to the west and northeast of the drill site. The main diversion channel was originally thought to be capable of accommodating only surface runoff resulting from a 10-year event (Plan of Operation 1984). This raised the concern that a larger event could wash stockpiled uranium ore downstream. Forest Soils personnel recalculated the runoff capacity of the main channel and found it capable of accommodating runoff generated by at least a 100-year event (Dave Brewer, pers. comm.).

McKlveen (1985) estimated the degree of contamination that would result from a hypothetical 500-year flood in the affected area. He concluded that a flood of this magnitude could conceivably release approximately 50 curies of radioactivity to the downstream wash. "Radionuclide concentrations in the water and residual concentrations in the soil would not be sufficient to create a health problem. Cattle or wildlife grazing in the the washes would not ingest harmful amounts of radioactive material. The animals would remain fit for human consumption." (McKlveen 1985).

b. Airborne Radioactivity

An initial concern was that radon gas and dust originating from the mine would pose a significant health hazard to wildlife. The alpha-emitting progeny of Radon-222 have been linked to lung cancer in humans; specifically in uranium miners and other underground miners (90th Congress 1967, Advisory Committee on the Biological Effects of Ionizing Radiation 1972; cited by McKlveen 1985).

Radon gas is a colorless, odorless, inert gas that will diffuse from the ore piles and be exhausted from the mine vent.

Uranium and its progeny will be present in dust blown off the ore piles and will be released from the mine vent.

McKlveen (1985) conducted a thorough assessment of the effects of radon gas and dust emissions from the Canyon Mine. He concluded that there would be no significant radiological impact on the environment from the release of radon gas or dust. A copy of Dr. McKlveen's report is on file at the Kaibab National Forest Supervisor's Office.

3. Disturbance Impacts from Mining Activities

The bulk of research studying wildlife responses to human disturbance has focused on elk.

Studies show that elk reaction to human noise and activity varies widely depending on the season of the year, cover, topography, kinds of equipment used, and the type and duration of activity. Several studies have been conducted on the reaction of elk to logging activities.

Thomas and Toweill (1982) state that "on both summer and winter ranges, the reaction generally recorded has been movement away from logging activity to areas without such disturbance." Ward (1976) concluded that elk prefer to stay at least .8 kilometer (.5 mile) from timber harvest operations. Beall (1974) and Lyon (1975) reported displacement of elk to distances of 3.2 - 6.4 kilometers (2-4 miles) from logging activities. "Apparently elk move only as far as necessary to escape line-of-sight contact with men and equipment by interposing a topographic barrier (Marcum 1975, Lyon 1975) or an area of timber cover (Ward 1976, Hershey and Leege 1976)" (Thomas and Toweill 1982).

Conclusions by Johnson (1984) and Merrill (1984) shed a different light on elk behavior. Johnson (1984) found no indication that elk were abandoning surface coal mining areas in northwestern Colorado. He found that there continued to be extensive elk use within a quarter mile of active mining operations. Conclusions were based on four years of monitoring 20-48 radio-collared elk.

Merrill (1984) quantified the impacts of two active phosphate mines on elk and moose using data obtained from pellet group transects. In the summer months, neither elk nor moose appeared to be displaced from areas adjacent to the Maybe Canyon Mine. Both mines had been in operation for ten years when the study was initiated so baseline data was not collected. "Displacement of big game from habitats adjacent to the mines could have occurred initially" (Merrill 1984).

The variability in research findings makes it impossible to positively predict how the Tusayan elk population will respond to mine site activities.

It is reasonable to assume that mining operations will disrupt elk foraging activities at least within the 32-acre mine site opening. (Note that the 17-acre Area of Operation is within a larger 32-acre opening.) Based on the bulk of elk research, it is predicted that elk will avoid the forage opening during active mining operations. Consequently, this 32-acre loss in habitat effectiveness should be mitigated.

C. Haul Route

Seven haul route alternatives will be assessed in this evaluation. Two routes are primarily off-Forest: (see Map 1).

Route 6 - Travels south on SR 64, east on Interstate 40, and north on U.S. Highway 89.

Haul route 6 is unique in that all but 4.8 of its miles are on existing paved roads. Highways 64, 40, and 89 all receive continuous, year round traffic. The impact of an additional 20 ore trucks per day on these roads will be insignificant to area wildlife populations.

Route 7 - Travels south on SR 64 to U.S. Highway 180, east on FR 417 across the Coconino National Forest, continues east across unpaved portions of state/ private land past SP Crater, and north on U.S. Highway 89.

Once ore production begins, an average of 10 20-25 ton trucks will enter and leave the AO daily. EFN has indicated that hauling may occur any time of the day or night.

1. Direct Impacts

Direct impacts associated with haul route construction and use include: 1) habitat loss through road corridor clearing; 2) an increased risk of wildlife-vehicle collisions.

a. Road Corridor Clearing

Table 1 displays the total miles of new road construction and corresponding habitat losses for each alternative.

Table 1. Direct Habitat Losses* from New Road Construction

Route	Route Length (on District)** (mi.)	New Construction (mi.)	Habitat Loss (ac.)
1	27.5	3.6	9.0
2	25.4	4.1	10.0
3	24.0	4.4	11.0
4	34.4	4.4	11.0
5	33.5	2.9	7.0
6	4.8	0	0
7	4.8	0	0

* Assumes that a 20-foot right-of-way will be cleared of vegetation (Dan Baertlein, pers. comm.)

** Haul route 7 mileage includes 4.8 miles on the District and 25.0 miles of unpaved road off-District.

Each haul route will require varying amounts of reconstruction (e.g. road widening, minor realignment, resurfacing). Additional losses in habitat can be expected during road reconstruction but are difficult to quantify.

The vegetation removed during corridor clearing represents a long-term habitat loss. New road construction will primarily occur in the ponderosa pine and pinyon-juniper types.

A number of the individual animals that inhabit the corridor would likely be killed during corridor clearing. Those animals that do disperse from the corridor would attempt to occupy adjacent habitats. Whether they would be successful in doing so would depend on such factors as the availability and suitability of adjacent habitats.

Any nest/roost/den sites within the corridor would be eliminated. This may include such key habitat components as snags (required by cavity-nesting species), turkey roost tree groups, and raptor nest sites.

The impacts of corridor clearing on most big game species would be minimal. Because the corridor disturbance would only be 32 feet in width, it would impact only a very small proportion of any one animal's home range.

Ultimately, the loss of 7-11 acres of habitat from new road construction should not reduce any affected population to the extent that its viability would be threatened. The only known exception to this might occur in reference to sensitive plants whose viability is already a concern. A thorough discussion of mining impacts on sensitive plant populations can be found in Section IV, "Threatened, Endangered, and Sensitive Species".

b. Wildlife - Vehicle Collisions

The upgrading of haul roads will allow vehicles to safely travel at higher speeds than they can on existing forest roads. This increase in vehicle speed combined with greater traffic flow would increase the risk of wildlife-vehicle collisions. Regardless of the increased risk, wildlife mortality and crippling losses would likely occur at such low levels that, overall, impacts would not be significant.

2. Indirect Impacts

Roads affect wildlife populations indirectly by inducing a disturbance factor, vehicle traffic and people, which can displace animals from habitat adjacent to roads. Only at high densities are roads, of themselves, a wildlife concern. It is the vehicular traffic associated with roads that can displace animals from otherwise favorable habitat.

The indirect impacts of traffic have not been quantified for the majority of nongame species. Most of the research on road impacts has focused on big game species. Rayborne (1968, cited by Neil et al. 1975) reported that vehicular disturbance by hunters appeared more responsible for the change in turkey range size and shape than did hunting pressure. Phillips (1982) felt that building of new roads and creation of additional access on the Kaibab National Forest could "only be detrimental to turkey populations." Ward (pers. comm.) noted that deer along Interstate 80 in Wyoming preferred to keep at least 100 meters from the right-of-way fence during the day but moved in closer than that at night to feed. No relevant literature was found concerning the impacts of traffic on antelope.

The bulk of research studying traffic impacts on wildlife has focused on elk. Studies indicate that the way elk respond to traffic varies greatly depending on whether the traffic represents a "predictable" or "unpredictable" disturbance.

a. Predictable Disturbances

It cannot always be assumed that the greater the traffic volume, the greater the impact on wildlife. The <u>type</u> of road use must also be considered. Ward (pers. comm.)

found that big game were able to adjust somewhat to high volumes of steady traffic on Interstate 80, a major four-lane highway in Wyoming. (The Wyoming Highway Department reported that, from 1972-1975, the average daily traffic on I-80 was 4,231 vehicles (Goodwin and Ward 1976)). Although elk preferred to keep a distance of at least 300-400 meters from the Interstate during the day, they would move closer than that at night to feed. The noise and movement of traffic was "predictable" and apparently was not associated with any immediate danger.

b. Unpredictable Disturbances

Elk were found to be less tolerant of "unpredictable" events. A telemetry study by Ward and Cupal (1979) found that elk were most alarmed by sudden, unpredictable events including people on foot, stopped occupied vehicles, gunshots, and sonic booms. Burbridge and Neff (1976) reported that slowlymoving vehicles on primitive roads appeared to be more disturbing to elk than rapidly-moving vehicles on an improved forest highway.

Vehicle traffic on forest roads is considered to be an "unpredictable" disturbance. Even the most heavily-used all-weather roads on the Forest do not consistently receive high volumes of steady traffic which could be considered "predictable".

c. Elk Response to Traffic on Forest Roads

Elk typically respond to human disturbance by abandoning and/ or avoiding the area of disturbance. "Evidence is consistent and overwhelming that vehicular traffic on forest roads evokes an avoidance response by elk. Even though habitat near roads is not denied elk, it is not fully used" (Lyon 1983). This apparent decline in elk habitat use adjacent to forest roads has been well-documented (Hershey and Leege 1976, Lyon 1979, Perry and Overly 1976, Thomas et al. 1979, Ward 1976).

"The width of the area avoided by elk has been reported as 0.4-2.9 kilometers (0.25-1.8 miles), depending on the amount and kind of traffic, quality of the road, and density of cover adjacent to the road" (Thomas and Toweill 1982). Hershey and Leege (1976) found that an established road open to traffic and crossing an elk use area was disruptive to elk within .25 mile on either side of the road. Perry and Overly (1976) reported that "Generally, we found that roads reduce big game use of adjacent habitat from road edge to more than one-half mile away."

In this report, it will be assumed that traffic will disrupt elk use of habitat within .5 mile of haul roads.

Discussion

Most of the roads proposed for hauling are currently in existence. Traffic on these roads already presents some degree of disturbance to elk in the area. Additional losses in elk habitat effectiveness are expected from haul route upgrading/use as a result of an overall increase in traffic flow. As Thomas and Toweill (1982) point out, "In general, greater traffic flow on higher quality unpaved roads produces a larger area of avoidance [for elk]" (Rost and Bailey 1979, Perry and Overly 1976, Hershey and Leege 1976).

Data from District traffic surveys were used to determine seasonal average daily traffic (SADT) counts for the proposed haul roads (See Map 3). (SADT figures are based on traffic averages for the eightmonth "snow-free" season occurring within the last five years). EFN's ore traffic (20 trucks/day) alone will account for increasing average daily traffic counts roughly 2-3 times above current SADT levels.

Additional increases in other types of traffic can be expected as well. Road upgrading will allow virtually yearlong access into areas that were previously inaccessible due to winter-spring snow and mud conditions. Heavier use of these improved roads by both commercial (e.g. log trucks) and recreational vehicles is expected.

Disturbance resulting from increasing haul route traffic is a concern primarily if it occurs in the proximity of 1) known elk calving areas, 2) important water sources, and/or 3) known migration corridors.

1. Traffic Impacts on Elk Calving Areas

   Traffic disturbance could initially affect the well-being of individual cows and calves. One of the most critical times of disturbance tends to be during late pregnancy when the fetus is particularly sensitive to maternal nutrition (Schmidt and Gilbert 1978). Harrassment elevates metabolism at the cost of energy reserves needed for the pregnant/lactating animal and its developing offspring.

   Elk may respond to disturbance within calving habitat by avoiding or abandoning traditional use areas. Kuck et al. (1984) studied the impacts of human disturbance on elk calves. Radio-collared calves were tracked by ground crews and disturbed until visual contact, noise, or radio signals indicated that the calf had run from the observer. Compared to undisturbed groups, disturbed calves showed divergent patterns of movement, larger use areas, and decreased habitat selectivity. Some elk cow/calf pairs abandoned traditional calf-rearing areas to avoid disturbance.

Table 2 displays the minimum acreages of calving habitat that would be disrupted, assuming that habitat within .5 mile of haul roads is reduced in effectiveness.

Table 2. Predicted Losses in Elk Calving Habitat Effectiveness Resulting from Haul Traffic Disturbance

Route No.	Route Length (on District)* (mi.)	Calving Habitat Impacted** (ac.)
1	27.5	228
2	25.4	55
3	24.0	449
4	34.4	0
5	33.5	0
6	4.8	0
7	4.8	0

* Haul route 7 mileage includes 4.8 miles on the District and 25.0 miles of unpaved road off-District.

** Assumes that habitat within .5 mile of the road is reduced in effectiveness.

The ultimate effect of impacting from 55-449 acres of elk calving habitat would be a reduction in the carrying capacity of elk habitat on the Tusayan District. This holds true regardless of whether the elk population is currently below, above, or in balance with the present carrying capacity. Carrying capacity is the maximum rate of animal stocking possible without inducing damage to the habitat. It is a term that describes habitat potential <u>not</u> animal population potential. A reduction in carrying capacity on the Tusayan District may not necessarily result in a reduction in the elk population. (The elk population may presently be below carrying capacity). A decline in carrying capacity would simply mean that the habitat's <u>potential</u> for supporting elk would be lower than it had been previously.

2. Traffic Impacts on Important Wildlife Waters

Water is severely limited on the Tusayan District. Although numerous stock tanks are present, only a fraction are of value to wildlife due to their poor location or their inability to consistently hold water.

Twenty-three tanks in the affected area have been identified as being important for wildlife (see Section II A(6)). These waters were considered "important" because they are known to consistently receive wildlife use on a seasonal basis. Possible reasons why wildlife are attracted to these waters may include 1) because they dependably hold water during the dry periods of May-June and September-October, or 2) because they are located within the proximity of suitable forage or cover.

Vehicle traffic on forest roads may disrupt elk use of habitat adjacent to roads, as discussed previously. Based on this, there is a concern that increased traffic on haul roads will disrupt the use of adjacent wildlife waters. A loss in the effectiveness of any important wildlife water is a concern because of the severe shortage of water on the district. The following waters would be affected:

Haul Route No.	Water Source
1	Trash Dam Twin Tanks Sand Tank
2	Trash Dam Sand Tank
3	Owl Tank
4	Owl Tank Antelope Tank
5	Owl Tank Antelope Tank Woodbridge Tank
6	Owl Tank
7	Owl Tank (includes water sources on the Tusayan District only)

3. Winter access - Traffic impacts on a big game migration corridor Roads chosen for hauling will be widened, graveled, and maintained to ensure adequate access for ore hauling. These upgraded roads will provide winter access into areas that have typically been inaccessible due to snow or mud conditions. Increased winter traffic from both ore trucks and recreationists can be expected on improved haul roads.

Increased winter traffic should have minimal effects on wildlife on the Tusayan District. By late fall, deer and elk migrate out of the summer habitat traversed by haul routes 1, 2, and 3. Routes 4 and 5 travel primarily through winter range which does not contain limited or critical habitat.

Arizona Game and Fish Department (AGFD) biologists have identified an important elk and deer migration route across the unpaved portion of haul route 7 near Cedar Ranch (Map 7). Heavy snows or a lingering winter tend to make deer and elk congregate on the lower ranges from Cedar Ranch north to Tubb's Camp. According to AGFD winter survey data, 8-13 percent of the observed deer (1982-1984) and 11 percent of the observed elk (1984) in Unit 7 crossed and wintered within 2 miles of Cedar Ranch (see Appendix B: AGFD letter to R.D. Lund, dated 7/26/85).

It is expected that winter traffic past Cedar Ranch would increase once access was improved. An increase in traffic disturbance might disrupt migration and habitat use patterns in the vicinity of Cedar Ranch, affecting as much as 11% of the Unit 7 elk population (based on AGFD 1984 Survey results). However, this is only speculation. The effects of increased traffic on the use of this migration corridor are presently unquantifiable based on available information. If additional information indicates that significant impacts may occur, the haul route could be temporarily closed during the migration period.

IV. Threatened, Endangered, and Sensitive Species

The Endangered Species Act of 1973, as amended (1978, 1979, 1982), directs Federal agencies to establish programs to ensure the conservation of threatened and endangered species. It is Forest Service policy (FSM 2670.32) to actively manage sensitive species in addition to those listed as threatened or endangered. Sensitive species are defined as those plant or animal species identified by a Regional Forester for which population viability is a concern (FSM 2670.519).

A. Fish and Wildlife

There are no known threatened, proposed, or sensitive fish or wildlife species in the affected area. The bald eagle and peregrine falcon are two endangered species that may be found seasonally on the Tusayan District.

The bald eagle is considered an endangered species in the lower 48 states. Johnson et al. (n.d.) lists this species as a rare winter migrant to the Grand Canyon region. Bald eagles are frequently sighted in Grand Canyon National Park (GCNP) during the annual Christmas Bird Count conducted by the Park Service. The most recent documented bald eagle sightings on the Tusayan District were reported during the winters of 1975, 1976, 1977, and 1982 (GCNP Study Collection records). Bald eagles probably move through the area each winter but the majority of sightings are not documented.

Breeding and wintering peregrine falcons may inhabit the Tusayan District on a seasonal basis. Ellis (1978) conducted peregrine falcon surveys on National Forest lands in Arizona from 1974-1978. He identified two areas on the District as "very suitable breeding habitat". Ellis suggested that the rim areas be managed as falcon hunting habitat. He noted that "falcons nesting in the Grand Canyon have been observed hunting over the forests on the rim".

Winter use on the District by peregrines is probably sporadic and scattered. Ellis (1978) felt that winter use in Arizona would be greatest where prey is abundant such as in areas with concentrations of waterfowl and other migratory birds.

B. Plants

There are no known threatened, endangered, or proposed plant species in the affected area. The following sensitive plants potentially exist on the Tusayan District (R-3 Sensitive Plant List 1984):

On Notice of Review

Category One

1. *Astragalus cremnophylax*

Category Two

1. *Chrysothamnus molestus*
2. *Clematis hirsutissima* var. *arizonica*
3. *Rosa stellata*
4. *Silene rectiramea*
5. *Talinum validulum*

Not On Notice of Review

1. *Aquilegia desertorum*
2. *Potentilla multifoliolata*

To date, *C. molestus* is the only sensitive plant known to exist in the affected area. The plant was located approximately five miles to the southwest of the mine site (Kaibab National Forest Herbarium, collected 8/13/84):

Results of Mine Site Plant Survey

Field clearances for A. cremnophylax, C. molestus, C. hirsutissima, and R. stellata were conducted within the AO on April 17 and May 8, 1985. None of the plants were found in the project area.

A. desertorum and P. multifoliolata are not expected to be found in the AO based on their known habitat requirements. A. desertorum is locally abundant in Coconino County where limestone bluffs, outcrops, or ledges are exposed (Brian et al. 1982a). The AO is characterized by deep alluvial soils (Dave Brewer, pers. comm.) with no obvious areas of exposed limestone.

Brian et al. (1982b) describes P. multifoliolata as being restricted to shallow, rocky drainage bottoms or washes with intermittent flow or subsurface water during a portion of the year. Drainages are of either basalt or sandstone with poor soil development and a high percentage of rocks or gravel. This habitat description contrasts with the limestonederived soils present in the project area (Dave Brewer, pers. comm.).

Very little site-specific information has been collected to date on the habitat requirements of S. rectiramea or T. validulum. S. rectiramea is known only from two locations (Bright Angel Trail and the vicinity of Hermit's Rest) on the South Rim of Grand Canyon National Park. The only detailed locality information comes from Bailey's 1935 collection. He reported that the species was found in the Sonoran-chaparral type, 200 feet below Hermit's Rest. The species has not been relocated since 1935 and it is possible that it has been extirpated or is extinct (Brian et al. 1982c). Based on this information, the plant is not expected to inhabit the AO.

Available habitat information is inadequate to rule out the chance of T. validulum existing in the AO. A field clearance should be conducted during its flowering period in late summer.

Additional plant surveys will be conducted in areas of new road construction/reconstruction and within the utility corridor (depending on which alternative is chosen).

C. Biological Evaluation

The Forest Service Manual (2670) sets forth specific procedures for implementing the Endangered Species Act. The first legal requirement is to initiate informal consultation with the U.S. Fish and Wildlife Service (FWS).

Informal consultation was initiated with a letter to FWS requesting a list of federally proposed and/or listed species that might occur in the affected area (see Appendix B: Letter to FWS, dated 7/17/85).

The FWS reply stated that there were no records of listed or proposed species in the project area. It was noted, however, that "the peregrine falcon (*Falco peregrinus*) is a resident of the Grand Canyon and may utilize portions of the project area" (see Appendix B: FWS letter to K. Peckham, dated 8/6/85).

A biological evaluation (see FSM 2672.41) was conducted to determine the effects of mining activities on the bald eagle, peregrine falcon, and the eight sensitive plant species (see Appendix B). Results of the evaluation concluded that there would be no adverse impact on bald eagles or peregrine falcons. Adverse impacts to sensitive plant populations can be avoided by minimizing surface disturbance within known plant habitats.

Summary of Impacts

Table 3. Summary of predicted wildlife impacts

	Haul Route Alternative No.						
Direct Habitat Loss (ac) [1/]	1	2	3	4	5	6	7
1. New Road Construction	9	10	11	11	7	0	0
2. Mine site clearing	17	17	17	17	17	17	17
Indirect Habitat Loss							
1. Mining disruption [2/] of foraging habitat use.	15	15	15	15	15	15	15
2. Traffic impacts a. elk calving habitat (ac)	228	55	449	0	0	0	-
b. deer fawning habitat (ac)	-No quantifiable impacts-			0	0	0	-
c. antelope fawning habitat (ac)	-No quantifiable impacts-			0	0	0	-
d. turkey nesting habitat (ac)	-No quantifiable impacts-			0	0	0	-
e. elk migration route (% of population affected)	0	0	0	0	0	0	11
f. important water sources -no. impacted	3	2	1	2	3	1	1 [3/]
-percent impacted (%)	13	9	4	9	13	4	4
Total Habitat Impacted (ac)	269	97	492	43	39	32	32

1/ Does not include the possible direct habitat losses from utility corridor clearing. (Depends on which utility alternative is chosen).

2/ Mine site activities will disrupt the use of an additional 15 acres of foraging habitat outside of the 17-acre AO. The combined total will be a loss of 32 acres.

3/ On Tusayan District.

VI. Recommendations

This evaluation has determined that the Canyon Mine has the potential to impact wildlife habitat on the Tusayan District. It is considered reasonable to expect EFN to:

- Avoid negetative impacts to wildlife populations and their habitats whenever possible.

- Mitigate predicted habitat losses which cannot be avoided.

A. Mitigation

1. Utility Corridor (no mitigation required for alternatives 3 or 4.

   a. Alternative 1 - Overhead powerline, shortest route.

      1. Objective: Minimize habitat losses from corridor clearing.

         Recommendation: Selectively remove only those trees in the corridor that will be a hindrance to the powerline itself.

2. Objective: Minimize disturbance to actively-nesting raptors during corridor clearing and powerline installation.

   Recommendation: Curtail construction activities within one-eighth mile of active raptor nests from April 15 - July 1.

   -or-

   Design the utility corridor so that it avoids any active raptor nests by a minimum of one-eighth mile.

* The District Wildlife Biologist will be responsible for locating active nest sites in the vicinity of the utility corridor.

3. Objective: Minimize the risk of raptor electrocution on the proposed powerline.

   Recommendation: Ensure that the phase and ground wires are separated a minimum of 60 inches (see Olendorff et al. 1981).

   b. Alternative 2 - Overhead powerline along FR 305/305A

      1. Objective: Minimize the risk of raptor electrocution on the proposed powerline.

         Recommendation: Same as mentioned above under Alternative 1.

2. Area of Operation

a. Objective: Mitigate the combined loss of habitat within the mine site opening (32 acres) and resulting from new road construction (acreage varies with each haul route alternative).

Recommendation: Create a 30-45 acre forage opening within the pinyon-juniper type. Approximate opening size will vary with each route alternative as follows:

Haul Route No	Mine Site (ac)	New Road Cons (ac)	Created Forage Opening Size (ac)
1	32	9	41
2	32	10	42
3	32	11	43
4	32	11	43
5	32	7	39
6	32	0	32
7	32	0	32

Project specifications will include:

- the forage opening will be located in an area with equal or higher site potential that the Area of Operation.
- maximum forage opening width will be limited to 1200 feet.
- the opening will be seeded with a grass-browse mix diserable for wildlife and suited to the site.
- the opening will be fenced to exclude livestock for a minimum of 3-5 years to ensure the establishment of seeded species. The fence will be built to Forest wildlife specifications.

b. Objective: Return the Area of Operation to its pre-mining condition.

Recommendation: In addition to the reclamation measures mentioned in the Plan of Operation (1984):

- abolish all water diversion channels
- remove any overhead powerline
- abolish all access roads into the Area of Operation
- reseed all disturbed areas with the seed mix in Tables 4 and 5

Table 4. Species Mix and Drilling Rates for Mine Site/Haul Route Reclamation*

Species	Pure Live Seed (%)	Lbs/ac at 25 seeds/sq. ft.	Percent of Mix (%)	Application Rate (lbs/ac)
1. Crested Wheatgrass *Agropyron cristatum*	81%	6.4	30	1.9
2. Pubescent Wheatgrass *Agropyron trichophorum*	77%	15.4	30	4.6
3. Smooth Brome *Bromus inermis*	78%	9.8	20	2.0
4. Yellow Sweet Clover (inoculated) *Melilotus officinalis*	84%	4.6	12	0.6
5. Winterfat *Eurotia lanata*	42%	12.0	4	.5
6. Four-wing Saltbush (de-winged) *Atriplex canescens*	40%	36.3	4	1.5
		TOTAL	100%	11.1 lbs/ac

* Application rates derived from the Range Nonstructural Improvements Handbook (FSH 2209.23)

NOTE: Winterfat and four-wing saltbush should be seeded separately.

Table 5. Species Mix and Broadcast Seeding Rates for Mine Site/Haul Route Reclamation*

Species	Pure Live Seed (%)	Lbs/ac at 35 seeds/sq. ft.	Percent of Mix (%)	Application Rate (lbs/ac)
1. Crested Wheatgrass *Agropyron cristatum*	81	9.1	30	2.7
2. Pubescent Wheatgrass *Agropyron trichophorum*	77	21.5	30	6.5
3. Smooth Brome *Bromus inermis*	78	13.4	20	2.7
4. Yellow Sweet Clover (inoculated) *Melilotus officinalis*	84	7.0	12	0.8
5. Winterfat *Eurotia lanata*	42	16.8	4	0.7
6. Four-wing Saltbush (de-winged) *Atriplex canescens*	40	50.9	4	2.0
		TOTAL	100%	15.4 lbs/ac

* Application rates derived from the Range Nonstructural Improvements Handbook (FSH 2209.23).

NOTE: Winterfat and Four-wing saltbush should be seeded separately.

3. Haul Route

a. Objective - Mitigate traffic impacts to important wildlife waters. The following wildlife waters will be impacted:

Haul route no.	Impacted Water
1	Trash Dam Twin Tanks Sand Tank
2	Trash Dam Sand Tank
3	Owl Tank
4	Owl Tank Antelope Tank
5	Owl Tank Antelope Tank Woodbridge Tank
6	Owl Tank
7	Owl Tank

Recommendation - Construct one earthen stock tank on the District for each "impacted" wildlife water identified above.

Each tank will be fenced to exclude livestock. Fences will be built to Forest Wildlife specifications.

b. Objective - Mitigate predicted impacts to elk calving habitat resulting from haul route traffic. A summary of impacts follows:

Haul route no.	Elk Calving Habitat Impacted (ac)
1	228
2	55
3	449
4	0
5	0
6	0
7	0

Recommendation - If haul route alternative 1, 2, or 3 is chosen:

- Construct one reliable earthen stock tank in suitable elk summer habitat.

-or-

- Close the haul route during the elk calving period, May 1 - June 30.

Justification - It has been determined that vehicle traffic may disrupt elk use of calving habitat within .5 miles of haul roads. The creation of a reliable water in an area with suitable cover and forage will partially mitigate the potential loss in calving habitat effectiveness.

Table 6. Summary of Wildlife Mitigation Measures

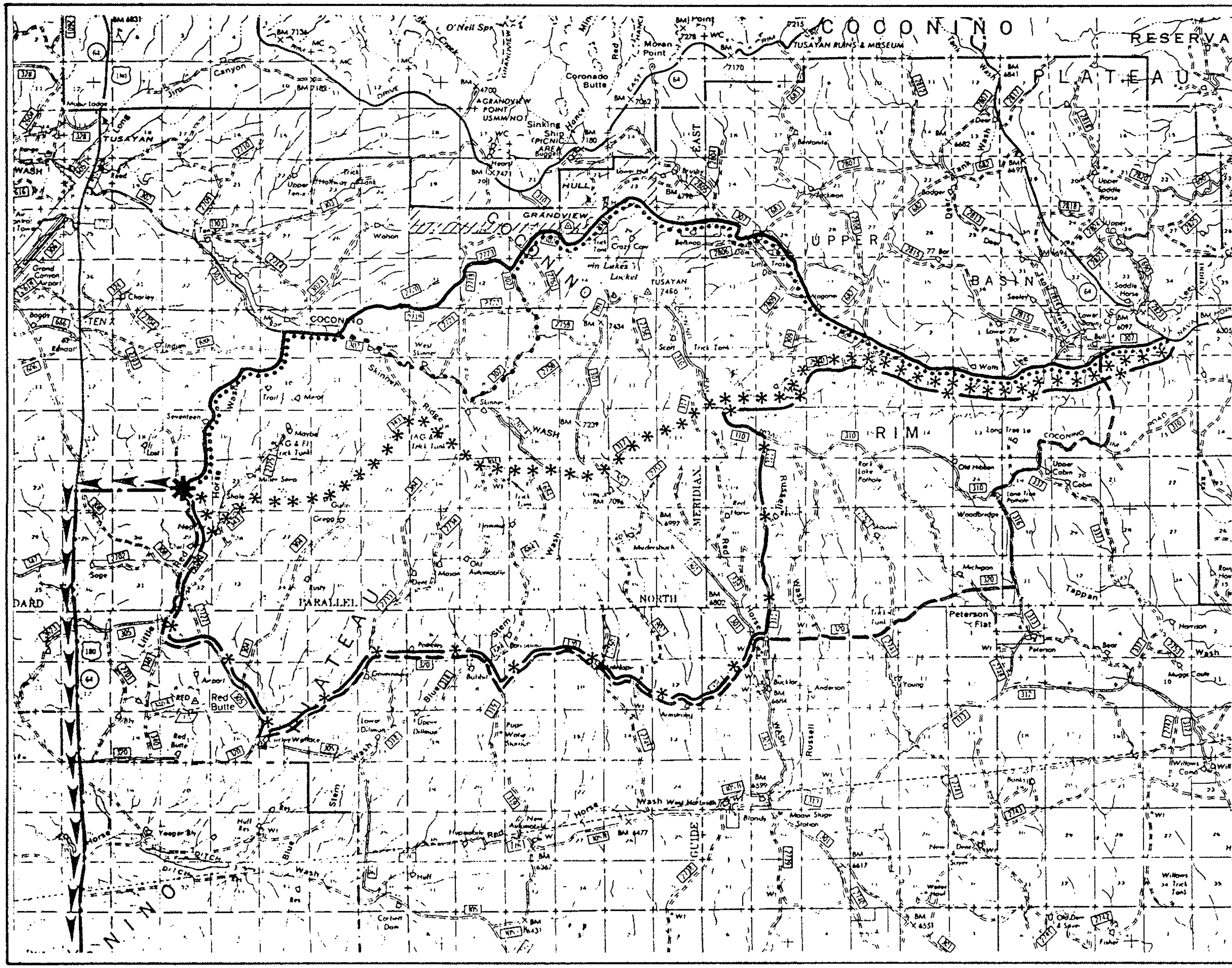
Mitigation of:	Haul Route Alternative No. 1	2	3	4	5	6	7
1. Powerline							
- min. 60-inch separation of wires (utility alternatives 1 and 2)	X	X	X	X	X	X	X
2. Utility Corridor Clearing							
- realign corridor or curtail construction during raptor nesting season (Utility alternative 1)	X	X	X	X	X	X	X
- selective clearing of overstory (Utility alternative 1)	X	X	X	X	X	X	X
3. Combined loss of habitat (new road cons/mine site)							
- create a 30-45 acre foraging area	X	X	X	X	X	X	X
4. Traffic impacts to wildlife waters							
- construct one earthen stock tank for each impacted water (no. of waters to construct)	3	2	1	2	3	1	1
5. Indirect loss of elk calving habitat effectiveness							
- construct one earthen stock tank OR close haul route from May 1 - June 30	X	X	X	-	-	-	-
Total no. of waters to construct	4	3	2	2	3	1	1

B. Monitoring

Monitoring wildlife populations and/or their habitats can be an effective way to determine if any adverse impacts are occurring during project implementation. Any wildlife monitoring that is done in connection with the Canyon Mine should meet the following criteria:

1. The monitoring studies must be intensive enough to be able to establish direct cause-effect relationships between mining activities and significant changes in wildlife population size or habitat quality.

2. Any significant impacts directly resulting from mining activities must be mitigated. Monitoring should not be conducted for the sake of gathering information with no guarantee of mitigation.



HAUL ROUTE OPTION BY PROJECT ALTERNATIVE

PROJECT	HAUL ROUTE
ALTERNATIVE 2&3	OPTION 1 ••••••••
ALTERNATIVE 3	OPTION 2 ———
(NO ALTERNATIVE)	OPTION 3 * * *
(NO ALTERNATIVE)	OPTION 4 —*—
ALTERNATIVE 4	OPTION 5 — — —
ALTERNATIVE 5	OPTION 6 —•—
ALTERNATIVE 5	OPTION 7 ➤ ➤

✱ CANYON MINE SITE

N

½" = 1 MILE

HAUL ROUTE OPTIONS

FIGURE 1

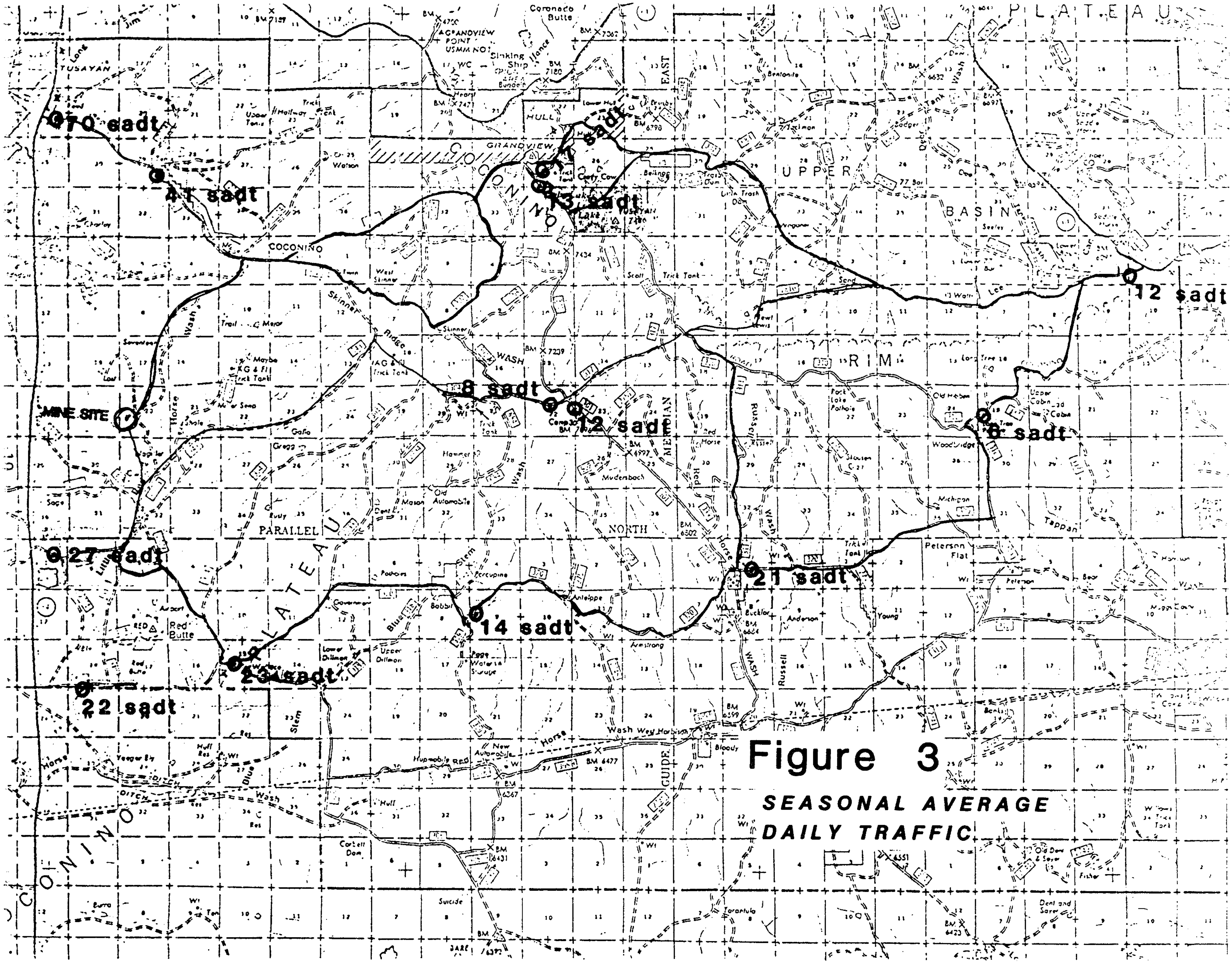
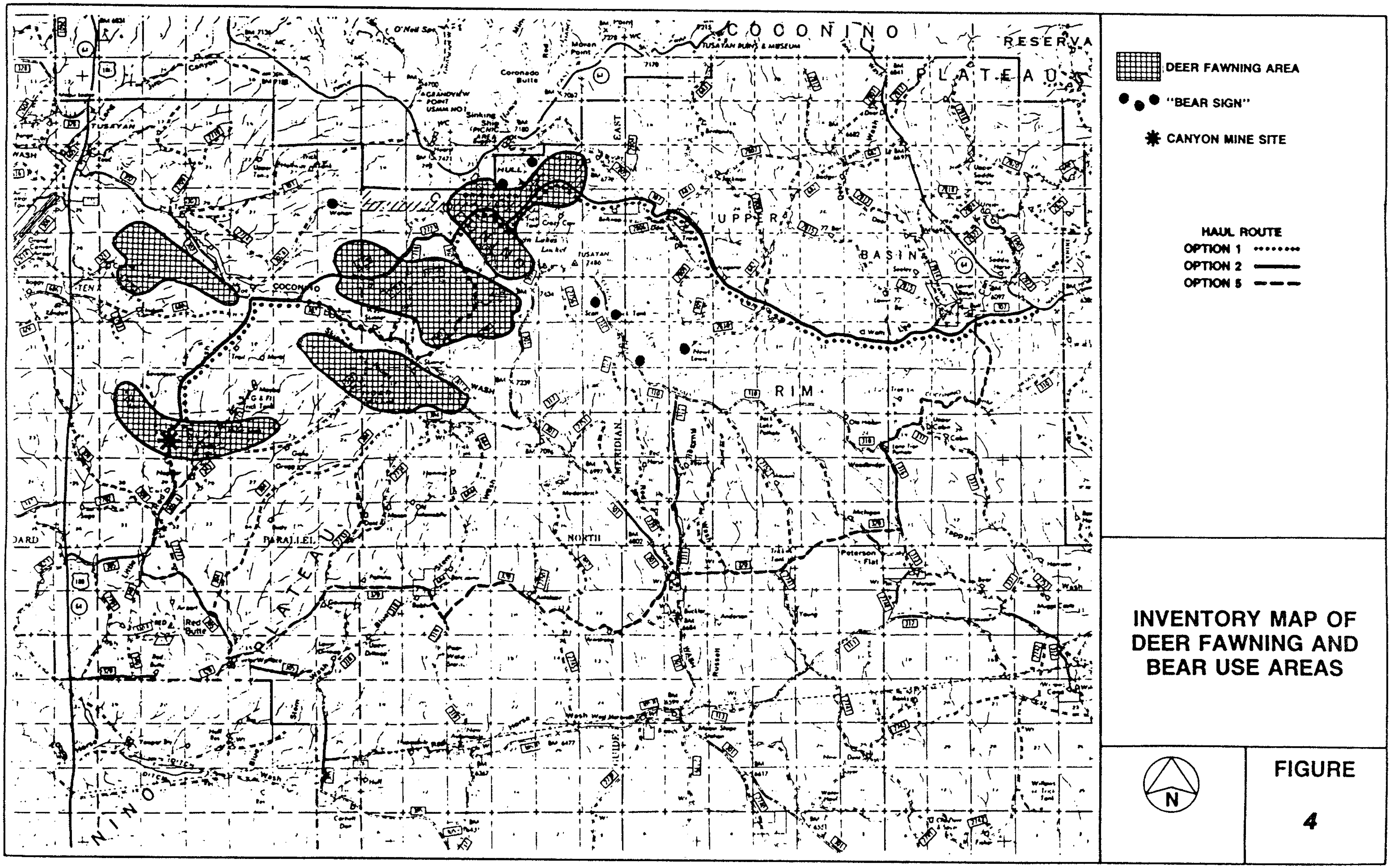


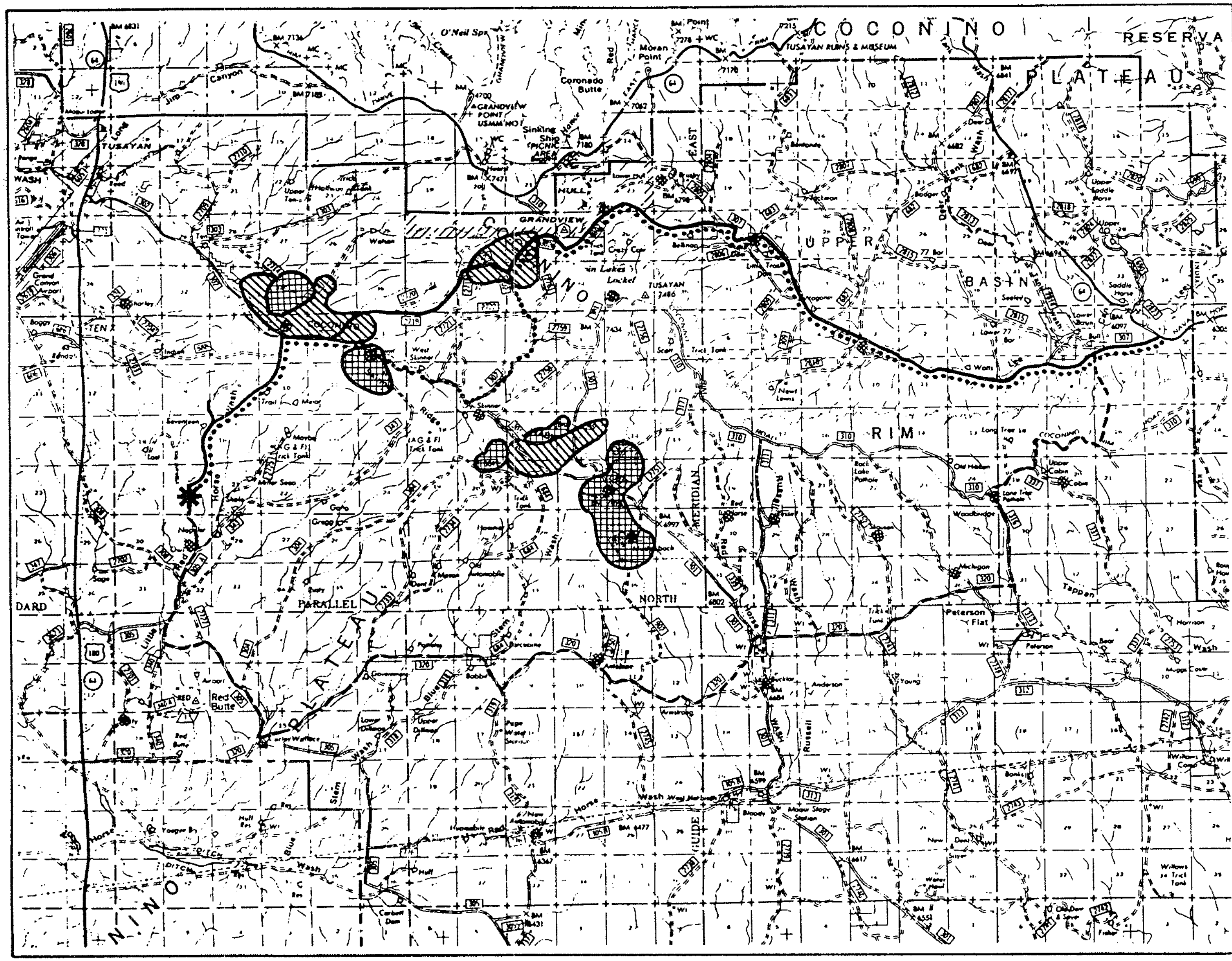
Figure 3

SEASONAL AVERAGE DAILY TRAFFIC



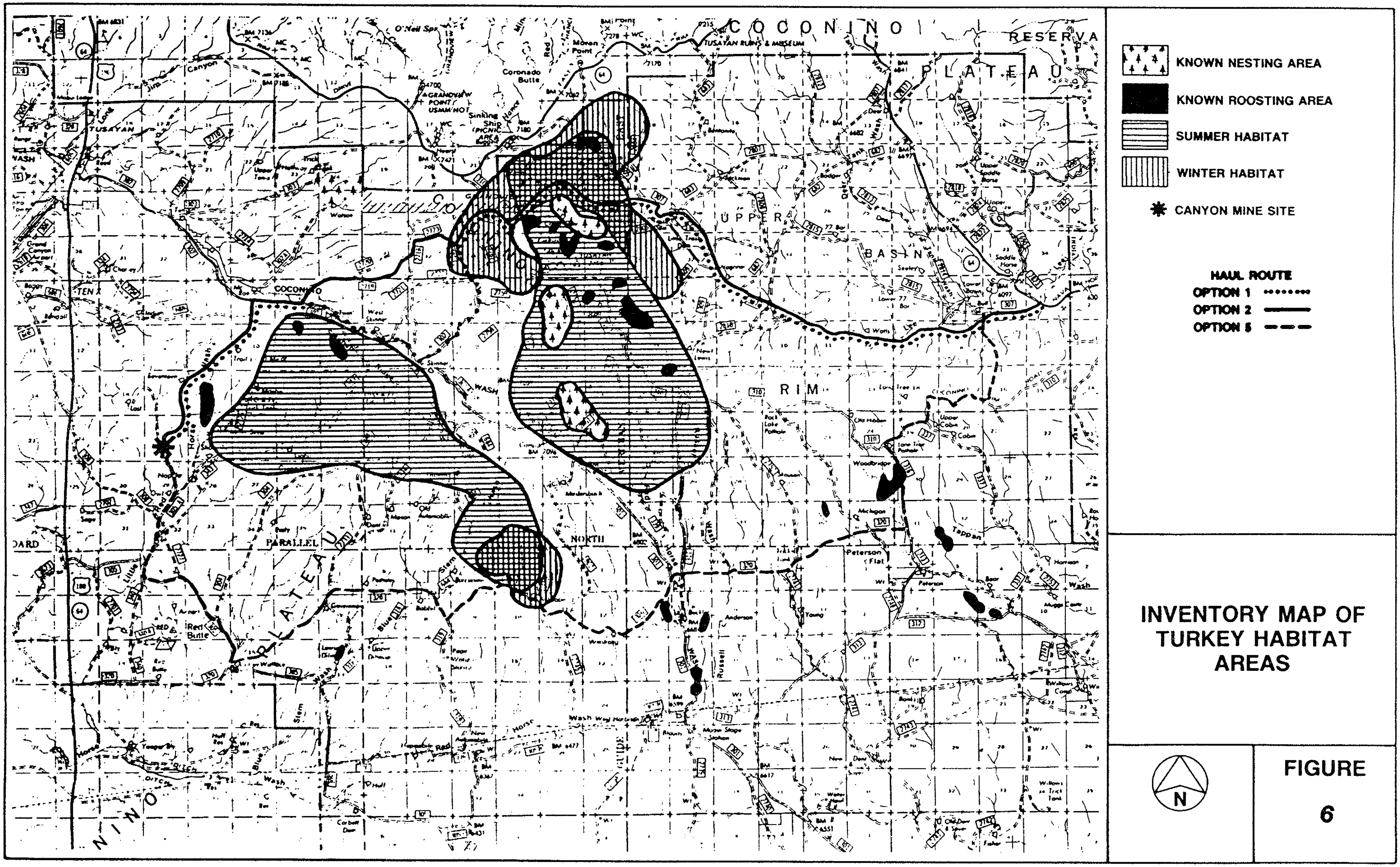
INVENTORY MAP OF DEER FAWNING AND BEAR USE AREAS

FIGURE 4



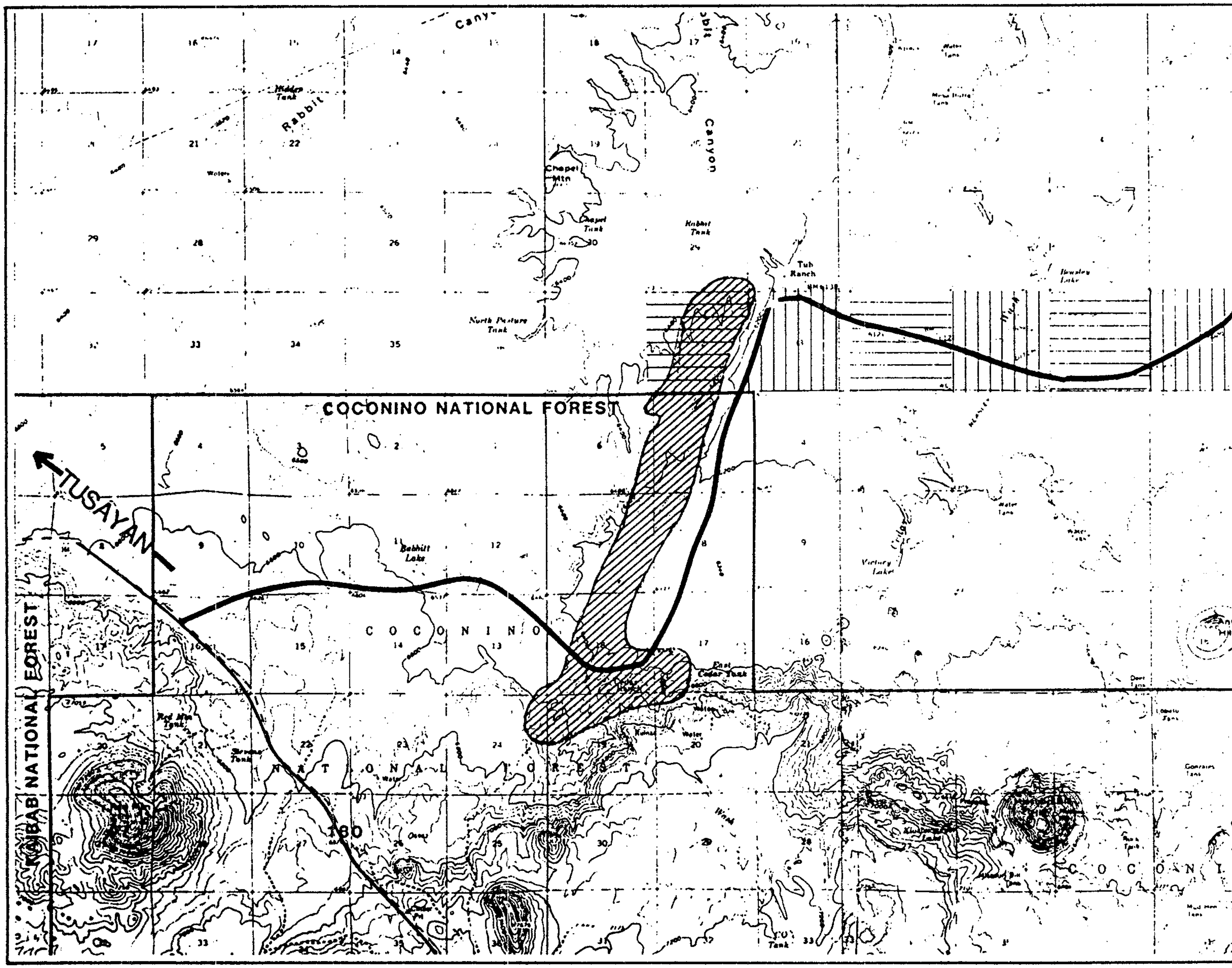
INVENTORY MAP OF ELK CALVING AND ANTELOPE FAWNING AREAS

FIGURE 5



INVENTORY MAP OF TURKEY HABITAT AREAS

FIGURE 6



INVENTORY MAP OF
MIGRATION CORRIDOR
FOR DEER AND ELK

HAUL ROUTE OPTION 7

FIGURE 7

APPENDIX A

Species Lists and Glossary

List 1. Bird Species List* for the Tusayan Ranger District (Robbins et al. 1983, Johnson et al. n.d.)

Turkey Vulture
Cooper's Hawk
Northern Goshawk
Red-tailed Hawk
Golden Eagle
Prairie Falcon
American Kestrel
Gambel's Quail
Wild Turkey
Band-tailed Pigeon
Mourning Dove
Screech Owl
Flammulated Owl
Great-horned Owl
Northern Pygmy Owl
Northern Saw-Whet Owl
Common Poorwill
Cliff Swallow
Stellar's Jay
Scrub Jay
Common Raven
Pinyon Jay
Clark's Nutcracker
Mountain Chickadee
Plain Titmouse
Common Bushtit
White-breated Nuthatch
Red-breasted Nuthatch
Pygmy Nuthatch
Brown Creeper
House Wren
Bewick's Wren
Canyon Wren
Rock Wren
Northern Mockingbird
American Robin
Hermit Thrush
Western Bluebird
Mountain Bluebird
Phainopepla
Loggerhead Shrike
Gray Vireo
Common Nighthawk
White-throated Swift
Black-chinned Hummingbird
Broad-tailed Hummingbird
Common Flicker
Acorn Woodpecker
Lewis' Woodpecker
Yellow-bellied Sapsucker
Hairy Woodpecker
Downy Woodpecker
Western Kingbird
Cassin's Kingbird
Ash-throated Flycatcher
Say's Phoebe
Western Wood Pewee
Olive-sided Flycatcher
Horned Lark
Violet-green Swallow
Solitary Vireo
Warbling Vireo
Virginia's Warbler
Yellow-rumped Warbler (Audubon's)
Black-throated Gray Warbler
Grace's Warbler
Western Meadowlark
Scott's Oriole
Brewer's Blackbird
Brown-headed Cowbird
Black-headed Grosbeak
Cassin's Finch
House Finch
Pine Siskin
Green-tailed Towhee
Rufous-sided Towhee
Vesper Sparrow
Lark Sparrow
Rufous-crowned Sparrow
Black-throated Sparrow
Dark-eyed Junco
Chipping Sparrow
Brewer's Sparrow
Black-chinned Sparrow
White-crowned Sparrow

* Does not include migrants, transients, or accidentals

List 2. Amphibians Species List for the Tusayan Ranger District (Stebbins 1966)

1. Western Spadefoot Toad (Scaphiopus hammondi)
2. Rocky Mountain Toad (Bufo woodhousei woodhousei)
3. Red-spotted Toad (Bufo punctatus)
4. Arizona Tiger Salamander (Ambystoma tigrinum nebulosum)

List 3. Reptile Species List for the Tusayan Ranger District (Stebbins 1966)

1.	Arizona Black Rattlesnake	(*Crotalus viridis cerberus*)
2.	Blacktail Rattlesnake	(*Crotalus molossus*)
3.	Sonora Mountain Kingsnake	(*Lampropeltis pyromelana*)
4.	Common Kingsnake	(*Lampropeltis getulus*)
5.	Spotted Night Snake	(*Hypsiglena torquata ochrorhyncha*)
6.	Wandering Garter Snake	(*Thamnophis elegans vagrans*)
7.	Sonora Gopher Snake	(*Pituophis melanoleucus affinis*)
8.	Red Racer	(*Masticophis flagellum piceus*)
9.	Striped Whipsnake	(*Masticophis taeniatus*)
10.	Southern Plateau Lizard	(*Sceloporus undulatus tristichus*)
11.	Collared Lizard	(*Crotaphytus collaris*)
12.	Lesser Earless Lizard	(*Holbrookia maculata*)
13.	Long-nosed Leopard Lizard	(*Crotaphytus wislizenii wislizenii*)
14.	Tree Lizard	(*Urosaurus ornatus*)
15.	Side-Blotched Lizard	(*Uta stansburiana*)
16.	Northern Whiptail	(*Cnemidophorus tigris septentrionalis*)
17.	Plateau Whiptail	(*Cnemidophorus velox*)
18.	Mountain Short-Horned Lizard	(*Phrynosoma douglassi hernandesi*)
19.	Great Plains Skink	(*Eumeces obsoletus*)
20.	Southern Many-Lined Skink	(*Eumeces multivirgatus epipleurotus*)

List 4. Mammal Species List for the Tusayan Ranger District (Burt and Grossenheider 1976)

1.	Merriam's Shrew	(*Sorex merriami*)
2.	Desert Shrew	(*Notiosorex crawfordi*)
3.	Long-eared Myotis	(*Myotis evotis*)
4.	Fringe-tailed Myotis	(*Myotis thysanodes*)
5.	Long-legged Myotis	(*Myotis volans*)
6.	Small-footed Myotis	(*Myotis subulatus*)
7.	Silver-Haired Bat	(*Lasionycteris noctivagans*)
8.	Big Brown Bat	(*Eptesicus fucus*)
9.	Townsend's Big-Eared Bat	(*Plecotus townsendii*)
10.	Big-eared Bat	(*Idionycteris phyllotis*)
11.	Pallid Bat	(*Antrozous pallidus*)
12.	Mexican Free-tailed Bat	(*Tadarida brasiliensis*)
13.	Big Free-tailed Bat	(*Tadarida macrotis*)
14.	Black-tailed Jack Rabbit	(*Lepus californicus*)
15.	Desert Cottontail	(*Sylvilagus audubonii*)
16.	Whitetail Prairie Dog	(*Cynomys gunnisoni*)
17.	Spotted Ground Squirrel	(*Citellus spilosoma*)
18.	Rock Squirrel	(*Spermophilus variegatus*)
19.	Golden-Mantled Ground Squirrel	(*Citellus lateralis*)
20.	Antelope Squirrel	(*Ammospermophilus leucurus*)
21.	Cliff Chipmunk	(*Eutamias dorsalis*)
22.	Abert Squirrel	(*Sciurus aberti*)
23.	Valley Pocket Gopher	(*Thomomys bottae*)
24.	Silky Pocket Mouse	(*Perognathus flavus*)
25.	Rock Pocket Mouse	(*Perognathus intermedius*)
26.	Ord's Kangaroo Rat	(*Dipodomys ordii*)
27.	Western Harvest Mouse	(*Reithrodomtomys megalotis*)
28.	Cactus Mouse	(*Peromyscus eremicus*)
29.	Deer Mouse	(*Peromyscus maniculatus*)
30.	Brush Mouse	(*Peromyscus boylii*)
31.	Pinyon Mouse	(*Peromyscus truei*)
32.	Northern Grasshopper Mouse	(*Onychomys leucogaster*)
33.	White-throated Wood Rat	(*Neotoma albigula*)
34.	Desert Wood Rat	(*Neotoma lepida*)
35.	Stephen's Wood Rat	(*Neotoma stephensi*)
36.	Mexican Wood Rat	(*Neotoma mexicana*)
37.	Mexican Vole	(*Microtus mexicanus*)
38.	Coyote	(*Canis latrans*)
39.	Gray Fox	(*Urocyon cinereoargenteus*)
40.	Black Bear	(*Ursus americanus*)
41.	Ringtail Cat	(*Bassariscus astutus*)
42.	Raccoon	(*Procyon lotor*)
43.	Long-tailed Weasel	(*Mustela frenata*)
44.	Badger	(*Taxidea taxus*)
45.	Striped Skunk	(*Mephitis mephitis*)
46.	Mountain Lion	(*Felis concolor*)
47.	Bobcat	(*Lynx rufus*)
48.	Elk	(*Cervus canadensis*)
49.	Mule Deer	(*Odocoileus hemionus*)
50.	Antelope	(*Antilocapra americana*)

List 5. Scientific Names of Common Plant Species Mentioned in Text

	Common Name in Text	Refers to
1.	Blue grama	Bouteloua gracilis
2.	Cliffrose	Cowania mexicana
3.	Crested wheatgrass	Agropyron cristatum
4.	Four-wing saltbush	Atriplex canescens
5.	Juniper	Juniperus osteosperma/Juniperus monosperma
6.	Mutton bluegrass	Poa fendleriana
7.	Pinyon pine	Pinus edulis
8.	Ponderosa pine	Pinus ponderosa
9.	Rabbitbrush	Chrysothamnus nauseosus
10.	Squirreltail	Sitanion hystrix
11.	Sagebrush	Artemisia tridentata
12.	Western wheatgrass	Agropyron smithii
13.	Winterfat	Eurotia lanata

Glossary of Terms Used in Text*

aquatic wildlife - all fish, amphibians, mollusks, crustaceans, and soft-shelled turtles (AGFD Hunting Regulations 1985).

big game - in the text: wild turkey, mule deer, elk, and antelope.

biological evaluation - a documented Forest Service review of Forest Service programs or activities in sufficient detail to determine how an action or proposed action may affect any threatened, endangered, proposed, or sensitive species (FSM 2670.5).

calving area - the areas, usually on spring-fall range where elk cows give birth to calves and maintain them during their first few days or weeks of life.

carrying capacity - the maximum rate of animal stocking possible without inducing damage to vegetation or related resources; may vary from year to year because of fluctuating forage production (Kothmann 1974).

category 1 species - sensitive species for which the Fish and Wildlife Service has sufficient information for consideration as a proposed, threatened, or endangered species.

category 2 species - sensitive species for which the Fish and Wildlife Service will require further research and study to determine their status.

conductor - the wires on a powerline. Conductors may be energized or neutral (at or near 0 volts).

cover - vegetation used by wildlife for protection from predators, to ameliorate conditions of weather, or in which to reproduce.

endangered species - any species in danger of extinction throughout all or a significant portion of its range (FSM 2670.5).

fawning area - an area, usually on spring-fall range, where does give birth to fawns and maintain them in their first few days or weeks of life.

forage - vegetation used for food by wildlife, particularly deer, elk, and antelope.

forb - any herbaceous plant species other than those in the grass (Gramineae), sedge (Cyperaceae), and rush (Juncaceae) families.

fur-bearing animals - in Arizona: muskrats, raccoons, otters, weasels, bobcats, beavers, badgers and ringtail cats (AGFD Hunting Regulations 1985).

game bird - in Arizona: upland game birds (quail, partridge, grouse, and pheasants) and migratory game birds (all wild waterfowl, all coots, all gallinutes, common snipe, wild doves, bandtail pigeons, and sandhill cranes) (AGFD Hunting Regulations 1985).

game mammal - in Arizona: deer, elk, bear, antelope, bighorn sheep, bison (buffalo), pecarry (javelina), mountain lion, tree squirrel, and cottontail rabbit (AGFD Hunting Regulations 1985).

ground wire - wires which usually run down the sides of powerpoles to drain off electrical charges from metal equipment (e.g. insulator pins, crossarm braces) on the pole. Electrical charges may build up because of wind, insulation contamination, moisture or other circumstances.

habitat - the sum total of environmental conditions of a specific place occupied by a wildlife species or a population of such species.

harassment (wildlife) - any activity of man and his associated domestic animals which increases the physiological costs of survival or decreases the probability of successful reproduction of wild animals (Neil et al. 1975).

home range - the area which an animal traverses in the scope of normal activities; not to be confused with territory.

informal consultation - all contacts, correspondence, or discussion between a Federal agency or its designated non-Federal representative and the Fish and Wildlife Service or the National Marine Fisheries Service that take place prior to initiation of any necessary formal consultation (FSM 2671.45a).

key area/habitat - a specific area or habitat which serves a special function; required for the sustenance of a viable wildlife population.

listed species - any species of fish, wildlife, or plant officially designated as endangered or threatened by the Secretary of the Interior or Commerce. Listed species are documented in 50 CFR 17.11 and .12.

migration corridor - a belt, band, or stringer of vegetation that provides a completely or partially suitable habitat in which animals follow during migrations.

migration route - a travel route used routinely by wildlife in their seasonal movement from one habitat to another.

nesting area - an area, usually on spring-fall range, where birds prepare nests, and lay and incubate eggs.

nongame species - all wildlife species except game mammals, game birds, fur-bearing animals, predatory animals, and aquatic wildlife (AGFD Hunting Regulations 1985).

overstory - composed of the plant species which form the uppermost layer of a plant community.

phase wire - another term for electrical conductor (see "conductor" definition).

population - a community of individuals that share a common gene pool.

predatory animals - in Arizona: foxes, skunks, coyotes, and bobcats (AGFD Hunting Regulations 1985).

proposed species - any species of fish, wildlife, or plant that is proposed by the Fish and Wildlife Service or the National Marine Fisheries Service to be listed as threatened or endangered (FSM 2670.5).

raptor - any predatory bird - such as a falcon, hawk, eagle, or owl - that has feet with sharp talons or claws adapted for seizing prey and a hooked beak for tearing flesh.

sedge - herbaceous or rushlike perennial plant belonging to the Cyperaceae family.

sensitive species - those plant or animal species identified by a Regional Forester for which population viability is a concern (FSM 2670.5).

snag - a standing dead tree.

summer range - an area, usually at higher elevation, used by wildlife during the late spring - early fall months.

"take" - means pursuing, shooting, hunting, fishing, trapping, killing, capturing, snaring, or netting wildlife or the placing or using of any net or other device or trap in a manner that may result in the capturing or killing of wildlife (AGFD Hunting Regulations 1985).

threatened species - any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range and that the appropriate Secretary has designated as a threatened species (FSM 2670.5).

understory - composed of the plant species which exist beneath the overstory layer.

viable population - a wildlife population of sufficient size to maintain its existence over time in spite of normal fluctuations in population levels.

* All or portions of many of these definitions are from Thomas (1979).

APPENDIX B

Consultation with Individuals, Organizations, and Agencies

Consultation with Others

Dan Baertlein, Facilities Engineer, Supervisor's Office - Kaibab National Forest; Williams, Arizona.

Tim Baumgarten, Unit 9 Wildlife Manager, Region II - Arizona Game and Fish Department; Tusayan, Arizona.

Dave Brewer, Forest Soil Scientist, Supervisor's Office - Kaibab National Forest; Williams, Arizona.

Tom Britt, Region II Supervisor, Arizona Game and Fish Department; Flagstaff, Arizona.

Ken Byford, Forest Biologist, Supervisor's Office - Kaibab National Forest; Williams, Arizona.

Glen Dickens, Habitat Specialist, Region II - Arizona Game and Fish Department; Flagstaff, Arizona.

Leon Fisher, Threatened and Endangered Fish and Wildlife Coordinator, Regional Office - Southwest Region of USDA - Forest Service; Albuquerque, New Mexico.

Lesley Fitzpatrick, Staff Biologist, Ecological Services Division, USDI - Fish and Wildlife Service; Phoenix, Arizona.

Reggie Fletcher, Regional Botanist, Regional Office - Southwest Region of USDA - Forest Service; Albuquerque, New Mexico.

Renee Galeano, Seasonal Botanist (former), Kaibab National Forest; Williams, Arizona.

Charles Jankiewicz, District Range and Wildlife Staff, Tusayan Ranger District - Kaibab National Forest; Tusayan, Arizona.

Terrell Johnson, Wildlife Biologist, Colorado Yampa Coal Company, Steamboat Springs, Colorado.

Thomas Leege, Wildlife Biologist, Idaho Department of Fish and Game; Coeur d' Alene, Idaho.

Robert Mesta, Acting Field Supervisor, Ecological Services Division, USDI - Fish and Wildlife Service, Phoenix, Arizona.

Johnny Ray, Resources Management Division, Grand Canyon National Park, USDI - Park Service; Grand Canyon, Arizona.

Don Richard, Range Conservationist, Supervisor's Office - Kaibab National Forest; Williams, Arizona.

Don Smith, Williams Office - Arizona Public Service Company; Williams, Arizona.

Randy Smith, Unit 7 Wildlife Manager (former), Region II - Arizona Game and Fish Department; Flagstaff, Arizona.

Ralph Stout, Forester, Tusayan Ranger District - Kaibab National Forest; Tusayan, Arizona.

John Vitt, Seligman Office - Arizona Public Service Company; Seligman, Arizona.

A. Lorin Ward, Principal Wildlife Biologist, Rocky Mountain Forest and Range Experiment Station - USDA Forest Service; Laramie, Wyoming.

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

Ecological Services
2934 W. Fairmount Avenue
Phoenix, Arizona 85017

2-21-85-I-92

September 10, 1985

Leonard A. Lindquist
Kaibab National Forest
800 South 6th Street
Williams, Arizona 86046

Dear Mr. Lindquist:

We have reviewed your biological evaluation for the proposed Canyon Uranium Mine and concur with your conclusion that no listed or proposed threatened or endangered species would be affected by the project.

Thank you for your concern for our endangered species.

Sincerely yours,

Frank M. Baucom
Acting Field Supervisor

cc: Director, Arizona Game and Fish Department, Phoenix, AZ
Regional Director, FWS, Albuquerque, NM (AHR)
Regional Director, FWS, Albuquerque, NM (SE)

United States Department of Agriculture

Forest Service

Reply to: 2670 Threatened and Endangered Plants and Animals
1950 National Environmental Policy Implementing Procedures

Date: July 17, 1985

Subject: Canyon Mine EIS - Informal Consultation with Fish And Wildlife Service

To: Lesley Fitzpatrick, Staff Biologist

The Kaibab National Forest has received a Plan of Operations from Energy Fuels Nuclear, Inc. for the development of a uranium mine on the Tusayan Ranger District. The Forest is preparing an environmental impact statement to identify issues, concerns, and opportunities relating to the proposed action.

A biological evaluation will be prepared as directed by Forest Service policy (FSM 2671.45 Exhibit 2) under the mandates of Section 7 of the Endangered Species Act (as amended). In order to conduct a thorough evaluation, a list of the following items is needed from your agency:

1. All proposed or listed species that are known or expected to inhabit the project area.

2. Any critical habitats on the Tusayan Ranger District.

A copy of the Plan of Operation and a map of the Tusayan Ranger District are enclosed. For purposes of this evaluation, consider the affected area to be the entire eastern half of the Tusayan Ranger District (east of Highway 64).

Sincerely,

Katherine A. Peckham

Katherine A. Peckham
Wildlife Biologist

ARIZONA GAME & FISH DEPARTMENT

2222 West Greenway Road Phoenix, Arizona 85023 942-3000

KAIBAB N. F.
RECEIVED JUL 29 1985

REGION II
310 LAKE MARY ROAD
FLAGSTAFF, ARIZONA 86001-9342

July 26, 1985

Dennis Lund
Kaibab National Forest
800 S. 6th St.
Williams, AZ 86046

Dear Dennis:

As per our discussion on 7-24-85 please review and include the following information provided by Randy Smith on the proposal to transport uranium over the existing Babbitt Ranch roads.

The proposed uraninum haul road from Highway 180 to the Babbitt Cedar Ranch, north to Babbitt's Tubb's Camp and eastward across Unit 7 to Highway 89A, has the potential to alter the use of wintering big game species. As noted on the map heavy populations of mule deer, elk and antelope inhabit the road site yearround. Primarily deer and elk winter along this area from December thru March. Heavy snows or a lingering winter tend to make mule deer and elk congregate on the lower ranges (Cedar Ranch - Tubb's Camp). This was very evident in 1984.

Initially deer are of primary concern as a major wintering area is exactly the Cedar Ranch. From the 1982-1984 survey data, 8%, 11% and 13% respectively, of all observed Unit 7 deer cross and winter within 2 miles of the Cedar Ranch property. Potentially, within 5 miles of the entire road length, 31% of the observed Unit 7 deer population is affected. Many wintering areas are south of the proposed haul road.

Similiary, heavy winters affect elk. During the 1984 winter survey effort, 11% of all observed and known population numbers, of elk in Unit 7 crossed and wintered within 2 miles of the Cedar Ranch and spent considerable time wintering north there to Tubb's Camp. Additionally, 18% more of all observed Unit 7 elk wintered within 5 miles of the haul road.

Antelope surveys accomplished from 1981-1984 reveal 26%, 42%,28% and 25% of all the observed Unit 7 antelope inhabit locale from Tubb's Camp to Highway 89A. The haul road bisects good antelope habitat, as observations were made equally north and south of the proposed haul road.

As you can see the potential for impact is there. But the consequences of increased vehicular traffic on these big game herds can only be speculated. My opinion as a professional is not encouraging.

An all-weather road would mean additional personnel access to this area, as currently winter access is limited. This, of course, means a potential for poaching and the necessity of our department to supply additional personnel man hours to patrol this area.

We appreciate the opportunity to provide comment on this proposal. Please feel free to call for further discussion if necessary.

Sincerely,

Tom

T.L. Britt
Supervisor, Region II

cc: R. Smith
G. Dickens
T. Baumgarten

TLB/rvb

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

Ecological Services
2934 W. Fairmount Avenue
Phoenix, Arizona 85017

2-21-85-I-92

August 6, 1985

Katherine A. Peckham
Kaibab National Forest
800 South 6th Street
Williams, Arizona 86046

Dear Ms. Peckham:

This responds to your letter dated July 17, 1985 which requested a list of species federally listed or proposed to be listed as threatened or endangered. The proposed action involves the Canyon Mine project on the Tusayan Ranger District of the Kaibab National Forest in Coconino County, Arizona.

We have no records of listed or proposed species on the project area. The peregrine falcon (Falco Peregrinus) is a resident of the Grand Canyon and may utilize portions of the project area. A Candidate Category 1 plant species, Astragalus cremnophylax has been found in limestone pavement areas near El Tovar, adjacent to the project area. Candidate species have no legal protection under the Endangered Species Act, but are species for which the Service has substantial information to support their listing as endangered or threatened. The development and publication of proposed rules for these species is anticipated. They are included in this document for planning purposes only.

If we can be of further assistance, please call our office at FTS 261-2493 or commercial 241-2493.

Sincerely,

Robert I. Mesta
Acting Field Supervisor

cc: Director, Arizona Game and Fish Department, Phoenix, Arizona
Regional Director, FWS, Albuquerque, New Mexico (AHR)
Regional Director, FWS, Albuquerque, New Mexico (SE)

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
KAIBAB NATIONAL FOREST
800 So. 6th St.
Williams, AZ 86046

2670

August 21, 1985

Robert I. Mesta
Ecological Services
2934 West Fairmount Avenue
Phoenix, AZ 85017

Dear Mr. Mesta:

The biological evaluation for the proposed Canyon Uranium Mine (reference Plan Of Operation 1984) is enclosed. This document has been prepared in accordance with legal requirements under Section 7 of the Endangered Species Act (16 USC 1536 (C)). The purpose of this biological evaluation is to determine whether the proposed Canyon Mine is likely to affect endangered, threatened, proposed, or sensitive species.

The evaluation has concluded that there will be "no adverse effect" on listed, proposed, or sensitive species in the project area. Please review the evaluation and notify this office of your agency's opinion of concurrence or nonconcurrence with the determination of effect.

Sincerely,

LEONARD A. LINDQUIST
Forest Supervisor

Enclosure

Region 3

USDA - Forest Service

Biological Evaluation

for the

PROPOSED CANYON URANIUM MINE

Kaibab National Forest
Supervisor's Office
800 South Sixth Street
Williams, Arizona 86046

Prepared by: Katherine A. Peckham Date: 8-24-85
Katherine A. Peckham
WILDLIFE BIOLOGIST

The purpose of this evaluation is to document the analysis of impacts from the proposed Canyon Mine on threatened, endangered, proposed, and sensitive species.

The "affected area" refers to the eastern half of the Tusayan Ranger District, Kaibab National Forest.

I. Threatened, Endangered, Proposed, and Sensitive Species

A list of threatened and/or endangered species that might occur in the project area was requested from the U.S. Fish and Wildlife Service (FWS) on July 17, 1985 (Appendix: Letter to Lesley Fitzpatrick). The FWS reply stated that the agency had no records of listed or proposed species in the project area. It was noted, however, that the peregrine falcon, an endangered species, is a resident of the Grand Canyon and may utilize portions of the area (Appendix: Letter to K. Peckham, dated 8/6/85).

In addition to the peregrine falcon, the bald eagle and eight sensitive plants potentially occur in the affected area.

A. Fish and Wildlife

The bald eagle is considered an endangered species in the lower 48 states. Johnson et al. (n.d.) lists this species as a rare winter migrant to the Grand Canyon region. Bald eagles are frequently sighted in Grand Canyon National Park (GCNP) during the annual Christmas Bird Count conducted by the Park Service. The most recent documented bald eagle sightings on the Tusayan District were reported during the winters of 1975, 1976, 1977, and 1982 (GCNP Study Collection records). Bald eagles probably move through the area each winter but the majority of sightings are not documented.

Breeding and wintering peregrine falcons may inhabit the Tusayan District on a seasonal basis. Ellis (1978) conducted peregrine falcon surveys on National Forest lands in Arizona from 1974-1978. He identified two areas on the District as "very suitable breeding habitat". Ellis suggested that the rim areas be managed as falcon hunting habitat. He noted that "falcons nesting in the Grand Canyon have been observed hunting over the forests on the rim".

Winter use on the District by peregrines is probably sporadic and scattered. Ellis (1978) felt that winter use in Arizona would be greatest where prey is abundant such as in areas with concentrations of waterfowl and other migratory birds.

B. Plants

There are no known threatened, endangered, or proposed plant species in the affected area. The following sensitive plants potentially exist on the Tusayan District (R-3 Sensitive Plant List 1984):

On Notice of Review

Category One
1. *Astragalus cremnophylax*

Category Two
1. *Chrysothamnus molestus*
2. *Clematis hirsutissima* var. *arizonica*
3. *Rosa stellata*
4. *Silene rectiramea*
5. *Talinum validulum*

Not On Notice of Review

1. *Aquilegia desertorum*
2. *Potentilla multifoliolata*

To date, *C. molestus* is the only sensitive plant known to exist in the affected area. The plant was located approximately five miles to the southwest of the mine site (Kaibab National Forest Herbarium, collected 8/13/84):

II. Critical or Essential Habitat

No critical or essential habitats (see FSM 2670.5) have been designated on the Tusayan District.

III. Analysis of Effects

There are three areas that will be disturbed during the life of the mine:

1) the powerline right-of-way; 2) the Area of Operation (mine site); and 3) the haul route.

Table 1 displays a summary of mining impacts and their expected effect on the bald eagle, peregrine falcon, and eight sensitive plant species.

Table 1. Summary of expected mining impacts and their effect on endangered and sensitive species.

	Expected Effect on:		
	Peregrine Falcon	Bald Eagle	Sensitive Plants
1. Powerline			
a) Right-of-way clearing (max. of 4.1 acres)	No effect	No effect	Possible effect
b) Powerline installation	Additional roost/hunt perches	Additional roost/hunt perches	No effect
	Possible Increased risk of raptor electrocution	Possible Increased risk of raptor electrocution	No Effect
2. Area of Operation			
a) Topsoil removal (17.4 acres)	No effect	No effect	Possible effect
b) Drilling Activities (human disturbance)	No effect	No effect	No effect
c) Radon gas/dust emissions	No effect	No effect	No effect
d) Potential for water contamination	No effect	No effect	No effect
3. Haul Route			
a) Road Construction and reconstruction	No effect	No effect	Possible effect
b) Traffic disturbance	No effect	No effect	No effect

Note: By "no effect" it is meant that there will be no significant adverse impacts on the species in question.

Discussion

A. Powerline

Powerline Design

Energy Fuels Nuclear, Inc. (EFN) proposes to install 1.7 miles of powerline from the mine site west to Highway 64 (see Plan of Operation 1984). Powerpoles will provide additional hunting and roosting perches for all raptors, including the bald eagle and peregrine falcon. Depending on its design, the powerline also has the potential to increase the risk of raptor electrocution.

Raptors are electrocuted on powerlines because of two major factors: 1) their distribution, size, and behavior; and 2) the design of some powerlines which places phase and ground wires close enough together that raptors simultaneously touch them with their wings or other parts of their bodies.

Between 70-90 percent of all raptor mortalities along powerlines are eagles (Boeker and Nickerson 1975, Peacock 1980, Ansell and Smith 1980). Current data shows that the overwhelming majority of eagle electrocution fatalities affect golden eagles.

Efforts to minimize electrocution of golden eagles will also benefit bald eagles and peregrine falcons. Adequate separation of phase wires, ground wires, and other metal hardware is the most important factor in preventing electrocutions. Olendorff et al. (1981) recommends a 60-inch minimum separation of wires (conductors and ground wires) to lessen the risk of electrocution. This minimum separation will be recommended as a mitigation measure in the draft EIS currently being prepared. Once mitigated, the powerline should present no significant electrocution risk to peregrine falcons or bald eagles in the affected area.

Right-of-way Clearing

It is assumed that the 1.7-mile powerline right-of-way (R/W) will have a standard 20-foot width and will be completely cleared of vegetation. This could affect any sensitive plant populations that might occur within the R/W.

A recommendation to selectively clear the overstory vegetation in the R/W will be included in the draft EIS. This should minimize impacts to any sensitive plants in the understory.

B. Area of Operation (AO)

Topsoil Removal

EFN proposes to remove the 6-inch topsoil layer within the 17.4 acre mine site. This has the potential to affect any sensitive plant populations in the area.

Field clearances for A. cremnophylax, C. molestus, C. hirsutissima, and R. stellata were conducted within the AO on April 17 and May 8, 1985. None of the plants were found in the project area.

A. desertorum and P. multifoliolata are not expected to be found in the AO based on their known habitat requirements. A. desertorum is locally abundant in Coconino County where limestone bluffs, outcrops, or ledges are exposed (Brian et al. 1982a). The AO is characterized by deep alluvial soils (Dave Brewer, pers. comm.) with no obvious areas of exposed limestone.

Brian et al. (1982b) describes P. multifoliolata as being restricted to shallow, rocky drainage bottoms or washes with intermittent flow or subsurface water during a portion of the year. Drainages are of either basalt or sandstone with poor soil development and a high percentage of rocks or gravel. This habitat description contrasts with the limestone-derived soils present in the project area (Dave Brewer, pers. comm.).

Very little site-specific information has been collected to date on the habitat requirements of S. rectiramea or T. validulum. S. rectiramea is known only from two locations (Bright Angel Trail and the vicinity of Hermit's Rest) on the South Rim of Grand Canyon National Park. The only detailed locality information comes from Bailey's 1935 collection. He reported that the species was found in the Sonoran-chaparral type, 200 feet below Hermit's Rest. The species has not been relocated since 1935 and it is possible that it has been extirpated or is extinct (Brian et al. 1982c). Based on this information, the plant is not expected to inhabit the AO.

Available habitat information is inadequate to rule out the chance of T. validulum existing in the AO. A field clearance should be conducted during its flowering period in late summer.

Radon Gas and Dust Emissions

An initial concern was that radon gas and dust originating from the mine would pose a significant health hazard to the bald eagle and/or peregrine falcon. The alpha-emitting progeny of Radon-222 have been linked to lung cancer in humans; specifically in uranium miners and other underground miners (90th Congress 1967, Advisory Committee on the Biological Effects of Ionizing Radiation 1972).

Radon gas is a colorless, odorless, inert gas that will diffuse from the ore piles and be exhausted from the mine vent. Uranium and its progeny will be present in dust blown off the ore piles and will be released from the mine vent.

McKlveen (1985) conducted a thorough assessment of the effects of radon gas and dust emissions from the Canyon Mine. He concluded that there would be no significant radiological impact on the environment from the release of radon gas or dust from the mine site. Consequently, there should be no adverse effect on the bald eagle or peregrine falcon.

Potential for Water Contamination

EFN proposes to construct water diversion channels to the west and northeast of the drill site. The main diversion channel was originally thought to be capable of accommodating only surface runoff resulting from a 10-year event (Plan of Operation 1984). This raised the concern that a larger event could wash stockpiled uranium ore downstream. Forest Soils personnel recalculated the runoff capacity of the main channel and found it capable of accommodating runoff generated by at least a 100-year event (Dave Brewer, pers. comm.).

McKlveen (1985) estimated the degree of contamination that would result from a hypothetical 500-year flood in the affected area. He concluded that a flood of this magnitude could conceivably release approximately 50 curies of radioactivity to the downstream wash. "Radionuclide concentrations in the water and residual concentrations in the soil would not be sufficient to create a health problem. Cattle or wildlife grazing in the washes would not ingest harmful amounts of radioactive material. The animals would remain fit for human consumption." (McKlveen 1985). Based on this information, it is highly unlikely that bald eagles and/or peregrine falcons would be adversely affected if the area outside of the mine site became contaminated.

C. Haul Routes

Four haul route alternatives are being considered in the draft EIS. New road construction will be needed on 3 of the 4 routes, resulting in direct habitat losses ranging from 11-21 acres. All routes will also require extensive reconstruction to make them suitable for all-weather use.

Vegetation clearing associated with road construction and reconstruction has the potential to affect sensitive plant populations. Plant surveys will be conducted within all disturbed road corridors to determine if mitigation measures are needed.

There should be no long-term cumulative impacts on bald eagles, peregrine falcons, or sensitive plant populations assuming that the recommended mitigation measures (see "Recommendations", Section VI) are implemented.

IV. Determination of Effect

It has been determined through this evaluation that the Canyon Mine will have no adverse impact on the peregrine falcon, bald eagle, or known sensitive plant species in the affected area.

V. Recommendations

A. Objective - Minimize the risk of raptor electrocution on the proposed powerline.

Recommendation - Ensure that phase and ground wires on the proposed powerline are separated a minimum of 60 inches (see Olendorff et al. 1981).

B. Objective - Minimize impacts to sensitive plant populations that may occur in the powerline right-of-way.

Recommendation - Selectively remove only those trees in the right-of-way that will be a hindrance to the powerline itself.

C. Objective - Determine if any sensitive plant populations exist in areas to be disturbed by mining activities.

Recommendation - Conduct further plant surveys in the Area of Operation and in the haul route corridor where vegetation removal will occur.

If sensitive plants are found within these areas, the line officer with project approval authority makes the decision to allow or disallow impact. The decision must not result in loss of species viability or create significant trends toward Federal listing (FSM 2670.324).

Consultation with Others

Dave Brewer, Forest Soil Scientist, Supervisor's Office - Kaibab National Forest; Williams, Arizona.

Ken Byford, Forest Biologist, Supervisor's Office - Kaibab National Forest; Williams, Arizona.

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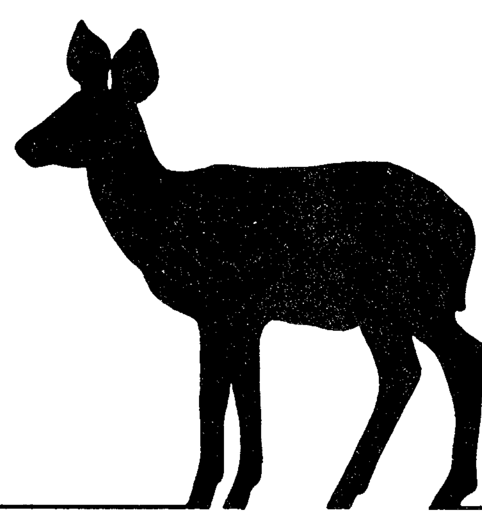
Appendix

D

Downstream Hydrologic Impacts



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DOWNSTREAM HYDROLOGIC IMPACTS

OF PROPOSED CANYON MINE

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July, 1985

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DRAINAGE PLAN AND DOWNSTREAM HYDROLOGIC IMPACTS OF PROPOSED CANYON MINE

I. DESCRIPTION OF TASKS

The proposed Canyon Mine will be located in an area that is subject to high intensity rainfall. While runoff generated from such storms normally lasts for only a short time, peak discharges can be large. Downstream impacts can be minimized by the measures taken to control surface runoff at the mine. Accordingly, a flood control system should be developed to insure that degradation of the surface runoff downstream will not likely occur during 100-year and lesser frequency events. Provided the control system chosen is properly constructed and maintained, even during larger floods, the risk of significant degradation downstream should be small.

In October, 1984, Energy Fuels Nuclear proposed as part of a plan of operation, a system of trapezoidal channels to divert storm runoff around the mine site. Task A was to evaluate the effectiveness of the proposed drainage plan to adequately handle intense storm events. Task B was to develop relationships for estimating downstream impacts from releases of: (1) sediment and (2) leacheate from the mine itself during local thunderstorm and general frontal-type storm runoff events of various magnitudes, assuming that installed drainage facilities fail for some reason to divert this runoff around the mine.

II. BACKGROUND INFORMATION

The proposed Canyon Mine is located in the Ponderosa Pine forest type. Snowfall accounts for about one-half of the annual precipitation, which averages almost 15 inches. Following is a summary of monthly precipitation in inches for the typical year at Grand Canyon National Park (NOAA, 1973):

Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Annual
1.35	1.28	1.47	1.00	0.54	0.48	1.50	2.11	1.21	1.07	.82	1.59	14.42

During dry and wet years, annual precipitation can be less than 8 inches or more than 25 inches respectively. For the 1931-1982 record period at Grand Canyon National Park, the driest year was 7.14 inches in 1976 and the wettest was 25.51 inches in 1982. Water yield from this area is perhaps 2 inches or less each year.

The area is subject to intensive rainfall and infrequent but major floods. High-intensity rainfall confined to small areas and lasting for a short time is responsible for most storm runoff. However, general frontal-type storms in the region over large areas sometimes occur causing extreme runoff from rainfall and/or snowmelt.

Canyon Mine Watersheds

Figure 1 shows watersheds considered in this study. The shaded area in Figure 1 identifies the watershed that would directly impact the proposed development. Five reference locations, or nodes, define the outlet of the primary drainage areas. Each Node represents the point past which storm runoff from the watershed must pass. Node 0 is located just upstream of the proposed mine site. This watershed drains approximately 1.0 square miles. Node 1 located just below the site, has a drainage area of 2.3 square miles. Node 2 is just below Owl Tank, and has a drainage area of 3.5 square miles. Node 3, just upstream from Highway 64, receives runoff from 22.7 square miles in Little Red Horse Wash. Finally, Node 4 is at the confluence of Little Red Horse Wash with Red Horse Wash some 13.5 miles downstream from the mine site. The drainage area at this location (Node 4) is 43.4 square miles.

Definitions of Terms

A number of terms used in this report are defined below:

Antecedent Moisture Conditions(AMC): An index of the amount of soil moisture on a watershed just prior to a given rainfall event. Antecedent soil moisture has a significant effect on runoff volume. Three AMC conditions are defined as follows:

- Condition I: soils are relatively dry with little or no rainfall during the previous 5 days.
- Condition II: average soil moisture conditions.
- Condition III: soils are saturated due to significant rainfall during the previous 5 days.

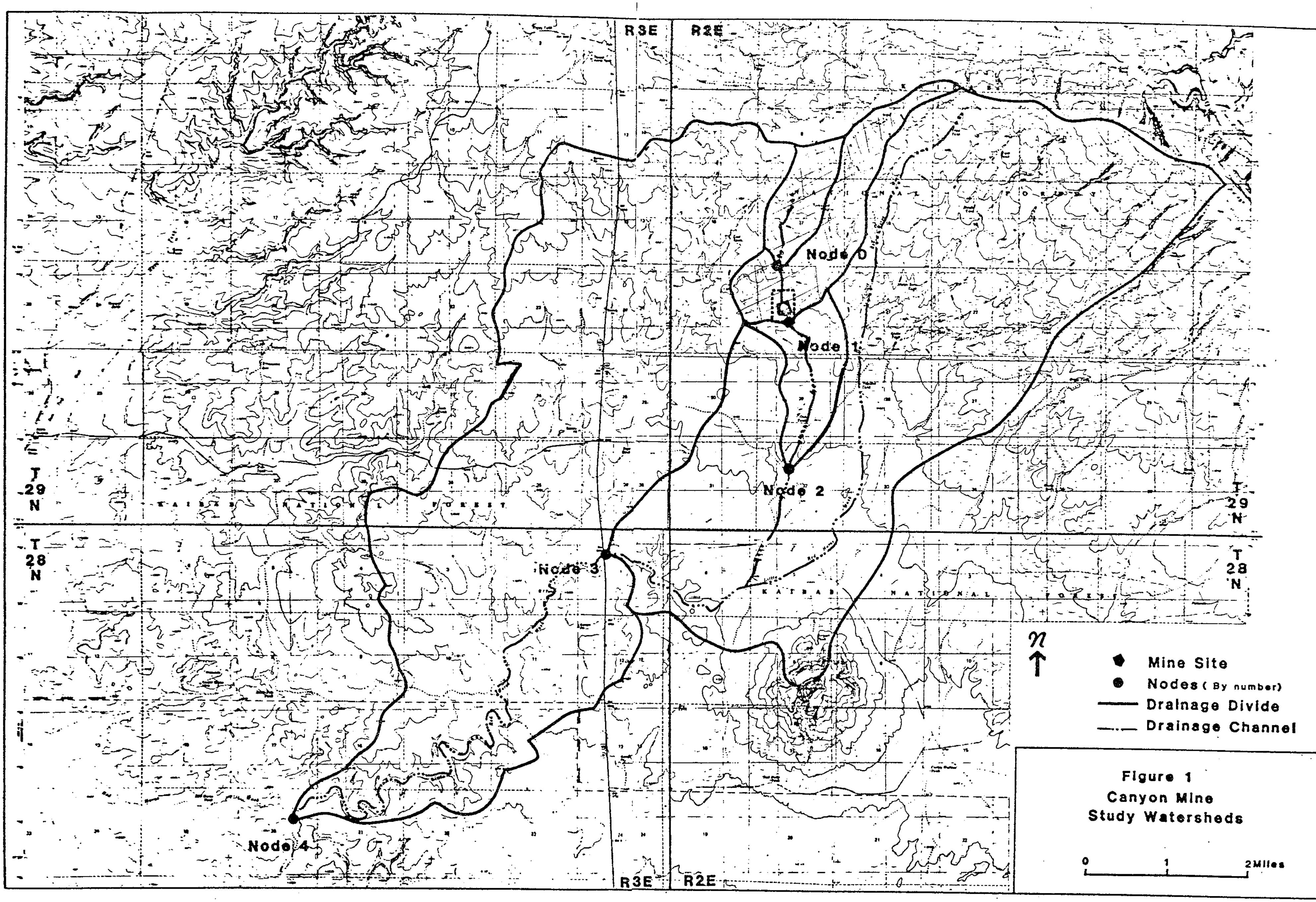

Figure 1
Canyon Mine
Study Watersheds

Flood Plain: The area, usually low lands, adjoining the channel of a river, stream or watercourse or ocean, lake, or other body of standing water, which has been or may be coverd by flood water (U.S.Army, 1972).

Hydrologic Soil Group: A soil classification system developed by the U.S. Soil Conservation Service, consisting of four groups labeled A,B,C,D as follows:

Group A: deep, permeable sandy silty or loamy soils.

Group B: shallow soils having infiltration characteristics similar to Group A soils.

Group C: less permeable clay loams, shallow sandy loams, soils with little organic content, and soils with a high clay content.

Group D: soils with a high shrink/swell potential; heavy plastic clays.

Node: A reference point along the stream channel referenced by distance upstream or downstream from the proposed Canyon Mine and by drainage area (see map, Figure 1). With respect to each Node, all upstream run-off from the respective watershed must pass the identified Node.

Recurrence Interval: The average length of time in years between events of a given magnitude. This is not to say that having experienced a 100-year flood, another flood of an equal magnitude will not occur again for 100 years.

Roeske (1978): An engineering report (see IV. REFERENCES) which presents regression equations for estimating flood magnitudes at ungaged sites for recurrence intervals of 2,5,10,25,50,100 and 500 years. The equations are applicable to Arizona. They relate flood peak to one or more of the following independent variables: size of drainage area, mean basin elevation, and mean annual precipitation. The regression equations, developed from historic runoff data from Arizona streams, apply in watersheds that are not significantly affected by regulation, diversion, or urbanization. Flood peaks computed from the equations developed by Roeske (1978) were used in this study for comparative purposes, since these statistical methods are widely used by forest hydrologists in Arizona.

Runoff Curve Number(CN): A runoff coefficient which integrates the combined hydrologic effect of soil, land use, hydrologic condition, and antecedent soil moisture. To illustrate, the runoff curve number for forest land under these various combinations is shown below.

Hydrologic Condition	Curve Number (CN) For AMC and Hydrologic Soil Group											
	AMC I				AMC II				AMC III			
	A	B	C	D	A	B	C	D	A	B	C	D
Poor	27	46	60	68	45	66	77	83	65	83	94	95
Fair	20	40	54	62	36	60	73	79	56	79	90	94
Good	12	35	51	60	25	55	70	77	45	75	87	93

Sheet Flow Area: An area of shallow flooding "where a clearly defined channel does not exist, where the path of flooding is unpredictable and indeterminate, and where velocity flow may be evident" (Fed.Emer. Mgt. Agency, 1979).

Time of Concentration (Tc): An index of the time for a hypothetical drop of water to travel from the most distant point on the watershed to the analysis point. In this study, Tc was estimated as:

$$Tc = \left(\frac{11.9\ L^3}{H} \right)^{0.385}$$

Where L = length of the longest watercourse in miles, and

H = difference in elevation between the drainage divide and the analysis point in feet.

Watercourse: Any natural or man-made depression with a bed and well-defined banks two feet or more below the surrounding land serving to give direction to a current of water at least nine months of the year or having a drainage area of one square mile or more (U.S. Army, 1972).

Historical Data (August 14, 1984 Flash Flood)

Both local thunderstorms and general storms of large magnitude have been documented near the mine site. In December, 1966, a large frontal-type storm lasting for several days generated runoff with a recurrence interval of several hundred years on the north rim of the Grand Canyon. This storm is described in U.S. Geological Survey Professional paper 980 (Cooley, et al, 1977).

In addition, and perhaps of more local significance is the extreme storm runoff event which occurred on Little Red Horse Wash in August 1984. This storm event provided a bench mark against which to base the evaluation of flood potential for Canyon Mine. Field reconnaissance of the area and data furnished by the Tusayan District Ranger indicates that this storm was confined to Little Red Horse Wash upstream from Node 3.

Peak flows computed by the Kaibab National Forest from high water marks and surveys of channel cross-sections and slope at Nodes 0-3 were as follows:

Node	Estimated Peak Discharge From August 14, 1984 Storm (c.f.s.)
0	106
1	908
2	1350
3	2447

According to observers who monitored the flood, the crest overtopped Highway 64, flowed downstream in Little Red Horse Wash, merged with main Red Horse Wash (Node 4) and dissipated in the large flat area some 4 miles downstream (see Figure 2). Apparently, no significant runoff from this event was observed beyond the large open area.

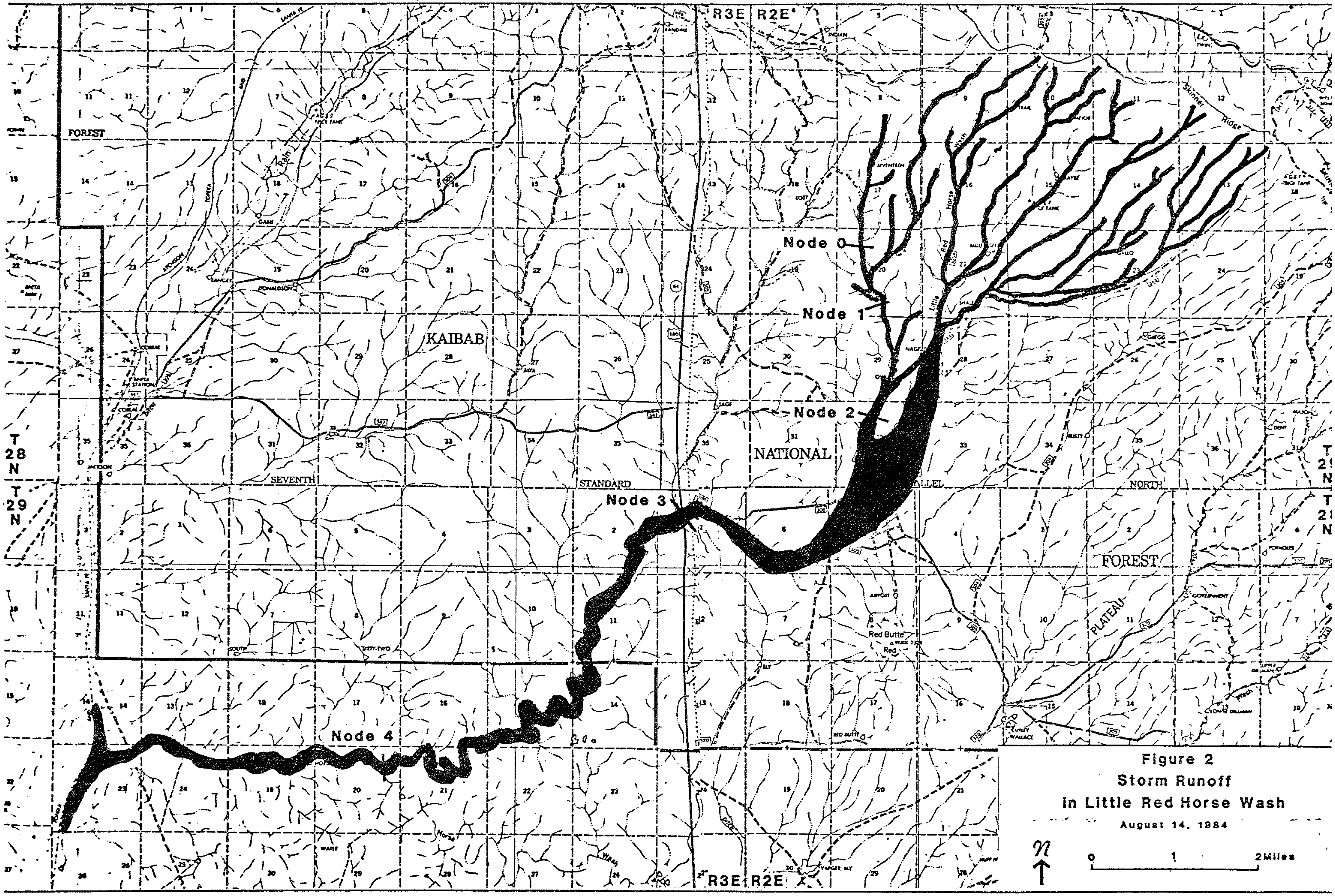

Figure 2
Storm Runoff
in Little Red Horse Wash
August 14, 1984

Methodology

Soil Conservation Service (SCS) hydrologic methods were used to determine the recurrence interval (10-yr., 50-yr., 100-yr., etc.) of the August, 1984 storm event. The handbook methods summarized in McCuen (1982) were used to compute volumes and peak flows from 2,10,25,50,100, and 500-year recurrence interval events at Nodes 0-4, respectively.

SCS hydrologic methods determine a storm peak and runoff volume from a given precipitation event by considering the following factors:

a. Area, shape, total relief, and length of the longest watercourse, and

b. Vegetation cover composition and density, and soil infiltration capacity. These watershed parameters are combined to identify flood potential by means of a curve number (CN).

Two types of runoff were assumed in this analysis as follows:

1. Thunderstorm on a initially dry watershed (AMC I).

2. Intense rainfall on a initially wet watershed (AMC III).

Field data indicate that watershed condition during the August, 1984 storm event closely approximated AMC I. The second storm runoff analysis used a similar rainfall distribution but the runoff coefficient was higher due to the assumed high levels of soil moisture.

The physical data necessary to make the analysis were obtained from USGS topographic quandrangle maps. Soils information was obtained from Soil Conservations Service (1983) and Forest Service (1979) soil survey reports. Forest cover composition and density was estimated from a field reconnaissance of the area. Precipitation data for the storm events considered in this analysis were obtained from a report by Canonie Engineers (1985). Table 1 summarizes watershed characteristics at each Node.

Results

Table 2 summarizes peak discharges and runoff volumes for AMC I and AMC III storms at each Node. Also shown for comparison are; (a) estimated peaks generated by the August, 1984 event, and (b) peak discharges using statistical equations developed by Roeske (1978).

Table 1

Watershed Characteristics

Hydrologic Features	NODE 0	1	2	3	4
Area (mi.^{2})	1.05	2.30	3.51	22.70	43.40
Distance Downstream From Node 1 (mi.)		0	1.7	5.5	13.5
Time of Concentration (hr.)	0.75	1.14	1.67	2.75	4.59
Hydrologic Soil Group SCS Classification	D	D	D	D	D
Vegetation	Pinon/Juniper, Ponderosa Pine, Scrub Oak on all watersheds.				
SCS Curve Number (CN)					
AMC I	68	68	68	68	68
AMC III	93	93	93	93	93
24-Hour Precipitation (in.)					
2-yr.	1.5	1.5	1.5	1.5	1.5
10	2.3	2.3	2.3	2.3	2.3
25	2.6	2.6	2.6	2.6	2.6
50	2.8	2.8	2.8	2.8	2.8
100	3.0	3.0	3.0	3.0	3.0
500	3.4	3.4	3.4	3.4	3.4

Table 2 - Summary of Peak Discharge
and Runoff Volume for Various Recurrence Interval Storms.

	NODE 0		1		2		3		4	
	Peak (cfs)	Vol. (a-f)	Peak (cfs)	Vol. (a-f)	Peak (cfs)	Vol. (a-f)	Peak (cfs)	Vol. (a-f)	Peak (cfs)	Vol. (a-f)
AMC I Tunderstorm										
2-yr.	41	5.6	67	12.3	77	18.7	340	121.1		
10	124	16.8	200	36.8	232	56.2	1021	363.2		
25	187	25.2	300	55.2	309	74.9	1362	484.3		
50	207	28.0	333	61.3	386	93.6	1702	605.3		
100	249	33.6	400	73.6	502	121.7	2213	786.9		
500	352	47.6	567	104.3	695	168.5	3064	1089.6		
AMC III General Storm										
2-yr.	228		367	67.5	425	103.0	1873	665.9	2014	925.9
10	664		1067	196.3	1235	299.5	5448	1937.1	8055	3704.0
25	767		1234	226.9	1429	346.3	6299	2239.7	9062	4166.4
50	829		1334	245.3	1544	374.4	6810	2421.3	10572	4860.8
100	954		1534	282.1	1776	430.6	7831	2784.5	11076	5092.3
500	1120		1801	331.2	2085	505.4	9193	3268.8	13593	6249.6
Roeske (1978)										
2-yr.	20		33		44		124		229	
10	131		203		258		743		1073	
25	259		392		491		1327		1873	
50	403		601		746		1932		2688	
100	598		878		1080		2697		3705	
500	1329		1893		2290		5315		7119	
Est. Aug. 14,1984	106		908		1350		2447			

As seen in Table 2, estimated peaks from the August, 1984 event had recurrence intervals of over 500 years at Nodes 1 and 2,and 100 years at Node 3 when compared with the AMC I and Roeske design peaks. At Node 0, the estimated peak had only a ten-year recurrence interval which is consistent with field observations. The small watershed immediately above the proposed Canyon Mine site apparently was just on the fringe of more intense rainfall to the east in Little Red Horse Wash.

Description of Proposed Concept Drainage Plan

The proposed Canyon Mine site lies in an area that is subject to shallow flooding during extreme runoff. Because clearly defined channels do not exist, water spreads out over a broad front before becoming concentrated flow in the channel below the mine site at Node 1. The mine site is in a "sheet flow area", whereas downstream at Node 1, a defined "flood plain" exists (see definitions). High water marks indicate that storm runoff from the August, 1984 storm event flowed across the site at depths of 6 to 8 inches. Peak flow was estimated to be 908 c.f.s. at Node 1 just below the site. Most of this Peak was generated from the watershed just east of the small drainage which contains Node 0.

The operations plan by Energy Fuels Nuclear (1984) proposes to divert storm runoff away from the mine site by means of two trapezoidal channels. In addition to the channels, protective dikes would be constructed. These dikes are discussed in the plan of operations.

III. ENVIRONMENTAL OBJECTIVES OF SURFACE RUNOFF CONTROL

In addition to mine safety and economic considerations, a number of environmental objectives are important in designing surface runoff control. These objectives are:

1. to prevent erosion of the ore stockpile even during extreme runoff events,
2. to prevent dispersion of radioactive material and other pollutants into the surface and groundwater systems, and
3. to accomplish objectives 1. and 2. above with the least impact to the existing environment.

IV. EVALUATION OF PROPOSED AND ALTERNATIVE DRAINAGE PLANS

Proposed Drainage Plan (Alternative 1)

The diversion channels proposed by Energy Fuels Nuclear (1984) would be sized to carry runoff from a 100-year, 1-hour, event. Additional diversion capacity would be provided by the protective dikes. A report by Canonie Engineers (1985) lists the following capacities of the proposed channels shown in figure 3:

Precipitation Event	Peak Flow, cfs[1/] Diversion Channel A	Diversion Channel B
10-yr, 24-hr	111	25
10-yr, 1-hr	213	67
100-yr, 1-hr	465	147

1/ AMC II

Advantages of the proposed system are that storm runoff up to a 100-yr recurrence interval could be safely handled by the diversion channels. However, during runoff from larger events, channel capacity, would be exceeded and flood control would depend on the effectiveness of the dikes. It is estimated that the proposed system would be totally effective in controlling floods of a 100-year recurrence interval or less Beyond that, the system may be only partially effective.

Disadvantages of the proposed system are that construction of the diversion channels would require considerable site disturbance. Moreover, the steeper gradients of the artificial channels and concentration of flow would cause: (1) increased erosion, and (2) possibly trigger head cutting and channel instability unless special precautions are taken to heavily armor the bed and banks.

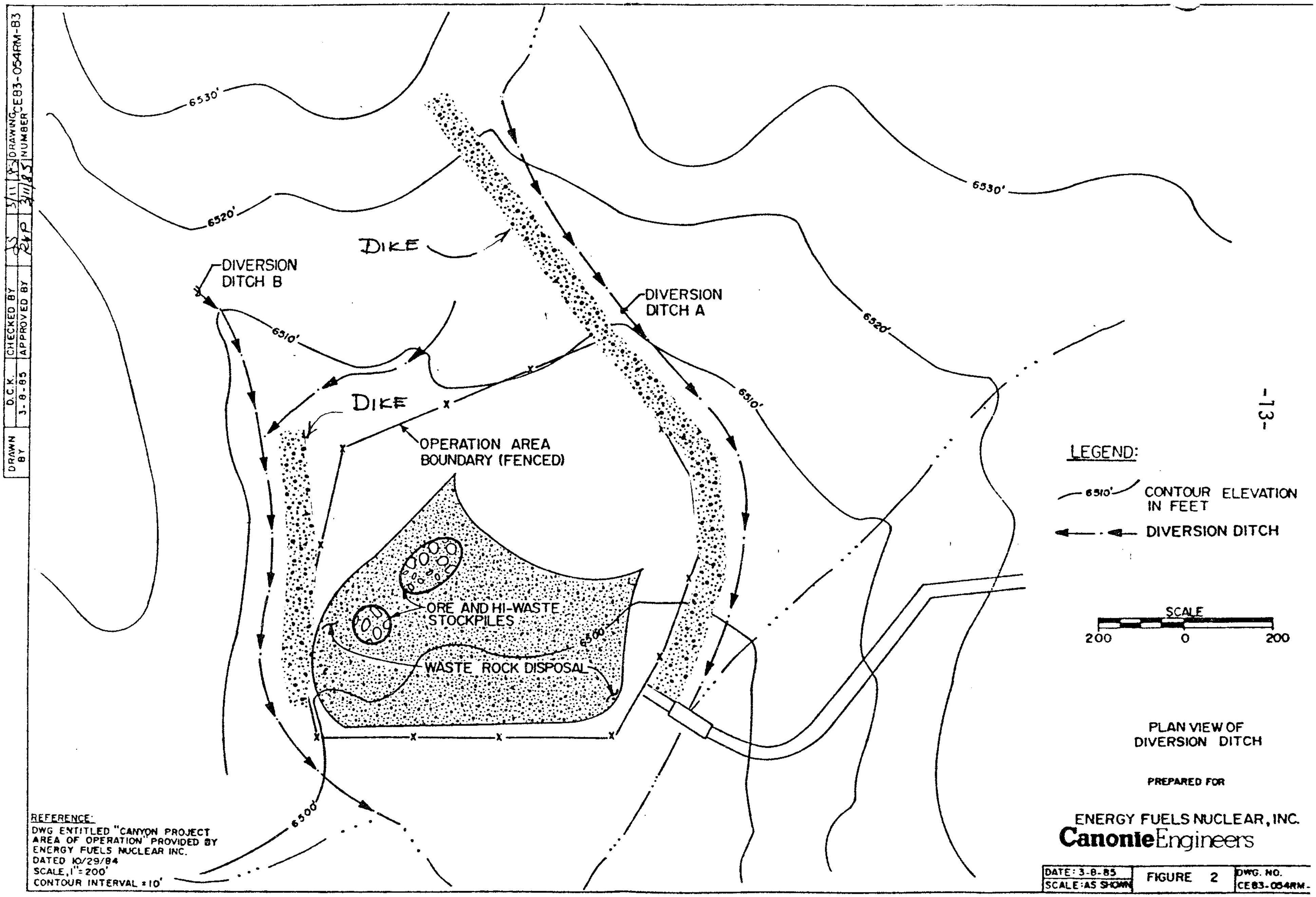

Figure 3 - Proposed Drainage Plan For Canyon Mine
(Canonie Engineers, 1985).

Alternative Drainage Plan (Alternative 2)

Alternative 2 would not use man-made channels to control storm runoff. Instead, a dike would be constructed from top soil and borrow material within the mine yard, around the upstream perimeter of the mine site. The borrow area will be later filled with waste rock generated during shaft sinking. This alternative would confine flows to existing natural channels, cause the least amount of site and channel disturbance, and be totally effective in controlling flood events on the order of at least a 500-year recurrence interval (see Table 2). A concept plan for Alternative 2 is shown in Figure 4. As seen in Figure 4, perimeter geometry would be modified slightly from the original mine plan to take maximum advantage of high ground and existing channel capacity. Another important feature of this concept plan is that by reducing perimeter width at the south end of the site, additional flow area would be provided in the channels that merge together in this area. The ford crossing and approach ramps into the site would efficiently control overland flow near the southwest corner of the mine site. Heavy riprap would be used to protect the dike from scour during high runoff events. Estimated flow characteristics at the southwest outfall and ford at sections A and B (see Fig. 4) are as follows:

Location (Fig. 4)	Recurrence Interval(yrs)	Discharge (c.f.s.)	Depth (ft.)	Velocity (ft./sec.)
A	500+	2,120	2.0	6.7
B	500+	1,827	2.0	6.3

Based on field inspection of the area following the August, 1984 storm event, peak discharge at Node 1, (which was the combined discharge from channels A and B) was approximately 980 c.f.s. From Table 2 it is seen that this flow exceeded a 500-year AMC I event.

Under Alternative 2, the capacity of the natural channels, with the proposed dike would be sufficient to carry runoff in excess of a 500-yr AMC III event. At locations A and B, flow depths are approximately 2 feet. Crest elevation of the dike would be at least 4 feet above natural grade. Based on these estimates, Alternative 2 has adequate safety factors to control flows during events greater than a 100-year recurrence interval.

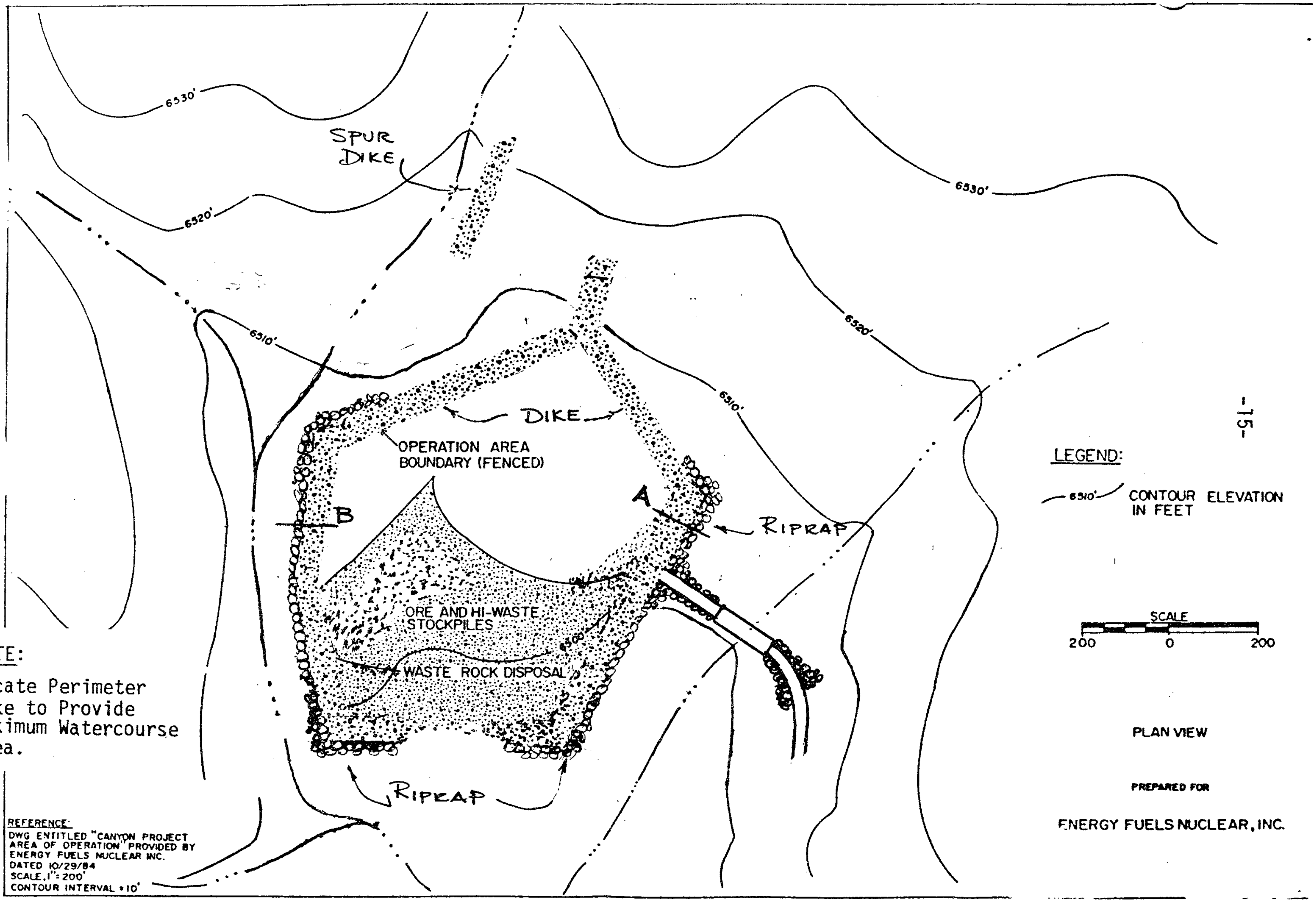

Figure 4 - Alternative 2 Conceptual Drainage Plan.

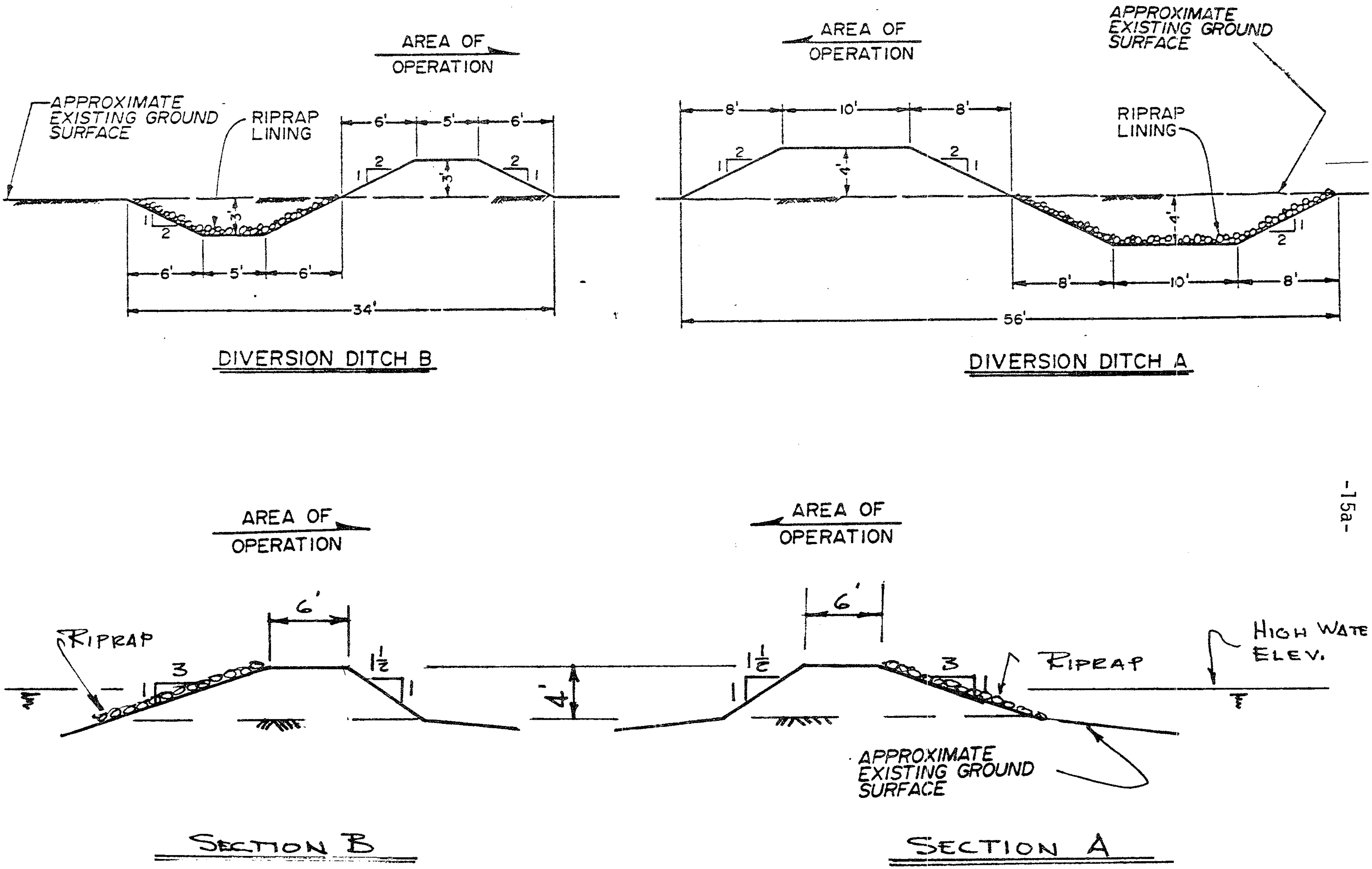

Figure 4A- Cross Sections For Proposed Drainage Plan (Top) and Alternative 2 (Bottom).

Advantages are that Alternative 2 could be implemented with much less disturbance than Alternative 1. Retention of original stream alighnment and gradient would result in significantly less channel erosion than Alternative 1. Also, sufficient capacity to safely carry large peak flows and channel stability are insured by not increasing natural gradients or concentrating runoff in sidehill ditches.

Controls

The following general guidelines for mitigating impacts are suggested under Alternatives 1 and 2:

- Drainage on relocated roads should be in accordance with U.S. Forest Service standards.
- There should be only minimum disturbance of existing channels around the mine perimeter.
- Channel improvements such as removal of all debris, selected trees, and minor excavation should be made to increase capacity.
- Revegetate all disturbed areas as soon as possible. Reseed previously reclaimed areas if necessary until a vigorous vegetation cover is established.
- The minimum elevation of the base of the ore pile should be at an approximate elevation of 6,500 feet, and not less than 5 feet above the ground surface outside the dike along the south edge of the mine yard. (This will ensure that erosion of the ore pile will not occur during flood events up to a recurrence interval of approximately 500 years.)
- The dike and spoil embankments as noted on Figure 4, should be riprapped at all areas where flow velocities are sufficient to cause erosion. Such areas include the approach ramp and ford on the access road and the entire south end of the perimeter, including the dike and spoil embankment.
- All abondoned roads outside the mine perimeter should be brought to original grade, water barred, and revegetated.
- The dike and primary stream channels in the vicinity of the mine should be routinely maintained to insure their integrity at all times.

Mine Area Drainage

Regulations require that drainage structures be sized to control the runoff from a 10-year, 24-hour runoff event. However,to be on the safe side, the retention pond should be sized to safely contain runoff from at least a 100-year, recurrence interval storm. It should also be lined to prevent seepage. To store a 100-year, 24-hour, AMC III runoff event would require a pond capacity of at least 2.8 acre feet. This compares with 2.0 acre feet necessary to store runoff from a 10-year, 24-hour event. Storage for expected mine water, etc. should be in addition to the 2.8 acre-foot minimum.

In addition to an established minimum elevation of approximately 6,500 feet for the base of the ore pile, the pad on which the pile rests should be made impervious and graded so that all runoff immediately flows into the retention pond. Grading inside the mine site should be away from the spoils embankment and perimeter dike.

V. DOWNSTREAM IMPACTS

An issue concerning the proposed Canyon Mine development is the potential downstream effects given the unlikely occurrence of ore pile and mine area runoff and sediment being introduced into the surface water system as the result of storm runoff. These effects would vary depending on the magnitude of storm runoff and the degree to which the diversion and drainage control facilities fail.

Assumptions

Two scenarios were assumed in addressing this issue as follows:

1. Potential downstream effects from a local AMC I thunderstorm centered immediately upstream of the proposed mine site. Affected area is approximately 1 $mi.^2$.
2. Potential downstream effects from an extreme AMC III rainfall event.
3. Total failure of the diversion and drainage control fac ilities at the mine site.

The affected area in excess of 40 $mi.^2$ would include all of the area drained by Little Red Horse Wash.

The first scenario assumes that the thunderstorm runoff is dissipated by the channel system much like the August, 1984 event. The second scenario assumes that the downstream impacts of initial storm runoff above the mine is subsequently reduced by dilution.

Methodology and Field Measurements

Figure 6 summarizes the estimated downstream effects of a thunderstorm centered over a 1-$mi.^2$ area for storms of various recurrence interval. In this scenario, it was assumed that the 500-year runoff generated upstream from the mine is dissipated in a linear fashion on logarithmic paper to some negligible amount some 18 miles downstream from the mine. This is believed to be a conservative assumption, since the August 14, 1984 event which was generated by rainfall over a considerably larger area than 1 square mile, was observed to dissipate in this distance. Runoff just above the mine site (at Node 0) was determined from Tables 1 and 2 for each recurrence interval storm. As seen in Figure 6, the estimated downstream reduction of initial runoff was estimated by scaling each recurrence interval storm parallel to the assumed 500-year relationship. The reader is referred to Figure 1 for the locations of each Node plotted in Figures 6 and 7.

Downstream dilution of initial impact from an AMC I thunderstorm and an AMC III general storm was computed by the ratio: $\frac{\text{runoff at Node 0}}{\text{runoff at downstream Node}}$ X 100. Data for computing each percentage for the AMC III general storm were obtained from Table 2. Data for computing each percentage for the AMC I thunderstorm were similarly obtained from Figure 6.

Results

Figure 7 summarizes percent of initial impact (concentration or load) as a function of distance downstream for the AMC I thunderstorm and AMC III general storm. Both scenarios show considerable reduction of initial impact (either concentration or load) in the first 2 miles. Just below Owl Tank at Node 2, the reduction of initial impact would be 70 percent for the AMC III general storm and 90 percent for the AMC I thunderstorm. At Node 4, some 13.5

Note: Assumes local storm on
approx. 1Mi. above Mine Site.

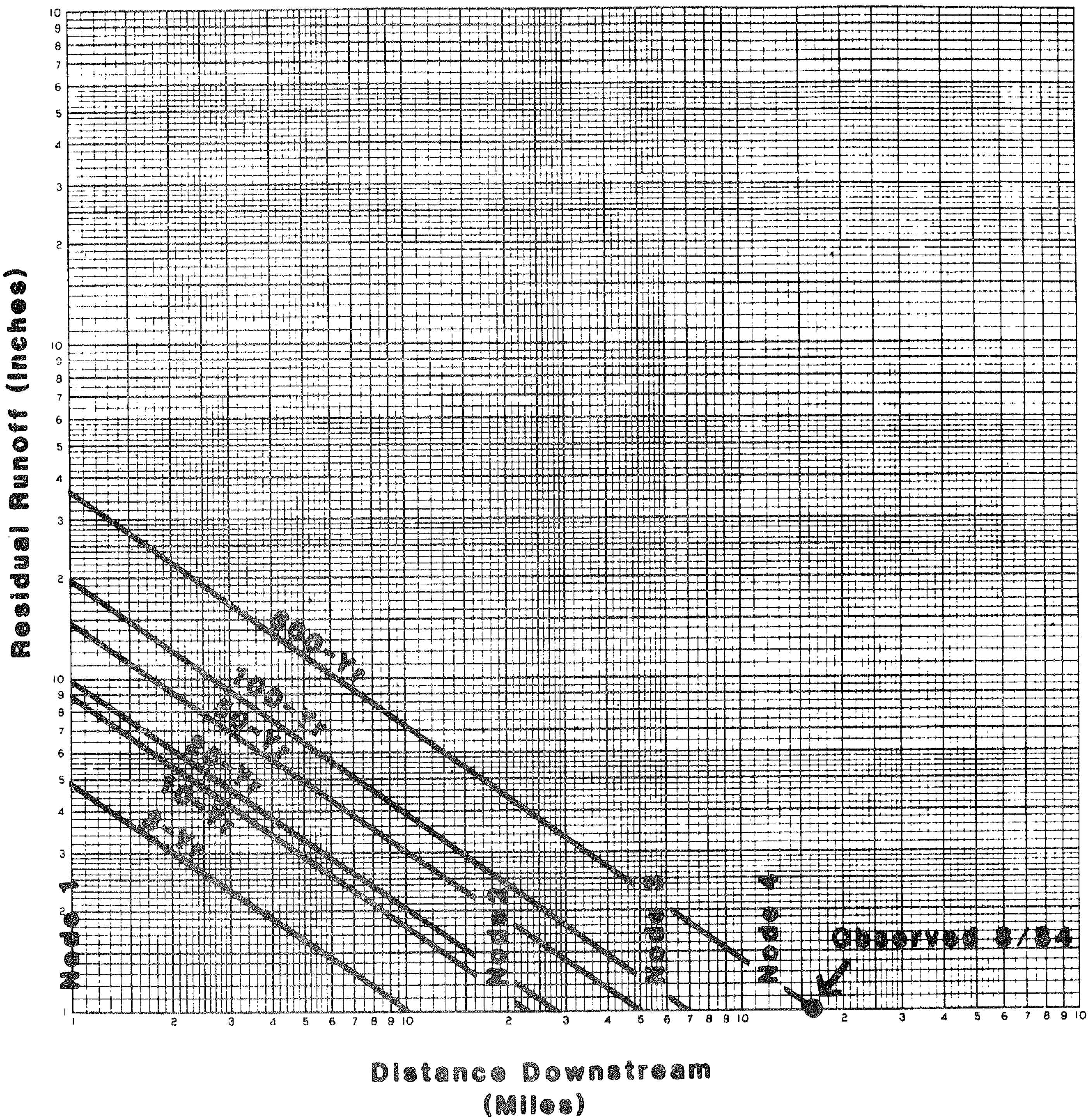

Figure 6

Local Thunderstorm

AMC-I

Residual Runoff vs. Distance Downstream

miles downstream, it is estimated that initial impact would be diminished about 98 percent under both scenarios.

Solubility and Sedimentation Analysis

The relationships in Figure 7 can be used to estimate downstream radioactivity and quantities of other pollutants as the result of possible releases of leacheate and/or sediment from the mine site. During a local thunderstorm, concentrations of these materials are assumed to be constant, and the residual impact is expressed as load. During a general storm, the initial concentration is reduced downstream as the result of inflows from a rapidly increasing drainage area.

VI. CONCLUSIONS

The proposed Canyon Mine can be protected from major storm runoff events by means of dikes and/or channels around the entire upstream perimeter of the area. Improvement of existing primary stream channels consisting of debris and selected tree removal, minor excavation and riprap would provide a watercourse adequate to safely carry at least a 500-year storm event around the mine site.

A minimum elevation for the base of the ore pile at approximately 6,500 feet and at least 5 feet above ground elevation outside the dike near the south edge of the mine yard and heavy riprap on the downstream face of the spoils embankment on which the ore pile will rest, would make any erosion of uranium ore unlikely during a major event.

Although both Alternatives can be designed to control runoff events exceeding a 100-year recurrence interval, Alternative 2 has more capacity and can provide storm runoff control with less environmental impact.

Impacts from any sediment or leacheate introduced at the mine rapidly diminish with distance downstream. At the confluence of Little Red Horse Wash with Red Horse Wash some 13.5 miles downstream, it is estimated that initial impact would be diminished by about 98 percent for both general and local thunderstorm flood occurrences.

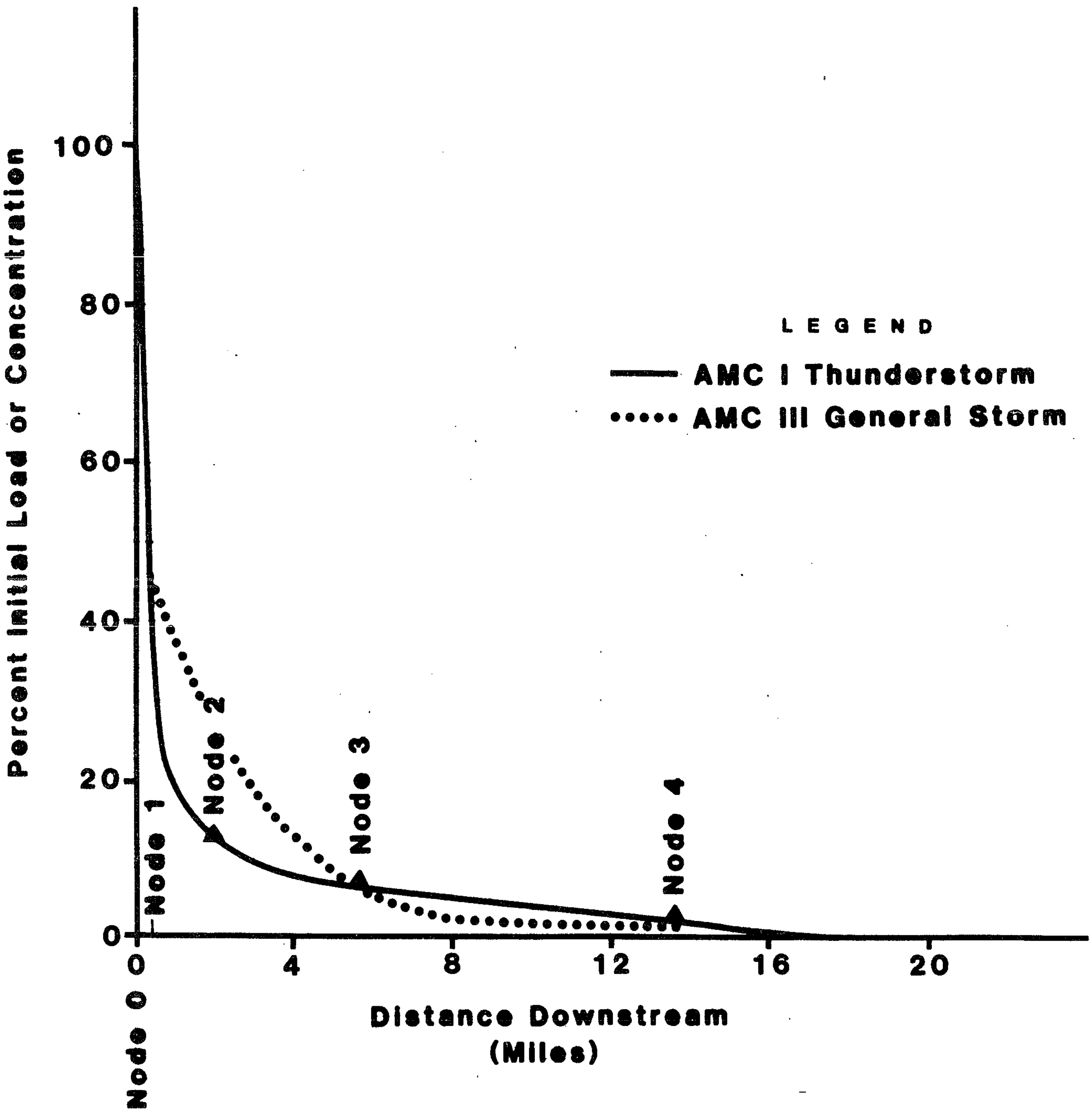

Figure 7

Estimated Downstream Effects Of Introduced Sediment or Leacheate From Proposed Canyon Mine For Thunderstorm & General Stoirm Flood Occurrences.

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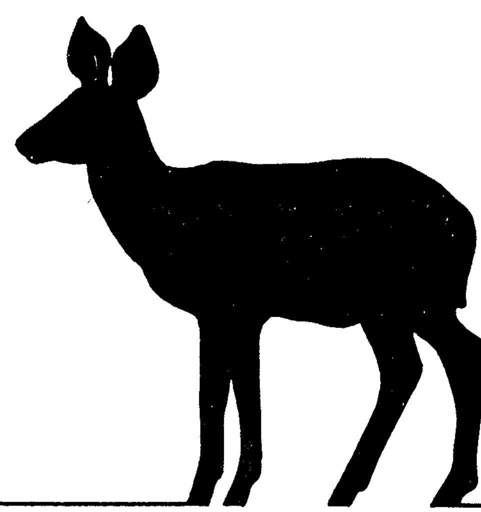
Appendix

E

Radiological Assessment



RADIOLOGICAL ASSESSMENT

OF THE

CANYON MINE PROJECT

KAIBAB NATIONAL FOREST

COCONINO COUNTY, ARIZONA

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July 25, 1985

RADIOLOGICAL ASSESSMENT OF THE CANYON MINE PROJECT
KAIBAB NATIONAL FOREST COCONINO COUNTY, ARIZONA

SUMMARY OF CONCLUSIONS

The conclusions stated herein are based on an analysis of the Canyon Mine Project described in the text of this report.

1. Direct radiation from the mining oprerations will probably not be measureable at distances greater than a few hundred meters from the mine yard.

2. For a ´hypothetical´ worst case meteorololgical situation the residents of Tusayan, Arizona (the closest community) can expect to receive a yearly increase in annual radiation lung dose from radon progeny of about 10%. This assumes that the residents live outdoors. If the residents spend time indoors, where radon progeny doses can be reasonably expected to be significantly greater, AND the meteorological conditions resemble those predicted by wind roses for the area, then an increase in lung dose from the mining operations should be on the order of 2% or less of the outdoor value. Consequently, any potential increase in lung doses which result in radon progeny from the Canyon Mine will not be measureable above normal variations in the natural radiation environment.

2. Dust releases from the mine vent and ore piles will be on the order of 300 times less than limits set for facilities which require a radioactive materials license. While the Canyon Mine Project does not come under this jurisdiction, the low amount of release is noteworthy.

3. A Maximum Probable Flood followed by a total loss of site integrity would release several Curies of radioactivity to the downstream wash. Resulting contamination could be removed easily and returned to the mine yard. There would be an inconvenience to the mining company, and cleanup would need to be assessed in an expeditious fashion, but there would be no radiological health hazard. A flood of this magnitude would have greater repercussions with respect to basic human and wildlife survival, so it is hoped that an event of this magnitude will never be experienced.

4. Ore transport will not expose individuals who reside along the route to any measureable increase in radiation dose. A few accidents should be expected during the life of the mine, but the radiological consequences will be negligible.

Based on evaluations of the radiological aspects of the proposed operation, and the committments expressed by the mining company, there appears to be no significant radiological impacts on humans or the environment in the vicinity of the Canyon Mine Project.

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RADIOLOGICAL ASSESSMENT OF THE CANYON MINE PROJECT

KAIBAB NATIONAL FOREST COCONINO COUNTY, ARIZONA

1.0 PROJECT OVERVIEW

Energy Fuels Nuclear, Inc. proposes to develop and operate an underground uranium mine at a site in the Kaibab National Forest approximately 6 miles (9.6 km) southeast from Tusayan, Coconino County, Arizona. The operation, called the "Canyon Mine Project," is expected to produce an average of approximately 200 tons per day of high-grade uranium ore and operate for at least 10 years. The ore body itself is situated in a breccia pipe formation located between 900 and 1,400 feet beneath the surface. Ore will be graded and stockpiled on-site. The high grade ore will be shipped to a mill in Utah.

For comparison purposes only, the deposit at the proposed Canyon Mine Site has several characteristics which are representative of the conditions at the Hack Canyon uranium mine. Hack Canyon is located on the Arizona Strip and operated by Energy Fuels Nuclear, Inc. Therefore, where applicable, radiological information has been obtained at Hack Canyon and applied to assess the potential impacts at the Canyon Mine.

2.0 SITE CHARACTERISTICS

The Canyon Mine Site will occupy about 14.7 acres. The area is part of a natural clearing which is about 0.5 miles (0.8 km) in diameter. The area is surrounded by pines and some scrub growth, but the forest is not dense.

Average rainfall in the area is approximately 15 inches per year. The amount of rainfall is about the same in the summer and winter, while the spring and fall are relatively dry. Summer precipitation usually is the result of thunderstorms which form over the heated canyon walls almost every afternoon from early July until the end of August. Although the storms are capable of producing locally heavy downpours, they rarely last more than 30 minutes and usually cease completely shortly after sundown. Winter precipitation is not as consistent as that of summer, varying greatly from year to year in both amount and frequency. It is associated with middle latitude storms moving eastward from the Pacific Ocean and normally falls in gentle to moderate showers which may persist for several days. When these storms intensify over the California coast, move directly into Northern Arizona from the west, and meet a cold front sweeping down from the northwest, severe storms with heavy snow and strong winds can be expected. Most of the winter precipitation occurs as snow. (NWS 85)

At the Canyon Site, small watersheds drain into the clearing from the north and northeast. Drainage reports to a common wash just south of the site and proceeds for approximately 1.25 miles (2 km) before reaching Owl Tank stock pond. Overflow from the pond returns to the wash and travels southwest approximately 2 miles (3.2 km) before joining Little Red Horse wash. This wash drains in a westerly direction for approximately 2 miles, crosses U.S. Highway 180, continues west for about 6 miles (9.6 km) and merges with Red Horse wash. In this area the wash becomes very broad and indistinguishable from the surrounding flatlands. The general slope of the area would take any flow around the south side of Howard Hill. The drainage then crosses the abandoned north-south, Williams to Grand Canyon railroad spur. Here the area opens up into a large, shallow valley or drainage basin. The basin is several miles wide and receives drainage from several other watersheds which are located north and northwest of the area. Any flow from the area would proceed in a southerly direction and cross the graded, unnamed, east-west dirt road just west of a cattle loading chute and an abandoned homestead called ´Wallaha´. It should be noted that there are no culverts under the railroad bed and only a small culvert beneath the road. Eventually the basin narrows to a more defined wash and joins the south-north draining, normally dry Cataract Creek. The creekbed forms Cataract Canyon, then Havasu Creek, passes the community of Supai and finally empties into the Colorado River.

There is little evidence of a stream bed or channeling along much of the drainage and the only consisent flow is in the last several miles of the spring-fed Havasu Creek. The only permanent residents along the entire route reside at Supai, approximately 55 miles (88 km) downwash from the Canyon Mine. The greatest rainfall reported to date for the area around the Canyon Site occurred during a late afternoon thunderstorm in August, 1984. (TH 85) Heavy runoff and sheet flooding was observed. Little Red Horse wash experienced a flash flood of short duration and the runoff from the localized storm was observed to flow approximately 4 miles (6.4 km) west of U.S. Highway 180 before disappearing into the ground. (LE 85)

The Site elevation is 6,500 feet (1950 m). The elevation increases toward the northeast and reaches about 7,000 feet (2,100 m) before dropping into the Grand Canyon about 13 miles (20.8 km) away. There is a general downslope of about 100 feet per mile from the Site toward the southwest.

The basic air movement is from the south and southwest during the daytime and reverses during the nighttime hours. The mean daytime wind has been calculated to be around 11.5 miles per hour (10 knots). (ST 85) The nighttime flow is estimated to be on the order of 2.3 miles per hour (2 knots) or less. The overall wind pattern seems to follow the daytime/nighttime thermal cycle with the respective upvalley/downvalley winds. No communities are in the direct path of the general wind movement. Additional wind information will be presented in Section 5.2.

Tusayan is the nearest community and has approximately 80 permanent residents. There are about 300 motel rooms and several concessionaires which support the large number of tourists who visit the Grand Canyon National Park. Summer is the most popular season and many businesses close part or all of their operations during the winter months.

The nearest residence to the Site is a part-time residence at the abandoned Grand Canyon airstrip, about 2.1 miles (3.37 km) south-southeast of the Site. There is a lookout tower atop Red Butte, a predominant lava-topped mesa located 4.5 miles (7.2 km) south of the Site. The tower is manned during the fire season which usually extends from May to early fall. There is a homestead just west of U.S. Highway 180 and about 7 miles (11.2 km) south-southwest of the mine site.

The nearest major communities are Williams (population 2,400) approximately 40 miles (64 km) south, Tuba City (population 800) about 50 miles (80 km) east, northeast and Flagstaff (population 27,000) about 60 miles (96 km) south-southeast.

3.0 BASIC RADIATION INFORMATION

Radiation refers to energy emitted in the form of waves or particles. The characteristics which define wave energy may be found in the electromagnetic spectrum. The energy emitted is a function of the frequency of the radiation and is defined as:

$E = hv$ where:

E is energy
h is Planck's constant and
v is the frequency of the wave.

When the available energy, E, is not sufficient to release orbiting electrons from an atom or molecule it is referred to as non-ionizing radiation. If, on the other hand, the energy is sufficient to eject an electron from its orbit the energy is a form of ionizing radiation.

Consider now the relationship between wavelength and frequency. Wavelength is inversely related to frequency by the mathematical expression:

$c = vl$ where:

v is velocity
c is the speed of light and
l is wavelength.

Note the inverse relationship between frequency and wavelength; as frequency increases, wavelength decreases.

3.1 Non-ionizing Radiation

Non-ionizing radiation occurs at the low frequency end of the electromagnetic spectrum. Examples of non-ionizing radiation, in order of increasing frequency include ultrasound, normal household current (60 cycle electricity), radiowaves, radar, microwave, infared, visible light, and some ultraviolet radiation. Given sufficient quantities, these forms of radiation may produce undesireable effects on the human body by heating (thermal effects) and/or physiological effects (called "non-thermal" effects). The U.S. Labor (OSHA) and Food and Drug (Radiological Health) regulations for non-ionizing radiation are based on the heating effects only. However, other nations recognize and acknowledge the controversial non-thermal possibilities and have adopted more stringent regulations for non-ionizing radiation. At present research is being conducted around the world to better understand the non-thermal phenomena associated with non-ionizing radiation.(LE 80) Although non-ionizing radiation is not a concern at the Canyon Mine Project it is noteworthy in that it is not completely understood and regulations vary among nations.

3.2 Ionizing Radiation

As the frequency increases through the ultraviolet region, the energy from the electromagnetic radiation becomes sufficient to release orbiting electrons from the surrounding matter. This is ionizing radiation. Examples of ionizing radiation, in order of increasing frequency, include ultraviolet radiation, x-rays, gamma rays, and, finally, cosmic rays. In addition to wave or frequency type radiation emissions, several particles are also included in the general category of ionizing radiation. The particles of interest here include alpha particles and beta particles.

The form of radiation that is of interest at the Canyon Mine Project Project is ionizing radiation. The specific types of ionizing radiation that need to be considered are x-rays, gamma rays, alpha particles and beta particles.

Like many chemicals and viruses, ionizing radiation is known to produce mutations (which may be beneficial or non-beneficial), is carcinogenic, and may cause genetic defects. However, the cause-effect relationship between forms of ionizing radiation and the potential for negative health effects is a function of many parameters including the amount of radiation received (dose), the rate in which the radiation is delivered (dose rate), the type of ionizing radiation (alpha, beta, x-ray, gamma), the organ of interest (whole body, thyroid, breast, lung, bone), age, sex, mental condition, and general health.

Occupational doses of ionizing radiation are regulated to minimize the probability that an individual will be exposed to doses of radiation which cause genetic effects or lethal somatic effects during a normal lifetime (with several orders of magnitude of conservatism built into the regulations). Limits on permissible doses to the public from regulated sources of ionizing radiation are reduced by a factor of 30 to provide an additional measure of safety. All regulatory limits exclude doses from the natural radiation environment AND from medical exposures (diagnostic and/or therapeutic). Ionizing radiation is probably the most studied and most well understood of all etiological agents. And, unlike regulations governing non-ionizing radiation, ionizing radiation regulations have worldwide acceptance among nations and among national and international radiation advisory commissions.

Finally, ionizing radiation regulations may be compared against some of the regulations which govern other hazardous substances such as air pollutants. It is worthy of note that only in the case of radiation are the standards for average exposure at about the same levels as that found in the natural radiation environment. For some of the other hazardous pollutants, the exposure levels are established in the area where adverse medical effects are definitely observable. This extremely conservative approach to radiation regulations evolved because the hazards of ionizing radiation were recognized early on and were subjected to detailed research as the sources and uses of ionizing radiation expanded. (ANS 80)

3.3 Types of Ionizing Radiation at the Canyon Mine

The ionizing radiations which will be present at the the Canyon Mine include x-rays, gamma rays, alpha particles and beta particles. These radiations are released from the radioactive materials found in and around the uranium ore body.

X-rays and gamma radiation have no mass or charge. They may be produced by x-ray machines, by ionization of atoms or molecules, or by the decay of radioactive atoms. Examples of radioactive materials which emit these types of electromagnetic radiation include radioactive Potassium-40, Cesium-137, Cobalt-60, Iodine-131, Radium-226, Bismuth-214 and Thallium-204. While this type of radiation has no mass it has great penetrating power and requires very dense materials for shielding. Diagnostic x-ray facilities often shield the walls and viewing windows with lead to prevent the release of the concentrated radiation they routinely and beneficially utilize. Similarly, radiation oncology (cancer therapy) units use massive quantities of radioactive Cobalt-60 and are shielded with considerable amounts of lead. In these units the gamma radiation is focused on the carcinoma by means of uranium collimators (uranium is used since it is about twice as dense as lead). Interestingly, radioactive materials which emit gamma radiation also emit beta particles.

Beta particles have a very small mass and a negative charge. Basically, beta particles are electrons which have been released from inside an atom as that atom decays and seeks a more stable configuration. While a few radioactive elements emit only beta particles, most decay by beta and gamma emissions . Examples of beta emitters include Carbon-14, Hydrogen-3, Cesium-137, Iodine-131, Thorium-234, Lead-214, Bismuth-214 and Lead-210. As the beta particles collide with orbiting electrons in the absorbing material they transfer a portion of their kinetic energy to the orbiting electrons. If the energy transfer is sufficient to cause an orbiting electron to be released from the attractive influence of the atom in the absorbing material, an ionization occurs. Beta particles may be readily stopped by light materials such as water, plastic or aluminum.

To conceptualize beta particle, x-ray and gamma radiation interactions with matter, consider a runaway car (the radiation source) in a forest (the absorbing material). If the car enters the forest with a specified velocity (kinetic energy) it may experience every conceivable type of collision from a glancing blow up to a head on collision. The car even has a probability, however small, of passing directly through the forest without striking any tree. Thus, these types of radiation may interact with the absorbing material in ways where the kinetic energy transfer ranges from zero (transmission) up to a total exchange (head-on collision).

Some radioactive materials may decay by releasing an alpha particle from its nucleus. The alpha particle has two positive charges and is identical to an ionized helium atom. Examples of alpha emitting radioactive materials include Uranium, Radium, Thorium, Polonium, Curium and Americium. Alpha particles are about 2,000 times larger and are ejected with about 10 times more kinetic energy than beta particles. Like beta particles, alphas dissipate their energy by ionizing collisions with the absorbing material. However, because of their large size alpha particles may be stopped by nothing more than a sheet of paper. Unfortunately, the deposition of such large quantities of energy in such a small area may cause the absorbing material to sustain a considerable amount of localized damage. Alpha particles are considered to be the greatest biological radiation hazard when ingested or inhaled. The critical areas are the lung, bone and the blood forming organs.

To conceptualize the interaction between alpha particles and matter consider a car in a corn field. If the car is pushed into the field with a specified velocity, then released, it will travel a straight path and eventually stop. A swath of destruction occurs as the vehicle imparts its kinetic energy to the corn stalks. Another car entering the field with identical kinetic energy will create another swath of similar length.

3.4 The Natural Radiation Environment

The natural radiation environment consists of cosmic radiation and many radioactive elements including Hydrogen-3, Carbon-14, Potassium-40, Rubidium-87, Uranium-235, Uranium-238 and Thorium-232. Importantly both Uranium-238 and Thorium-232 are ubiquitous in soil with average concentrations of a few parts per million. Each are ´parent´ elements of a radioactive decay series. The parents decay to daughters, or progeny, which are radioactive also. After many decays each chain terminates with the formation of stable lead. The thorium decay series is not significant in the Canyon ore body or other uranium deposits in Arizona so it will not be discussed here. Natural uranium is about 99.3% U-238 so the radiation contribution from the U-235 series is insignficant. The decay scheme for U-238 is reported below.

==

Table 3.1 Uranium-238 Decay Scheme

Radionuclide	Type of Decay	Remarks
Uranium-238	alpha	Chemical toxicity greater hazard than radiotoxicity
Thorium-234	beta	
Protactinium-234m	beta	
Uranium-234	alpha	
Thorium-230	alpha	
Radium-226	alpha and gamma	Chemically similar to calcium
Radon-222	alpha	Inert gas
Pollonium-218	alpha	
Lead-214	beta and gamma	
Bismuth-214	beta and gamma	
Pollonium-214	alpha	
Lead-210	beta	
Bismuth-210	beta	
Pollonium-210	alpha	
Lead-206	=====	Stable

==

Radioactive materials are present in air, water and soil. Their concentrations are expressed in units of radioactivity per volume or mass. Typical concentrations of naturally occurring uranium and Radium-226 in normal soil are on the order of 1 pico-Curie per gram. A pico-Curie (pCi) is equivalent to 2.22 atoms of the radionuclide decaying each minute - a very small number. Typical concentrations of Uranium and Ra-226 in surface, ground and domestic water are on the order of 1,3,2 pCi/L (L = liter) respectively - again, a very small number. Arizona´s uranium concentrations in water have been reported to be between 2.5 and 2.7 pCi/L.(LA 85) These values may vary considerably depending on the extent of uranium mineralization in the area being examined. Because the energy released by radioactive materials is known and quantifiable, once the intake of radioactive materials through air water and the food chain is determined as a consequence of such intake modes, it is possible to calculate the radiation dose delivered to the organ of interest.

3.5 Dose from Ionizing Radiation

When ionizing radiation deposits energy in living matter it produces a physical and biological effect which may be quantified in terms of dose. The actual damaging effects are thought to be caused by the production of reactive chemicals, the result of ionization of water molecules in the living cells. It is the chemicals which in turn may alter or destroy chromosomes. The radiation does not produce excessive heat nor is it suspected of reacting directly with chromosomes.

The units of dose are rem (roentgen equivalent man). However, because this unit is so large it is often useful to divide the value by one thousand and discuss radation dose in terms of 1/1000 rem, or millirem (mrem). The dose rate may be described in terms of mrem per hour (mrem/hr), or mrem per year (mrem/yr) etc. Possible sources of radiation dose include cosmic ray interactions, radioactive materials in the natural radiation environment, medical ionizing radiation treatments, radioactivity in numerous consumer products, and radiation from the nuclear power fuel cycle. Examples of possible doses are listed in Table 3.2. Unless specifically stated, doses are expressed in terms of the amount of radiation delivered to the whole body.

===

Table 3.2 Typical Radiation Doses

Source	millirem	
Cancer treatment (to specific organ)	5,000,000	per cancer
Lethal Dose	450,000	instantaneous
First physiological effects	25,000	instantaneous
Maximum allowable average occupational dose (medical and natural background excluded)	5,000	per year
Maximum allowable dose to an individual member of general public (medical and natural background excluded)	500	per year
Cosmic ray doses to flight crew (McK 75)	380	per year
Average dose received by all workers in uranium mines, mills and power plants	365	per year
Average allowable dose to general public (medical and natural background excluded)	170	per year

Average dose from natural background	100	per year
Phoenix, Arizona (McK 85)	100	per year
Arizona Strip near Hack Canyon Mine (McK 85)	70	per year
Window Rock, Cove and Red Valley, Az.(McK 80)	70	per year
Average dose from diagnostic x-rays (also studied by McK 80)	70	per year
Control Room Operator at Nuclear Power Plant	50	per year
X-ray Technician	50	per year
Cigarettes dose to lung (Po-210 from U-238 decay chain present)	30	per pack
Water and food; U.S. average	25	per year
Work in granite buildings like U.S. Capitol	20	per year

3.6 Radon Gas and Dose Delivered from Progeny

A progeny of U-238 is Radon-222. Radon is a colorless, odorless and inert gas which diffuses into the atmosphere from rocks, soil and building materials. Normal environmental outdoor concentrations are generally less than 1 pCi/L. However, in uranium mines and energy efficient buildings, or whenever air stagnates as a result of reduced dilution (mixing with relatively radon-free outside air), radon concentrations may increase measurably.

However, radon itself poses no health concern. Rather it is the Radon progeny from Pollonium-218 to Lead-210 (see U-238 decay chain in Table 3.1) which need to be considered. Lead-210 is a radionuclide with such a long half life (time to decay to 1/2 of the original activity) that the radon daughter problem is considered to terminate at this point. All the Radon-222 progeny of interest are particulates and many decay by alpha particle emission. It is the alpha emitting progeny of Radon-222 which have been linked to lung cancer in uranium miners as well as lung cancer found in other underground miners. (CONG 67, BEIR 72)

To better understand the relationship between radon progeny concentrations and the units derived which quantify the permissible dose to an underground miner and the evolution of mining regulations during the late 1950's it is necessary to develop a historical perspective on the issue.

Mining in Schneeburg (Central Europe) began about 1400 A.D., first for copper, iron and silver, then for several metals and finally for Uranium. A lung disease peculiar to workers in these mines was described as early as 1500 A.D., but not recognized as cancer until 1879. The etiological role of radon (Rn-222) was not suspected until about 1932 and not generally accepted until the 1960´s. Recognizing the problem, the U.S. Atomic Energy Commission established a concentration limit for uranium mines of 100 pCi/L in 1955.(NCRP 84) However, since the progeny of Rn-222 are the source of the health problem a means had to be developed to quantify the permissible dose from the presence of the daughters.

In 1957 the U.S Health Service introduced the working level (WL) unit in an attempt to quantify the exposure (dose) delivered to the lungs from radon daughters. Its reason for the particular value was to set a level which "appeares to be safe, but not unnecessarily restrictive to industrial operations." (BL 82)
By definition,

> A "working level" (WL) is a standard measure of radon daughter concentration in air. It is an expression of potential alpha energy. One WL is any combination of radon daughters per liter of air that will result in the emission of 1.3E+05 (130,000) Mev of alpha energy in their decay through Po-214.

Whenever radon and progeny are present in identical concentrations, a special situation exists which is called ´secular equilibrium.´ If this condition is satisfied (which rarely occurs in nature) then 100 pCi/L of Rn-222 is equal to one Working Level: That is to say,

100 pCi/L Rn-222 = 1 WL.

A "working level month" (WLM) is a standard measurement of cumulative exposure. A WLM is an exposure equivalent to working in an atmosphere containing 1 WL of radon daughters for 173 hours (this is sometimes rounded to 170 hours). To determine the cumulative WLM multiply the WL measured in the atmosphere by the number of hours/year exposed and divide by 170 hours/month. The result is WLM per year (WLM/yr) and this value may then be converted into an expression of dose to the bronchial epithelium (lung tissue). This requires that a number of conservative assumptions be made to account for daughter product deposition, radioactive build-up and decay, removal by mucociliary clearance and physical dose to specific cells in the lungs. The generally accepted result is that;

1 WLM = 5,000 mrem occupational dose to the bronchial epithelium.

For continuous, non-occupational, environmental exposures to radon progeny additional assumptions are made regarding daughter product concentrations in outdoor air, breathing rates of an average individual (which is about 0.5 times that of a working miner), and the number of cumulative working-level-months of radon daughter exposure for an average individual surrounded by air at a constant concentration of one WL (which for continuous exposure is about 25 WLM/yr), then,

1 pCi/L Rn-222 = 625 mrem dose to the bronchial epithelium from the daughter products,

and

1 pCi/L Rn-222 = 5 mWL. (USNRC 79)

Note, as with radiation dose, ´Working Level´ is such a large value that it is oftentimes reduced by a factor of 1,000 and expressed in terms of milliWorking Level (mWL).

Radon concentration, daughter exposures in WL, and doses to the lung are correlated in Table 3.3.

==

Table 3.3 Radon Doses to Lung Compared to Radon Gas Concentrations and Radon Progeny Exposure

Source of Radon/progeny	Concentration or working level	lung dose (mrem/year)
Occupational limit, underground mining	4 WLM/yr	20,000
U.S. uranium miners, current average (NCRP 84)	2 WLM/yr or less	10,000
Hack Canyon Miners (average) (HU 85)	2.2 WLM/yr	11,000
Average exposure to public from natural environment (NCRP 84)	0.2 WLM/yr(3 mWL)	375
Average radon levels atop high-grade uranium ore pile (McK 85)	150 pCi/L	93,750
Average radon levels atop mill tailings pile (MO 79)	10 pCi/L	6,250
Energy efficient homes (higher or lower depending on amount of ventilation etc.)	5 pCi/L	3,125

Concrete buildings in Arizona (McK 85, NCRP 75)	1.7 pCi/L	1,062
Conference Room, Canyon Squire Inn, night of public meeting on Canyon Mine Project (McK 85)	1.2 pCi/L	750
New Mexico, average outside air (MO 79)	0.5 pCi/L	312
Western U.S. Average outside air (USNRC 79)	0.2 pCi/L	125
Owl Tank & Mine Site (McK 85)	0.2 pCi/L or less	125
Historical Cabin, Bright Angel Lodge, South Rim (McK 85)	0.2 pCi/L	125

In a mine environment radon and radon progeny may be easily diluted to acceptable concentrations by forced ventilation. The objectives are to remove the radon gas as it diffuses from the ore into the mine atmosphere, but before it has a chance to decay, AND to flush the mine environment with fresh, outside air. It is not uncommon to find ventilated mine atmospheres with radon and progeny concentrations which approach outside air. Measurements obtained by McKlveen from 1979 to present have identified ventilated mine environments with radon progeny concentrations that are less than his ´energy efficient´ home.

3.7 General Perspectives Concerning Risks Associated with Dose

The radiation information may be summarized by analyzing their contributions to population dose. The main contribution to the dose received by individuals (about 87%) is due to the natural radiation environment. This includes indoor exposure to radon decay products which is the largest single source of exposure. The largest man-made contribution (about 11.5%) is from the use of ionizing radiation in medical procedures.(HU 84)

The maximum exposures from the natural radiation environment are on the order of 13,000 mrem/yr and occur in locations such as Kurala, India and sites in Brazil. The inhabitants of these areas have been studied and no adverse health affects observed. It should be emphasized that these values are almost three times the maximum occupational dose limits (see Table 3.2). The maximum radon and progeny concentrations were recently found in homes in an area around Boyertown, Pennsylvania.(DV85) The homes were apparently built on top of a uranium deposit known as the Reading Prong and concentrations as high as 2700 pCi/l have been found; this will result in a lung dose of about 1,687,500 mrem/yr. If secular equilibrium is assumed then the concentration is equal to 27 WL. If an individual occupies the residence for 12 hours each day then the cumulative yearly expression becomes 700 WLM. This is approximately 175 times the allowed occupational exposure for uranium miners. See Table 3.3 for additional comparisons.

The main health concern from radiation exposure is cancer. Radiation sensitive organs include the blood (leukemia), lungs and breasts. However, only about 4% of all carcinomas are generally thought to be radiation induced; the remainder are caused by chemicals, viruses and other etiological agents. Radiation effects have been observed at very high doses. However, no studies have shown detrimental effects from radiation doses which approach the regulatory limits for occupational workers. (BEIR 80)

With respect to lung cancer, definite correlations have been made above 1,000 WLM (5,000,000 mrem), cumulative exposure, and correlations with slightly increased lung cancer levels appear to have been made for cumulative levels above 100 WLM (500,000 mrem). Cumulative exposure means the sum total of all exposures received during a lifetime. The correlations are based on studies of uranium miners who worked in unventilated mines where the exposures were several times today's regulated levels (i.e. on the order of 10 WLM/yr or greater). However, studies of U.S. miners with less than 60 WLM (300,000 mrem) cumulative exposure indicate a deficit in lung cancers (statistically not significant) rather than an excess in lung cancer. Also, it has been found that U.S. uranium miners experience less lung cancer than uranium miners in other countries and also other non-uranium mining operations (i.e. studies of zinc miners in Sweden). (CONG 67, BEIR 72, BEIR 80) A recently published review of all studies and available information concluded that, assuming current WL exposures found in today's mine environment and the current average time of 10 years that a U.S. uranium miner spends in the mine, an average U.S. uranium miner may have up to a 0.5% increase in risk of developing lung cancer. For comparison, there is a 0.5% increase in risk of death caused by working in industries which are classified as "safe industries". (NCRP 84)

For comparison, using the same studies and information it can be estimated that for the annual, environmental radon progeny exposure to the public (0.2 WLM) (NCRP 1984), there is a lifetime risk of death from lung cancer of 1800 per million exposed. For the U.S. this translates to about 400,000 deaths (out of a population of over 220,000,000). For the case of energy efficient homes, it would not be unreasonable to expect a doubling of the radon daughter concentrations (see Table 3.3). Based on this increase an additional 1800 lung cancer deaths per million population (who live in these homes) can be anticipated. Put in terms of increased risk, the lifetime risk of a lung cancer death due to environmental radon progeny is on the order of 0.2 %. For those living in an energy efficient home the risk is doubled, or is about the same as that for a U.S. uranium miner. Finally, the total probability of death from all forms of cancer is on the order of 17%.

Mutations and genetic effects are concerns also. By extrapolating data obtained at very high doses it can be estimated that the doubling dose (that dose necessary to double the number of mutations that normally occur due to environmental radiation) is between 20,000 and 250,000 mrem. However, no effects have ever been observed at doses on the order of 100,000 mrem or less. Furthermore, studies of individuals living in areas where the natural radiation is considerably above average have shown no adverse effects.

4.0 URANIUM MINING RADIATION REGULATIONS

The pertinent regulations which govern the radiological aspects of uranium mining operation are summarized here.

Note: CFR = Code of Federal Regulations

30 CFR 57 Mine Safety and Health Administration

No Uranium miner permitted to receive more than 4 WLM/year.

Records kept on all miners where concentrations of radon daughters are in excess of 0.3 WL.

Respirators required when levels exceed 1 WL.

Additional protection against radon gas itself required when radon daughter concentrations exceed 10 WL.

If gamma radiation levels exceed 2 mrem/hr dosimeters must be worn and records kept. Limit of 5 rems/yr.

Note: The regulations apply only to uranium mining activities. They do not apply to other underground mining operations or other possible sources of enhanced radiation such as energy efficient buildings.

U.S. EPA National Interim Primary Drinking Water Standards (1976)

If gross alpha particle activity in water is greater than 5 pCi/L, perform Ra-226 analysis. If Ra-226 analysis greater than 3 pCi/L, perform Ra-228 analysis. There are other regulations if gross alpha exceeds 15 pCi/L or gross beta activity exceeds 50 pCi/L.

40 CFR 61 Environmental Protection Agency

Subpart B--- National Emission Standard for Radon-222 Emissions from Underground Uranium Mines.

Governs the positioning of bulkheads to reduce radon releases from areas of inactivity within the mine.

49 CFR Transportation

Governs proper containers and methods for transporting ore from mine to mill.

5.0 RADIOLOGICAL ASSESSMENT OF CANYON MINE

The area around the Canyon Mine Site has been radiologically surveyed and the findings are presented. The radiological aspects have been categorized into background radiation, airborne radioactivity, surface and ground water radioactivity, and transportation. Where possible radiological data will be compared with the existing regulations or the natural radiation environment.

5.1 Background Radiation

Monitoring stations which measure the background gamma radiation were established in April, 1985. The twelve sites are listed below and depicted in Figure 5.1.

Mine Sites - Eight compass headings and a special additional location in the wash immediately south of site. Each site is about 1/4 mile from proposed mine shaft.

Owl Tank - In center of wash just north of tank.

Tusayan - Grand Canyon Airport.

Tusayan - Kaibab National Forest Service Office.

Data will be collected on a quarterly basis using a suite of radiation detectors. Passive thermoluminescent radiation dosimeters (Panasonic UD-804 environmental dosimeters with three redundant $CaSO_4$ phosphors encapsulated in 1,000 mg/cm-2 of plastic and lead) are placed at each site to monitor the cumulative exposure. When dosimeters are exchanged, additional measurements are taken using a Reuter-Stokes RSS-111, Pressurized Ion Chamber (PIC) and two Ludlum micro-R scintillometers. The environmental gamma radiation measurements obtained to date are presented in Appendix A and summarized here.

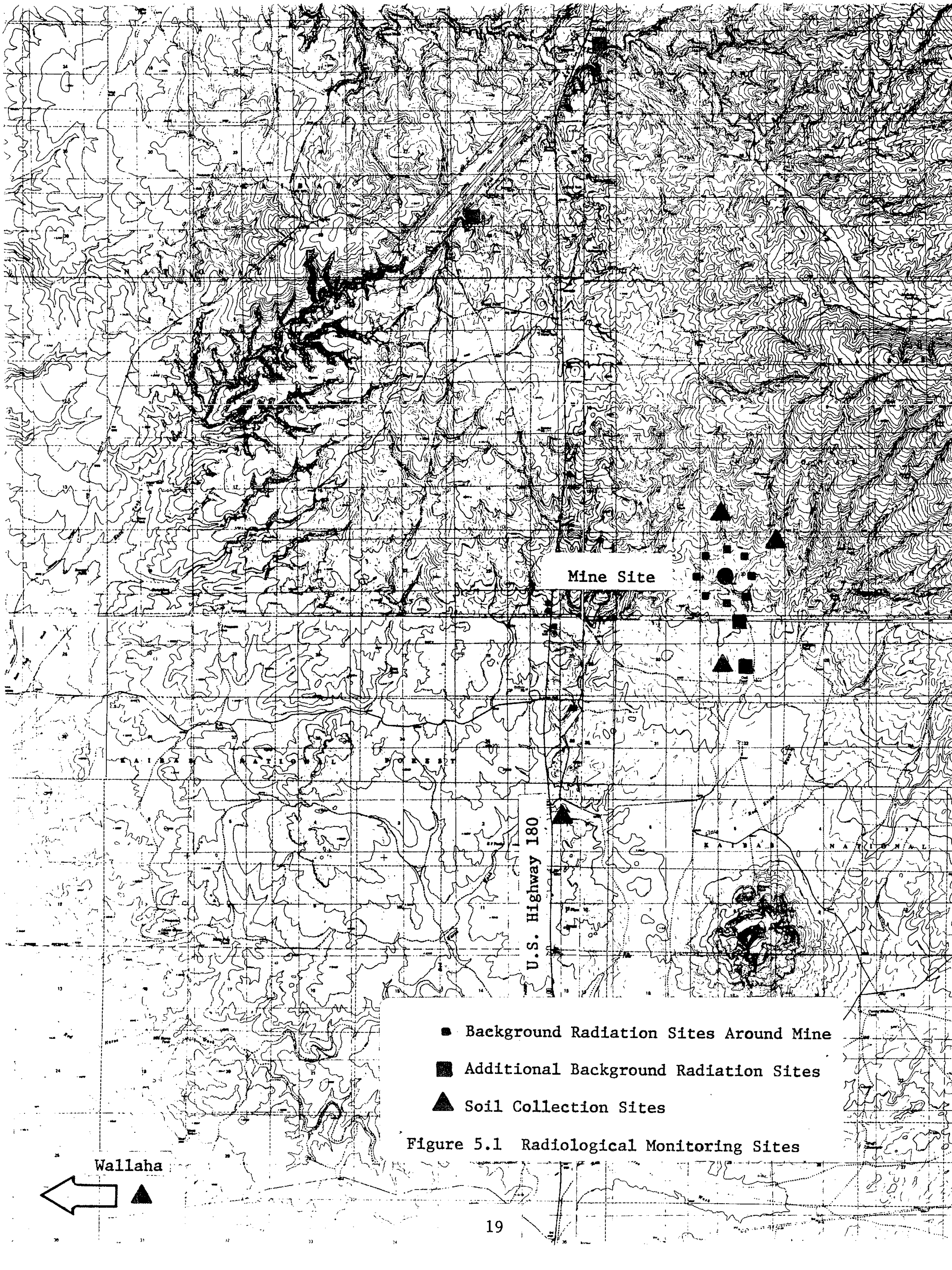


Figure 5.1 Radiological Monitoring Sites

Background gamma radiation ranges between 90 and 130 mrem/yr. The lowest radiation measurements were observed at the stations which are to the south and west of the mine site. Owl Tank registers one of the higher background areas. There is a small, localized anomoly in the wash just south of the site. Here radiation is elevated to approximately 300 mrem/year. Perhaps this is caused by uranium mineralization which is closer to the surface than the main ore body. The area of elevated radiation will be staked for future identification.

During mine operation the radiation levels in the vicinity of the high-grade ore stockpile will be on the order of 1 mrem/hr. Levels should be expected to return to background a few hundred meters from the pile. A small increase in radiation will occur in the immediate vicinity of the low-grade material pile, but the amount is insignificant. It is anticipated that gamma radiation will remain unchanged at the monitoring stations around the perimeter of the mine.

5.2 Airborne Radioactivity

Radon gas will diffuse from the ore piles and be exhausted from the mine vent. Once airborne the gas will be transported away from the area by prevailing winds and will decay to its progeny. Radon progeny will be exhausted from the mine vent also. However, they quickly decay and become no concern.

Uranium and all progeny will be present in dust blown off the ore piles and in dust released from the mine vent.

The potential impact from these radionuclides may be determined based on the magnitude of each release and the prevailing meteorological conditions. Several computer codes are available which model the atmospheric dispersion of radionuclides. The MILDOS Code, developed to study releases from uranium mills, was selected to quantify the radon gas releases while the Industrial Source Code was used to generate isopleths of the potentially radioactive dust.

Initially, a wind rose was located which provided general wind pattern information for the abandoned Grand Canyon Airport.(AZ 85) This airport was located in a large clearing about 2 miles (3.4 km) south-southeast of the Canyon Mine site. However, no information on the time or frequency of data collection was provided. Therefore, additional meteorological information was sought. Raw data for the existing airport was obtained from the National Climatic Center, Ashville, North Carolina and used to construct a more comprehensive wind rose.(BS 85) Unfortunately, the airport data is only available for the daytime when the control tower is operational. The wind roses are presented in Figure 5.2. Both wind roses are similar and reveal a general airflow from the south and southwest. It is reasonable to expect that the pattern reverses at night when the cooler air drains from the higher elevations. Nighttime conditions should be much more stable due to the absence of solar thermal effects.

Since neither wind rose presented the entire 24 hour meteorological conditions, for purposes of dispersion analysis it was decided to use the generic wind rose created by the U.S. Nuclear Regulatory Commission. The rose depicts the meteorology for a typical western city (West City).(USNRC 79) As shown in Figure 5.2, this wind rose is similar to the actual conditions observed in the vicinity of the Canyon Mine Project.

The annual radon gas release from the high-grade ore stockpile and low-grade material storage pile was calculated to be 764 Ci. Details of the calculation are presented in Appendix B. A vent release of 4,300 Ci was determined by measuring the actual radon emission from the vent at the Hack Canyon mine.(McK 85) The MILDOS Code modeled the dispersion of these radon sources using the generic wind rose. In addition, the code modeled radon concentrations for a ´worst case´ scenerio. For this case, ´hypothetical´ meteorology and wind conditions were established to provide maximum radon at the locations of interest. Basically, the wind rose was rotated so that the prevailing winds carried the radon directly to each location of interest. Results for the normal and ´worst case´ situations are presented in Table 5.1. A detailed discussion of the calculations and a table which shows the airborne radon concentrations expected in the four primary directions from the Site ranging from 1.5 to 75 km, is presented in Appendix B.

Table 5.1 Radon Concentrations at Specific Locations

Location	Distance from Site (km)	Radon (pCi/L) Normal Conditions	Radon (pCi/L) Worst Case
Owl Tank	2.2 SSE	0.019	0.120
House, Old Grand Canyon Airport	3.4 SSE	0.011	0.061
U.S. Highway 180	3.2 W	0.028	0.068
Tusayan	9.9 NW	0.005	0.020

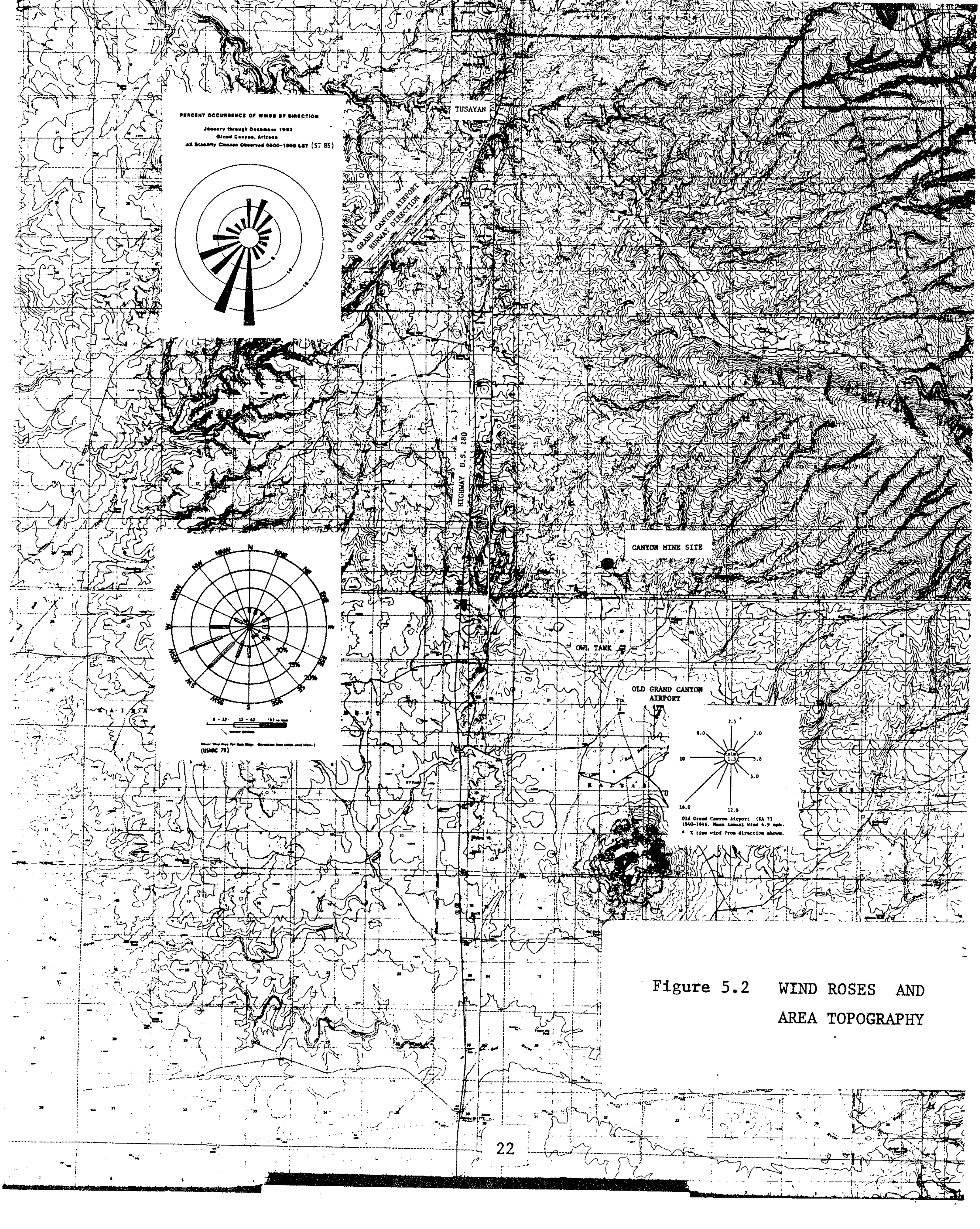


Figure 5.2 WIND ROSES AND AREA TOPOGRAPHY

For the residents of Tusayan the ´worst case´ concentration (0.02 pCi/L) results in an increased lung dose of only 12.5 mrem/yr. This may be compared against the normal background outdoor Rn-222 concentrations for this area which are on the order of 0.2 pCi/L.(McK 85) and provide a lung dose of about 125 mrem/yr. However, since individuals spend time indoors where radon levels are higher, or may even reside in an energy-efficient dwelling, lung doses may increase measurably. If the winds behave as predicted by the generic wind rose then the mine radon which reaches Tusayan will be on the order of 0.005 pCi/L and would contribute an additional dose of only 3 mrem/yr. Therefore, when compared to normal outdoor concentrations, radon doses to residents of Tusayan might increase about 10% assuming a ´worst case´ scenerio and realistically will increase about 2% or less. None of these potential increases could be distinguished from normal fluctuations in the natural radon environment. See Table 3.3 for other comparisons.

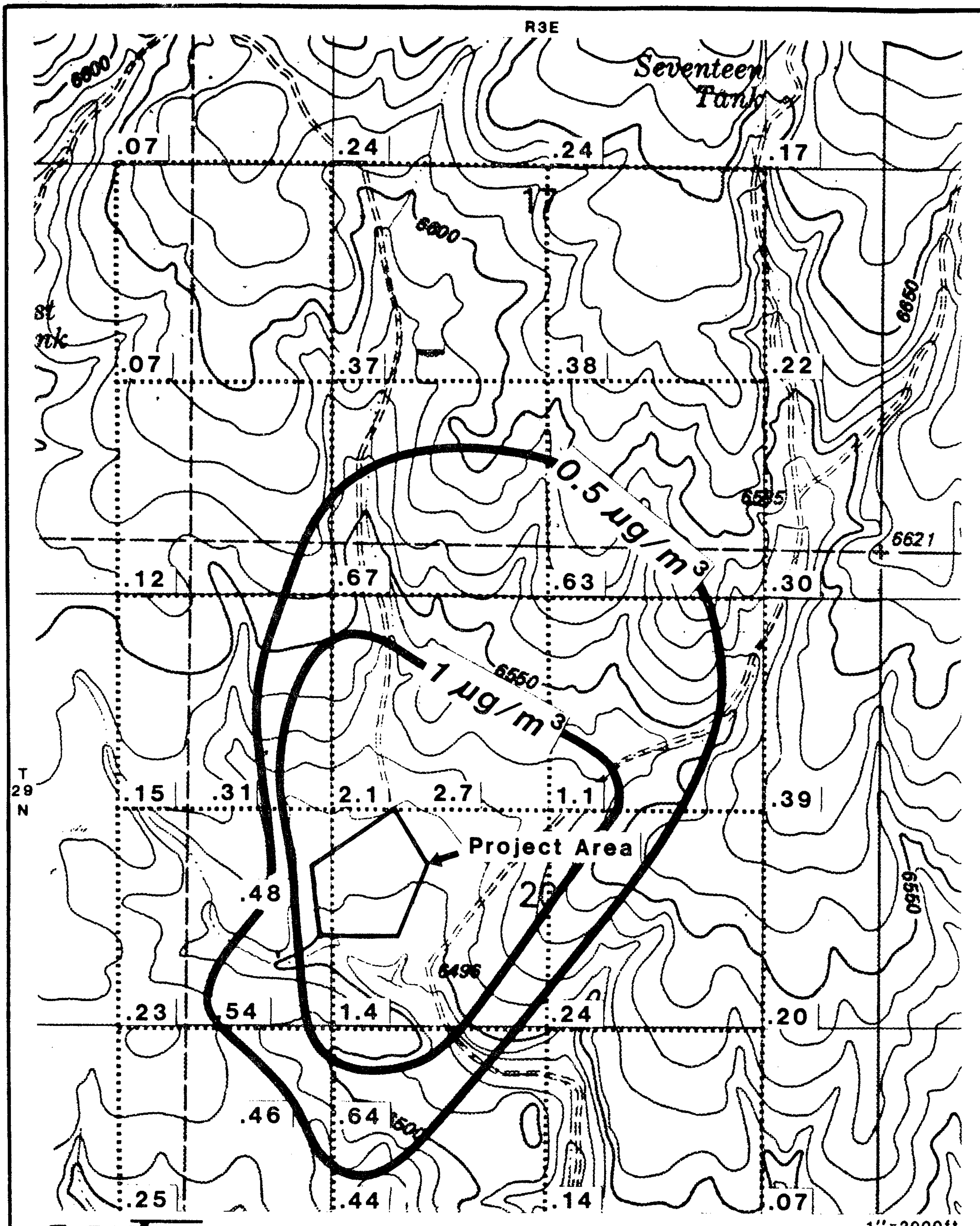
Radioactivity in dust emissions from the ore piles and mine vent was analyzed using the Industrial Source Code. A discussion of the model is provided in the air quality report for the Canyon Project which was submitted by EneoTecht. (ST 85) The code was run using inputs for the potentially radioactive sources of dust and the resulting isopleths are presented in Figure 5.3.

Assuming that all the potentially radioactive dust is 1% uranium, the 1 ug/m-3 dust isopleth has a natural uranium concentration of 0.01 ug/m-3. For comparison purposes only, this concentration may be compared with the 10 CFR 20 regulation limit of 3.0 ugm/m-3 for natural airborne uranium releases to an uncontrolled area at facilities which possess a radioactive source materials license. Although the uranium mine is not governed by 10 CFR 20 regulations the releases are, nevertheless, approximately 300 times less than the permissible releases would be under these regulations.

In summary there will be no signficicant radiological impact on the environment from the release of radon gas or dust from the mine site.

5.3 Groundwater

There are no known wells in the vicinity of the mine, and no wells known to be operating in Tusayan. Potable water for the community is trucked from Williams, Arizona. Water for the facilities at the South Rim is piped from Roaring Springs which is located on the North Rim. Based on mining operations in ore bodies with similar characteristics on the South Rim (Orphan Lode) and on the North Rim (Hack Canyon), no significant amounts of ground water should be anticipated. A complete evaluation of the groundwater potential is provided by Montgomery.(MO 85)



EnecoTech
Denver, Colorado

PROJECT Canyon Project

PROCESS RELATED ANNUAL AVERAGE CONCENTRATION

FILE NO. ______ DATE 6/18/85 FIGURE NO. 5.3

To monitor for possible groundwater contamination, baseline radiological data is being obtained from water samples collected at Havasu Springs (50 km NW), Indian Gardens Spring (18 km N) and Blue Springs (40 km NE). Results of these water supplies, along with radiological information on water supplies in the vicinity of the Grand Canyon is provided in Appendix C.

It is anticipated that a well will be drilled at the mine site. If water is found then samples can be assayed to monitor for possible increases in radioactivity content. It is reasonable to assume that no changes would occur.

5.4 Surface Water

A trickle of runoff from snow-melt was observed during the February, 1985 site inspection. No surface water has been observed subsequent to this visit. A baseline water sample was obtained from Owl Tank in April, 1985. During the June site survey, Owl Tank was nearly dry.

To monitor for possible radionuclide releases into the wash, baseline soil samples were analyzed for the locations listed below and displayed in Figure 5.1.

- Upwash north of Canyon Mine Site (background)
- Upwash northwest of Canyon Mine Site (background)
- Downwash immediately below Canyon Mine Site
- Owl Tank
- Little Red Horse Wash at U.S Highway 180
- Big Red Horse Wash at east-west dirt road (unnamed) crossing just west of north-south railroad spur, and about 1 mile (1.6 km) west of Wallaha ranch-house ruins.

Radionuclide results for Owl Tank water and all soil samples are presented in Appendix C.

Because an accidental release of site water may contaminate the wash a hypothetical accident situation was analyzed. The scenerio considers the amount of radioactivity released, the extent of comtamination and outlines the measures needed to restore the affected areas of the wash.

To estimate the potential radionuclide release from the mine site a sample of ore from Hack Canyon was immersed in water for 18 hours. Thereafter, the water was assayed for radionuclide content and results extrapolated to determine the maximum amount leached from the high-grade ore stockpile and low-grade material. Assuming the stockpiles to be at maximum size when the hypothetical release event occurs, it is conservatively estimated that approximately 50 Ci of uranium and progeny, including Rn-222, might be released. Radioactivity in the evaporating pond, if present, would be insignificant by comparison.

For the Probable Maximum Flood it has been estimated that approximately 11 inches of rain would fall in a 24 hour period and produce about 23,000 acre-feet (2.88 E+10 liters) of runoff. (LE 85) This is about three times the quantity of water estimated to be produced as a result of a storm event with a 500 year recurrence interval. Based on a 50 Ci release, the average concentration of radioactivity in the water would be on the order of 1,700 pCi/L. If Ra-226 were assumed to be about 10% of the original release a concentration of 170 pCi/L would be present in the water. It is reasonable to assume that most of the Rn-222 gas will be released to the atmosphere. This reduces the contributions from four of the radon progeny and will provide about a 30% reduction in radionuclide concentation. Of the nine radionuclides which might remain, five (or about 60%) decay by alpha emission. As a result the gross alpha concentration may be on the order of 300 pCi/L.

The gross alpha concentration is approximately 20 times greater and the Ra-226 concentration is about 55 times greater than the limits specified in the EPA drinking water standards. Though the wash-water is certainly not potable (dirt, cattle feces etc.), a thirsty individual would need to drink approximately 150 gallons in order to ingest sufficient Ra-226 to approach the 0.1 micro-Curie maximum permissible body burden suggested for that radionuclide.(NBS 63) It should be noted that the scenerio described here is a one time, accidental release and if the radionuclide concentrations were averaged over time (i.e. average yearly release), as is often permitted by regulations, the releases would probably not exceed the EPA interim drinking water standards.

Direct radiation from the gamma emitting progeny of U-238 would not create a problem because it would be difficult to distinguish any increase from normal variations in natural gamma backgrounds.

As the water evaporated or sank into the wash radionuclide deposition would occur on the surface of the soil and it is reasonable to assume that radionuclides would not penetrate to depths greater than a few centimeters. Soil concentrations might be expected to be on the order of 80 pCi/gm gross alpha. Water samples from Owl Tank, or other ponds which survived the flood could be used to determine if radionuclide concentrations were sufficiently low to permit consumption by animals. Temporary fences could be constructed around unacceptable water. Radiometric surveys, soil and water samples could be obtained to determine the exent of the contamination. However, it should be emphasized that the anticipated increases in radioactivity may be so low that laboratory analysis, rather than field surveys, will be needed.

Cleanup procedures would be straight forward and would not jeopardize humans or wildlife. Contaminated soil would be scraped from the affected areas and trucked to the mine, or to an approved storage site.

Based on the Maximum Probable Flood scenerio the radionuclide concentrations in the water and the residual concentrations in the soil would not be sufficient to create a health problem. Cattle or wildlife grazing in the washes would not ingest harmful amounts of radioactive material. The animals would remain fit for human consumption.

In summary, the Maximum Probable Flood with a concurrent failure of the mine yard barriers could conceiveably release approximately 50 Curies of radioactivity to the flood waters, but the environmental impact would be minimal.

For any excursion where radioactive materials are released to the wash the immediate, prudent actions would be to determine the extent of the contamination and to clean up the affected areas.

5.5 Ore Transport Radiation and Radioactivity

Ore will be shipped via independent truck contractors using single trailer trucks of 20-ton capacity or double-trailer trucks of 25-ton capacity. Each load will be covered with a tarpaulin, lapping over the side about a foot and secured every few feet around the truck bed. Thus, wind erosion, storms, and uneven roads will not cause loss of material during transit.

Direct radiation from an ore truck will be about 2 mrem/hr at the truck bed, about 0.3 mrem/hr on the shoulder of the roadbed and normal background at about 60 m (96 ft) from the trailer. As a truck passes, individuals standing on the shoulder of the highway will receive a dose of radiation too small to quantify.

The truck driver will receive measureable radiation and doses to about 500 mrem/yr may be expected. As shown in Table 3.2, this dose is only slightly higher than that received by airline flight crews.

Truck accident statistics include three categories of events: collisions, noncollisions, and other events. "Collisions" are between the transport vehicle and other objects, whether moving vehicles or fixed objects. "Noncollisions" are accidents involving only the one vehicle, such as when it leaves the road and rolls over. Accidents classified as "other events" include personal injuries suffered on the vehicle, persons falling from or being thrown against a standing vehicle, cases of stolen vehicles, and fires occurring on a standing vehicle. The probability of a truck accident of any kind is about 1.3E-06/km. (USNRC 79)

The mine will ship an average of 10 trucks loads per day to the mill in Blanding, Utah. The mill is about 260 miles (416 km) away. Thus, the probability of an accident is about 5.4E-03 per day OR about one accident of some type every 185 days. It should be noted that only a fraction of all accidents will result in ore spillage. Nevertheless, a couple of spillage accidents should be anticipated during the operational life of the mine.

The ore from the mine is moist, uncrushed rocks and will contain only a small percentage of respirable dust which might be released during an accident. For an ore truck accident it is reasonable to assume that about 2.1 kg (4.6 lbm) of ore dust might be released to the atmosphere.(USNRC 79) If all the dust were in the respirable range then a maximum individual 50 year lung dose commitment would be on the order of 130 mrem at 500 m (1600 ft) and 14 mrem at 2000 m (6500 ft) from the accident scene. (USNRC 79) Direct radiation would be the same whether or not the ore were in the truck. Thus, an individual must remain on top of the ore for about 50 hours per week in order to receive the suggested weekly occupational exposure limit, OR, remain atop the pile for about 80 hours before receiving the suggested, yearly non-occupational exposure limit. The remoteness of the haulage route, the low specific activity of the material (amount of radioactivity per gram of ore) and the ease with which the contamination can be removed (shovel ore into another truck) results in a potential impact which should not be considered signficiant.

Energy Fuels Nuclear has committed to a timely and thorough clean up of any spillage.(EFN 84)

5.6 Radiation in Mine Environment

The miners can expect direct radiation levels to be on the order of 0.8 mrem/hr.(HU 85) The direct radiation limits, dosimetry and record keeping requirements are mandated by 30 CFR 57. Theoretically, a miner can remain at or near the high-grade ore body during entire work period and not exceed the weekly guidelines (100 mrem) or the annual limit (5,000 mrem).

Radon gas and progeny will be flushed from the mine with a 150,000 cfm vent fan. Based on measurements atop the Hack Canyon Mine vent, radon gas concentrations will be on the order of 2400 pCi/L and 1600 mWL.(McK 85) Thus, the daughters will be present at approximately 10% of their potential equilibrium values. This means that much of the radon gas will be removed from the mine before it is able to decay to its hazardous daughter products. The occupational radon progeny limit is 4 WLM/yr. Miners at Hack Canyon are currently experiencing an average of about 2.2 WLM/yr.

Currently, uranium miners work an average of 10 years underground; thus the cumulative 10 to 25 WLM is well below the 100 WLM value where studies indicate possible increases in lung cancer might appear.

6.0 PROPOSED RADIOLOGICAL MONITORING PROGRAM

The proposed radiological monitoring program involves collection of appropriate data before the mine is operational. Additional measurements will be made as needed during mine operation and in the event of an accidental release of radioactivity to the wash. A final survey will be conducted at the time the mine is closed. Each part of the monitoring program will be described here.

6.1 Preoperational Baseline Information

The preoperational baseline data collection program will last one year and will involve background measurements of direct gamma radiation, radon gas and progeny concentrations, and radioactivity concentrations in air, soil and water.

Direct gamma radiation measurements will be obtained by at least three independent monitoring devices and at a minimum of 12 locations. Passive thermoluminescent dosimeters will be exchanged quarterly and provide cumulative dose information. Readings from a pressurized ion chamber and two micro-R scintillometers will be recorded whenever the thermoluminescent dosimeters are exchanged. The monitoring sites are described in Section 5.1 and shown in Figure 5.1. Measurements to date are reported in Appendix A.

Radon measurements will be performed quarterly using an instrument which obtains independent measurements of radon gas concentrations and the daughter product ´working level´ exposure. Measurements will be made at the mine site, Tusayan, and other locations as deemed necessary.

When electricity is available at the site low-volume air sampling can be initiated to determine the baseline radioactivity concentrations in the atmosphere.

Water samples will be collected from the wash and/or Owl Tank semi-annually based on availability of water. Additional samples will be collected at Havasu Springs, Indian Gardens and Blue Springs. Results to date are reported in Appendix C.

Soil samples will be collected from the sites listed in Section 5.4 and shown in Figure 5.2. Results to date are reported in Appendix C.

6.2 Operational Measurements

The quarterly thermoluminescent dosimetry measurements, pressurized ion chamber, and scintillometer measurements will continue at the 12 established sites. Additional sites may be established along the haulage route.

Based on time and need, radon measurements will continue at Tusayan and will be rotated among other sites such as Owl Tank, the ore and waste piles, in the mine office, and atop the exhaust vent. The objective will be to collect sufficient radon information to ensure no measureable increase occurs at Tusayan.

Soil and water samples will be collected until such time as sufficient data is available to delineate possible radionuclide increases from accidental releases and to ensure that ground water, if present, will not be adversely impacted. Thereafter, except for water from the mine well and soil from the survey location immediately downwash from the mine yard, routine soil and water sampling will not be needed.

It is hoped that the water information may be used by the Forest and Park Service to assist with ongoing assessments of water quality in the Grand Canyon area.

Whenever a haulage accident occurs a radiological report will be prepared. The report will contain such information as the amount of material spilled, the extent of area affected, measures taken to provide an adequate cleanup, results of the final radiological survey, and estimates of any possible non-occupational exposures.

7.0 SUMMARY

Energy Fuels Nuclear, Inc. intends to design, construct, and operate a uranium mine at the Canyon Mine Site. When the mine is closed the area will be cleaned up to the extent dictated by regulations which are applicable at the the time of closure.

Based on an evaluation of the direct radiation, radon and dust emissions previously described herein, and the commitment by Energy Fuels Nuclear not to allow a liquid release from the mine yard unless it meets the discharge standards under the National Pollution Discharged Elimination system Permit (EFN 84), there do not appear to be any adverse radiological environmental impacts from the Canyon Mine Project.

During mine operation the direct radiation from the ore piles will probably not be measureable at distances greater than a few hundred meters from the mine site. In any event, it should not be possible to distinguish the mine induced radiation from the variations in the natural radiation environment which currently exist in the vicinity of the site.

For a ´hypothetical´ worst case meteorlogical scenerio in which the wind blows from the site directly towards Tusayan (instead of the established directions which are generally away from away from the community), the yearly radon progeny lung dose to a permanent resident would be on the order of 12 mrem, or about a 10 % increase above the normal outdoor dose currently received in

Tusayan. If meteorology follows the predicted patterns the lung dose would probably increase by about 2% or less. This increase would be much less than the 50% or more increase that occurs due the to elevated radon concentrations which are present indoors. In any event, the potential increases in radon are too small to detect above normal radon fluctuations in the environment.

A Maximum Probable Flood followed by a total loss of site integrity would release several Curies of radioactivity from the ore piles to the wash. However, residual contamination could be easily removed and returned to the mine yard. There would be no health hazard. The mine site is being designed to preclude accidental discharges to the wash. However, if an accidental release occurs the impact must be assessed immediately and cleanup effected if the situation warrants.

Ore transport to the mill will not expose inhabitants along the haulage route to any statistically significant doses of radiation. A few accidents may occur during the life of the mine where ore spillage occurs. Energy Fuels Nuclear has commited to a thorough and timely cleanup of any spill.(EFN 84) The radiation from the ore will not pose a health hazard.

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APPENDIX A BACKGROUND GAMMA RADIATION MEASUREMENTS
uR/hr (microRoentgens per hour)

LOCATION AND DATE	THERMOLUMINESCENT DOSIMETRY	PRESSURIZED ION CHAMBER	SCINTILLOMETER MICRO-R METER
North -- of Mine Site			
4/13/85	****	11.5	9.5
6/21/85	10.2	10.7	8.5
Northeast			
4/13/85	****	13.3	14.0
6/21/85	12.0	13.1	11.5
East			
4/13/85	****	11.5	10.0
6/21/85	10.0	12.0	9.5
Southeast			
4/13/85	****	12.5	11.0
6/21/85	10.3	12.0	10.5
South in Wash			
4/13/85	****	14.2	13.5
6/21/85	13.8	14.6	14.5
South			
4/13/85	****	11.2	8.5
6/21/85	9.3	10.8	9.0
Southwest			
4/13/85	****	10.5	9.0
6/21/85	8.9	9.8	8.0
West			
4/13/85	****	10.4	8.5
6/21/85	9.3	10.5	9.0
Northwest			
4/13/85	****	11.8	10.0
6/21/85	11.5	11.6	10.5
Owl Tank			
4/13/85	****	13.0	14.5
6/21/85	12.9	15.1	14.0
Airport			
4/13/85	****	13.8	12.0
6/21/85	13.6	13.3	12.0
Tusayan			
4/13/85	****	13.3	11.5
6/21/85	11.3	13.6	11.5

APPENDIX B RADON DAUGHTER DOSE CALCULATIONS

1.0 Background

A highly conservative approach was used to assess the dispersion of radon gas from the ore and waste rock piles. This conservatism included: (1) determining the annual radon source term from the maximum sizes of the piles assumed to occur concurrently, (2) selecting the largest calculated value of the annual radon release from the piles, (3) using meteorological data representative of the "model" processing facility in the GEIS on Uranium Milling (NR-80) which incorporates relatively extreme conditions, and (4) modeling the dispersion at the selected locations based both on the meteorological data and also considering the maximum concentration at that radial distance from the source.

The annual radon source term from the stack release was determined from measurements performed on the Hack Canyon Vent by McKlveen (McK-85).

2.0 Ore and Waste Pile Parameters

During the course of mining operations at the Canyon Project Mine, two rock piles are developed on site. One pile, referred to as the ore pile, consists of rock containing 0.7%, U3O8 which will be shipped for processing; the second, referred to as the waste pile, consists of 0.1% U3O8, a concentration that is currently below the cutoff for processing.

The ore pile will eventually reach a maximum size of 500x250x15 ft., while the waste stockpile will reach a maximum size of 160x320x15 ft. It will be conservatively assumed in developing the source term for the analysis that both piles reach their maximum size concurrently. The piles are not presumed to be covered with any natural or artificial cover.

3.0 Evaluation of Radon Dispersion from Ore Piles and Mine Stack and Vents

The radium in the rock material in the ore and waste piles emits radon gas which diffuses to the surface of the pile and then into the surrounding air.

The radium concentration in the rock is determined from the fact that a concentration balance is reached (secular equilibrium) in the material among the radionuclides in the uranium decay chain where 0.1% U3O8 = 282 pCi/gm Ra-226 (DO-83). Thus, using measured concentrations of U3O8 permits evaluation of radium concentration as follows:

(A) Ore Grade Pile

Ra-226 concentration = $\frac{\text{Ore Grade}}{0.1\%\ U_3O_8}$ x282 pCi/gm = $\frac{0.7\%\ U_3O_8}{0.1\%\ U_3O_8}$ x282 pCi/gm

= 1974 pCi/gm

(B) Waste Stockpile

Ra-226 concentration = $\frac{0.1\%\ U_3O_8}{0.1\%\ U_3O_8}$ x282 pCi/gm = 282 pCi/gm = 282 pCi/gm

The radon emission from the piles is now evaluated by two different accepted approaches with the more conservative (larger) emission being used as the source term. In the first approach, the annual radon release source term for the two piles is calculated from the solution of the diffusion equation for an infinite slab in the vertical dimension.

$$J_o = (C_{Ra}) \;\; E \; (D_o/P_o)^{1/2} \times 10^4$$

Where:

J_o = the radon-222 flux (pCi/m^2-sec)

C_{Ra} = Radium concentration (pCi/gm)

= density of the rock material (gm/cm^3) = 2.50 gm/cm^3

E = Emanation coefficient

= $\frac{\text{Radon activity that escapes pore space}}{\text{Radon activity in a grain of material}}$

= 0.2

= Radon decay constant = 2.11x10^{-6} sec^{-1}

D_o = Diffusion coefficient for rock material (cm^2/sec)

P_o = Porosity of rock material

The ratio (D_o/P_o) is a function of the moisture content (m) of the material and can be expressed as:

$$\frac{D_o}{P_o} = 0.106 \exp-(0.20xm) \frac{m^2}{sec}$$

Using a moisture content of 10% (range is 8-12%) and a porosity of 0.2 as representative of the distribution in the piles give (D_o/P_o) = 7.87×10^{-3} cm^2/sec.

The annual radon-222 release J(Ci) is then equal to:

$J = J_oAk$

Where:

A = the area of the pile (m^2)

k = 3.154×10^7 sec/yr.

Thus, the release from the piles is:

(A) Ore Grade Pile

$$J_o = (1974)\frac{pCi}{gm}(2.50\frac{gm}{cm^3})(0.2)[(2.11 \times 10^{-6} sec^{-1})(7.87 \times 10^{-3} \frac{cm^2}{sec})]^{1/2} \times 10^4$$

$J_o = 1272$ pCi/m^2-sec

and $J = (1272\ pCi/m^2\text{-sec})(11600\ m^2)(3.154 \times 10^7\ sec/yr)$

$J = 464$ Ci

(B) Waste Stockpile

$$J_o = (181\ pCi/gm)(2.50\ gm/cm^3)(0.2)[(2.11 \times 10^{-6} sec^{-1})(7.87 \times 10^{-3} cm^2/sec)]^{1/2} \times 10^4$$

$J_o = 181$ pCi/m^2-sec

and $J = (181\ pCi/m^2\text{-sec})(4757\ m^2)(3.154 \times 10^7\ sec/yr)$

$J = 27$ Ci

and the total annual radon release from the 2 piles is 464+27 = 491 Ci.

In the second method for evaluating the source radon emission from the piles, the NRC accepted approach (NR-80) of using a radon flux-to-radium concentration ratio of 1 is used. With this approach:

$$J_o/C_{Ra} = 1.0$$

and $J = (1.0)(C_{Ra})(A)(k)\left(\frac{1\ Ci}{1x10^{12}\ pCi}\right)$

Thus, the release from the piles is determined to be:

(A) Ore Grade Pile

$$J = \left(1.0\ \frac{gm}{m^2\text{-sec}}\right)\left(1974\ \frac{pCi}{gm}\right)(11600\ m^2)\left(3.154x10^7\ \frac{sec}{yr.}\right)\left(\frac{Ci}{10^{12}pCi}\right)$$

J = 722 Ci

(B) Waste Stockpile

$$J = \left(1.0\ \frac{gm}{m^2\text{-sec}}\right)\left(282\ \frac{pCi}{gm}\right)(4757\ m^2)\left(3.154x10^7\ \frac{sec}{yr.}\right)\left(\frac{Ci}{10^{12}pCi}\right)$$

J = 42 Ci

and the total annual radon release from the 2 piles is 722+42 = 764 Ci.

To assure that the most conservative approach is considered, the value of 764 Ci/yr radon release is used as the source term for the dispersion analysis.

3.1 Radon Emanating From Stack

Based on measurements made at the site (McK 85) an annual release of 4300 Ci of radon from the mine stack at a releases height of 30 feet has been determined. This release is taken at a rate of 150,000 cfm from a diameter of approximately 7 feet at the release point.

3.2 Environmental Radon Concentrations from Emissions from Piles and Stack

The radon concentrations in the environment around the site resulting from the annual emission of 764 Ci from the piles and 4300 Ci from the stack is calculated using the MILDOS dispersion model.(BE 85)

The MILDOS model was specifically developed for use in evaluating airborne release from uranium processing and disposal facilities and is relevant to the releasses from the ore and waste piles and mine stack. This model is also accepted by regulatory agencies as a for dose projections in licensing actions. Applying the model involves determination of the source-term for each case being evaluated and use of the source term in conjunction with meteorological and demographic parameters as input data. The results of the modeling effort are the concentrations and doses (if desired) for the exposed individual and the population within 80 kms of the site.

The MILDOS model simulates emissions of radioactive materials from fixed point source locations and from areal sources using sector-averaged Gaussian plume dispersion model. Mechanisms such as deposition of particulates, resuspension, radioacive decay and ingrowth of daughter radionuclides are included in the transport model. Annual average air concentrations are computed. Table B.1 presents the environmental (air) concentrations of radon in the four primary directions for radial distances from the piles ranging from 1.5 to 75.0 km based on the generic meteorology set forth in the GEIS on uranium milling (NR-80).

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TABLE B.1

Environmental Radon Concentrations As a Function of Distance From the Piles and the Mine Stack

Radial Distance From The Piles (Km)	Total Radon Concentration in Air As A Function of Direction From the Piles and the Stack (pCi/l)			
	North	East	South	West
1.5	.0530	.1869	.0431	.0733
2.5	.0253	.0886	.0197	.0363
3.5	.0169	.0571	.0118	.0244
4.5	.0127	.0418	.0081	.0185
7.5	.0073	.0229	.0039	.0108
15.0	.0035	.0105	.0016	.0052
25.0	.0020	.0059	.0009	.0029
35.0	.0014	.0040	.0006	.0020
45.0	.0011	.0030	.0005	.0015
55.0	.0008	.0023	.0003	.0012
65.0	.0007	.0019	.0003	.0010
75.0	.0006	.0016	.0003	.0008

APPENDIX C RADIONUCLIDE ASSAYS OF SOIL AND WATER

Baseline soil and water samples have been obtained at the locations listed in Table C.1.

Table C.1 Soil and water sample locations.

Location	Soil	Water
Wash NNW of Mine	Y	Dry
Wash NNE of Mine	Y	Dry
Wash SSW of Mine	Y	Dry
Owl Tank	Y	Y
Red Horse Wash at U.S. Highway 180	Y	Dry
Red Horse Wash west of Wallaha	Y	Dry
Blue Spring	N	Y
Havasu Spring	N	Y
Indian Gardens Spring	N	Y

All soil samples and water from Owl Tank were collected in April, 1985. Water from the springs was obtained in May, 1985. Assays reported below were performed by the Arizona State University Radiation Measurements Facility. Results for the soil assays are reported in Table C.2 and results for the water analysis are reported in Table C.3.

Table C.2 Results of Radionuclide Assays in Soil (pCi/gm).

Sample	Ra-226	Gross Alpha	Gross Beta	Th-232	Tl-208	K-40	Cs-137
Wash NNW	1.3 (9)	20 (10)	21	0.7 (6)	0.24 (4)	13 (3)	0.42
Wash NNE	1.3 (9)	35 (11)	25	1.0 (5)	0.36 (3)	17 (2)	0.32
Wash SSW	1.8 (14)	23 (10)	32	1.3 (8)	0.42 (7)	21 (4)	1.10
Owl Tank	1.6 (11)	35 (9)	28	1.0 (6)	0.35 (4)	18 (2)	0.83

Values in parenthesis are the % error at one standard deviation.

The results for soil collected from Red Horse Wash at U.S. Highway 180 and at Wallah were not available at time the report was prepared. All soil is being analyzed for uranium content but results were not available at time the report was prepared.

The Ra-226 reported is normal for Arizona soil.(McK 85) The gross alpha and gross beta results are not sufficiently accurate to provide useful informatiion. Improvement in assay technique is not possible due magnitude of the the self absorption corrections which need to be made. Th-232 and Tl-208 radionuclides are members of the Thorium decay chain and are normal. The naturally occurring K-40 concentrations are the same as other soils measured in Arizona.(McK 85) Fallout Cs-137 concentrations are approximately a factor of two higher than those measured in the Phoenix area. (McK 85) In summary, the radionuclide concentrations in the soil around the Canyon Mine Site are normal and do not indicate the presence of surface deposits of natural radioactivity. It appears that the two prime indicators for changes in the natural radiation environment will be Ra-226 and uranium. Therefore, it is recommended that further soil sampling analysis be limited to these radionuclides.

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Table C.3 Results of Radioactivity in Water (pCi/L).

Sample	Ra-226	Gross Alpha	Gross Beta	K-40
Owl Tank	0.76 (17)	<2	5.6 (25)	3.3
Owl Tank (insol.)	0.15 (33)	--	--	--
Havasu Spring	0.45 (38)	<8	6.4 (30)	4.1
Indian Gardens	0.25 (40)	<4	3.2 (56)	1.4
Blue Springs	0.31 (39)	<21	9.4 (26)	6.6

Values in parenthesis are the % error at one standard deviation.
-- No analysis performed

==

The results compare favorably with the statewide averages for gross alpha, gross beta and Ra-226 in ground water which are 4.9 pCi/L, 6.4 pCi/L and 0.2 pCi/l respectively. (McK 78) Ra-226 in Owl Tank surface water appears to be higher than the other samples and this would be expected as the direct radiation measurements are also slightly higher than some of the other sites. (Mo 85, McK 85) Impurities (such as calcium) in water increase the detection thresholds for gross alpha assays. The impurities increase self-absorption corrections and reduce detection efficiencies. An obvious example of the problem is the greatly increased gross alpha detection threshold for Blue Spring, whose Calcium content is reported to be about twice as high as Havasu Spring and about five times larger than Indian Gardens. Gross beta sufferes from the same problem, but not to the same extent as gross alpha. Uranium isotopic analysis appears to be an accurate assay technique, but the results for these water samples are not yet available.

Identical samples for Blue Springs, Havasu Springs and Indian Gardens were assayed by other laboratories and the results are reported by Montgomery. (Mo 85) There is poor agreement between laboratories, but this is not unusual as the amounts of radioacivity are so small that assay at these levels approaches the minimum detection limits of the laboratory. A good example of the inaccuracies associated with gross alpha detection can be seen for the Havasu Spring results shown in Table C.4.

Table C.4 Gross Alpha and Gross Beta Activity Results for Havasu Spring (pCi/L).

Laboratory	Gross Alpha	Gross Beta
EAL (MO 85)	41 +/- 34	45 +/- 40
CFEP (MO 85)	<2	<3
This report	<8	6 +/- 2

The preferred methods to monitor for potential changes in radioactivity in water samples appear to be isotopic Ra-226 and uranium. Gross alpha and gross beta data may be used, but their limitations and insensitivity must be understood.

References:

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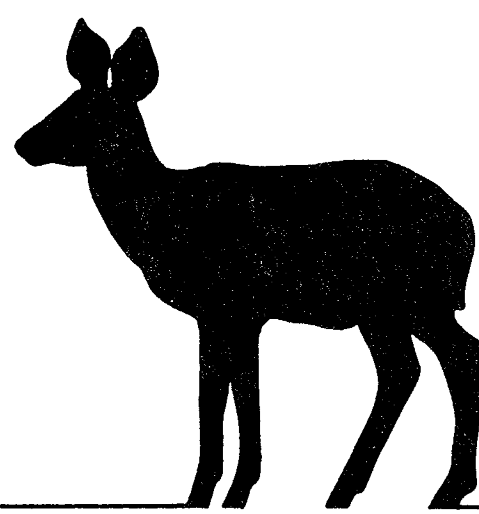
Appendix

F

Groundwater Conditions



Report

July 17, 1985

GROUNDWATER CONDITIONS
CANYON MINE REGION
COCONINO COUNTY, ARIZONA

PREPARED FOR
U. S. FOREST SERVICE
KAIBAB NATIONAL FOREST
WILLIAMS, ARIZONA

CONTENTS

CONTENTS - continued.

TABLES

ILLUSTRATIONS

(*Not included; on file at Kaibab National Forest)

APPENDIX

GROUNDWATER CONDITIONS
CANYON MINE REGION
COCONINO COUNTY, ARIZONA

SUMMARY OF CONCLUSIONS

The following conclusions are based on analysis of hydrogeologic and hydrochemical data obtained during the Canyon Mine environmental impact investigations.

1. The proposed mining operations at the Canyon Mine site will have little or no impact on groundwater circulation and storage in perched aquifers, and will have negligible or no impact on yield from springs and wells which yield groundwater from perched aquifers.

2. The proposed mining operations will have little or no impact on chemical quality of groundwater in perched aquifers.

3. The proposed mining operations will have negligible impact on groundwater circulation and storage in the Redwall-Muav aquifer, and will have negligible impact on yield from springs which issue from the Redwall-Muav aquifer.

4. With the implementation of planned mitigation actions, the possibility for deterioration of chemical quality of groundwater in the Redwall-Muav aquifer due to proposed

mining operations is small. Any deterioration of chemical quality of groundwater in the Redwall-Muav aquifer would be detected by the groundwater monitoring program.

INTRODUCTION

Underground mining operations to extract uranium ore for a period of approximately ten years have been proposed by Energy Fuels (Energy Fuels Nuclear, Inc.) for the Canyon Mine site located about six miles southeast of Tusayan, Arizona. At the mine site, the ore-bearing zone occurs within a mineralized breccia pipe which is believed to extend upward to the land surface from the Redwall Limestone. During mining operations, a vertical shaft will be constructed outside the breccia pipe structure, and tunnels will extend laterally from the shaft to intersect ore-bearing zones. The mine openings will penetrate from the land surface to the upper part of the Supai Group, about 1,400 feet below land surface. Water for domestic and industrial use will be needed at the mine site. The quantity required for domestic use is projected by Energy Fuels personnel to be about five gpm (gallons per minute), and might be obtained from a groundwater supply and monitoring well which will be completed in the Redwall-Muav aquifer at the mine site. The depth to the top of this aquifer at the mine site is about 2,300 feet below land surface. Shaft construction and mining operations will take place in rock formations which are well known from descriptions by eminent geologists at exposures in the walls of the Grand Canyon. The rim of the Grand Canyon, at its closest point, lies about nine miles north of the Canyon Mine site.

PREVIOUS INVESTIGATIONS

Hydrogeologic conditions on the Coconino Plateau along the south rim of the Grand Canyon have been reported by many authors; five publications are most pertinent to understanding the occurrence and circulation of groundwater in the Canyon Mine site area. Metzger (1961) discusses relations between geology and groundwater resources along the south rim of the Grand Canyon and gives preliminary conclusions for quantity and rate of recharge and discharge. Huntoon (1982) reports results of investigations on groundwater circulation in the plateau regions adjacent to the Grand Canyon and indicates that groundwater discharge from these regions is chiefly to springs in the Grand Canyon. A compilation of data for groundwater discharge at springs along the Colorado River in the Grand Canyon is given by Johnson and Sanderson (1968). The Grand Canyon National Park, Water Resources Management Plan (1984) provides an excellent summary of hydrogeologic and hydrochemical data for the Park and adjacent areas. Loughlin (1983) provides interpretations and conclusions for hydrodynamic conditions at the time of formation of breccia pipes in the Grand Canyon area and for groundwater circulation near important springs.

HYDROGEOLOGIC CONDITIONS

The lithology and deformation of the rock formations in the Canyon Mine site area are principal controls for circulation and storage of groundwater. The outcrop areas of the geologic units and the surface traces of principal structural features in the Canyon Mine area are shown on **Figure 1.** A hydrogeologic section showing thickness of the sedimentary rock formations, geometry of the mineralized breccia pipe, and planned locations of the mine openings are shown on **Figure 2.** Locations of water wells and springs in the Canyon Mine site area are shown on **Figure 3.** An inventory of data for water wells and test holes in the Canyon Mine area is given in **Table 1.** Records for the principal springs which issue from the southern wall of the Grand Canyon and in southern tributary canyons from Havasu Springs on the west to Blue Springs on the east **(Figure 1)** are summarized in **Table 2.** The well numbering system used by the Arizona Department of Water Resources and in this report is described and illustrated in **Appendix A.**

STRATIGRAPHY AND HYDROGEOLOGIC CHARACTERISTICS

Alluvial deposits, Moenkopi Formation, and Kaibab Limestone crop out at the land surface in the Canyon Mine area. Volcanic rocks crop out in the southern part of the area shown on **Figure 1.** Navajo Sandstone and Chinle Formation crop out east of the Little Colorado River, but these rocks do not occur at the mine site. Geologic units which do not crop out but exist in the subsurface in the Canyon Mine area, to the projected base of the mine openings, are in descending order: Toroweap Formation, Coconino Sandstone, Hermit Shale, and the upper part of the Supai Group. The lower part of the Supai Group and the Redwall, Temple Butte, and Muav Limestones, Bright Angel Shale, Tapeats Sandstone, and Precambrian rocks lie at depths below the deepest projected depth for the mine openings **(Figure 2).**

Alluvial Deposits

The alluvial deposits comprise a heterogenous mixture of unconsolidated to consolidated rocks ranging in grain size from silt and clay to boulders. The alluvium is of Quaternary and Tertiary age and crops out chiefly in valley floors and along the margins of volcanic rocks (Figure 1). The thickness of alluvial deposits ranges from a feather edge to a few feet where exposed in valley floors. The older alluvial deposits may be more than 100 feet in thickness at the margins of the volcanic rocks.

Alluvial deposits which occur in the valley floors are permeable and transmit recharge waters from the land surface to underlying formations. Occasionally, where alluvial deposits overlie less permeable rocks, temporary perched groundwater reservoirs may exist in these deposits. Such perched reservoirs are usually ephemeral and the stored water is lost to evapotranspiration and slow downward seepage after periods of precipitation deficit.

Volcanic Rocks

The volcanic rock sequence comprises pyroclastics, including volcanic ash and cinders, lava-flow rocks, dikes, and plugs. The thickness of the volcanic rock sequence ranges from approximately 20 feet at the edge of some lava flows to more than 1,000 feet near eruptive centers.

Surficial cinder cover provides excellent infiltration media. The subsurface sequence of volcanic rocks commonly has a low vertical permeability and retards downward water movement unless extensively fractured. Perched groundwater zones occur locally in the volcanics and discharge at seeps and springs. Locally, these perched groundwater zones have been penetrated by wells and yield small, and often poorly reliable, quantities of water for domestic and stock use.

Navajo Sandstone and Chinle Formation

Sedimentary rocks including Navajo Sandstone and Chinle Formation overlie Moenkopi Formation at places east of the Little Colorado River (Figure 1). These units are isolated from the Canyon Mine site area by the Little Colorado River Gorge, lie above the water table in the regional aquifer, and lie above the strata in which the mine openings will occur.

Moenkopi Formation

The Moenkopi Formation in the Canyon Mine area is a thin-bedded, fine grained, red sandstone and mudstone. Near the Canyon Mine site the Moenkopi has been completly eroded in most areas. However, at the land surface directly over the breccia pipe, Moenkopi occurs in thicknesses ranging from a feather edge to about 60 feet. The presence of the remnant Moenkopi strata is due to collapse of the pipe prior to erosional stripping of Moenkopi and subsidence of the lowermost part of the unit into the collapse depression.

The fine grain size and poor sorting in the strata of the Moenkopi Formation cause the unit to function as a confining layer; the formation transmits water only where it is extensively fractured (Cosner 1962). Because of the small area where the Moenkopi crops out, and the abundant fractures which would occur in the brittle sandstone strata during subsidence, the Moenkopi Formation is not expected to function as an effective confining layer and perched groundwater would not be expected to occur in the unit at the Canyon Mine site.

Kaibab Limestone

The Kaibab Limestone comprises thick- to thin-bedded, jointed, cherty, and sandy dolomitic limestone. It crops out over large areas in northern Arizona including the Canyon Mine site, and forms the rim rock of the Grand Canyon (Figure 1). At the Canyon Mine site the thickness of the Kaibab is about 300 feet (Figure 2).

The Kaibab Limestone is a brittle formation and is extensively fractured in areas where geologic structural movements have occurred. Water percolation through these fractures has enlarged the openings by solution and, at many places, has created extensive cavern systems. Large caverns in the Kaibab may be inspected at Grand Canyon Village, and have been observed at Wupatki National Monument (Cosner, 1962), at Babbitt Ranch west of the Canyon Mine site (Harshbarger, 1973), and at many other localities in northern Arizona. Where Kaibab is exposed, surface water percolates readily downward via the fractures and solution openings and thus the unit comprises an important recharge medium.

Toroweap Formation

The Toroweap Formation consists of upper and lower fine-grained sandstone and shale members separated by a middle massive limestone member (McKee, 1974). Due to variability in composition, the topographic expression of the Toroweap ranges from a weak slope-forming unit to a cliff-former. At the Canyon Mine site the thickness of the Toroweap is about 300 feet (Figure 2).

The sandstone in the upper and lower members of the Toroweap is similar to the sand of the Coconino Sandstone; however, the cementation for the Toroweap is weaker. Shale beds within the upper and lower members of the formation are confining layers and locally cause accumulation of thin and discontinuous perched groundwater zones in overlying sandstone strata. The Toroweap is considered to be a minor aquifer and yields small quantities of groundwater to wells in the Canyon Mine site area.

The middle massive limestone member of the Toroweap is brittle and is extensively fractured. Fractures in the limestone are commonly enlarged by solution activity and solution openings are abundant in this member. Groundwater percolates downward readily via fractures and solution openings in the limestone member.

Coconino Sandstone

The Coconino Sandstone is very fine- to fine-grained, cross-bedded sandstone composed of subangular to well rounded, frosted quartz grains. The Coconino is usually a cliff-former in outcrops, is a well-lithified and brittle rock unit, and contains extensive fractures near fault zones. At the Canyon Mine site the thickness of the Coconino is about 550 feet (Figure 2).

The Coconino Sandstone is the principal aquifer throughout much of northern Arizona at locations where the regional water table occurs above the base of the unit. At Flagstaff, municipal water supply wells obtain groundwater from the Coconino aquifer, and hydraulic coefficients have been computed from results of pumping tests. Average transmissivity and coefficient of storage for the Coconino aquifer at the Flagstaff Woody Mountain municipal well field are reported by Montgomery and DeWitt (1975) to be 30,000 gpd/ft (gallons per day per foot width of aquifer at 1:1 hydraulic gradient) and 0.05 (dimensionless; ratio of volume of water released per unit surface area per unit decline in head), respectively. Average permeability is about 50 gpd/ft^2. At the Woody Mountain well field, the permeability of the formation is large due to the occurence of abundant fractures (Montgomery and DeWitt, 1975), and pumping rates from individual wells are as much as 1,000 gpm. Where the sandstone is not abundantly fractured, permeability is small, and pumping rates from individual wells are commonly less than 100 gpm.

Along the south rim of the Grand Canyon the water table occurs below the base of the unit and the Coconino does not contain groundwater at most locations. Where favorable structural conditions exist, and where mudstone strata in the underlying Hermit Shale form a confining layer, perched groundwater zones may occur, and may supply small quantities of water to springs and wells for domestic and stock use.

Hermit Shale

The Hermit Shale consists of red sandy shale and fine-grained friable sandstone. Where it crops out, it forms a slope between the overlying cliff-forming Coconino Sandstone and the underlying bench- and slope-forming Supai Group. At the Canyon Mine site the thickness of the Hermit is about 100 feet (Figure 2).

Due to its fine-grained lithology, the Hermit Shale generally retards the downward percolation of groundwater and the unit is considered to be an important confining layer.

Supai Group

The Supai Group consists of alternating siltstone, fine-grained sandstone, and some limestone beds. Where the Supai crops out in the Grand Canyon north of the Canyon Mine site, the formation is a ledge- and slope-former. The siltstone units are red and are in flat lenticular beds. The sandstone units are light brown but in many places are stained red by the overlying siltstone. At the Canyon Mine site the Supai is about 1,050 feet thick (Figure 2).

Because the Supai Group is composed chiefly of siltstone and fine-grained sandstone, groundwater does not move readily through the fine-grained rock matrix, although some downward percolation of groundwater does occur (Metzger, 1961). The upper part of the Supai contains sandstone beds which yield small quantities of water from local perched groundwater zones to seeps in the Grand Canyon; the unit is reported to yield small quantities of groundwater to wells in the Canyon Mine site area. However, the Supai functions chiefly as a confining layer, retarding downward water movement to the more permeable underlying formations.

Redwall, Temple Butte, and Muav Limestones

The Redwall Limestone is a thick-bedded, cliff-forming, fine-grained limestone and dolomite. Although the top of the unit has been encountered, the formation has not been completely penetrated by exploration boreholes at the Canyon mine site. The thickness of the Redwall at the Canyon Mine site is estimated from thicknesses reported from the Grand Canyon to be about 450 feet. The depth to the top of the Redwall at the mine site is about 2,300 feet. The Temple Butte Limestone underlies the Redwall and consists of interbedded dolomite, dolomitic sandstone, sandy limestone, siltstone, and sandstone. The unit crops out as thin ledges and occupies small channels cut into the underlying Muav Limestone. The thickness of the Temple Butte at the mine site is estimated from exposures in the Grand Canyon to range from a feather edge to as much as 140 feet. The Muav Limestone consists chiefly of dolomitic limestone. The lower part of the unit is gradational with the underlying Bright Angel Shale and contains a few beds of shale and sandstone. The Muav forms alternating cliffs and slopes. The thickness of the Muav Limestone at the mine site is estimated from exposures in the Grand Canyon to be about 300 feet. The depth to the top and base of the Redwall-Temple Butte-Muav sequence is approximately 2,300 and 3,050 feet, respectively, at the Canyon Mine site (Figure 2).

The Redwall-Temple Butte-Muav sequence lies below or partly below the regional water table and comprises the extensive and prolific Redwall-Muav aquifer in northern Arizona. Although the permeability of unfractured rock in the Redwall-Muav aquifer is very small, the presence of solution openings which have developed along fractures provides for the transmission of large quantities of groundwater. Data are presently (1985) insufficient to quantify permeability and porosity of the Redwall-Muav aquifer.

At Grand Canyon Village, and at most locations along the South Rim, the upper part of this aquifer system has been drained due to the downcutting of the Grand Canyon. However, large quantities of groundwater discharge from the aquifer at Havasu Spring and Blue Spring, where the strata have been flexed downward, and where major faults occur **(Figure 1)**. Indian Gardens Spring, located on the Bright Angel Fault about 14 miles north of the Canyon Mine site, is the closest spring which discharges from the Redwall-Muav aquifer.

Bright Angel Shale and Tapeats Sandstone

The Bright Angel Shale is composed chiefly of mudstone and shale strata but also contains minor thicknesses of sandstone and limestone. The unit functions as an effective confining layer; no large springs issue from formations below this shale. The Tapeats Sandstone consists of cross-bedded, poorly sorted, coarse sandstone and conglomerate. Because the Tapeats is overlain by the Bright Angel, only small quantities of groundwater issue from seeps in the Tapeats. The Bright Angel Shale and the Tapeats Sandstone are not known to yield groundwater to wells in the Grand Canyon region. The thicknesses of the Bright Angel and the Tapeats at the Canyon Mine site are estimated from exposures in the Grand Canyon to be about 200 and 250 feet, respectively **(Figure 2)**.

PRECAMBRIAN ROCKS

The presence of sedimentary, metamorphic, and igneous rocks of Precambrian age which underlie the Tapeats Sandstone at the Canyon Mine site are indicated from geologic relations in the Grand Canyon and from analysis of deep oil test holes in the Flagstaff vicinity. The permeability and porosity of the Precambrian rocks exposed in the Grand Canyon are very low, and these rocks together with the Tapeats Sandstone and the Bright Angel Shale are expected to function as the basal confining layer to the important groundwater transmission system contained in the Redwall-Muav aquifer.

STRUCTURAL FEATURES

The principal structural features in the Canyon Mine site area are a series of north to northeast trending faults, including the Vishnu and Bright Angel Faults; and major north to northwest trending flexures, including the Havasu Downwarp, and the Supai, Grandview-Phantom, and East Kaibab Monoclines **(Figure 1)**. Abundant fractures occur along the axial traces of these flexures (Huntoon, 1982). The altitude of the strata in the area of the Canyon Mine site is higher than the strata to the east which has been flexed downward along the Grandview-Phantom Monocline and the East Kaibab Monocline, and is higher than the strata to the west which has been flexed downward along the Supai Monocline **(Figure 1)**. The regional dip of the Kaibab Limestone and underlying strata of Paleozoic age in the Canyon Mine site area ranges from 1/2 to 1-1/2 degrees and is to the southwest.

The effects of faults and other fractures on movement and occurrence of groundwater in the Canyon Mine site area cannot be overemphasized. Recharge from precipitation, snowmelt, and streamflow percolates readily downward through the fractured rocks to the underlying perched and principal aquifer systems. Solution cavities, which also enhance water movement, are concentrated along these fractures. Lateral groundwater movement in the Redwall-Muav aquifer occurs chiefly in fractures and solution openings which are concentrated along the principal structural features. Most of the groundwater discharge from this aquifer occurs at springs which lie on the principal structural features.

Energy Fuels geologic personnel report that field investigations and exploration drilling operations have not encountered major faults or fractures outside the breccia pipe at the Canyon Mine site.

HYDROGEOLOGIC CHARACTERISTICS OF BRECCIA PIPES

The most common mining operations in the Grand Canyon area are associated with breccia pipes, which are cylindrical or conical collapse features in sedimentary rocks and at some locations are mineralized (National Park Service, 1984). Breccia pipes are believed to result from collapse of roof rocks, commonly to the land surface, over solution cavities in the Redwall Limestone (Loughlin, 1983). The structures are generally circular in surface exposure and are commonly rimmed by inward dipping collapsed strata (Billingsley, Ulrich, and Barnes, 1983). Brecciated rock exposed at the surface or in mine workings consists of angular blocks ranging in size from less than one inch to more than ten feet in diameter, and is composed of rocks from adjacent or overlying strata. Locations of more than 40 breccia pipe structures are shown on **Figure 1**. Two pipes are located in the walls of Havasu Canyon, near Supai Village (**Figure 1**). The Orphan Pipe is located on the rim of the Grand Canyon about 1-1/2 miles northwest of Grand Canyon Village (**Figure 1**). Many breccia pipes have been observed in the vicinity of the Little Colorado River Gorge. Several of the pipes in the Grand Canyon area have been mined, chiefly for their copper and uranium minerals.

ORPHAN MINE

Possibly the best known breccia pipe mine in the Grand Canyon area is the Orphan Mine near Grand Canyon Village. The Orphan breccia pipe is about 350 feet in diameter (Gornitz, 1969), and has a vertical dimension of about 2,000 feet. The mineralized portion of the pipe and mine openings occur at similar stratigraphic levels as for the Canyon Mine site. The most abundant minerals in the mineralized parts of the Orphan pipe were: uraninite, chalcopyrite, bornite, chalcocite, tennanite, and pyrite. The ore deposit was discovered in 1893 and the mining claim was patented in 1906. Commercial mining of uranium minerals from the Orphan Mine began in 1956 and mining operations ceased in 1969 (National Park Service, 1984).

HACK CANYON MINES

Mining operations by Energy Fuels are presently active at several breccia pipe mines north of the Grand Canyon. The Hack Canyon mines have been producing uranium minerals for several years. The mineralized portions of the pipes and mine openings occur at similar stratigraphic levels as for the Canyon Mine site. Inspection of hydrogeologic conditions in the Hack II and III mines in June 1985 indicated that the breccia blocks are firmly cemented by carbonate, ferrugenous, or ore minerals. The porosity of the breccia is low; voids between blocks are filled with firmly cemented matrix.

The Hack Canyon mine workings were nearly dry; small quantities of groundwater were yielded from a perched groundwater body at the base of the Coconino Sandstone. The quantity of water yielded was estimated to be less than five gpm, and was captured and used in the mine. Energy Fuels personnel indicated that the discharge rate shows seasonal variation, and that discharge has decreased from the time of commencement of mining operations.

EXISTING WELLS

Records are available for more than 150 wells and exploration boreholes in the Canyon Mine site area which are sufficiently nearby to provide data pertinent to this study. These records are summarized in Table 1. Locations of wells and exploration boreholes are shown on Figure 3. Most of the wells yield small quantities of groundwater from discontinuous perched aquifers in alluvial deposits, in volcanic rocks south of the Canyon Mine site, in the Chinle or Moenkopi Formations east of the mine site, in the Toroweap Formation, in the basal part of the Coconino Sandstone, or in the Supai Group. Several wells which yielded small quantities of water when drilled are presently dry.

Records for exploration borehole (A-29-3)20bdc, located at the Canyon Mine site, indicate that it is owned by the U. S. Forest Service and was drilled by Gulf Mineral Resources Company to a depth of 1,580 feet (Table 1, Figure 3). Examination of the drilling data for this borehole indicates that, during drilling operations, perched groundwater was encountered in the Kaibab Limestone at a depth of 140 feet. Initial groundwater yield from this borehole was reported to be about eight gpm. Exploration borehole (A-29-3)31cda, located about 2-1/2 miles southwest from the Canyon Mine site, is owned by the U. S. Forest Service and was drilled by Gulf Mineral Resources Company to a depth of 1,560 feet (Table 1, Figure 3). Examination of the drilling data for this borehole indicates that, during drilling operations, perched groundwater was encountered in the Kaibab Limestone at a depth of 160 feet. Initial groundwater yield from this borehole was reported to be about 12 gpm. Groundwater yield from these two boreholes reportedly decreased as drilling operations continued and eventually ceased. Cement plugs were installed in these boreholes at land surface and at a depth of 200 feet, and the boreholes were abandoned.

Records indicate that the closest water wells to the Canyon Mine site include: well (A-29-2)34dbb owned by Hatch and located four miles southwest of the mine site; and six wells [(A-30-2)24a1, (A-30-2)24a2, (A-30-2)24bbb, (A-30-2)25b, (A-30-2)25c, and (A-30-2)25dd], located at Tusayan, six miles northwest of the mine site **(Table 1; Figure 3)**. No hydrologic data are reported for the Hatch well; the six wells at Tusayan are reported to yield groundwater from the Toroweap Formation. Four of the wells at Tusayan were inspected in 1977 and were reported to be not used due to inadequate yield.

The Anita Copper Company shaft (A-29-2)16 is reported to be 514 feet deep and is located five miles southwest of the Canyon Mine site **(Table 1; Figure 3)**. The shaft is reported to bottom in the Coconino Sandstone. Depth to water in the shaft was reported to be 500 feet at time of completion in 1904.

Well (A-25-2)27aba, owned by Black Mesa Pipeline Company and located 25 miles south of the Canyon Mine site, was drilled sufficiently deep to penetrate the Redwall-Muav aquifer **(Table 1; Figure 3)**. Water level for the well is reported to be 2,839 feet below land surface, and altitude of water level is reported to be 3,326 feet msl (feet above mean sea level). Exploration boreholes (A-27-9)15ccc, (A-27-9)21abd, (A-33-8)22cd, and (B-28-1)35cab were drilled sufficiently deep to penetrate the Redwall-Muav aquifer, but the reports do not indicate that groundwater was encountered in this aquifer.

Discharge rates for the wells listed in **Table 1** range from less than 0.1 gpm to 50 gpm. Records and notes in the files of the Water Resources Division, U. S. Geological Survey, Flagstaff, Arizona, suggest that recorded pumping rates were excessive for many wells which obtain groundwater from perched aquifers in the Toroweap Formation and the Coconino Sandstone.

GROUNDWATER CIRCULATION

Groundwater moves from areas of recharge to areas of discharge. In the Canyon Mine site area, groundwater recharge occurs chiefly from infiltration of rainfall and snowmelt on the plateau south and southeast of the Grand Canyon. The Grand Canyon and its larger tributary canyons function as groundwater drains; groundwater discharges to the Canyon at many small springs and seeps and at a few large springs.

The absence of perennial streams, other than those fed by springs in the Grand Canyon and its tributaries, is one of the most noticeable hydrologic characteristics of the Canyon Mine site area. Although precipitation in the mine area is approximately 15 inches per year (Sellers and Hill, 1974), much of the rainfall and snowmelt is lost through evapotranspiration, and most of the remaining fraction infiltrates via permeable surficial deposits and via fractures and solution openings in the Kaibab Limestone. This water moves downward until it meets a confining rock layer with sufficiently small permeability to detain the flow. Where the water is detained, a saturated zone forms above the confining layer, and lateral groundwater movement begins. Because the confining layers are not completely impermeable, part of the perched water eventually leaks downward through the confining layer. The remaining groundwater will move laterally until it encounters fractures which permit the water to move downward and bypass the confining layer, or until the water discharges along canyon walls at seeps and springs.

Circulation in Perched Aquifers

Substantial quantities of groundwater may be perched above confining layers in areas where fractures are sparse. These conditions occur most commonly in the Toroweap Formation where groundwater is perched in sandstone units overlying shaley confining strata, and in the base of the Coconino Sandstone where groundwater may be perched on the mudstone strata of the Hermit Shale. At these places, the perched aquifers may yield small quantities of groundwater for domestic and stock use. Because the perched water leaks slowly downward through the confining layers and moves downward along fractures, the perched reservoirs are commonly small, thin, and discontinuous. If the groundwater stored in these perched reservoirs is not replenished annually by rainfall and snowmelt, wells and springs which yield from the perched aquifers may fail. A comparison of the quantity of groundwater yielded to seeps and springs from the perched aquifers to the quantity yielded from the Redwall-Muav aquifer is interpreted to indicate that the principal direction of groundwater movement is downward in the rocks overlying the Redwall-Muav aquifer.

Yield from Perched Aquifer Springs

Several springs issue from fractures or sandstone strata in the Toroweap Formation, Coconino Sandstone, and the Supai Group along the south wall of the Grand Canyon and its southern tributary canyons from Havasu Spring to Blue Spring. Records are available for three of these springs **(Table 2)** and indicate that average discharge is less than one gpm. The most important springs that discharge from these strata are Sinyella Spring in the western wall of Havasu Canyon, Great Thumb Spring in 140 Mile Canyon, Fossil Spring in Fossil Canyon, and Dripping Springs and Santa Maria Spring in Hermit Creek Canyon **(Figure 3)**.

Small springs and seeps discharge from volcanic rocks south of the Canyon Mine site. These springs and seeps are exit points for groundwater which has become perched on poorly permeable, unfractured lava-flow rocks. These perched aquifers are discontinuous and lie above the strata in which the mine openings will occur.

Circulation in the Redwall-Muav Aquifer

Groundwater enters the Redwall-Muav aquifer from overlying rocks where the direction of water movement is chiefly downward. When this groundwater enters the saturated zone in the Redwall-Muav aquifer, the direction of water movement becomes chiefly lateral toward large springs along the south wall of the Grand Canyon and its southern tributary canyons. Water movement is believed to occur principally in widely spaced fracture and solution openings which are concentrated along principal structural features (Huntoon, 1974). These principal structural features include the Havasu Downwarp, and the Supai, Grandview-Phantom, and East Kaibab Monoclines **(Figure 1)**.

Only one water well penetrates the Redwall-Muav aquifer in the Canyon Mine Site area and only sparse data are available for water levels. Well (A-25-2)27aba, located about 25 miles south of the Canyon Mine site **(Figure 3)**, obtains water from the Redwall-Muav aquifer. Altitude of static water level is reported to be 3,326 feet msl **(Table 1)**.

Yield from Redwall-Muav Aquifer Springs

More than 60 springs issue from fractures or solution openings in the Redwall-Muav aquifer along the south wall of the Grand Canyon and its southern tributary canyons. The largest springs in the Grand Canyon discharge from this aquifer and include Havasu Spring and Blue Spring. Average discharge rate from Havasu Spring is about 30,000 gpm, from Blue Spring is about 44,000 gpm, and from composite flow in the Blue Springs area is about 100,000 gpm (Loughlin and Huntoon, 1983). The large discharge rate from these springs has caused hydrologists to conclude that essentially all groundwater in the region along the south rim of the Grand Canyon issues either at Blue Springs or at Havasu Spring. The nearly constant rate of groundwater discharge from these springs is interpreted to indicate that the groundwater basins tributary to the springs are extensive and that the quantity of groundwater in storage in the aquifer system is large with respect to annual replenishment.

Many smaller springs also discharge from fractures or solution openings in the Redwall-Muav aquifer. The most important smaller springs are Hermit Spring (about 210 gpm) in the lower reaches of Hermit Creek Canyon and Indian Gardens Spring (about 300 gpm) in Garden Creek Canyon (Table 2; Figure 3). Because the discharge rates for these springs follow a seasonal pattern, the drainage areas for the springs are believed to be small and restricted to areas near the rim of the Grand Canyon.

Salient data for Havasu Spring, Indian Gardens Spring, and Blue Springs are summarized as follows:

Spring	Distance from Canyon Mine (miles)	Altitude (feet, msl)	Discharge Rate (gallons per minute)
Havasu Spring	42	3,250	30,000
Indian Gardens	14	3,740	300
Blue Springs (composite)	28	3,165	100,000

The altitude of the top of the Redwall-Muav aquifer at the Canyon Mine site is projected to be about 4,200 feet msl, about 900 feet below the base of the mine openings (Figure 2). The altitude of the base of the aquifer system at the site is projected to be about 3,450 feet msl. These relations indicate that the base of the Redwall-Muav aquifer at the Canyon Mine site is higher than the groundwater discharge points at Havasu and Blue Springs, and lower than the groundwater discharge point at Indian Gardens Spring. The top of the Redwall-Muav aquifer at the Canyon Mine site is higher than the groundwater discharge point at each of the three springs. The altitude of static water level at well (A-25-2)27aba, which penetrates the Redwall-Muav aquifer, was given as 3,326 feet msl (Table 1). These relations also indicate that the reported water level in well (A-25-2)27aba is lower than the base of the Redwall-Muav aquifer at the Canyon Mine site.

CHEMICAL QUALITY OF GROUNDWATER

Chemical quality of groundwater in the Canyon Mine site area is known from existing water quality data reported for wells and springs. These data provide documentation for baseline groundwater quality conditions prior to mining operations at the Canyon Mine site. Results of laboratory chemical analyses for water samples from 22 wells in the area shown on Figure 3 have been reported by Kister and Hatchett (1963), McGavock (1968), Loughlin (1983), and Loughlin and Huntoon (1983). These results are summarized in Table 3. In addition, results of analyses for water samples collected from more than 30 springs and creeks fed by groundwater discharge have been reported by Kister and Hatchett (1963), McGavock (1968), Johnson and Sanderson (1968), Walther (1970), Peterson et al. (1977), Cole and Kulby (1976 and 1979), Giegengack et al. (1979), Arizona Game & Fish Department (1983), National Park Service (1983), Loughlin (1983), Loughlin and Huntoon (1983), Usher et al. (1984), and Foust and Hoppe (1985). Results of analyses reported for Havasu, Indian Gardens, and Blue Springs, the three largest springs in the area, are summarized in Tables 4 and 5.

Existing water quality data for water wells in the Canyon Mine site area comprise analyses for routine constituents in water samples obtained from several perched aquifers (Table 3). Four exploration boreholes [(A-27-9)15ccc, (A-27-9)21abd, (A-33-8)22cd, and (B-28-1)35cab] and one water well [(A-25-2)27aba] are known to have penetrated the Redwall-Muav aquifer. However, the boreholes were abandoned and water quality data have not been reported for the water well. Water quality in the Redwall-Muav aquifer in the Canyon Mine site area is inferred from data for springs which discharge from the aquifer along the south wall of the Grand Canyon and its southern tributary canyons from Havasu Spring to Blue Springs.

PERCHED AQUIFER SYSTEMS

Perched aquifers reported to yield groundwater to the wells listed in **Table 3** include, in descending order: alluvial deposits, volcanic rocks, Navajo Sandstone, Shinarump Member of the Chinle Formation, Moenkopi Formation, Kaibab Limestone, Toroweap Formation, and Coconino Sandstone.

Alluvial Deposits, Volcanic Rocks, Navajo Sandstone, Shinarump Member, Moenkopi Formation, and Kaibab Limestone

Perched groundwater in the alluvial deposits, volcanic rocks, Navajo Sandstone, Shinarump Member, Moenkopi Formation, and the Kaibab Limestone generally occurs large distances to the east, south, and southwest from the Canyon Mine site. Laboratory chemical analyses for groundwater samples from well (B-27-6)1adc, completed in alluvial deposits southwest from the mine site, indicate a calcium-sulfate water type with total dissolved solids content of 2,220 mg/l (milligrams per liter). Analyses for samples from well (A-25-6)20bdd, completed in volcanic rocks south from the mine site, indicate a calcium-bicarbonate water type. Analyses for groundwater from well (A-34-9)22b, completed in the Navajo Sandstone east from the mine site, indicate a calcium-bicarbonate water type with total dissolved solids content of 145 mg/l **(Table 3)**. Analyses for samples from well (A-34-9)30a, completed in the Shinarump Member of the Chinle Formation east from the mine site, indicate a sodium-bicarbonate water type with total dissolved solids content of 1,000 mg/l. Analyses for groundwater from well (A-29-9)22dd, completed in the Moenkopi Formation east from the mine site, indicate a sodium-magnesium-bicarbonate water type with total dissolved solids content of 567 mg/l. Analyses for groundwater from well (A-28-9)35bac, completed in the Kaibab Limestone east from the mine site, indicate a sodium-chloride water type with total dissolved solids content of 2,920 mg/l.

Toroweap Formation and Coconino Sandstone

The Toroweap Formation and Coconino Sandstone comprise the most important perched aquifer system in the Canyon Mine site area. Results of laboratory chemical analyses for 13 wells completed in this system at large distances east from the mine site indicate calcium-magnesium-bicarbonate and sodium-chloride water types, with total dissolved solids content ranging from 447 to 4,110 mg/l (Table 3); average is about 1,360 mg/l. Results of analyses for three wells completed in the Toroweap-Coconino aquifer system several miles north and west from the mine site indicate a calcium-sulfate water type, with total dissolved solids content ranging from 594 to 1,120 mg/l (Table 3); average is about 790 mg/l.

Federal drinking water standards for parameters analyzed are given in Table 6. Results of analyses for eight of the 16 wells completed in the Toroweap-Coconino perched aquifer system indicate that concentrations of one or more of the following chemical parameters exceeded Federal standards for drinking water: sulfate, chloride, and total dissolved solids (Table 3). Water from seven of the 16 wells would be classified as slightly or moderately saline according to the criteria developed by Winslow and Kister (1956) for total dissolved solids content.

Discharge from Perched Aquifer Springs

Springs and seeps which occur above the Redwall-Muav aquifer along the south wall of the Grand Canyon and its southern tributary canyons discharge from perched aquifers. Discharge from these springs and seeps is generally less than one gpm (Loughlin and Huntoon, 1983; and National Park Service, 1984), and commonly occurs only during periods of rainfall and snowmelt (Johnson and Sanderson, 1968). Water quality data for routine constituents have been reported for Dripping Springs, which discharge from the Coconino Sandstone, and for Santa Maria Spring, which discharges from a sandstone unit in the Supai Group. These data indicate a magnesium-bicarbonate water type, with total dissolved solids content ranging from 179 to 276 mg/l (Metzger, 1961).

REDWALL-MUAV AQUIFER

Existing water quality data reported for springs which discharge from the Redwall-Muav aquifer comprise one or more of the following types of analyses: routine constituents, trace elements, bacteriological parameters, and radiological parameters. These data are voluminous and have been reported by many scientists. The types of analyses most useful for providing baseline data to monitor effects of mining operations are the routine constituents, trace elements, and radiological parameters.

Foust and Hoppe (1985) evaluated available data and reported average concentrations of routine constituents and concentrations of trace elements in water from the following springs and creeks which are fed by the Redwall-Muav aquifer **(Figure 3)**: Boucher Creek, Cottonwood Creek, Garden Creek, Hance Creek, Hermit Creek, Horn Creek, and Pipe Creek. Results reported by Foust and Hoppe (1985) and results summarized in **Table 4** for Havasu Spring and Indian Gardens Spring indicate that discharge from springs along the south wall of the Grand Canyon west of the Little Colorado River is predominantly a calcium-magnesium-bicarbonate water type. A few of these springs discharge a magnesium-calcium-sulfate water type. Results for Blue Spring, and other springs which issue from the walls of the Little Colorado River Gorge, indicate a sodium-chloride water type (Loughlin and Huntoon, 1983).

Results of analyses for trace elements reported by Foust and Hoppe (1985) for several springs and creeks, and results summarized in **Table 5** for Havasu Spring and Indian Gardens Spring, indicate that concentrations of the trace elements analyzed did not exceed Federal drinking water standards near the headwater areas **(Table 6)**. However, analyses of water samples collected near the mouths of creeks along the south wall of the Grand Canyon commonly indicated concentrations of arsenic, chromium, selenium, and silver which exceed Federal drinking water standards.

Reports of radiological analyses for water samples collected from springs and creeks along the south wall of the Grand Canyon are sparce. Results of analyses for dissolved uranium indicate the following: a concentration of 0.001 mg/l in a water sample collected from Garden Creek below the pumphouse; a concentration of 0.0026 mg/l in a water sample collected from Garden Creek near the mouth; and an activity of 3.5 picocuries per liter in a water sample collected from Havasu Creek near the confluence with the Colorado River (National Park Service, 1983).

Results of analyses reported by Peterson et al. (1977) for samples from five springs on the north wall of the Grand Canyon and Warm Spring, on the south wall about 60 miles northwest of the Canyon Mine site, which discharge from the Redwall-Muav aquifer indicate radium concentrations ranged from 0.10 to 0.66 picograms per liter, and uranium concentrations ranged from 0.0005 to 0.0085 mg/l.

GROUNDWATER MONITORING PROGRAM

A program for monitoring chemical quality of groundwater has been implemented for the Canyon Mine site area and comprises three program elements: an inventory of existing data for chemical quality of groundwater in the Canyon Mine site area, periodic collection and chemical analysis of water samples from Havasu, Indian Gardens, and Blue Springs, and construction of a groundwater supply and monitoring well at the Canyon Mine site.

EXISTING HYDROCHEMICAL DATA

Existing data for chemical quality of groundwater from wells which penetrate perched aquifers are summarized in Table 3. Existing data for chemical quality of groundwater which discharges from the Redwall-Muav aquifer at Havasu, Indian Gardens, and Blue Springs have been compiled and are summarized in Tables 4 and 5.

PERIODIC ANALYSIS OF SAMPLES FROM SPRINGS

In cooperation with the National Park Service, and with the Havasupai, Hopi, and Navajo Indian Tribes, a water quality monitoring program has been established by Energy Fuels and comprises periodic collection and laboratory chemical analyses of groundwater samples from Havasu, Indian Gardens, and Blue Springs, which are the largest springs along the south wall of the Grand Canyon. Water samples for laboratory chemical analyses will be obtained at six-month intervals during the first year of the sampling program. After results for the first year are analyzed, the frequency of sample collection may be modified.

Results of laboratory chemical analyses for the initial samples from the monitoring program have been obtained and are summarized in **Tables 7, 8, and 9.** The parameters analyzed include routine constituents, trace elements, gross alpha/beta radiation, uranium (isotopic and fluorometric), thorium, radium 226, and radium 228. These parameters were selected to provide comprehensive documentation of water quality at the springs prior to mining operations, and to provide a basis for monitoring water quality during mining operations. The initial samples were collected in duplicate on May 16-17, 1985 and were transmitted to qualified chemical laboratories in accordance with EPA (U. S. Environmental Protection Agency) protocol and in accordance with instructions from the laboratories. The samples were collected by personnel of Errol L. Montgomery & Associates, Inc. The water samples were analyzed using EPA recommended laboratory methods.

At the request of the Havasupai Indian Tribe, duplicate water samples were collected from Havasu Spring for submittal to an independent chemical laboratory selected by the Tribe. A representative of the Tribe observed the sample collection procedures and approved the sampling site. Sinyella Spring was suggested by the Tribe as an additional sampling site and the sampling party visited the spring on May 16, 1985. Sinyella Spring occurs approximately 22 miles southeast from Supai Village, in a small tributary canyon along the west wall of Havasu Canyon **(Figure 3)**, and discharges from a perched aquifer near the base of the Coconino Sandstone. Flow from Sinyella Spring did not reach the mouth of the tributary canyon. This spring is isolated from the Canyon Mine site by Havasu Canyon and lies above the water table in the regional aquifer. Therefore, the spring was not included in the sampling round.

Results for routine constituents indicate the following: a calcium-bicarbonate water type for Havasu Spring, with average total dissolved solids content of 610 mg/l; a magnesium-bicarbonate water type for Indian Gardens Spring, with total dissolved solids content of 330 mg/l; and a sodium-chloride water type for Blue Spring, with total dissolved solids content of 2,315 mg/l **(Table 7)**. These results corroborate historic water quality data reported for the three springs (Table 4). The concentrations of total dissolved solids and chloride, and the specific electrical conductance for the sample collected from Blue Spring exceed Federal drinking water standards (Table 7).

Results for trace elements indicate the following: low concentrations of arsenic, barium, and boron were detected in the sample from Havasu Spring; no trace elements were detected in the sample from Indian Gardens Spring; and a low concentration of boron was detected in the sample from Blue Spring (Table 8).

Results for radiological parameters indicate that isotopes of uranium and thorium occur naturally in the discharge from each of the three springs. In addition, radium 226 was detected at low levels in the samples from Indian Gardens Spring and Blue Spring (Table 9). The gross alpha particle activity reported by EAL (EAL Corporation, Richmond, California) for a sample collected from Havasu Spring exceeds the Federal standard for drinking water (Table 6). The concentration of total uranium reported by EAL for a sample from Havasu Spring was higher than the range of values reported by Peterson et al. (1977) for six springs which discharge from the Redwall-Muav aquifer. Duplicate water samples from the three springs are being analyzed for radiological parameters by Arizona State University, Tempe, Arizona; however, results were not available for inclusion in this report.

As part of the sampling procedure, field measurements of relative ambient radiation were made at each sampling site using a scintillometer. At each site, one measurement was made directly above the water surface where samples were collected. A second measurement was made over dry ground, approximately 50 feet from the sampling site. Results of the scintillometer measurements are as follows:

SPRING	SCINTILLOMETER READING (microrems per hour) AT WATER SAMPLING SITE	50 FEET FROM SAMPLING SITE
Havasu	5-7	5-7
Indian Gardens	4-6	4-6
Blue	2	5

Radon is a radioactive daughter-product of radium, and commonly occurs as a gaseous emission from springs fed by groundwater containing elevated levels of radionuclides. Radon emissions from springs commonly result in ambient radiation near the springs which is higher than background levels. Results of the scintillometer measurements indicate that radiation detected near the springs was not higher than background radiation detected 50 feet from the springs.

GROUNDWATER SUPPLY AND MONITORING WELL

A water well to the Redwall-Muav aquifer will be constructed and tested at the Canyon Mine site prior to the intersection of ore by mining operations. If fractures and solution openings in the Redwall-Muav aquifer are sufficiently abundant that groundwater is yielded, the well would be completed with blank and steel casing, and a standard five-day single bore-hole pumping test, followed by a five-day recovery period, would be conducted to determine aquifer permeability and to obtain groundwater samples for laboratory chemical analyses. After the pumping test program is complete, the well would be equipped as a water supply and groundwater monitoring well. Water samples for chemical analyses will be obtained at six-month intervals during the first year of the sampling program. After results for the first year are analyzed, the frequency of sample collection may be modified. The water samples will be analyzed for routine constituents, trace elements, gross alpha/beta radiation, uranium (isotopic and fluorometric), thorium, radium 226, and radium 228.

If fractures and solution openings are sufficiently sparse that groundwater is not yielded from the Redwall-Muav aquifer at the mine site, the test borehole will be plugged and abandoned in accordance with requirements of the Arizona Department of Water Resources.

CONCLUSIONS ON POTENTIAL IMPACT OF MINING OPERATIONS

Potential impacts on the groundwater systems due to proposed uranium mining operations at the Canyon Mine are: potential effects on groundwater circulation and storage in perched aquifers; potential effects on chemical quality of groundwater in the perched aquifers; potential effects on groundwater circulation and storage in the Redwall-Muav aquifer, and potential effects on chemical quality of groundwater in the Redwall-Muav aquifer. The following conclusions are based on analysis of hydrogeologic and hydrochemical data obtained during the Canyon Mine environmental impact investigation.

1. Potential effects on groundwater circulation and storage in perched aquifers. Perched aquifers do not occur at most locations in the Canyon Mine site area. If perched aquifers are not encountered by the mine openings, then the mining operations will have no effect on circulation and storage of perched groundwater.

   If perched groundwater is encountered by the mine openings, the perched water will drain to the mine openings and will be used for industrial purposes in the mine. Drainage of perched groundwater to the mine openings may remove groundwater from storage in the local perched system, but because the perched groundwater zones are commonly thin and discontinuous, the drainage would not be expected to influence other groundwater users.

   Application of the Theis (1935) non-equilibrium equation is the classical method for computing drawdown impact at various distances from the point of groundwater withdrawal and for various periods and rates of withdrawal. If very conservative and worst case conditions were assumed, where the perched groundwater zone would be 100 feet thick and areally extensive, the aquifer permeability and coefficient of storage would be about 50 gpd/ft^2 and 0.05, respectively, as at the municipal wells at Flagstaff, and groundwater discharge at the Canyon Mine site would be 20 gpm for a period of 50 years, then standard hydraulic calculations using the Theis (1935) method predicts that drawdown of water level at the nearest well, located about 2-1/2 miles from the mine site, would be about 0.6 feet. The drawdown at Tusayan, located six miles from the mine site, would be about 0.1 foot. The drawdown impact would be less at pumping wells and at springs located at greater distances.

Because the assumed conditions are very conservative, our conclusion is that the proposed mining operations at the Canyon Mine site would have little or no impact on groundwater circulation and storage in perched aquifers, and will have negligible or no impact on springs and wells which yield groundwater from perched aquifers.

2. <u>Potential effects on chemical quality of groundwater in the perched aquifers</u>. Perched aquifers do not occur at most locations in the Canyon Mine site area. If perched aquifers are not encountered by the mine openings, then mining operations will have no effect on chemical quality of groundwater in the perched aquifers.

If perched groundwater is encountered by the mine openings, small amounts of native minerals, including radioactive minerals, in the mineralized pipe and in the rocks excavated from the mine may enter the perched groundwater system. The entry may occur via contact of seepage water with aquifer strata in the mine openings or via recharge from the land surface of dissolved constituents or finely divided mineral fragments. Because the mine openings would function as a drain for local perched groundwater, small quantities of contaminants which might enter the perched groundwater would also tend to drain to the mine openings.

Because small quantities of potential contaminants in perched groundwater would tend to drain to the mine openings, our conclusion is that the proposed mining operations at the Canyon Mine site would have little or no impact on chemical quality of groundwater in perched aquifers.

3. Potential effects on groundwater circulation and storage in the Redwall-Muav aquifer. Energy Fuels plans to construct a test well at the Canyon Mine site. If sufficient permeability via fractures and solution openings occurs in the aquifer at the site, and if the potential for groundwater yield is sufficient, the well will be completed as a water supply and groundwater monitoring well. Total water requirements for domestic use at the mine are projected to be about five gpm.

Because discharge from the Redwall-Muav aquifer at springs is large, about 30,000 gpm at Havasu Spring, about 300 gpm at Indian Gardens Spring, and about 100,000 gpm (composite) at Blue Springs, and because groundwater storage in this aquifer is large, the extraction of five gpm at the mine will have negligible impact on yield from the springs. No water wells are presently constructed to yield from the Redwall-Muav aquifer within 20 miles of the Canyon Mine site. Therefore, extraction of five gpm from the Redwall-Muav aquifer at the mine site will have no impact on water withdrawn from existing wells completed in this aquifer.

We conclude that the proposed mining operations will have negligible impact on groundwater circulation and storage in the Redwall-Muav aquifer,and will have negligible impact on yield from springs which issue from the Redwall-Muav aquifer.

4. Potential effects on chemical quality of groundwater in the Redwall-Muav aquifer. Recharge to the Redwall-Muav aquifer in the Canyon Mine site area occurs via infiltration of rainfall and snowmelt through the rocks which underlie the plateau south of the Grand Canyon. Under natural conditions, a fraction of this recharge water passes through mineralized breccia pipes. Small quantities of native minerals, including radioactive minerals, are continuously leached from the breccia pipes and travel in solution in the water. During mining operations the mine workings will be ventilated and much of the water will evaporate; excess water which may drain to the mine will be collected and used for industrial purposes.

Therefore, it is believed that the quantity of recharge water passing through the breccia pipe during mining operations will be reduced and the potential for movement of dissolved minerals will be reduced. After mining operations are complete and the natural recharge system at the mine site is reestablished, native minerals, including radioactive minerals, will continue to be leached and to move to points of discharge with the groundwater.

Because the richest concentrations of minerals will be removed during mining operations, the quantity of minerals remaining to be leached will be reduced significantly.

Because the mine openings will penetrate the rocks from the land surface to the upper part of the Supai Group (Figure 2), the mine openings could function as a conduit and tend to concentrate movement of recharge water through the lower unmined parts of the breccia pipe after mining operations are complete. This potential concentration of flow will be mitigated by sealing the mine openings at the land surface to reduce the rate of inflow of recharge water in the immediate vicinity of the mine.

During mining operations, minerals in the walls of the mine openings in the breccia pipe are exposed to strongly oxidizing conditions. These conditions promote oxidation and tend to increase mobility of radioactive minerals. In the absence of mitigation, the rate of leaching of radioactive minerals by recharge water passing through the deposit could increase after mining operations are complete. This potential increase in rate of leaching will be mitigated by sealing the mine.

Although the possibility for deterioration in chemical quality of groundwater in the Redwall-Muav aquifer is believed to be small, a groundwater monitoring program to detect changes in water quality has been implemented by establishing a program of periodic collection of groundwater samples from Havasu, Indian Gardens, and Blue

Springs for laboratory chemical analyses. Prior to intersection of ore zones by the mine workings, the monitoring program will be augmented by periodic collection of groundwater samples from the Redwall-Muav aquifer at the mine site from the groundwater supply and monitoring well.

The groundwater monitoring program will be continued through the period of mining operations. In the unlikely event that a significant deterioration in chemical quality of groundwater in the Redwall-Muav aquifer occurs during mining operations, the groundwater supply and monitoring well could be used for access to the aquifer at the mine site for remedial actions.

We conclude that, with the implementation of planned mitigation actions, the possibility for deterioration of chemical quality of groundwater in the Redwall-Muav aquifer due to proposed mining operations at the Canyon Mine is small. Any deterioration of chemical quality of groundwater in the Redwall-Muav aquifer would be detected by the groundwater monitoring program.

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TABLE 1. RECORDS FOR WATER WELLS AND EXPLORATION BOREHOLES
CANYON MINE PROJECT AREA
COCONINO COUNTY, ARIZONA

STATE WELL LOCATION NUMBER	DATA[1/] SOURCE	DATE DRILLED OR COMPLETED	DEPTH DRILLED (Feet)	......CASING...... DIAMETER (inches)	DEPTH INTERVAL (Feet)	LAND SURFACE ALTITUDE (Feet msl)	......STATIC WATER LEVEL...... DEPTH (Feet)	DATE MEASURED	ALTITUDE (Feet msl)	USE[2/]	AQUIFER[3/]	LOG[4/] AVAIL-ABLE	REMARKS[5/]
(A-25-1)22bd	USGS	1946	109	--	---	5,775	86	01-05-67	5,689	---	A		
22bda	DWR	---	100	--	---	---	73	---	---	---	---		Arizona State Land Dept.
(A-25-2)27aba	OGC	01-10-70	3,685	7	0-3,324	6,165	2,839	01-07-70	3,326	I	R	YES	Black Mesa Pipeline Company #1, Station #3; perforated from 2,880 to 3,050 feet, open hole below 3,324 feet; "gas noted in water"; reported yield 28 gpm.
(A-25-5)21c	ASLD	---	300	--	---	7,000	DRY-R	---	---	U	V	---	Red Mountain well
27ccb	ASLD	01- -61	320	--	---	6,895	DRY-R	01- -61	---	U	V,K	YES	Upper Slate Mountain well
(A-25-6)17bcd	DWR	1961	300	6	---	---	295	---	---	S	---	---	C O Bar Livestock Co.
17ccc	DWR	1960	350	6	---	---	248	---	---	S	---	---	C O Bar Livestock Co.
20acc	ASLD	---	139	--	---	6,968	86	10-03-66	6,882	---	V,A	---	C O Bar Livestock Co.
20baa	ASLD	03- -61	60	--	---	6,815	30	10-03-66	6,785	---	A	---	C O Bar Livestock Co.
20bbb	ASLD	02- -61	437	5	---	6,580	407R	02- -61	6,173	D,S	M,Sh	YES	Reported yield 15 gpm with no drawdown; C
20bdd	ASLD	1953	142	--	---	6,965	83	10-03-66	6,882	---	V	---	Plugged back to 112 feet; C
20caa	USGS	---	---	--	---	6,965	84	08-24-78	6,881	---	---	---	John Babbitt
29	ASLD	---	730	8	---	7,100	---	---	---	U	A,Ch,K	YES	Reported yield 4 gpm
32cd	DWR	---	---	--	---	---	---	---	---	S	---	---	Coconino National Forest
33bcb	ASLD	---	450	--	---	7,195	374	10-03-66	6,821	U	V	---	Reported yield 10 gpm
(A-25-7)27bdb	DWR	---	468	--	---	6,530	DRY	10-03-66	---	U	K	---	Hole may have been drilled deeper and caved
(A-25-9) 6ccd	USGS	12- -66	1,800	8	0-1,788	5,381	1,583	01-23-67	3,798	U	Co	D,L	Citadel well, National Park Service; reported yield 17.5 gpm; C
(A-25-10)30bca	ASLD	10- -58	904	10	---	4,855	781	10-27-58	4,074	PS	Co	YES	Wupatki National Monument Headquarters well; reported yield 50 gpm; C
(A-26-2) 8aca	USGS	11- -64?	375	--	---	5,870	DRY-R	06-28-65	---	U	K	D	Dave Blair
11aad	ASLD	1937?	1,800	8	---	5,990	1,600R	---	4,390	U	Su	---	Airport Well, J. T. Rubideau; bailed at 1 gpm
(A-26-5)19ddd	DWR	1940	1,500	8	---	---	---	---	---	S	---	---	C O Bar Livestock Co.
(A-26-8) 1bcd	ASLD	02- -57	1,550	8	---	5,200	1,475R	02-23-57	3,725	D,S	Co	YES	Spider Web headquarters well, C O Bar Livestock Co.; reportedly bailed at 15 gpm; C
35cbc	USGS	1925?	1,662	8	---	5,450	1,500R	1954	3,950	U	Su	D,L	C O Bar Livestock Co.
(A-26-9)15dad	USGS	02-14-67?	1,250	6	0-1,250	5,075	1,152R	02-14-67	3,923	S	Co	D,L	Bar Doney well, C O Bar Livestock Co.; reportedly bailed at 15 gpm; C
33cad	USGS	1952	1,440	8	---	5,345	1,343	10-22-54	4,002	S	Co	D,L	Mesa Well; C O Bar Livestock Co.; reportedly bailed at 15 gpm; C
33dd	ASLD	---	1,410	8	---	5,392	1,343	10-22-54	4,049	S	Co	D	Reported yield 15 gpm
(A-26-10)31ca	ASLD	---	1,009	8	---	5,085	927	---	4,158	S	Co	---	Savage Well, John Babbitt; reported yield 12-15 gpm; C
(A-27-1)29c	USGS	11- -46	1,470	--	---	5,550	---	---	---	U	H	YES	Seep reported at 1,285 feet
(A-27-4)13bbb	ASLD	1942	1,600	12(8?)	---	6,450	DRY?	08-12-66	---	U	Co,Su?	---	C O Bar Livestock Co.
23dcc	ASLD	1948	2,250	8	---	6,415	DRY R	01- -66	---	U	Su	---	C O Bar Livestock Co.
(A-27-7)23bbc	ASLD	11- -51	300	--	---	5,390	DRY	11- -51	---	U	A, V	L	BIA well 3T-314
23cdb	ASLD	12- -51	133	--	---	5,395	DRY	12- -51	---	---	A, V	---	BIA well 3T-314A

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CANYON MINE PROJECT AREA
COCONINO COUNTY, ARIZONA

STATE WELL LOCATION NUMBER	DATA SOURCE[1]	DATE DRILLED OR COMPLETED	DEPTH DRILLED (feet)	CASING: DIAMETER (inches)	CASING: DEPTH INTERVAL (feet)	LAND SURFACE ALTITUDE (feet msl)	STATIC WATER LEVEL: DEPTH (feet)	STATIC WATER LEVEL: DATE MEASURED	STATIC WATER LEVEL: ALTITUDE (feet msl)	USE[2]	AQUIFER[3]	LOG[4] AVAIL-ABLE	REMARKS[5]
(A-27-9) 6ada	USGS	09-28-78	1,600	8	0-1,600	4,980	1,236	09-28-78	3,744	U	Su	D,L	Arizona Dept. of Transportation; reported pump capacity 36 gpm
6ad	----	1971	---	--	---	4,980	1,215R	01-06-72	3,765	D	Su	---	Flagstaff Mission to the Navajos
6dca1	ASLD	09- -55	1,408	8	---	5,030	1,250	09-30-55	3,780	D,PS	Co	---	BIA well Gray Mtn. T. P. No. 1; reportedly bailed at 6 and 10 gpm; C
6dca2	ASLD	1963?	1,500	8	---	5,030	1,308R	05-12-66	3,722	PS	Co	---	Gray Mtn. T. P. No. 2 well; reportedly bailed at 20 gpm; C
7abb1	ASLD	1958	1,613	--	---	5,040	---	---	---	PS	Co	---	Reportedly bailed at 25 gpm; C
7abb2	DWR	03-11-77	1,500	8	0-1,500	5,035	1,325R	03-11-77	3,710	I	Su	D,L	Whiting Bros. Oil Co.; reported yield 15 gpm
7abb3	DWR	1960	1,500	8	35	---	1,200	---	---	I	---	---	Whiting Bros. Oil Co.; reported yield 18 gpm
7abb4	DWR	06-30-76	1,600	8	40	---	1,200	---	---	I	---	---	Whiting Bros. Oil Co.; reported yield 18 gpm
7baa	USGS	02-26-67	1,450	8	0- 270	5,280?	1,150R	02- -67	3,890	D,PS	Su	D	Pickens-Myers well; reportedly bailed at 9 gpm; reported pump capacity 32 gpm
11ddd	ASLD	1966	750	6	---	4,590	706	11-10-66	3,884	S	Co	---	Maize Wash well, C O Bar Livestock Co.; bailed at 7 gpm; C
15ccc	ABM	04- -48	2,165	12	---	5,093	1,315	---	3,778	S	Su?	L	Barron-Steele #1 Babbitt-Bar; reported yield 8 gpm; oil test
21abd	ABM	02- -49	3,624	12-3/4 7	0- 150 3,464	5,096	309	10-05-66	3,787	U	Co ?	L	Lockhart Brothers - Babbitt #1; oil and gas test hole; reported yield 8 gpm
(A-28-2)19c	DWRO	6-14-84	405	3	---	---	---	---	---	T	---	---	Uranerz U. S. A., Inc.
(A-28-4)19dcb1	DWR	1925	40	--	---	---	39	---	---	---	---	---	C O Bar Livestock Co.
19dcb2	DWR	---	1,200	8	---	6,550	---	---	---	S	Co ?	NO	C O Bar Livestock Co.
(A-28-8) 1cbb	USGS	03-08-68	74	--	---	4,560	DRY	03-08-68	---	---	A,M	---	Navajo Nation
25bcd	DWR	05-12-69	1,292	8	0-1,093	4,830	1,062R	---	3,768	I	Co ?	NO	Black Mesa Pipeline Co.
36bac	ASLD	06- -58	1,320	8	0-1,320	4,915	1,146	03-24-64	3,769	D,S	Co	---	BIA well 3T-341; reported yield 15 gpm; C
(A-28-9)24cb	ASLD	---	5	--	---	4,370	DRY	07-14-54	---	---	A	---	BIA well 3A-60
28aa	ASLD	02- -42	9	--	---	4,440	3	07-14-54	4,437	---	A	---	BIA well 3A-61
35bac	ASLD	04- -55	828	6	0- 741	4,410	641	03-21-55	3,769	S	K	D	BIA well 3K-331; reported yield 14 gpm; C
(A-29-1)29bad1	USGS	1958	1,275	--	---	5,760	---	---	---	U	Co	YES	Anita No. 1 Well, Cataract Livestock Co.
29bad2	DWR	---	150	--	---	---	---	---	---	---	---	---	Arizona State Land Dept.
29dbd	DWR	10-15-62	1,130	8	---	5,780	1,020R	---	4,760	S?	Co ?	NO	Arizona State Land Department; reported yield 1 gpm
29dc	USGS	04- -58	1,130	8	---	5,775	1,020R	04- -58	4,755	U	H ?	YES	Anita No. 2 Well, Cataract Livestock Co.; reported yield .5 gpm
(A-29-2)16	USGS	1904	514	--	---	6,450	500R	1904	5,950	U	T ?	NO	Anita Copper Company shaft
34dbb	DWR	1968	---	--	---	---	---	---	---	D,S	---	---	Hatch
(A-29-3)20bdc	USFS	10- -80	1,580	7	0- 20	6,500	---	---	---	U	K ?	NO	Kaibab National Forest; reported yield 8 gpm; perched groundwater encountered at 140 feet during drilling; cement plugs at land surface and 200 feet
31cda	USFS	10- -80	1,560	7	0- 20	6,330	---	---	---	U	K ?	NO	Kaibab National Forest; reported yield 12 gpm; perched groundwater encountered at 160 feet during drilling; cement plugs at land surface and 200 feet

TABLE 1. RECORDS FOR WATER WELLS AND EXPLORATION BOREHOLES
CANYON MINE PROJECT AREA
COCONINO COUNTY, ARIZONA

STATE WELL LOCATION NUMBER	DATA[1] SOURCE	DATE DRILLED OR COMPLETED	DEPTH DRILLED (feet)	CASING: DIAMETER (inches)	CASING: DEPTH INTERVAL (feet)	LAND SURFACE ALTITUDE (feet msl)	STATIC WATER LEVEL: DEPTH (feet)	STATIC WATER LEVEL: DATE MEASURED	STATIC WATER LEVEL: ALTITUDE (feet msl)	USE[2]	AQUIFER[3]	LOG[4] AVAILABLE	REMARKS[5]
(A-29-6) 5dbc	ASLD	---	1,440	8	---	6,180	DRY	06-06-67	---	U	Co	NO	77-Bar Ranch well
29	---	---	1,200	--	---	6,600	DRY	---	---	---	---	---	
(A-29-9)22	DWR	---	---	--	---	---	--	---	---	D	---	---	Chevron U. S. A.
22dca1	ASLD	03- -51	1,012	10	0- 280	4,230	600	03- -51	3,630	U	T,Co	---	BIA well Cameron 2; reported yield 17 gpm; C
22dca2	ASLD	---	164	--	---	4,230E	120R	---	4,110	---	M	---	BIA well Cameron 3
22dca3	ASLD	---	170	--	---	4,230E	120R	---	4,110	---	M	---	BIA well Cameron 4
22dca4	ASLD	---	170	--	---	4,230E	120R	---	4,110	---	M	---	BIA well Cameron 5
22dca5	ASLD	1956	600	4	---	4,230	---	---	---	---	M, K	---	BIA well Cameron 6; injection well
22dca6	DWR	1966	45	--	---	---	5	---	---	---	---	---	Standard Oil of California
22dca7	DWR	1966	46	--	---	---	3	---	---	---	---	---	Standard Oil of California
22dca8	LOU	---	---	--	---	4,210	495	---	3,715	---	Co	---	BIA well 3P-352
22dd	ASLD	---	370	--	---	4,230	102	08-24-54	4,128	U	M	---	BIA well Cameron 1; reported yield 5 gpm; C
22ddd1	DWR	10-20-66	41	--	---	---	18	---	---	---	---	---	Cameron Trading Post
22ddd2	DWR	10-20-66	41	--	---	---	---	---	---	---	---	---	Cameron Trading, Inc.
25dd	ASLD	02- -55	40	--	---	4,160	14	02-17-55	4,146	---	Sh	---	BIA well "Rare Metals test"
32db	ASLD	08- -53	432	8	0- 7	4,470	DRY	---	---	U	M	---	BIA well 3K-319
33bb	ASLD	06- -58	92	--	---	4,410	67	07-01-58	4,343	---	V	---	BIA well 3T-501
33daa	DWR	1964	856	6	---	4,420	746	---	3,674	---	Co?	---	Buck Rodgers Trading Post; C
(A-30-1) 5dda	DWR	1968	---	--	---	---	---	---	---	D,S	---	---	Hatch
(A-30-2) 8aaa	DWR	1968	---	--	---	---	---	---	---	D,S	---	---	Hatch
8a1	USGS	10- -68	733	5	0- 2	6,500	430	10-04-68	6,070	U	---	YES	Gray Dick Drill Hole #2; plugged back to 600 feet "because water was lost into Coconino"; reported yield <0.1 gpm
8a2	USGS	12- -62	660	8	0- 3	6,500	512	01-25-72	5,988	U	---	YES	Gray Dick Drill hole #1; plugged back to 540 feet; reported yield <0.1 gpm
17	USGS	1930?	1,000	--	---	6,425	DRYR	---	---	U	Co	YES	Santa Fe-Anita Well
18cda	DWR	1968	---	--	---	---	---	---	---	D,S	---	---	Hatch
24a1	USGS	1966	735	--	---	6,600	550R	10-17-66	6,050	U	T	NO	Thurston #1 Well; plugged back to 628 feet; reported yield 1.5 gpm
24a2	USGS	1966	650	--	---	6,600	---	---	---	U	T	NO	Thurston #2 Well; reported yield 0.75 gpm
24bbb	USGS	09- -66	730	10	---	6,550	542	10-17-66	6,006	U	T	YES	Thurston #3 Well; reported yield 0.5 gpm
25b	USGS	1962	630	--	---	6,650	---	---	---	U	T	YES	McAfee-Meeks #2 Well; reported yield <0.1 gpm
25c	USGS	11- -61	1,400	8	0- 15	6,725	560R	09-01-64	6,165	PS	T,Co	YES	McAfee-Meeks #1 Well; plugged back to 623 feet; reported yield 4.5 gpm; C
25dd	DWR	1960	600	8	0- 43	6,700	574R	---	6,126	D	T	NO	Kaibab National Forest; reported yield 12 gpm
(A-30-6)32cc	USGS	1968	1,330	--	---	6,220	DRYR	04- -70	---	U	---	---	77-Bar Ranch
(A-31-2)33abb	USGS	---	---	18	---	6,675	14	12-09-64	6,661	U	K	NO	Rowes Well - dug well
(A-31-9)14aa	USGS	---	---	--	---	---	---	---	4,383	---	Sh	---	Reported yield 30 gpm; C
27dd	ASLD	---	---	--	---	4,440	DRY	06-25-54	---	---	A	---	BIA well 3A-47
28cb	ASLD	---	6	--	---	4,530	2	06-25-54	4,528	---	A	---	BIA well 3A-48
29ab	ASLD	11- -57	316	--	---	4,620	DRYR	11-30-57	---	U	Sh	D	BIA well 3K-339, seep of salt water
35ba	USGS	---	---	--	---	---	---	---	4,313	---	Ch	---	C
(A-32-7)32dba	DWR	08-10-75	137	--	---	---	80	---	---	---	---	---	Rhoton
(A-32-9)29ad	ASLD	07- -59	245	--	---	4,900	200	07-21-59	4,700	---	Sh	---	BIA well 3K-341

TABLE 1. RECORDS FOR WATER WELLS AND EXPLORATION BOREHOLES
CANYON MINE PROJECT AREA
COCONINO COUNTY, ARIZONA

STATE WELL LOCATION NUMBER	DATA[1/] SOURCE	DATE DRILLED OR COMPLETED	DEPTH DRILLED (feet)	......CASING...... DIAMETER (inches)	DEPTH INTERVAL (feet)	LAND SURFACE ALTITUDE (feet msl)	......STATIC WATER LEVEL...... DEPTH (feet)	DATE MEASURED	ALTITUDE (feet msl)	USE[2/]	AQUIFER[3/]	LOG[4/] AVAIL-ABLE	REMARKS[5/]
(A-33-7) 1a	ASLD	08- -60	1,292	8	0- 21	5,480	DRY	07-11-60	---	A	Co	L	BIA well 3K-340
(A-33-8)22cd	OGC	1947	3,440	6-5/8	0-3,184	5,830	2,200	---	3,630	---	---	L	Collins-Cobb #1-x Natoine-Navajo; oil test
(A-33-9)23c	ASLD	---	10	--	---	4,920	8	06-23-54	4,912	---	A	---	BIA well 3A-201
(A-34-3) 6cc	DWR	---	18	--	---	---	12	---	---	---	---	---	Kaibab National Forest
6c	USGS	1801	10	--	---	8,750	2	08-07-76	8,748	---	A	---	Mason Well
9ba	DWR	1893	16	--	---	---	12	---	---	---	---	---	Kaibab National Forest
9b	USGS	1963	10	--	---	8,810	7	08-07-76	8,803	---	A	---	U. S. Forest Service
(A-34-5) 4bdd	DWR	1965	45	--	---	---	15	---	---	---	---	---	Evans
(A-34-8) 2d	ASLD	02- -32	10	--	---	5,640	10	06-23-54	5,630	---	A	---	BIA well 3A-183
(A-34-9)19d1	ASLD	11- -31	23	--	---	5,260	10	06-23-54	5,250	---	A	---	BIA well 3A-184
19d2	ASLD	11- -31	20	--	---	5,260	10	06-23-54	5,250	---	A	---	BIA well 3A-184A
22b	ASLD	10- -52	467	10	0- 4	5,440	79	10-01-52	5,361	D,S	N	L	BIA well 3K-317; reported yield 3-4 gpm; tested at 35 gpm; C
30a	ASLD	02- -55	100	--	---	5,280	15	02-10-55	5,265	---	Sh	---	BIA well Gap T. P. 1; C
32a	ASLD	02- -37	11	--	---	5,170	9	05-02-52	5,161	---	A	---	BIA well 3A-209
(B-25-3) 3cc1	USGS	06- -62	140	--	---	5,950	80R	01-05-67	5,870	---	V	---	Espee No. 3 Well
3cc2	USGS	06-01-67	130	--	---	5,950	80R	10-12-67	5,870	---	V	---	Espee No. 4 Well
3baa	USGS	1967	250	--	---	6,183	DRY	08-21-67	---	---	V	---	
10ccd	DWR	1962	140	--	---	---	80	---	---	---	---	---	C O Bar Livestock Co.
(B-25-4) 3cdd	USGS	1967	330	--	---	6,090	DRY	08-19-67	---	---	V	---	
(B-26-3)10baa	DWR	1962	130	--	---	---	65	---	---	---	---	---	C O Bar Livestock Co.
19b	USGS	1962	354	--	---	6,015	DRYR	01- -62	---	---	V	YES	Espee No. 1 Well; seeps reported at 122 feet and 186 feet
20acc1	DWR	1962	98	--	---	---	5	---	---	---	---	---	C O Bar Livestock Co.
20acc2	DWR	1962	102	--	---	---	50	---	---	---	---	---	C O Bar Livestock Co.
20bd	USGS	1962	98	--	---	6,025	52	01-05-67	5,973	---	V	---	Espee No. 2 Well
(B-26-4)27bda	USGS	1967	207	--	---	6,140	DRY	---	---	---	V	---	
27ccc	USGS	1967	340	--	---	6,145	DRY	---	---	--	V	---	
(B-27-1) 3	USGS	---	---	8	---	5,675	1,400	05-04-58	4,275	U	Co?	NO	Babbitt Bros. Ranch
28aaa	DWR	1974	300	3	0- 300	---	100	---	---	D,S	---	---	Cataract Livestock Co.; reported yield 18 gpm
32bdb1	DWR	1974	482	--	---	---	434	---	---	D,S	---	---	Cataract Livestock Co.
32bdb2	DWR	01-01-74	---	--	---	---	---	---	---	---	---	---	Arizona State Land Dept.
(B-27-2)34	----	---	1,300A	--	---	5,575	---	---	---	---	Co ?	---	Rogers Tank Well #3
(B-27-5) 5bdd	DWR	---	200	--	---	---	100	---	---	---	---	---	Boquillas Cattle Co.
(B-27-6) 1adc	ASLD	---	128	--	---	5,925	72	05-03-66	5,853	---	A	---	Rose well; reported yield 73 gpm; C
12bdb1	DWR	---	28	--	---	---	26	---	---	---	---	---	Boquillas Cattle Co.
12bdb2	DWR	---	128	--	---	---	65	---	---	---	---	---	Boquillas Cattle Co.
12bdb3	DWR	---	128	--	---	---	65	---	---	---	---	---	Boquillas Cattle Co.
12bdb4	DWR	---	128	--	---	---	63	---	---	---	---	---	Boquillas Cattle Co.
12bdd1	DWR	---	20	--	---	---	19	---	---	---	---	---	Boquillas Cattle Co.
12bdd2	DWR	---	20	--	---	---	19	---	---	---	---	---	Boquillas Cattle Co.
(B-28-1)18c	USGS	05- -73	485	--	---	5,375	435	06-01-73	4,940	S	T	YES	C. O. Bar Ranch - Redlands; John Babbitt; reported yield 20 gpm

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA

TABLE 1. RECORDS FOR WATER WELLS AND EXPLORATION BOREHOLES
CANYON MINE PROJECT AREA
COCONINO COUNTY, ARIZONA

STATE WELL LOCATION NUMBER	DATA[1/] SOURCE	DATE DRILLED OR COMPLETED	DEPTH DRILLED (feet)	CASING: DIAMETER (inches)	CASING: DEPTH INTERVAL (feet)	LAND SURFACE ALTITUDE (feet msl)	STATIC WATER LEVEL: DEPTH (feet)	STATIC WATER LEVEL: DATE MEASURED	STATIC WATER LEVEL: ALTITUDE (feet msl)	USE[2/]	AQUIFER[3/]	LOG[4/] AVAIL-ABLE	REMARKS[5/]
18caa	USGS	06-02-73	1,210	6	0-1,210	5,440	434	06- -73	5,006	D,S	T,Co	D,L	Babbitt Redlands Well, Cataract Livestock Co.; deepened from 482' on 04-15-74; reported yield 4 gpm
35cab	ABM	05- -52	3,544	13-3/8 9-5/8	0- 316 2,205	6,005	---	---	---	U	---	YES	Sinclair-Santa Fe-Pacific No. 1 oil test
(B-28-3)12	USGS	08- -62	1,400	--	---	5,525	DRY	08- -62	---	U	Co	YES	Seep reported at about 1,140 feet
(B-29-1) 2cad	USGS	07-12-66	1,059	8	0- 52	5,650	988R	07-12-66	4,662	S	Co?	D	Cataract Livestock Co.; reported yield 2 gpm
2dab	DWR	1962	1,059	8	0-1,059	5,700	988R	---	4,712	S	Co	NO	Arizona State Land Dept.; reported yield 2 gpm
12dbd1	USGS	04-10-58	1,080	8	0- 12	5,675	959	10-17-66	4,716	S	Co	D	Anita No. 3 Well, Cataract Livestock Co.; reported yield 2 gpm; C
12dbd2	DWR	1958	1,080	8	---	---	---	---	---	S	---	---	Arizona State Land Dept.; reported yield 2 gpm
(B-30-1)28aaa1	USGS	09- -42	990	8	---	5,715	900R	1942	4,815	U	Co	YES	John Babbitt; tools reportedly lost in hole
28aaa2	USGS	1943	1,020	8	---	5,725	939	10-14-66	4,786	D,S	Co	NO	John Babbitt; C
28baa	USGS	09- -60	1,051	8	---	5,680	905R	09- -60	4,775	U	Co	YES	John Babbitt - Cataract #2 well; reported yield 5 gpm
(B-30-5)14	DWR	---	---	--	---	---	---	---	---	T	---	---	Rocky Mountain Energy
(B-33-4)23bbb	DWR	---	20	--	---	---	---	---	---	---	---	---	
23bcc1	USGS	11-10-75	90	--	---	---	---	---	---	---	---	---	
23bcc2	USGS	11-19-75	90	--	---	---	---	---	---	---	---	---	

1/ USGS - U. S. Geological Survey
DWR - Arizona Department of Water Resources
OGC - Arizona Oil and Gas Conservation Commission
ASLD - Arizona State Land Department
LOU - Loughlin (1983)
USFS - U. S. Forest Service

2/ I - Industrial
S - Stock
D - Domestic
PS - Public Supply
T - Testhole
U - Unused

3/ A - Alluvium
Ch - Chinle Formation
Co - Coconino Sandstone
H - Hermit Shale
K - Kaibab Limestone
M - Moenkopi Formation
R - Redwall Limestone
Sh - Shinarump Member of Chinle Formation
Su - Supai Group
T - Toroweap Formation
V - Volcanic Rocks

4/ D - Drillers' Log
L - Lithologic Log

5/ C - Chemical Water Quality Data Reported to be Available

TABLE 2. SUMMARY OF REPORTED DISCHARGE FROM SPRINGS ALONG SOUTH WALL OF GRAND CANYON, FROM LITTLE COLORADO RIVER GORGE TO HAVASU CANYON

SPRING IDENTIFIER	SOURCE[1/] ROCK	DISCHARGE (gpm)
BLUE SPRING	R-M	44,000
BLUE SPRINGS (AGGREGATE)	R-M,Ta	100,000
COTTONWOOD SPRING	R-M	5
GRAPEVINE SPRING	R-M	10
BOULDER SPRING	BA	1
LONETREE SPRING	BA	1
PIPE SPRING	R-M	1
BURRO SPRING	R-M	1
UNNAMED	pC	1
UNNAMED	BA	1
UNNAMED	BA	1
INDIAN GARDENS SPRING	R-M	300
SALT CREEK SPRING	Ta	1
CEDAR SPRING	Ta	1
MONUMENT SPRING	Ta	5
DRIPPING SPRING NO. 1	Co	1
DRIPPING SPRING NO. 2	Co	1
SANTA MARIA SPRING	Su	1
HERMIT SPRING (UPPERMOST)	R-M	5
HERMIT SPRINGS (COMPOSITE)	R-M	210
ELVES MAIN SPRING	R-M	25
ELVES JOINT SPRING	R-M	15
BOUCHER SPRING	---	20
MATKATAMIBA SPRING	R-M	30
HAVASU SPRING	R-M	30,000

1/ Co - Coconino Sandstone
Su - Supai Group
R-M - Redwall-Muav aquifer
Ba - Bright Angel Shale
Ta - Tapeats Sandstone
pC = Precambrian rocks

TABLE 3. SUMMARY OF RESULTS FOR CHEMICAL ANALYSES FOR GROUNDWATER SAMPLES FROM WELLS CANYON MINE PROJECT AREA

WELL IDENTIFIER:	(A-25-6) 20bdd	(A-25-9) 6ccd	(A-25-10) 30bca		(A-26-8) 1bcd	(A-26-9) 15dad	(A-26-9) 33cad	(A-26-10) 31ca	(A-27-9) 6dca1	
WATER-BEARING UNIT[1/]:	V	Co	Co		Co,Su	Co	Co	Co	Co	
DATE SAMPLED:	06-25-65	01-25-67	10-27-58	02-01-61	10-05-66	11-27-68	11-27-67	10-26-54	05-15-56	05-12-66
CONSTITUENTS (mg/l)										
Calcium	42	102	69	76	212	70	34	67	101	95
Magnesium	16	48	62	68	68	96	53	62	58	62
Sodium	---	---	---	---	---	---	---	---	---	---
Potassium	---	---	---	---	---	---	---	---	---	---
Sodium + Potassium	14	60	218	244	71	235	79	257	27	39
Carbonate	0	0	0	0	0	---	---	---	0	0
Bicarbonate	174	452	224	243	890	296	362	240	536	527
Sulfate	18	83	200	219	92	202	51	198	32	43
Chloride	28	90	360	405	98	442	88	408	53	70
Fluoride	0.1	0.5	0.8	0.2	0.8	1.0	0.7	0.8	0.4	0.4
Nitrate	---	---	1.3	1.1	---	---	---	1.7	0.6	---
Silica	---	16	10	10	18	11	11	9.4	11	---
Iron	---	0.02	---	---	0.01	---	---	---	---	0
Total Dissolved Solids	---	622	1,030	1,140	998	1,203	495	1,120	547	---
PARAMETERS										
Specific Electrical Conductance (umho/cm)	407	1,050	1,850	1,990	1,630	---	---	2,010	980	1,000
pH	8.1	7.4	7.7	7.8	6.8	---	---	---	7.5	7.6
Temperature (°C)	---	20	19	19	---	---	---	---	17	---

[1/] A-Alluvium, V-Volcanics, N-Navajo Sandstone, Sh-Shinarump Member, M-Moenkopi Formation, K-Kaibab Limestone, T-Toroweap Formation, Co-Coconino Sandstone

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TUCSON, ARIZONA

TABLE 3. SUMMARY OF RESULTS FOR CHEMICAL ANALYSES
FOR GROUNDWATER SAMPLES FROM WELLS
CANYON MINE PROJECT AREA

WELL IDENTIFIER:	(A-27-9)			(A-28-8)	(A-28-9)	(A-29-9)			(A-30-2)	(A-34-9)
	6dca2	7abb1	11ddd	36bac	35bac	22dca1	22dd	33daa	25c	22b
WATER-BEARING UNIT[1/]:	Co	Co	Co	Co	K	T,Co	M	Co?	T	N
DATE SAMPLED:	05-12-66	05-12-66	11-12-66	06-20-58	04-05-55	04-20-51	08-19-49	08-30-70	12- -63	01-14-54
CONSTITUENTS (mg/l)										
Calcium	102	85	66	77	95	118	37	110	124	26
Magnesium	57	71	91	39	63	61	51	57	41	7.9
Sodium	---	---	---	---	---	---	---	870	---	---
Potassium	---	---	---	---	---	---	---	5	---	---
Sodium + Potassium	41	36	1,380	38	927	973	98	---	10	15
Carbonate	0	0	0	0	0	0	0	---	---	0
Bicarbonate	532	564	276	441	265	300	358	300	---	124
Sulfate	43	39	280	36	250	258	151	240	255	12
Chloride	68	58	2,150	24	1,440	1,520	43	1,400	21	9
Fluoride	0.5	0.2	0.5	0.7	0.5	0.3	1.7	0.4	0.3	0.3
Nitrate	---	---	---	0.1	3.8	1.9	0.2	---	---	3.0
Silica	14	15	10	15	9.1	13	9.0	17	---	17
Iron	0	0	0.02	---	---	---	---	---	<0.5	---
Total Dissolved Solids	588	582	4,110	447	2,920	3,090	567	2,847	658	145
PARAMETERS										
Specific Electrical Conductance (umho/cm)	1,000	1,010	7,220	776	5,180	5,480	936	---	---	250
pH	7.2	7.5	7.8	7.7	7.3	---	---	---	---	---
Temperature (°C)	---	---	---	18	17	---	19	---	---	---

1/ A-Alluvium, V-Volcanics, N-Navajo Sandstone, Sh-Shinarump Member, M-Moenkopi Formation, K-Kaibab Limestone, T-Toroweap Formation, Co-Coconino Sandstone

TABLE 3. SUMMARY OF RESULTS FOR CHEMICAL ANALYSES
FOR GROUNDWATER SAMPLES FROM WELLS
CANYON MINE PROJECT AREA

WELL IDENTIFIER:	(A-34-9) 30a	(B-27-6) 1adc	(B-29-1) 12dbd1	(B-30-1) 28aaa2
WATER-BEARING UNIT[1/]:	Sh	A	Co	Co
DATE SAMPLED:	02-10-55	05-02-66	10-14-66	06-03-58
CONSTITUENTS (mg/l)				
Calcium	40	486	134	229
Magnesium	25	106	33	64
Sodium	---	---	---	---
Potassium	---	---	---	---
Sodium + Potassium	300	30	14	27
Carbonate	---	0	0	0
Bicarbonate	650	93	264	225
Sulfate	260	1,480	262	667
Chloride	38	70	8.0	8.5
Fluoride	1.6	0.6	0.6	0.3
Nitrate	4.5	---	---	2.4
Silica	11	---	12	10
Iron	---	---	0.02	---
Total Dissolved Solids	1,000	2,220	594	1,120
PARAMETERS				
Specific Electrical Conductance (umho/cm)	1,530	2,580	848	1,390
pH	---	7.8	7.3	8.2
Temperature (°C)	---	---	---	19

[1/] A-Alluvium, V-Volcanics, N-Navajo Sandstone, Sh-Shinarump Member, M-Moenkopi Formation, K-Kaibab Limestone, T-Toroweap Formation, Co-Coconino Sandstone

TABLE 4. SUMMARY OF EXISTING DATA FOR ROUTINE CONSTITUENTS FOR HAVASU SPRING, INDIAN GARDENS SPRING, AND BLUE SPRING

SOURCE:	INDIAN GARDENS SPRING		BLUE SPRING				
REPORTED LOCATION:	CREEK ON TONTO PLATFORM	CREEK BELOW PUMP HOUSE	BLUE SPRING	BLUE SPRING	BLUE SPRING	BLUE SPRING	BLUE SPRING
DATE SAMPLED:	MAR-JUN[1/]	12-19-81	06-14-50	06-21-51	06-21-51	05-17-66	03-81
DISCHARGE (gpm):	---	310	41,900	---	---	44,600	43,500
CONSTITUENTS (mg/l)							
CALCIUM	53	38	264	167	---	252	251
MAGNESIUM	23	20	79	75	---	76	64
SODIUM	7.9	2.8	513	---	---	---	510
POTASSIUM	2.5	0.9	23	---	---	---	5.7
SODIUM + POTASSIUM	---	---	534	707	---	535	---
CARBONATE	---	---	0	0	0	0	---
BICARBONATE	181	---	964	622	914	951	933
SULFATE	20	< 1.0	147	165	---	140	142
CHLORIDE	12	3.8	815	1,120	825	835	821
FLUORIDE	0.10	0.10	0.2	0.2	---	0.3	0.4
NITRATE	---	0.29	3.2	1.1	---	---	---
PHOSPHATE	---	0.02	---	---	---	---	---
SILICA	---	7.4	19	15	---	17	17.5
TOTAL DISSOLVED SOLIDS	---	187	2,340	2,560	---	2,320	2,270
HARDNESS (as $CaCO_3$)	---	180	984	725	---	940	---
NONCARBONATE HARDNESS	---	---	194	216	---	161	---
ALKALINITY (as $CaCO_3$)	---	---	---	---	---	---	---
PARAMETERS							
SPECIFIC ELECTRICAL CONDUCTANCE (umho/cm):	---	345	3,940	4,500	3,910	3,960	---
pH	8.26	8.1	6.5	---	---	6.8	---
TEMPERATURE (°C)	---	17	21	---	20	21	21
REFERENCE[2/]:	F&H	NPS	J&S	K&H	J&S	Mc	L

[1/] Average Values

[2/] Reference:
- M: Metzger (1961)
- J&S: Johnson and Sanderson (1968)
- NPS: National Park Service (1983)
- C&P: Corothers and Phillips (1983)
- F&H: Foust and Hoppe (1985)
- Mc: McGavock (1968)
- L: Loughlin (1983)

TABLE 4. SUMMARY OF EXISTING DATA FOR ROUTINE CONSTITUENTS FOR HAVASU SPRING, INDIAN GARDENS SPRING, AND BLUE SPRING

SOURCE:	HAVASU SPRING					INDIAN GARDENS SPRING								
REPORTED LOCATION:	CREEK AT HEADWATERS	SPRING BELOW MOONEY FALLS	CREEK AT HEADWATERS	HAVASU SPRING	CREEK NEAR SUPAI, AZ	INDIAN GARDENS SPRINGS	INDIAN GARDENS SPRING #1	INDIAN GARDENS SPRING #2	INDIAN GARDENS SPRING	INDIAN GARDENS SPRING	INDIAN GARDENS SPRING	INDIAN GARDENS SPRING	INDIAN GARDENS SPRING	CREEK ON TONTO PLATFORM
DATE SAMPLED:	10-20-50	06-16-51	06-17-51	08-07-65	09-25-82	04-09-58	04-09-58	04-09-58	6/80-02/81[1]	03-20-77	06-06-79	06-09-80	10-12-80	JUN-MAR[1]
DISCHARGE (gpm):	29,600	---	26,600	26,700	27,400	300	---	---	---	---	---	---	---	---
CONSTITUENTS (mg/l)														
CALCIUM	133	109	---	74	130	54	42	54	38.63	46.4	73.0	32.6	41.5	42
MAGNESIUM	48	47	---	45	43	35	29	32	24.39	24.2	26.3	20.4	24.8	26
SODIUM	---	---	---	---	34	---	---	---	7.52	5.8	5.4	10.4	8.91	5.7
POTASSIUM	---	---	---	---	4.6	---	---	---	1.76	4.2	3.1	1.92	0.92	2.51
SODIUM + POTASSIUM	27	36	---	36	---	11	9.0	11	---	---	---	---	---	---
CARBONATE	0	0	0	0	---	0	0	0	---	---	---	---	---	---
BICARBONATE	588	526	574	416	---	308	254	308	---	---	---	---	---	221
SULFATE	36	44	---	36	38	28	16	17	---	14.0	26.3	13.2	10.6	15
CHLORIDE	48	48	46	48	48	14	12	13	---	---	11.9	---	3.5	21
FLUORIDE	0.2	0	---	0.2	0.3	0.2	0.2	0.2	0.08	---	0.11	0.10	0.08	0.10
NITRATE	1.4	0	---	---	---	0.2	1.8	1.0	0.74	---	---	---	0.93	---
PHOSPHATE	---	---	---	---	---	---	---	---	0.31	---	---	---	0.43	---
SILICA	18	---	---	---	18	12	13	14	---	---	---	---	---	---
TOTAL DISSOLVED SOLIDS	602	543	---	444	584	305	248	293	---	---	---	---	---	---
HARDNESS (as $CaCO_3$)	530	466	---	368	500	278	224	266	199.70	215.5	290.5	165.4	205.7	---
NONCARBONATE HARDNESS	48	34	---	27	---	26	16	14	---	---	---	---	---	---
ALKALINITY (as $CaCO_3$)	---	---	---	---	---	---	---	---	---	232.0	185.4	177.5	200.0	---
PARAMETERS														
SPECIFIC ELECTRICAL CONDUCTANCE (umho/cm):	1,030	959	1,000	820	1,000	543	454	523	---	---	390	390	380	---
pH	---	---	---	7.7	6.9	---	---	---	---	8.2	8.32	8.49	8.56	8.26
TEMPERATURE (°C)	21	22	22	---	21	12	17	15	---	---	17.4	17.0	18.0	---
REFERENCE[2]:	M	J&S	J&S	J&S	NPS	M	M	M	C&P	F&H	F&H	F&H	F&H	F&H

1/ Average Values

2/ Reference:
- M: Metzger (1961)
- J&S: Johnson and Sanderson (1968)
- NPS: National Park Service (1983)
- C&P: Corothers and Phillips (1983)
- F&H: Foust and Hoppe (1985)
- Mc: McGavock (1968)
- L: Loughlin (1983)

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TABLE 5. SUMMARY OF EXISTING DATA FOR TRACE ELEMENTS FOR HAVASU SPRING AND INDIAN GARDENS SPRING

SOURCE:	HAVASU SPRING	INDIAN GARDENS SPRING	
REPORTED LOCATION:	CREEK NEAR SUPAI, AZ	CREEK BELOW PUMP HOUSE	CREEK ON TONTO PLATFORM
DATE SAMPLED:	09-25-82	12-19-81	03-77
CONSTITUENTS (mg/l)			
ALUMINUM	---	0.0300	---
ARSENIC	0.0190	0.0020	---
BARIUM	0.170	---	---
BORON	---	0.0100	---
CADMIUM	< 0.0010	< 0.0010	0.00023
CHROMIUM	< 0.010	---	0.0070
COBALT	< 0.0010	---	---
COPPER	0.0030	0.0030	0.0189
IRON	0.010	< 0.0100	0.0807
LEAD	0.004	0	0.0041
MANGANESE	0.002	0.0020	0.0089
MERCURY	< 0.0001	0	---
MOLYBDENUM	---	< 0.0100	---
NICKEL	0.006	0.0010	0.0094
SELENIUM	0.002	0.0010	---
SILVER	< 0.001	---	---
URANIUM	---	0.0010	---
VANADIUM	---	0.0030	0.0208
ZINC	0.021	0.0050	0.075
REFERENCE:	NATIONAL PARK SERVICE 1983	NATIONAL PARK SERVICE 1983	FOUST and HOPPE 1985

TABLE 6. FEDERAL DRINKING WATER STANDARDS FOR PARAMETERS ANALYZED

PARAMETERS	MAXIMUM LIMIT [2]
PRIMARY:	
ARSENIC	0.05 mg/l
BARIUM	1.0 mg/l
CADMIUM	0.01 mg/l
CHROMIUM (TOTAL)	0.05 mg/l
LEAD	0.05 mg/l
MERCURY	0.002 mg/l
NITRATE (AS NO_3)	45 mg/l
SELENIUM	0.01 mg/l
SILVER	0.05 mg/l
FLUORIDE [1]	1.4 - 2.4 mg/l
RADIUM 226	3 pCi/l
COMBINED RADIUM 226 AND RADIUM 228	5 pCi/l
GROSS ALPHA PARTICLE ACTIVITY	15 pCi/l
GROSS BETA PARTICLE ACTIVITY	50 pCi/l
SECONDARY:	
CHLORIDE	500 mg/l
COPPER	1.0 mg/l
IRON	0.3 mg/l
MANGANESE	0.05 mg/l
SULFATE	500 mg/l
ZINC	5.0 mg/l
TOTAL DISSOLVED SOLIDS	1,000 mg/l
SPECIFIC ELECTRICAL CONDUCTANCE	1,600 umho/cm

[1] Temperature dependent

[2] mg/l - milligrams per liter
pCi/l - picocuries per liter
umho/cm - micromhos per centimeter

TABLE 7. SUMMARY OF RESULTS FOR ROUTINE CONSTITUENTS IN WATER SAMPLES COLLECTED FROM SPRINGS GROUNDWATER MONITORING PROGRAM

SOURCE:	HAVASU SPRING		INDIAN GARDENS SPRING	BLUE SPRING
DATE SAMPLED:	05-16-85	05-16-85	05-17-85	05-16-85
LABORATORY[1/]:	BC	CFEP	BC	BC
CONSTITUENTS (mg/l)				
CALCIUM	130	127	45	243
MAGNESIUM	44	51	32	74
SODIUM	32	30	7	540
POTASSIUM	4.9	5.2	2	6.4
CARBONATE	0	0	0	0
BICARBONATE	580	438	275	889
SULFATE	37	35	17	156
CHLORIDE	44.6	44	9.9	846
FLUORIDE	0.25	0.25	0.16	0.36
NITRATE	1.8	1.3	2.2	1.8
PHOSPHATE	<0.1	<0.1	<0.1	<0.1
SILICA	16	16.2	10	16
ALKALINITY (as CaCO)	476	438	225	728
HARDNESS (as CaCO)	506	505	244	912
TOTAL DISSOLVED SOLIDS (residue @ 180 F)	605	614	330	2,315
PARAMETERS				
SPECIFIC ELECTRICAL CONDUCTANCE (umho/cm):				
field	1,200	1,200	520	5,500
laboratory	1,040	1,060	470	4,100
pH: field	6.7	6.7	6-7	6.3
laboratory	7.5	7.27	8.1	7.3
FIELD TEMPERATURE(^{o}C)	21.5	21.5	18	20.5

[1/] BC - BC Laboratories, Inc., Bakersfield, California
CFEP - Controls for Environmental Pollution, Inc., Santa Fe, New Mexico

TABLE 8. SUMMARY OF RESULTS FOR TRACE ELEMENTS IN WATER SAMPLES COLLECTED FROM SPRINGS GROUNDWATER MONITORING PROGRAM

SOURCE:	HAVASU SPRING		INDIAN GARDENS SPRING	BLUE SPRING
DATE SAMPLED:	05-16-85	05-16-85	05-17-85	05-16-85
LABORATORY[1/]:	BC	CFEP	BC	BC
CONSTITUENTS (mg/l)				
ALUMINUM	< 0.1	< 0.1	< 0.1	< 0.1
ANTIMONY	< 1.0	< 0.003	< 1.0	< 1.0
ARSENIC	0.01	0.01	< 0.01	< 0.01
BARIUM	< 0.5	0.2	< 0.5	< 0.5
BERYLLIUM	< 0.05	< 0.0001	< 0.05	< 0.05
BORON	0.27	0.3	< 0.1	0.39
CADMIUM	< 0.005	< 0.001	< 0.005	< 0.005
CHROMIUM (total)	< 0.01	< 0.01	< 0.01	< 0.01
COPPER	< 0.01	< 0.01	< 0.01	< 0.01
IRON	< 0.05	< 0.01	< 0.05	< 0.05
LEAD	< 0.01	< 0.01	< 0.01	< 0.01
MANGANESE	< 0.01	< 0.01	< 0.01	< 0.01
MERCURY	< 0.0002	< 0.0004	< 0.0002	< 0.0002
MOLYBDENUM	< 0.1	< 0.01	< 0.1	< 0.1
NICKEL	< 0.05	< 0.01	< 0.05	< 0.05
SELENIUM	< 0.005	< 0.01	< 0.005	< 0.005
SILVER	< 0.01	< 0.01	< 0.01	< 0.01
THALLIUM	< 0.5	< 0.01	< 0.5	< 0.5
VANADIUM	< 0.5	< 0.01	< 0.5	< 0.5
ZINC	< 0.01	< 0.005	< 0.01	< 0.01

[1/] BC - BC Laboratories, Inc., Bakersfield, California
CFEP - Controls for Environmental Pollution, Inc., Santa Fe, New Mexico

TABLE 9. SUMMARY OF RESULTS FOR RADIOLOGICAL PARAMETERS IN WATER SAMPLES COLLECTED FROM SPRINGS GROUNDWATER MONITORING PROGRAM

SOURCE:	HAVASU SPRING		INDIAN GARDENS SPRING	BLUE SPRING	BLANK SAMPLE[2/]
DATE SAMPLED:	05-16-85	05-16-85	05-17-85	05-16-85	05-17-85
LABORATORY[1/]:	EAL	CFEP	EAL	EAL	EAL
PARAMETER (in picocuries per liter ± two standard deviations)					
GROSS ALPHA	41.6 ± 34.7	<2	1.5 ± 2.5	1.5 ± 17.9	0.2 ± 0.6
GROSS BETA	44.8 ± 40.4	<3	2.2 ± 2.0	8.4 ± 8.1	<0.2 ± 1.7
TOTAL URANIUM	7 ± 2	3 ± 1	3 ± 2	5 ± 2	0 ± 2
URANIUM 234	3.6 ± 0.2	<0.6	2.5 ± 0.1	4.4 ± 0.2	0 ± 0.1
URANIUM 235	0 ± 0.2	<0.6	0 ± 0.1	0 ± 0.2	0 ± 0.1
URANIUM 238	1.3 ± 0.1	<0.6	0.6 ± 0.1	1.8 ± 0.1	0 ± 0.1
THORIUM 228	2.1 ± 0.5	<0.6	1.4 ± 0.4	1.7 ± 0.3	0 ± 0.5
THORIUM 230	0 ± 0.2	<0.6	0 ± 0.2	0 ± 0.2	0 ± 0.2
THORIUM 232	0 ± 0.2	<0.6	0 ± 0.2	0 ± 0.2	0 ± 0.2
RADIUM 226	0 ± 0.05	<0.6	0.14 ± 0.05	0.12 ± 0.05	0 ± 0.05
RADIUM 228	0 ± 0.5	<1	0 ± 0.5	0 ± 0.5	0 ± 0.5

1/ EAL - EAL Corporation, Richmond, California
CFEP - Controls for Environmental Pollution, Inc., Santa Fe, New Mexico

2/ Taken from bottled deionized drinking water.

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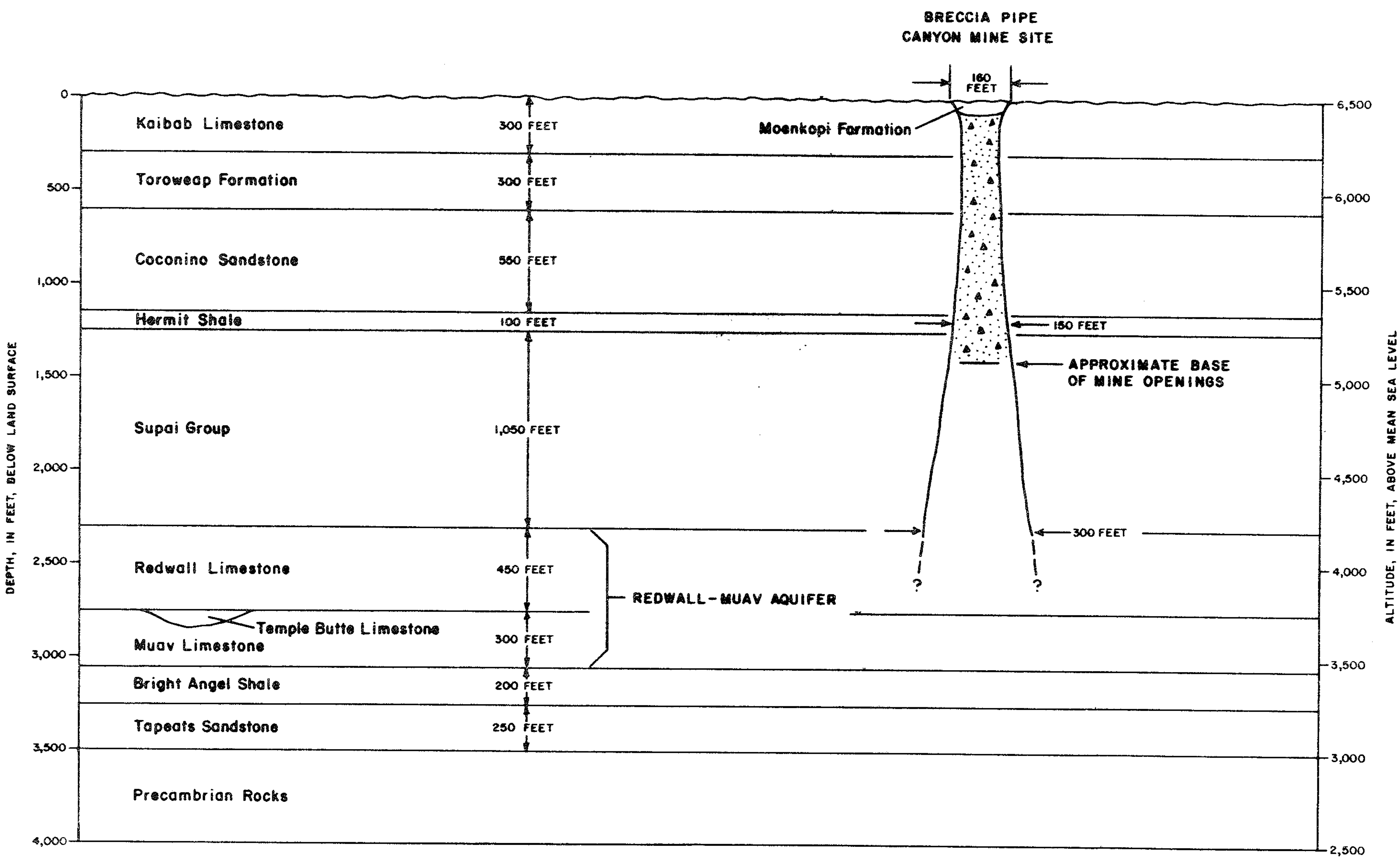

FIGURE 2. SCHEMATIC SECTION FOR CANYON MINE SITE

APPENDIX A

WELL NUMBERING SYSTEM

APPENDIX A

WELL NUMBERING SYSTEM

The well numbers used in this report are in accordance with the Bureau of Land Management's system of land subdivision. The land survey in Arizona is based on the Gila and Salt River meridian and base line, which divide the state into four quadrants. These quadrants are designated, counter-clockwise, by the capital letters A, B, C, and D. All land north and east of the point of origin is in quadrant A; all land north and west of the origin is in quadrant B; all land south and west is in quadrant C; and all land south and east is in quadrant D. The first digit of a well number indicates the township, the second digit the range, and the third digit the section in which the well is located. The lowercase letters a, b, c, and d after the section number indicate the well location within the section. The first letter denotes a particular 160-acre tract or quarter section; the second letter denotes the 40-acre tract or quarter-quarter section; and the third letter denotes the 10-acre tract or quarter-quarter-quarter section. These letters are also assigned in a counter-clockwise direction, beginning in the northeast quarter. As **Figure A-1** shows, well number (A-26-5)19ddd designates the well as being located in the southeast quarter of the southeast quarter of the southeast quarter of Section 19, Township 26 North, Range 5 East. Where more than one well is within a 10-acre tract, consecutive numbers beginning with "1" are added as suffixes.

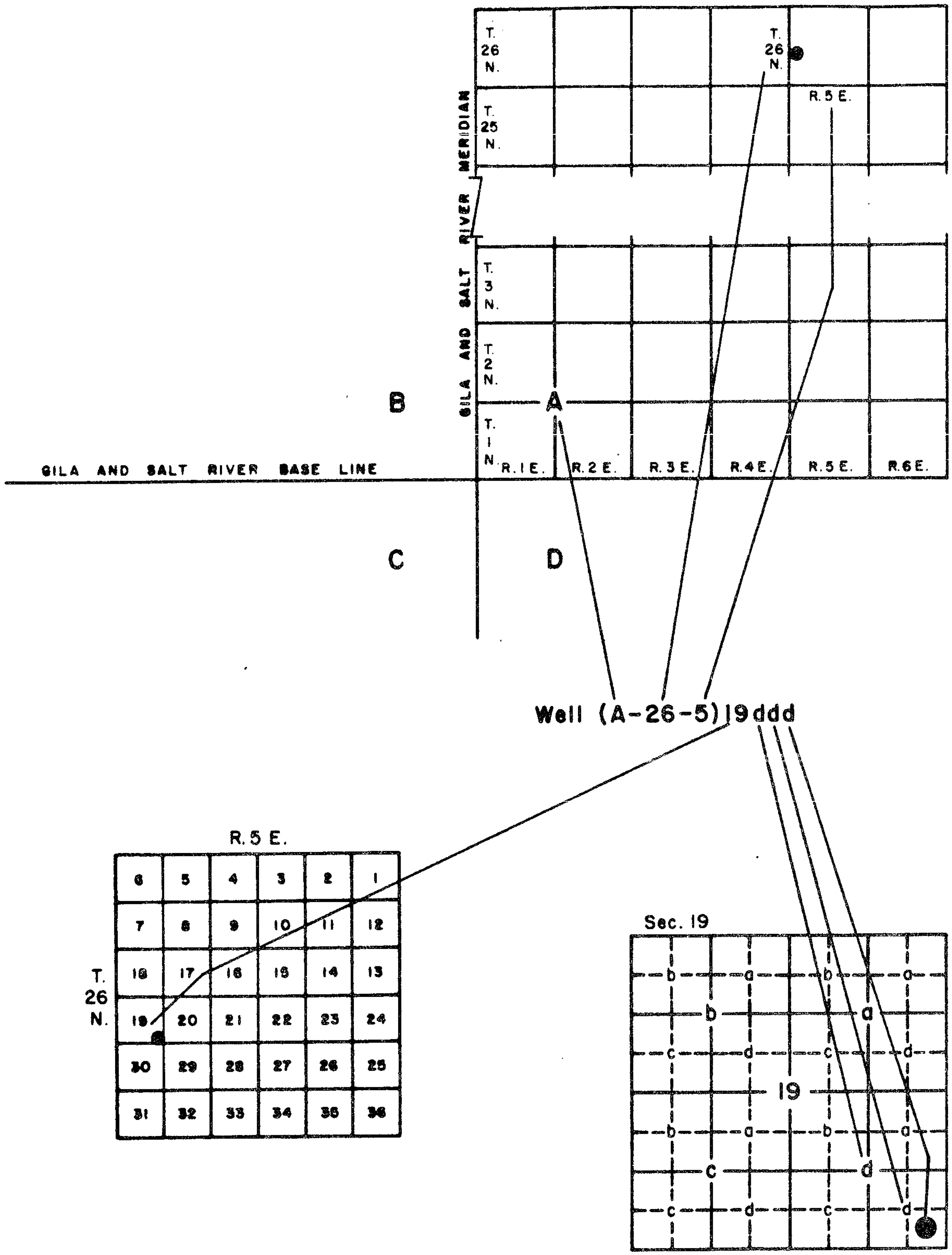

FIGURE A-1. WELL NUMBERING DIAGRAM

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September 10, 1985

Mr. Ed McElwain
Tribal Planner
HAVASUPAI TRIBE
P. O. Box 10
Supai, Arizona 86435

Dear Mr. McElwain:

In response to your request via telephone on August 1, 1985, this letter has been prepared to further explain results of laboratory chemical analyses given in our Report dated July 17, 1985 and entitled, GROUNDWATER CONDITIONS, CANYON MINE REGION, COCONINO COUNTY, ARIZONA. The Report was prepared for the U. S. Forest Service, Kaibab National Forest, Williams, Arizona, for inclusion in the environmental impact statement for the Canyon Mine site. Copies of the following tables from the Report are enclosed with this letter:

TABLE NO.	TITLE
6	FEDERAL DRINKING WATER STANDARDS FOR PARAMETERS ANALYZED
7	SUMMARY OF RESULTS FOR ROUTINE CONSTITUENTS IN WATER SAMPLES COLLECTED FROM SPRINGS, GROUNDWATER MONITORING PROGRAM
8	SUMMARY OF RESULTS FOR TRACE ELEMENTS IN WATER SAMPLES COLLECTED FROM SPRINGS, GROUNDWATER MONITORING PROGRAM

Table 9 from the Report, entitled SUMMARY OF RESULTS FOR RADIOLOGICAL PARAMETERS IN WATER SAMPLES COLLECTED FROM SPRINGS, GROUNDWATER MONITORING PROGRAM, has been modified to include results of analyses conducted by ASU (Arizona State University). The modified table is designated Table 9a and is enclosed with this letter.

In cooperation with the National Park Service, and with the Havasupai, Hopi, and Navajo Indian Tribes, a water quality monitoring program has been established by Energy Fuels Nuclear, Inc., Denver, Colorado. The monitoring program comprises periodic collection and laboratory chemical analyses of groundwater samples from Havasu, Indian Gardens, and Blue Springs. Water samples for laboratory chemical analyses will be collected at six-month intervals during the first year of the sampling program. After results for the first year are analyzed, the frequency of sample collection may be modified.

During the initial sampling round on May 16, 1985, water samples were collected from Havasu Spring and other springs for laboratory chemical analyses. The samples were collected and transmitted to four qualified independent laboratories in accordance with EPA (U. S. Environmental Protection Agency) protocol and in accordance with instructions from the laboratories. The samples were collected by Errol L. Montgomery & Associates, Inc. personnel. The samples were analyzed using EPA recommended laboratory methods.

Three of the laboratories were selected by Errol L. Montgomery & Associates, Inc. and one laboratory was selected by the Havasupai Tribe. Analyses requested for each laboratory are as follows:

LABORATORY	ANALYSES REQUESTED
BC Laboratories, Inc., Bakersfield, California	Routine constituents and trace elements
EAL Corporation, Richmond, California	Radiological parameters
Arizona State University, Tempe, Arizona	Radiological parameters
Controls for Environmental Pollution, Inc., Santa Fe, New Mexico	Routine constituents, trace elements, and radiological parameters

CFEP (Controls for Environmental Pollution, Inc.) was the laboratory selected by the Havasupai Tribe.

ROUTINE CONSTITUENTS

Results for routine constituents in the water samples from Havasu Spring indicate a calcium-bicarbonate water type, with average total dissolved solids content of about 610 mg/l (milligrams per liter). Drinking water standards recommended by the U. S. Public Health Service (Public Health Service Drinking Water Standards, Public Health Service Publication 956, 1962) indicate that water with total dissolved solids content exceeding 500 mg/l should not be used if other less mineralized water is available. However, the total dissolved solids content of the water samples from Havasu Spring does not exceed the Federal drinking water standard of 1,000 mg/l (Table 6), and water with total dissolved solids content ranging from 500 to 1,000 mg/l is used by many municipalities with no adverse health effects. Based on the results for routine constituents, the water samples are considered to be of good quality.

Average hardness, as calcium-carbonate, for the water samples from Havasu Spring is about 506 mg/l (Table 7). Hardness of water is due chiefly to calcium and magnesium content. Water with hardness of more than 180 mg/l is classified as very hard (U. S. Geological Survey Water-Supply Paper 2220, 1984).

Results reported by BC Laboratories, Inc. and CFEP are in agreement. However, the percent error for the ion balance for the CFEP results exceeds the allowable percent error. The CFEP results indicate a total dissolved solids content of 614 mg/l (Table 7). The allowable error for the ion balance for water with this total dissolved solids content is from three to four percent (K. E. Anderson, Water Well Handbook, 1979). Error calculated for the ion balance for the CFEP results is about 13 percent.

TRACE ELEMENTS

Trace elements analyzed include EPA priority pollutant trace elements, and other trace elements selected based on concentrations reported for other water sources in the Grand Canyon. Limits of detection were more stringent than Federal standards for drinking water. Results for water samples from Havasu Spring indicate that reported concentrations of trace elements do not exceed Federal standards for drinking water.

Results reported by BC Laboratories, Inc. and CFEP are in agreement. Low concentrations of arsenic and boron were detected by both laboratories (Table 8), and a low concentration of barium was detected by CFEP. All other trace elements analyzed were not detected. Based on the laboratory results for concentrations of trace elements, the water samples from Havasu Spring are considered to be of good quality.

RADIOLOGICAL PARAMETERS

Water samples collected from Havasu Spring were analyzed for the following radiological parameters: gross alpha activity; gross beta activity; total uranium; uranium 234; uranium 235; uranium 238; thorium 228; thorium 230; thorium 232; radium 226; radium 228; and potassium 40 (Table 9a). The EPA has established drinking water standards for gross alpha activity, gross beta activity, radium 226, and combined radium 226 and radium 228 (Table 6). These standards are intended to limit the annual radiation dose to four millirems per year for a person drinking two liters of water per day (Standard Methods for the Examination of Water and Wastewater, 15th Edition, 1980).

For monitoring purposes, gross alpha activity may be used in place of radium analyses if the gross alpha activity is less than five pCi/l (picocuries per liter). Gross alpha activity may be used in place of uranium analyses if the gross alpha activity, excluding radon and uranium, is less than 15 pCi/l (Supplement to the Fifteenth Edition of Standard Methods for the Examination of Water and Wastewater, 1981). If the gross beta activity exceeds 50 pCi/l, the major radiological parameters must be identified (Standard Methods for the Examination of Water and Wastewater, 15th Edition, 1980).

Radiological results reported by EAL Corporation, CFEP, and ASU are in poor agreement for several of the parameters analyzed in the water samples from Havasu Spring; however, this relation is not unusual because assay of such small amounts of radioactivity approaches the minimum detection limits of the laboratories (J. W. McKlveen, Radiological Assessment of the Canyon Mine Project, Kaibab National Forest, Coconino County, Arizona, 1985). Analyses for gross alpha activity may be affected by impurities in water, such as calcium, which increase the detection thresholds and self-absorption corrections and reduce detection efficiencies. Gross beta analyses may also be affected by impurities, but to a lesser extent (J. W. McKlveen, Radiological Assessment of the Canyon Mine Project, Kaibab National Forest, Coconino County, Arizona, 1985).

Results are commonly reported as a concentration plus/minus the measurement error, which indicates that there is a 95 percent confidence that the true concentration is within the range from the reported concentration minus the measurement error to the reported concentration plus the measurement error. For example, the total uranium concentration reported by EAL Corporation for the water samples from Havasu Spring is seven plus/minus two pCi/l (Table 9a). This result indicates that there is a 95 percent confidence that the true concentration is within the range from five to nine pCi/l. For problematic analyses, the measurement error may be large.

Federal drinking water standards were exceeded only by the gross alpha activity reported by EAL Corporation. Measurement error for this analysis was large and the result was not corroborated by results reported by CFEP and ASU (Table 9a). In addition, isotopic and fluorometric analyses do not indicate elevated levels of uranium and radium in the water samples. Total uranium occurs in surface water and groundwater at concentrations generally less than 14 pCi/l (Supplement to the Fifteenth Edition of Standard Methods for the Examination of Water and Wastewater, 1981). The highest concentration of total uranium reported for the water samples from Havasu Spring was 7 +/- 2 pCi/l by EAL Corporation (Table 9a). The highest concentration of radium 226 reported for the water samples from Havasu Spring is 0.45 +/- 0.34 pCi/l by ASU, which is slightly higher than the average concentration of 0.2 pCi/l for Arizona groundwater (J. W. McKlveen and P. J. Thompson, Baseline Radioactivity in Arizona's Water in: Health Physics, Vol. 34, pp. 697-700, 1978).

Because radiological parameters are analyzed on a statistical basis, results of analyses for several samples from a water source must be obtained to evaluate the radiological content of the source. Conclusions based on results from one sampling round must be regarded as preliminary and tentative. However, results for the initial round of water samples collected from Havasu Spring do not indicate that the water is unsafe to drink due to content of radiological parameters.

MONITORING PROGRAM

The next round of water sample collection from Havasu Spring is scheduled for December 1985. We plan to collect water samples from Havasu Spring at the same site at which the initial samples were collected on May 16, 1985. The laboratories and the parameters analyzed will be the same for the second round of samples as for the initial round. Analyses of the second round of samples will yield additional data for evaluation and documentation of water quality prior to mining operations at Canyon Mine.

If you have questions or require further discussion, please contact us.

Very truly yours,

ERROL L. MONTGOMERY & ASSOCIATES, INC.

William R. Victor

William R. Victor

cc: Dr. J. W. McKlveen
Mr. J. R. Thompson
Mr. B. L. Doores

TABLE 6. FEDERAL DRINKING WATER STANDARDS FOR PARAMETERS ANALYZED

PARAMETERS	MAXIMUM[2] LIMIT
PRIMARY:	
ARSENIC	0.05 mg/l
BARIUM	1.0 mg/l
CADMIUM	0.01 mg/l
CHROMIUM (TOTAL)	0.05 mg/l
LEAD	0.05 mg/l
MERCURY	0.002 mg/l
NITRATE (AS NO)	45 mg/l
SELENIUM	0.01 mg/l
SILVER	0.05 mg/l
FLUORIDE[1]	1.4 - 2.4 mg/l
RADIUM 226	3 pCi/l
COMBINED RADIUM 226 AND RADIUM 228	5 pCi/l
GROSS ALPHA PARTICLE ACTIVITY (EXCLUDING RADON AND URANIUM)	15 pCi/l
GROSS BETA PARTICLE ACTIVITY	50 pCi/l
SECONDARY:	
CHLORIDE	500 mg/l
COPPER	1.0 mg/l
IRON	0.3 mg/l
MANGANESE	0.05 mg/l
SULFATE	500 mg/l
ZINC	5.0 mg/l
TOTAL DISSOLVED SOLIDS	1,000 mg/l
SPECIFIC ELECTRICAL CONDUCTANCE	1,600 umho/cm

[1] Temperature dependent

[2] mg/l - milligrams per liter
pCi/l - picocuries per liter
umho/cm - micromhos per centimeter

TABLE 7. SUMMARY OF RESULTS FOR ROUTINE CONSTITUENTS IN WATER SAMPLES COLLECTED FROM SPRINGS GROUNDWATER MONITORING PROGRAM

SOURCE:	HAVASU SPRING		INDIAN GARDENS SPRING	BLUE SPRING
DATE SAMPLED:	05-16-85	05-16-85	05-17-85	05-16-85
LABORATORY[1]:	BC	CFEP	BC	BC
CONSTITUENTS (mg/l)				
CALCIUM	130	127	45	243
MAGNESIUM	44	51	32	74
SODIUM	32	30	7	540
POTASSIUM	4.9	---	2	6.4
CARBONATE	0	0	0	0
BICARBONATE	580		275	889
SULFATE	37	35	17	156
CHLORIDE	44.6	44	9.9	846
FLUORIDE	0.25	0.25	0.16	0.36
NITRATE	1.8	1.3	2.2	1.8
PHOSPHATE	< 0.1	< 0.1	< 0.1	< 0.1
SILICA	16	16.2	10	16
ALKALINITY (as $CaCO_3$)	476	438	225	728
HARDNESS (as $CaCO_3$)	506	505	244	912
TOTAL DISSOLVED SOLIDS (residue @ 180°F)	605	614	330	2,315
PARAMETERS				
SPECIFIC ELECTRICAL CONDUCTANCE (umho/cm):				
field	1,200	1,200	520	5,500
laboratory	1,040	1,060	470	4,100
pH: field	6.7	6.7	6-7	6.3
laboratory	7.5	7.27	8.1	7.3
FIELD TEMPERATURE (°C)	21.5	21.5	18	20.5

[1] BC - BC Laboratories, Inc., Bakersfield, California
CFEP - Controls for Environmental Pollution, Inc., Santa Fe, New Mexico

TABLE 8. SUMMARY OF RESULTS FOR TRACE ELEMENTS
IN WATER SAMPLES COLLECTED FROM SPRINGS
GROUNDWATER MONITORING PROGRAM

SOURCE:	HAVASU SPRING		INDIAN GARDENS SPRING	BLUE SPRING
DATE SAMPLED:	05-16-85	05-16-85	05-17-85	05-16-85
LABORATORY[1]:	BC	CFEP	BC	BC
CONSTITUENTS (mg/l)				
ALUMINUM	< 0.1	< 0.1	< 0.1	< 0.1
ANTIMONY	< 1.0	< 0.003	< 1.0	< 1.0
ARSENIC	0.01	0.01	< 0.01	< 0.01
BARIUM	< 0.5	0.2	< 0.5	< 0.5
BERYLLIUM	< 0.05	< 0.0001	< 0.05	< 0.05
BORON	0.27	0.3	< 0.1	0.39
CADMIUM	< 0.005	< 0.001	< 0.005	< 0.005
CHROMIUM (total)	< 0.01	< 0.01	< 0.01	< 0.01
COPPER	< 0.01	< 0.01	< 0.01	< 0.01
IRON	< 0.05	< 0.01	< 0.05	< 0.05
LEAD	< 0.01	< 0.01	< 0.01	< 0.01
MANGANESE	< 0.01	< 0.01	< 0.01	< 0.01
MERCURY	< 0.0002	< 0.0004	< 0.0002	< 0.0002
MOLYBDENUM	< 0.1	< 0.01	< 0.1	< 0.1
NICKEL	< 0.05	< 0.01	< 0.05	< 0.05
SELENIUM	< 0.005	< 0.01	< 0.005	< 0.005
SILVER	< 0.01	< 0.01	< 0.01	< 0.01
THALLIUM	< 0.5	< 0.01	< 0.5	< 0.5
VANADIUM	< 0.5	< 0.01	< 0.5	< 0.5
ZINC	< 0.01	< 0.005	< 0.01	< 0.01

[1] BC - BC Laboratories, Inc., Bakersfield, California
CFEP - Controls for Environmental Pollution, Inc., Santa Fe, New Mexico

TABLE 9a. SUMMARY OF RESULTS FOR RADIOLOGICAL PARAMETERS IN WATER SAMPLES COLLECTED FROM SPRINGS GROUNDWATER MONITORING PROGRAM

SOURCE:	HAVASU SPRING			INDIAN GARDENS SPRING		BLUE SPRING		BLANK SAMPLE[2/]
DATE SAMPLED:	05-16-85	05-16-85	05-16-85	05-17-85	05-16-85	05-16-85	05-16-85	05-17-85
LABORATORY[1/]:	EAL	CFEP	ASU	EAL	ASU	EAL	ASU	EAL
PARAMETER (in picocuries per liter ± two standard deviations)								
GROSS ALPHA	41.6 ± 34.7	< 2	<8	1.5 ± 2.5	< 4	1.5 ± 17.9	<21	0.2 ± 0.6
GROSS BETA	44.8 ± 40.4	< 3	6.4 ± 3.8	2.2 ± 2.0	3.2 ± 3.6	8.4 ± 8.1	9.4 ± 4.9	< 0.2 ± 1.7
TOTAL URANIUM	7 ± 2	3 ± 1	---	3 ± 2	---	5 ± 2	---	0 ± 2
URANIUM 234	3.6 ± 0.2	<0.6	3.1 ± 1.2	2.5 ± 0.1	3.1 ± 0.8	4.4 ± 0.2	4.4 ± 0.9	0 ± 0.1
URANIUM 235	0 ± 0.2	<0.6	0.3 ± 0.4	0 ± 0.1	0.1 ± 0.1	0 ± 0.2	0.4 ± 0.2	0 ± 0.1
URANIUM 238	1.3 ± 0.1	<0.6	1.6 ± 0.8	0.6 ± 0.1	0.8 ± 0.4	1.8 ± 0.1	1.4 ± 0.4	0 ± 0.1
THORIUM 228	2.1 ± 0.5	<0.6	---	1.4 ± 0.4	---	1.7 ± 0.3	---	0 ± 0.5
THORIUM 230	0 ± 0.2	<0.6	---	0 ± 0.2	---	0 ± 0.2	---	0 ± 0.2
THORIUM 232	0 ± 0.2	<0.6	---	0 ± 0.2	---	0 ± 0.2	---	0 ± 0.2
RADIUM 226	0 ± 0.05	<0.6	0.45 ± 0.34	0.14 ± 0.05	0.25 ± 0.20	0.12 ± 0.05	0.31 ± 0.24	0 ± 0.05
RADIUM 228	0 ± 0.5	< 1	---	0 ± 0.5	---	0 ± 0.5	---	0 ± 0.5
POTASSIUM 40	---	---	4.1	---	1.4	---	6.6	---

1/ EAL - EAL Corporation, Richmond, California
CFEP - Controls for Environmental Pollution, Inc., Santa Fe, New Mexico
ASU - Arizona State University, Tempe, Arizona

2/ Taken from bottled deionized drinking water.

ERROL L. MONTGOMERY & ASSOCIATES, INC.
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