NUREG-0925

Final Environmental Statement
related to the operation of the Teton Uranium ISL Project

Docket No. 40-8781

Teton Exploration Drilling, Inc.

U.S. Nuclear Regulatory Commission

Uranium Recovery Field Office
Region IV

August 1983

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SUMMARY AND CONCLUSIONS

This Final Environmental Statement (FES) was prepared under the direction of the staff of the U.S. Nuclear Regulatory Commission (NRC) and issued by the Uranium Recovery Field Office, Region IV.

1. This action is administrative.

2. After an evaluation of the applicant's R&D solution mining operation at the same site, which demonstrated successful mining and restoration, and assessment of concerns and alternatives specifically related to the proposed commercial-scale mining, the proposed action is the issuance of a combined Source and Byproduct Material License subject to license conditions discussed below to Teton Exploration Drilling, Inc. On October 10, 1980, Teton applied to the NRC for an NRC Source Material License to construct and operate, in Converse County, Wyoming, an in situ solution uranium mine and recovery plant designated to produce 1.04 x 10^6 kg (2.3 x 10^6 lb) of U_3O_8 at a rate of about 1.3 x 10^5 kg/year (2.9 x 10^5 lb/year).

   The total project site area under lease by the applicant consists of about 308 ha (760 acres) located approximately 12 km (7.5 miles) northeast of Glenrock, Wyoming, and about 40 km (25 miles) by air east of Casper.

   The applicant proposes to mine, in situ, uranium ore contained in two geologic intervals in the upper portion of the Fort Union Formation, using sodium carbonate/bicarbonate solution and an oxidizing agent injected and recovered through a complex of well patterns. Each pattern will consist of four injection wells surrounding a central production well. Each production well will be pumped at about 95 L/min (25 gpm), and enough patterns will be operated simultaneously to supply up to 5678 L/min (1500 gpm) of uranium-containing solution to an onsite extraction and concentrating plant producing the final product (U_3O_8). Of the 308 ha (760 acres) under lease, about 32 ha (80 acres) are proposed for actual mining. A total of 11.8 ha (29.2 acres) will be excavated for building the processing plant and for evaporation ponds. An additional 4.4 ha (10.8 acres) will be disturbed for parking lot and auxillary building construction, access roads, pipelines, etc.

   The applicant proposes to restore the groundwater system after mining to baseline levels on a parameter by parameter basis. Individual groundwater parameters that can not be returned to baseline by reasonable efforts will at least be returned to levels commensurate with the groundwater's highest potential premining use based on Wyoming drinking water and livestock standards. Restoration will be accomplished by recycling mined formation water through an electrodialysis cleanup system and back into the formation until satisfactory

water quality has been reached. The aboveground solid wastes produced by the mining process are defined as by-product material by the Uranium Mill Tailings Radiation Control Act and will be removed to a licensed disposal site.

3. The major categories of concern, including issues for which analysis and assessment were necessary, were:

   a. the effect of the mining operation on both availability and quality of groundwater;

   b. the impact of the mining operation, roads, fences, and employee activities on wildlife, recreational activities, and archaeological resources;

   c. the management of waste disposal facilities during operation, with particular emphasis on the evaporation ponds, groundwater restoration, final disposal of project wastes, and surface reclamation;

   d. the definition of the geology of the ore body to ensure that it is adequately confined above and below by rock layers of low permeability with continuous properties that will prevent vertical movement;

   e. the details of well completion, testing, and operating and monitoring procedures to prevent or detect excursions; and

   f. the socioeconomic effects of the project.

4. Including the proposed action, the following alternatives were considered:

   a. Alternative of no licensing action: If a source material license was not issued, the applicant could open pit or deep mine the ore body and have the ore processed at an existing mill. The staff considers these alternatives neither economically viable nor in the public interest.

   b. Alternative energy sources: Fossil and nuclear fuels were compared; and solar, geothermal, synthetic fuels, and energy conservation were considered. The staff conclusion is that effective implementation of all these options will not preclude the need for additional uranium production.

   c. Alternatives if uranium ore is mined and refined on the site: The staff considered the following:

      - mining alternatives,

      - processing alternatives,

- mining and milling waste disposal alternatives,
- uranium extraction facility siting alternatives,
- alternative of processing in an existing mill, and
- alternatives specific to in situ leaching, including alternative lixiviants and oxidants, and alternative aquifer restoration methods.

The staff evaluated the applicant's proposed operation in relationship to the above alternatives. Staff conclusions were as follows:

a. Conventional mining and milling are not economically viable for recovering uranium from this ore body at present or in the foreseeable future, as discussed in Sect. 2.3.3.

b. Based on all of the hydrogeologic data presented and the R&D operation, the geological and hydrological conditions appear to meet the criteria for in situ leaching, as specified in Sect. 2.3.3.2, including vertical confinement of the fluid to the ore zone by lithologic zones of low permeability. Acquisition of additional hydrogeological data, as proposed by Teton, in units I through VIII is required before authorized well field expansion into each unit.

c. The applicant has provided aquifer restoration data from the pilot project indicating the ore-bearing aquifer can be restored to a condition of potential use equal to or better than its present condition as established by baseline measurements.

d. The applicant's proposed operation will result in less solid wastes for disposal than any other alternative.

e. The applicant's proposed operation will minimize groundwater usage.

The staff concurs with the applicant's choice of in situ leaching to extract uranium at this site.

5. From the analysis and evaluations made in this Statement, it is proposed that the Source Material License contain at least the following conditions:

   a. The applicant shall implement the monitoring programs and mitigating measures described in Sect. 4.4, including the associated reporting requirements and establishment of excursion action levels known as upper control limits (UCLs).

   b. The residual aboveground solid radioactive wastes from solution mining activities shall be finally disposed off-site at an active mill tailings disposal site or other licensed waste disposal facility.

c. Before use in conducting mining operations, the applicant shall verify well integrity by conducting packer tests in accordance with test procedures described in Sect. 2.3.10.1. During mining operations, wellhead injection pressures shall be monitored and shall not exceed the pressures to which the individual wells were previously tested. Individual wellhead injection pressures shall in no case exceed 0.63 psi per foot of well depth.

d. The applicant shall not use any lixiviant other than sodium bicarbonate/carbonate, and shall not use any oxidant other than oxygen and/or hydrogen peroxide, without NRC review and approval by license amendment.

e. The applicant shall conduct eight additional aquifer pump tests, designed with NRC approval, one in each mining unit, to demonstrate confinement of ore zone aquifers, as described in Sect. 4.2. The applicant shall submit reports on these tests for NRC review and approval prior to mining in each mining unit.

f. The applicant shall not initiate construction of any evaporation ponds until the NRC has reviewed, and approved by license amendment, complete engineering, design, and construction plan specifications and details for all embankments, leak detection systems, and liners.

g. The applicant shall obtain NRC approval, by license amendment, of a quality assurance program to assure the validity of all environmental sample analysis, in accordance with the recommendations and criteria contained in U.S. NRC Regulatory Guide 4.15, before mining.

h. The applicant shall implement a groundwater restoration program on mined-out well field areas, which shall include restoration of all mining-affected groundwater, in accordance with the general plan described in Sect. 2.3.10.3 and the criteria discussed in Sect. 4.3.1. Active restoration of each mined-out well field unit shall commence no later than six months following the cessation of mining in that unit. Restoration shall be performed without the injection into groundwater of any chemicals to assist in restoration, unless otherwise authorized by the NRC in the form of a license amendment.

i. The applicant shall not mine or transfer groundwater from one mining unit to another in other than mining units I, II, and III until the ability to achieve restoration in mining unit I has been favorably determined and the NRC has concurred.

j. The applicant shall provide, for NRC review and approval, detailed hydrogeologic data, as specified in Sect. 4.2, confirming individual mining unit suitability to in situ leaching before mining in unit I and in each successive unit.

k. The applicant shall obtain NRC approval, by license amendment, for the specific number and location of all monitoring and restoration sampling wells for mining unit II and subsequent mining units prior to drilling.

l. The applicant shall immediately notify the NRC, by the telephone and telegraph, of any failure of any evaporation pond, pipeline, or any other fluid or material conduit or storage facility that results in a release of radioactive materials to unrestricted or restricted areas, and/or of any unusual conditions which, if not corrected, could lead to such a failure. Such notification shall be followed within seven days by submittal of a written report detailing the conditions leading to the failure or potential failure, corrective actions taken, and results obtained.

m. The applicant shall establish a program that shall include written procedures and instructions to control all process activities and all environmental monitoring and control programs.

n. Before engaging in any activity not evaluated by the NRC staff, the applicant shall prepare and record an environmental evaluation of such activity. When the evaluation indicates that such activity may result in a significant adverse environmental impact that was not evaluated or that is significantly greater than that evaluated in this Environmental Statement, the applicant shall provide a written evaluation of such activities and obtain prior approval of NRC.

o. If unexpected harmful effects or evidence of irreversible damage not otherwise identified in this Statement are detected during construction or operations, the applicant shall provide to the NRC an acceptable analysis of the problem and a plan of action to eliminate or significantly reduce the harmful effects or damage.

p. Prior to disturbing any land, including topsoil removal and site decommissioning, outside the area previously surveyed as indicated in Appendix C of the applicant's Environmental Report for solution mining activities, including site decommissioning, the applicant shall have an archaeological survey of each area performed and shall not disturb the area until the NRC has evaluated the report and given the applicant approval to proceed.

q. The applicant shall not conduct surface disturbing actities in or around the four sites discussed in Sect. 4.5.2 having potential for subsurface archaeological deposits. Before any future disturbing activites in these site areas, the sites must be evaluated for National Register of Historic Places eligibility.

If any archaeological materials are discovered during construction, work in the area must halt immediately and the SHPO office contacted. Work in the area must not resume until the archaeological materials have been evaluated and adequate measures for their protection taken.

r. The applicant shall provide surety that funds will be available for aquifer restoration, surface reclamation, decommissioning, including any necessary surveys, and final waste disposal and shall obtain NRC approval thereof by license amendment before commencing mining operations.

s. Adequate reserve capacity shall be maintained in the evaporation pond system to provide for temporary storage of solution from any pond in event of a leak.

6. With these specific license conditions and conformity with other local, state, and federal regulations, the expected environmental consequences are the following:

   a. Total suspended particulates (mostly wind erosion and dust) would not likely exceed State or Federal standards and would not be expected to harm living plants, animals, or humans.

   b. During operations the only land use associated impacts should be a minor reduction in carrying capacity of the local grazing resource and some reduction in hunting opportunities. The project site and surrounding land are primarily used for cattle grazing, which will not be permitted on the 49 ha (120 acres) to be affected by the project. Most commonly observed wildlife at the site include pronghorn antelope, white-tailed jackrabbits, desert cottontails, and coyotes. Evaporation ponds occupying 11.6 ha (28.6 acres) will be fenced to exclude wildlife and livestock. Well-field development, operation, and restoration on 32 ha (80 acres) will have no appreciable effect on land use. After the project termination all disturbed areas, including the 11.6 ha (28.6 acres) of evaporation ponds and the 4.6 ha (11.4 acres) for the plant, parking lot, auxillary building, access roads, pipelines, etc., will be reclaimed to original use condition or better.

   c. The total use of groundwater from the upper portion of the Fort Union Formation is estimated to be about 7.95×10^5 m^3 (645 acre-ft) over the eleven-year project lifetime. Groundwater in the mining zone will temporarily be degraded during operation of the well fields. Restoration is required to return this water to a condition consistent with premining potential use of better. Total groundwater use will not affect local or regional supplies.

Surface water may be temporarily affected by increased sediment loading. Impacts on surface water quality will be minor during construction and operation of the project. The single exception would be from accidental failure of an evaporation pond embankment. These embankments will be constructed to the engineering standards of NRC Regulatory Guide 3.11, and total failure is not considered credible.

d. There will be a temporary loss of sagebrush and cushion plant communities. No unique plant communities or endangered plant species will be affected. No endangered or threatened animal species are involved. Wildlife mortality from vehicle collisions should be minimal because of the unrestricted visibility. The scarcity of aquatic life in the intermittent playas and drainage channels near the site preclude significant impacts for aquatic biota. Because no liquid effluents will be discharged during normal operation, significant impacts on aquatic biota are possible only under unlikely accident scenarios.

e. The estimated radiation dose to the nearest members of the general public will be small in comparison with natural background (see Tables 4.7, 4.8, 4.9, and 4.10).

f. The proposed project will not produce any significant socioeconomic impact on the local area because of the small number of employees.

g. The staff opinion is that any potential accident postulated for this project will not result in significant permanent damage to the environment.

7. The proposed position of the NRC is as follows: After weighing the environmental, economic, technical, and other benefits of the Teton solution mining project against environmental and other costs and considering available alternatives, the action called for under the National Environmental Policy Act of 1969 (NEPA) and 10 CFR Part 51 is the issuance of a combined Source and Byproduct Material License to the applicant, subject to at least the conditions presented in 5a through 5s above.

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1. PURPOSE AND NEED FOR ACTION

1.1 INTRODUCTION

This Final Environmental Statement (FES) is issued by the U.S. Nuclear Regulatory Commission (NRC), Uranium Recovery Field Office, Region IV, in response to the request by Teton-Nedco for the issuance of an NRC Source and Byproduct Material License authorizing operation of a proposed commercial uranium in situ mining operation (Teton project). This document has been prepared in accordance with Commission regulation Title 10, *Code of Federal Regulations* (CFR), Part 51, which implements requirements of the National Environmental Policy Act of 1969 (NEPA; P.L. 91-190). The project will be operated by the Teton Exploration Drilling Company.

The principal objectives of the NEPA process are to build into the agency decision-making process an appropriate and careful consideration of environmental aspects of proposed actions and to make environmental information available to public officials and citizens before decisions are made and actions are taken. The process is intended to help public officials make decisions that are based on an understanding of environmental consequences and take actions that will protect, restore, and enhance the environment.

The NEPA states, among other things, that it is the continuing responsibility of the federal government to use all practicable means, consistent with other essential considerations of national policy, to improve and coordinate federal plans, functions, programs, and resources to the end that the nation may

- fulfill the responsibilities of each generation as trustee of the environment for succeeding generations;
- assure for all Americans safe, healthful, productive, aesthetic, and culturally pleasing surroundings;
- attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences;
- preserve important historic, cultural, and natural aspects of our national heritage and maintain, wherever possible, an environment that supports diversity and variety of individual choice;
- achieve a balance between population and resource use that will permit high standards of living and a wide sharing of life's amenities; and
- enhance the quality of renewable resources and approach the maximum attainable recycling of depletable resources.

Pursuant to the above responsibilities and in accordance with 10 CFR Part 51, the Uranium Recovery Field Office has prepared this detailed statement on the foregoing considerations with respect to the application for a Source and Byproduct Material License for the above project.

In accordance with 10 CFR Part 40.31(f), the applicant submitted an Environmental Report (ER)[1] to the NRC to accompany the license application. In conducting the required NEPA review, Commission representatives (the staff) met with the applicant to discuss items of information in the ER, to seek additional information that might be needed for an adequate assessment, and generally to ensure that the Commission has a thorough understanding of the project. In addition, the staff sought information from other sources to assist in the evaluation, conducted field inspections of the project site and surrounding area, met with state and local officials charged with protecting state and local interests, and conducted a public scoping process to identify the significant issues to be analyzed in depth. On the basis of the foregoing activities and other such activities or inquiries as were deemed useful and appropriate, the staff has made an independent assessment of the considerations specified in Section 102(2) of the NEPA.

1.2 SUMMARY OF THE PROPOSAL

Pursuant to 10 CFR Part 40.31 and 10 CFR Part 51, Teton-Nedco, on October 10, 1980, applied to the NRC for an NRC Source and Byproduct Material License to construct and operate an in situ leach uranium mine and recovery plant in Converse County, Wyoming. This project, hereafter referred to as the Teton project, is designed to produce 1.04×10^6 kg (2.3×10^6 lb) of U_3O_8 (yellowcake) at a rate of about 1.3×10^5 kg/year (2.9×10^5 lb/ year).

The project site consists of about 308 ha (760 acres) approximately 12 km (7.5 miles) northeast of Glenrock, Wyoming. The relationship of the site to the surrounding region is shown in Fig. 1.1. The applicant has claims or leases for onsite minerals and plans to mine approximately 32 ha (80 acres).

The design and operation of the proposed commercial mine is based on the successful mining and restoration of an R&D test facility located near the center of the 49 ha (120 acres) to be effected by the proposed project.

The applicant proposes to mine in situ uranium ore contained in two geologic intervals, using sodium carbonate/bicarbonate solution and an oxidizing agent injected and recovered through a complex of well patterns. Each well pattern will consist of four injection wells surrounding a central production well. Each production well will be pumped at about 95 L/min (25 gpm), and enough patterns will be operated simultaneously to supply up to 5678 L/min (1500 gpm) of uranium-containing solution to an onsite extraction and concentrating plant producing the final product (U_3O_8).

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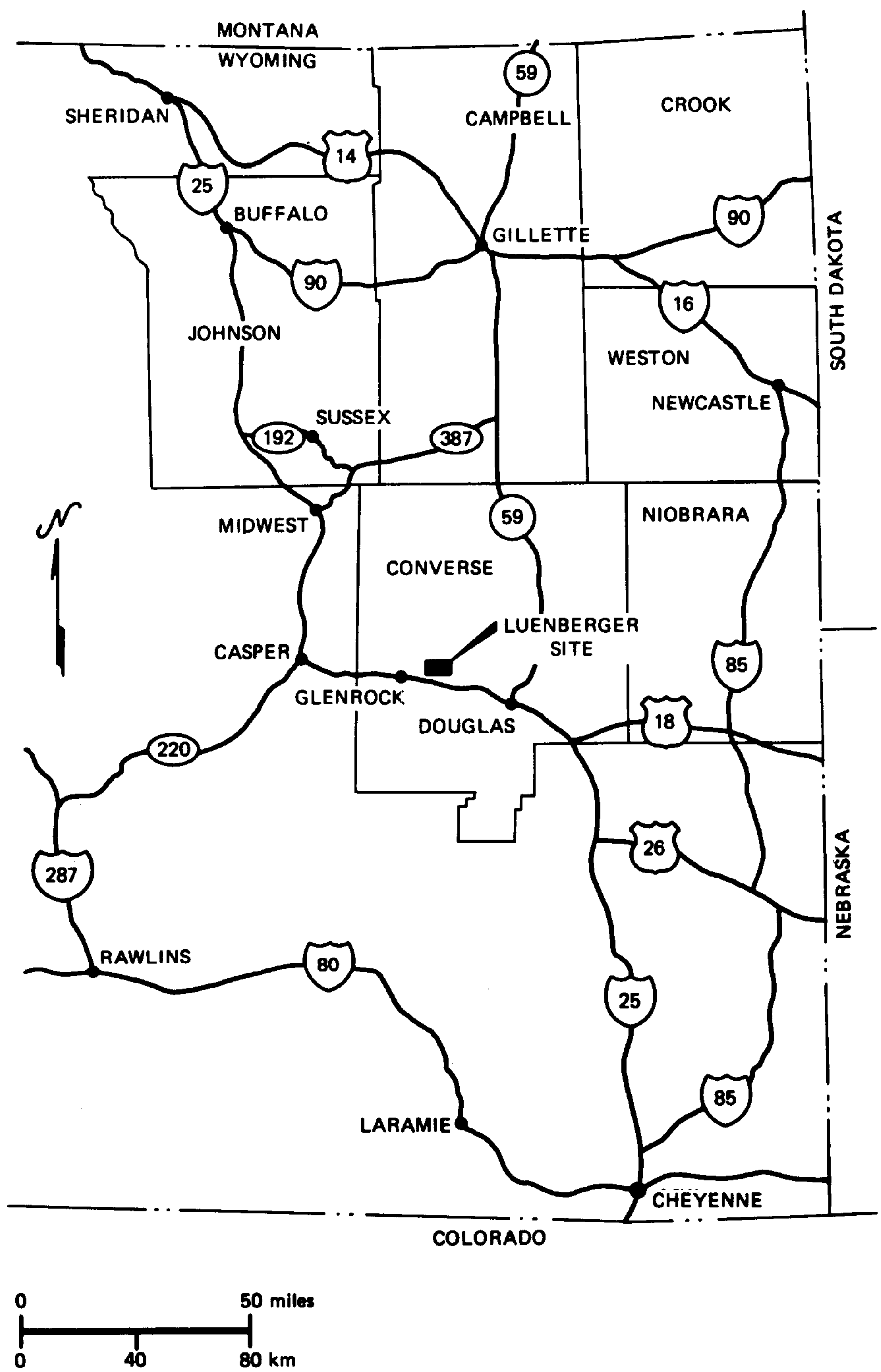

Fig. 1.1. Regional location of the Teton-Nedco project site.

The applicant proposes to restore the groundwater system after mining to baseline levels on a parameter by parameter basis. Individual groundwater parameters that can not be returned to baseline by reasonable efforts will at least be returned to levels commensurate with the groundwater's highest potential premining use based on Wyoming drinking water and livestock standards. Restoration will be accomplished by recycling mined formation water through an electrodialysis cleanup system and back into the formation until satisfactory water quality has been achieved. Successful restoration by these methods has been demonstrated at the R&D facility and is discussed in detail in Sect. 4.3.2. Solids produced in the cleanup process will be disposed of at a licensed disposal site.

Details of proposed procedures and viable alternatives are discussed in later sections.

1.3 FEDERAL AND STATE AUTHORITIES AND RESPONSIBILITIES

Under 10 CFR Part 40, an NRC license is required in order to "receive title to, receive, possess, use, transfer, deliver . . . any source . . . material . . ." (i.e., uranium and/or thorium in any form, or ores containing 0.05% or more by weight of those substances). In addition, under the Uranium Mill Tailings Radiation Control Act, the above-ground solid wastes produced by uranium in situ extraction are defined as by-product material and therefore must be disposed of in an approved manner. Pursuant to NEPA, 10 CFR Part 51 requires the preparation of a detailed environmental statement prior to the issuance of an NRC license for an action that may significantly affect the quality of the human environment.

The Wyoming Department of Environmental Quality (DEQ) administers the state's Environmental Quality Act of 1973 and implements rules and regulations. Among the state rules and regulations is the In Situ Mining Act, which became effective on May 25, 1980. The act provides specific regulations to be met by operators. Article 4 of the act established a permit and licensing scheme designed to ensure adequate reclamation of mined lands. The licensing procedure requires the operator's submission of a detailed reclamation plan to the state. For uranium solution-mining operations, this plan is contained in the *Application for In Situ Permit to Mine* submitted to the Land Quality Division of DEQ. This document also contains specific well field monitoring programs and groundwater restoration criteria as required by the state of Wyoming.

The state has completed its review of the proposed Teton project, which culminated with the issuance of Wyoming DEQ Permit to Mine No. 522. Under the terms and conditions of the permit to mine, the applicant was required to establish an effective financial surety covering the costs of all surface reclamation and groundwater restoration. Teton-Nedco has also received all necessary state engineer's permits for construction, including those necessary for the evaporation ponds.

1.4 NEED FOR ACTION

Among the alternative actions available to the NRC is the denial of a Source and Byproduct Material License to the applicant (see Sect. 2.1).

A comparison between estimated total requirements for electrical generating capacity and the projected nuclear capacity through the year 1988 indicates that nuclear generating plants are expected to furnish 42.6% of new electrical capacity supplied during the 1981-1990 period or 17.9% of total capacity (currently furnishing about 12.3%). New fossil fuel plants will provide approximately 46.7%.[2] The considerable uncertainty inherent in forecasting electricity demand, nuclear power plant cancellations, the unpredictable path of government nuclear-related policies and programs (breeder reactors, spent fuel reprocessing, etc.), and the availability and economic competition of alternative conventional and unconventional energy sources preclude rational forecasts past 1988.[2]

Table 2.4 indicates the quantities of U_3O_8 needed to sustain the nuclear power capacity growth shown in Table 2.3. The mid-range estimate would necessitate a 50% increase in annual domestic production above production in the 1980s [∿18,200 t (20,000 tons)] by 1993. However, presently, there is a stockpile of uranium already mined that can meet about 5 years of present demand.

After comparing the quantity of U_3O_8 required to satisfy projected reactor demand (Table 2.4) with the estimated domestic uranium resources (Table 2.5) and U_3O_8 production capabilities, the staff has formulated the following conclusions:

1. Currently known reserves and probable resources should be adequate to support installed reactor capacity through 2000 and the expected lifetime (40 years) of the reactors.

2. It is evident that there is and will be more production capability for U_3O_8 than will be needed during the 1980 decade. Cost factors and U_3O_8 price fluctuations will determine which mines and mills will be profitable. Production capability may, however, have to expand in the 1990s and after the turn of the century to satisfy increasing domestic demands.

The staff considers that market forces should determine prices; therefore, denial of a Source and Byproduct Material License would be considered only if issues of public health and safety and the mandates of the NEPA cannot be resolved to the satisfaction of the regulatory authorities involved.

1.5 RESULTS OF THE SCOPING PROCESS

In accordance with the guidelines developed by the Council on Environmental Quality (CEQ) in 40 CFR Part 1501.7, the NRC followed the scoping process to identify significant issues. As required under CEQ Rules and Regulations, the NRC issued a Federal Register notice, May 4, 1981,[4] concerning the DES requesting written comments.

The staff received no written comments on scoping.

Concerns identified in a comment letter from the U.S. Environmental Protection Agency on various aspects of the proposed project are appropriately addressed as are those received from several Wyoming State agencies.

The staff consulted with the U.S. Fish and Wildlife Service in regard to the endangered species, and has received a cultural clearance letter from the Wyoming Historic State Preservation Officer (SHPO).

No comments were received suggesting disapproval of the project.

Comments on the Draft Environmental Impact Statement and staff responses to these comments are presented in Appendix A of the Final Environmental Impact Statement.

REFERENCES FOR SECTION 1

1. Teton Exploration Drilling Company, Inc., *Environmental Report for U.S. Nuclear Regulatory Commission, Source Material License Application, Uranium In Situ Leaching, Leuenberger Site, Converse County, Wyoming*, October 1980. Docket No. 40-8781.

2. U.S. Department of Energy, *Electric Power Supply and Demand for the Contiguous United States 1981-1990*, DOE/EP-0022, July 1981.

3. P. C. deVergie et al., "Production Capability of the U.S. Uranium Industry," paper presented at the U.S. Department of Energy Uranium Industry Seminar, Grand Junction, Colo., October 1980.

4. *Fed. Regist.* 46(85): 13370 (1981).

2. ALTERNATIVES INCLUDING THE PROPOSED ACTION

2.1 ALTERNATIVE OF NO LICENSING ACTION

Among the alternative actions available to the U.S. Nuclear Regulatory Commission (NRC) is the denial of a Source Material License to the applicant. Exercise of the license denial option by the NRC would leave the applicant with three possible courses of action: (a) to use conventional mining techniques (surface or deep mining) and, if economically feasible, have the ore processed at an existing mill possessing a Source Material License; (b) to postpone the project while attempting to remove the objections that led to the denial of the license; or (c) to abandon the project. Alternative (a) is discussed in Sects. 2 and 4. Alternative (b) would mean alteration of the applicant's proposal as discussed in this statement. Alternative (c) is discussed below in this section.

The yellowcake produced by the Teton solution-mining project will contribute to the worldwide supply of uranium and will be used as fuel in nuclear reactors that are either operating or under construction in the United States or abroad. Contracted imports of U_3O_8 will exceed contracted exports over the next few years (Sect. 2.2.1.4). Therefore, even though the applicant may export the yellowcake produced by the proposed solution-mining project, failure to license this project would only result in foreign demand being filled by other domestic mills that could be producing uranium for use in the United States or by foreign mills. Lack of fuel could require some reactors to reduce their output and could conceivably result in their eventual shutdown (the portion of electrical energy from nuclear power — current and anticipated — over the next few years is discussed in Sect. 2.2).

The alternative of no licensing action, as qualified in Sect. 1.4, is not considered to be in the public interest.

2.2 ALTERNATIVE ENERGY SOURCES

2.2.1 Fossil and nuclear fuels

2.2.1.1 Introduction

Because uranium has changed from a commodity of only commercial uses such as ceramic coloring agents to one vital for nuclear weapons and nuclear reactors, the uranium industry has undergone a series of transformations. Coal was the first fuel used in quantity for electrical power generation; but, until recently, its use declined because of the ready availability and low price of oil and natural gas, both of which burn cleaner than coal and are easier to use. Uranium fuel is even cleaner (chemically) than oil or gas and, at present, is less expensive on a thermal basis than any other fuel used to generate electric power. The following discussion concerns the requirements for and the availability of fossil and nuclear fuels for power generation over the next

10 to 15 years. Also, the health effects of using coal and/or nuclear fuels as energy sources are compared.

2.2.1.2 Overview of U.S. energy use and availability

According to *The National Energy Plan,* published by the Carter Administration in April 1977, the United States uses more energy to produce goods and services than any other nation, consuming twice as much energy per capita as does West Germany, which has a similar standard of living.[1] In 1982, the United States consumed approximately 71 quads of energy (1 quad = 10^{15} Btu); about 91% of this energy was supplied by three fossil fuels: oil, natural gas, and coal.[2] During 1982, energy consumption decreased 4.3%, compared with 1981.[2] Decreases in the consumption rates of petroleum (5.3%), coal (2.9%), and natural gas (8.1%) contributed to the overall decline in energy consumption during this period.[2] Importation of foreign-based petroleum products had, until recently, increased despite highly inflationary Organization of Petroleum Exporting Countries (OPEC) pricing policies. However, because of the concomitant effect of recession and energy conservation, net imports of energy during 1982 totaled 7.3 quads, 22.1% below the 1982 consumption. Net imports of petroleum fell 21.1%, and natural gas rose 8.1% over this time period.[2] Energy production and consumption statistics for 1982 are summarized in Table 2.1 and illustrate our continuing dependence on petroleum imports to supply our energy needs.

Despite concentrated efforts to decrease our consumption of oil and natural gas, increase the usage of coal-burning facilities, and further the utilization of nonconventional energy sources, energy demand forecasts indicate that by 2000, approximately 47% of our energy needs will still be filled by oil and gas, 32% by coal, 10% by nuclear facilities, and only a small percentage ($\sim$11%) by other energy sources (Table 2.2). As shown in Table 2.2, coal will probably be the nation's primary energy source by 2000.

Of the 71 quads of energy consumed by the United States in 1982, 24.4 quads consisted of electrical energy.[2] An estimated 12.3% of this electrical energy was generated utilizing nuclear fuels; the percentages for oil and gas 7.4 and 15.3%, respectively; coal was used for producing 52%.[2] Due to the volatility of prices and unreliable sources of supply, the demand for oil and natural gas to generate electric power has decreased over the last five years. The use of oil and gas for electrical power generation should continue to decline in the future. Therefore, it is apparent that, of the resources currently used in electric-power-generating stations (coal, uranium, oil, gas, and hydro), an increasing portion of U.S. electrical energy needs will have to be supplied by coal and/or uranium — at least until the end of this century (Table 2.2). Although coal and uranium resources are adequate for foreseeable energy needs, major expansion of both uranium- and coal-producing industries will be required because neither of these industries alone can supply future energy requirements. Additionally, because of the time lag

Table 2.1. Production and consumption of energy by source for 1982

Energy source	Production of energy by source		Consumption of energy by source	
	Quads	Percent of total	Quads	Percent of total
Coal[a]	19.1	26.7	15.7	22.1
Crude oil	18.3	25.7	30.4	42.8
Natural gas[b]	20.4	28.5	18.3	25.8
Hydroelectric power[c]	3.2	4.5	3.5	4.9
Nuclear electric power	3.0	4.2	3.0	4.2
Other[d]	0.1	0.2	0.1	0.2
Net imports	7.3	10.2		
Total	71.4	100.0	71.0	100.00

[a]Includes bituminous coal, lignite, and anthracite.

[b]Inclues natural gas plant liquids and dry natural gas.

[c]Includes industrial and utility production of hydropower.

[d]Includes geothermal power and electricity produced from wood and waste.

Source: U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review*, Report DOE/EIA-0035 (83/01), February 1983.

Table 2.2. Forecast of energy consumption by energy source for 1990 and 2000

Energy source	1990		2000	
	Quads	Percentage of total	Quads	Percentage of total
Coal	26.5	29.8	34.4	31.9
Natural gas	19.4	21.8	17.0	15.7
Domestic oil	19.6	22.0	20.5	19.0
Imported oil	11.7	13.2	13.1	12.1
Nuclear	8.1	9.1	11.3	10.5
Other	3.7	4.2	11.7	10.8
Total	89.0	100.0	108.0	100.0

Source: "A Special Report in the Public Interest: Energy, Facing Up to the Problem, Getting Down to Solutions," published by *National Geographic,* February 1981; original source, U.S. Department of Energy, Energy Information Administration projections.

between initial extraction and consumption of the resource for energy production (three to five years from mine to generation plant for uranium and coal, five to seven years for construction of a coal generating plant, and seven to ten years for construction of a nuclear generating plant), the exploitation of both coal and uranium resources must be integrated with contemporary energy needs.

2.2.1.3 Coal production

Congress has stressed (in passed and proposed legislation) the need to reduce our future oil demands to lessen our dependence on foreign energy sources and to reorient our energy consumption patterns. Both the *Project Independence* report of November 1974 and the *National Energy Outlook* of February 1976 proposed that coal production be increased.[2-4] The major expansion of coal production will likely be in the West because of the low sulfur content of most western coals. (Sulfur is a major source of air pollution.) The potential for environmental damage (because of disturbance of generally fragile ecosystems) in the western United States will be increased. Because the major markets for the coal produced will be located hundreds of kilometers from the western mines, transportation costs will be high, as will the environmental impacts associated with the transportation systems. Currently, transportation costs for bringing western coal to the eastern United States account for the major part of the market price. Also, for a given thermal energy content, annual transportation requirements for U_3O_8 are minimal compared with those for coal because of the much higher energy content of uranium fuel. Approximately 227 MT (250 tons) of U_3O_8 per year are required for a 1000-MW nuclear plant operating at a plant factor of 0.8. Annual western coal requirements for an equivalent 1000-MW coal plant would be more than 2.7 x 10^6 MT (3 x 10^6 tons), or the load capacity of about one unit-train [100 cars of 91 t (100 tons) each] per day of plant operation.

2.2.1.4 Uranium fuel requirements, available resources, domestic production capabilities, and comparison of uranium resources and production capabilities with uranium requirements

Uranium fuel requirements

The need for uranium in commercial reactors in the United States has been and will continue to be primarily a function of two factors:

1. Installed nuclear reactor capacity. As of November 30, 1982, there were 79 licensed reactors in the United States with a net generating capacity of 61,523 MWe.[2] Of these licensed facilities, 51 were generating near capacity; six were in power ascendency or low-power testing; and 22 other units generated no electricity or operated substantially below capacity.[2] Humboldt Bay, Dresden-1,

and Three Mile Island-2 are not included in these statistics because their futures are so uncertain. A total of 144 reactors were in operation, had been granted construction permits, had permits pending, were on order or were in other stages of planning.[2] Nuclear generating capacity is expected to increase, at most, to 126,000 MWe by 1990 and 195,000 MWe by 2000 (Table 2.3).[5] The forecasts shown in Table 2.3 are lower than previous projections; for example, the 1990 forecast was 170,000 MWe in February 1979 and 160,000 MWe in October 1979. These downward predictions are the result of recent drops in the demand for electricity, increased nuclear power plant construction costs, and other reasons.

Table 2.3. U.S. nuclear power growth projections

Year	OUEA[a] projections, Aug. 1981 (GWe)			EIA[b] projections, 1981 (GWe)		
	Low	Medium	High	Low	Medium	High
1985	80	90	99	86	90	98
1990	177	122	126	116	121	124
1995	130	140	150	123	136	142
2000	148	170	195	145	165	185

[a]OUEA is the the U.S. Department of Energy's Office of Uranium Enrichment and Assessment.

[b]EIA is the U.S. Department of Energy, Energy Information Administration.

Sources: U.S. Department of Energy, Energy Information Administration, *Annual Report to Congress, 1981*, Volume 3, February 1982.

A comparison between estimated total requirements for electrical generating capacity and the projected nuclear capacity through the year 1988 indicates that nuclear generating plants are expected to furnish 38.6% of new electrical capacity supplied during the 1979-1988 period (currently furnishing about 12.3%). New fossil fuel plants will provide approximately 50.8%.[6] The considerable uncertainty inherent in forecasting electricity demand, the unpredictable path of government nuclear-related policies and programs (breeder reactors, spent fuel reprocessing, etc.), and the availability and economic competition of alternative conventional and unconventional energy sources preclude rational forecasts past 1988.[6]

2. Uranium enrichment policies. For use in commercial light-water reactors, the atomic percentage of the fissile nuclide ^{235}U must be enriched from its natural abundance of 0.71%. The amount of natural uranium required to produce a desired amount of product

material of a given enrichment is related to the percentage of ^{235}U remaining in the enrichment tails, the residual uranium from which some of the ^{235}U left in the tailings or the required delivery time of U_3O_8 to the enrichment plant, will change U_3O_8 requirements.

Table 2.4 indicates the quantities of U_3O_8 needed to sustain the nuclear power capacity growth shown in Table 2.3. Filling these requirements may pose a challenge to the domestic uranium industry. For example, the midrange estimate would necessitate a 50% increase in annual domestic production above production in the 1980s [∿18,200 MT (20,000 tons)] by 1992 and a threefold increase by 2015; for the high-range case, annual uranium requirements would be twice the estimated 1981 production by 1997 and almost four times the estimated production by 2020.[7]

Table 2.4. Forecasts of domestic uranium requirements[a]
[t (tons) of $U_3O_8 \times 10^3$]

Year	Low case		Middle case		High case	
1985	15.6	(17.2)	16.8	(18.5)	19.5	(21.5)
1990	21.6	(23.8)	21.9	(24.1)	23.3	(25.7)
1992	22.3	(24.6)	24.9	(27.4)	27.3	(30.1)
1997	26.2	(28.9)	29.7	(32.5)	33.6	(37.1)
2000	29.2	(32.2)	33.2	(36.6)	38.4	(42.3)
2015	39.2	(43.2)	48.2	(53.1)	57.4	(63.3)
2020	41.4	(45.7)	52.1	(57.4)	62.9	(69.3)

[a]Based on July 1980 enrichment planning studies by the U.S. Department of Energy's Office of Uranium Resources and Enrichment; enrichment tails assay at 0.20%.

Source: S. A. Thomas et al., "Production Capability of the U.S. Uranium Industry," paper presented at the U.S. Department of Energy Uranium Industry Seminar, Grand Junction, Colo., October 1981.

Available resources

Conventional ore resources. Table 2.5 presents January 1982 estimates of the quantities of uranium available from conventional ore reserves at different recovery cost levels. These statistics indicate that known reserves range from approximately 1.86 x 10^5 MT (2.05 x 10^5 tons) at a forward cost of production of \$66/kg (\$30/lb) up to 8.11 x 10^5 MT (8.94 x 10^5 tons) at \$220/kg (\$100/lb). Adding in potential reserves (known + probable + possible + speculative), as much as 3.72 x 10^6 MT (4.10 x 10^6 tons) of U_3O_8 are available at forward costs up to \$220/kg (\$100/lb).

Table 2.5. Conventional uranium (U_3O_8) resources in the United States as of Jan. 1, 1982

Cost category[a] [$/kg ($/lb)]	Reserves[b] (t)	Potential resources (t)		
		Probable[c]	Possible[d]	Speculative[e]
33 (15)	000,000	000,000	000,000	000,000
66 (30)	705,000	596,000	227,000	236,000
110 (50)	594,000	1,080,000	473,000	424,000
220 (100)	894,000	1,740,000	784,000	685,000

[a]Each cost category includes all lower cost reserves and resources.

[b]Reserves are in known deposits.

[c]Probable potential resources are those estimated to occur in known productive uranium areas, where "productive" means that past production of U_3O_8 plus known reserves exceed 10 t.

[d]Possible potential resources are those estimated to occur in undiscovered or partly defined deposits in formations or geologic settings productive elsewhere within the same geologic province or subprovince.

[e]Speculative potential resources are those estimated to occur in undiscovered or partly defined deposits in formations or geologic settings not previously productive within a productive geologic province or subprovince or within a geologic province or subprovince not previously productive.

Sources: C. H. Roach and L. L. Smith, "1980 Uranium Assessment Report, Results, and Future NURE Plans," paper presented at U.S. Department of Energy Uranium Industry Seminar, Grand Junction, Colo., October 1980; U.S. Department of Energy, *Statistical Data of the Uranium Industry*, Report GJO-100(80), Washington, D.C., Jan. 1, 1980; DOE Press Release 82-64, Grand Junction, Colo., May 27, 1981; DOE Press Release, 82-70, June 17, 1982.

Unconventional ore resources. In addition to the relatively high-grade conventional uranium resources, there are other unconventional resources: low-grade ores; U_3O_8 by-product from phosphate, copper, aluminum, and beryllium processes; Chattanooga shale; seawater; enrichment plant tails; and mill tailings. Uranium recoverable as a by-product of phosphate fertilizer and copper production is estimated to be about 6.8×10^4 MT (7.5×10^4 tons) through 2000.[7] The amount of uranium available as a by-product from processing beryllium ore and from the red mud remaining after removing alumina from bauxite is expected to be no more than a few hundred tons per year.[8] Approximately 4.7×10^5 MT (5.2×10^5 tons) of U_3O_8 could be recovered from very low grade ore and Chattanooga shale for about $220/kg ($100/lb) and approximately 3.6×10^9 MT (4×10^9 tons) of U_3O_8 from seawater for an estimated cost of between $660/kg ($300/lb) and $1653/kg ($750/lb).[9,10] Based on current U.S. Department of Energy (DOE) enrichment plans, it is estimated that from 1980 through 2009 about 6.52×10^5 MT (7.18×10^5 tons) of uranium will be residual in tails material, assuming a 0.20% ^{235}U operating tails assay level. If this material is further enriched at a 0.10% tails assay level, about 1.26×10^5 MT (1.39×10^5 tons) of U_3O_8 could be available.[8] As of January 1, 1980, approximately 8.6×10^3 MT (9.5×10^3 tons) of U_3O_8

were contained in both active and inactive uranium mill tailings piles that were recoverable at \$220/kg (\$100/lb); 3.3 x 10^3 MT (3.6 x 10^3 tons) were recoverable at \$66/kg (\$30/lb).[8] An additional 21.1 x 10^3 MT (23.2 x 10^3 tons) of U_3O_8 are expected to accumulate in piles from 1980 to 2009 and could be recovered at \$220/kg (\$100/lb).[8] Much effort has been expended to determine the amounts of uranium that might be recovered from coal and lignite. Some uranium was recovered from lignite ash in the early 1960s, but the lignite itself was not a suitable fuel for the process because supplementary fuel was needed for the necessary conversion to ash. No uranium has been recovered as a byproduct from the ash of coal- or lignite-fired power plants. Ash samples continue to be analyzed for uranium, but so far no ash containing more than 20 ppm of U_3O_8 has been found, and most ash samples contain from 1 to 10 ppm of U_3O_8.[11]

Domestic production capabilities

According to DOE, total domestic production from all sources — both conventional and unconventional — for 1981 was approximately 1.7 x 10^4 MT (1.9 x 10^4 tons).[12] This output would represent a 12% decrease over 1980 production.[12]

Conventional mill production. The total design capacity of the 20 conventional uranium mills operating in 1981 was about 43,363 MT (47,800 tons) of ore per day.[12] Twenty-two of these mills produced approximately 14,206 MT (15,660 tons) of U_3O_8 concentrate in 1981, or approximately 81% of the total production. During 1981 and 1982 the market for uranium has remained depressed. Cutbacks in mine and mill production that started in 1980 continued throughout 1981, 1982, and into 1983. Production in 1983 is expected to be less than in 1981; thus mills scheduled for start up in 1980-1982[14] have been delayed.

Production by unconventional methods. Although most uranium is produced via conventional acid- or alkaline-leaching processes, unconventional methods are used for some production. Such methods include solution mining (also known as in situ mining); uranium recovery from wet-process phosphoric acid effluents, copper-dump leach liquor, and mine water; and percolation leaching of ore in piles or vats. Production by these methods totaled 3030 MT (3340 tons) in 1980 and 3247 MT (3580 tons) in 1981.[12]

Until 1977, production from solution mining had been relatively constant at less than 1% of total uranium production for more than 15 years. This percentage has substantially increased since 1977; it was 3.5% in 1977, 6.6% in 1978, 7.6% in 1979, 8.4% in 1980, and 12% in 1981.[12] The DOE estimated that as of January 1, 1981, the nominal capacity of solution mining operations ranged from 1542 MT (1700 tons) to 1905 MT (2100 tons) per year.[7] Pacific Northwest Laboratory listed production figures for all operating solution mines and those in the licensing process as of May 1980; the 17 projects had a nominal production capacity of 3370 MT

(3715 tons) of U_3O_8 per year.[15] Other test projects are operating and may file permit applications for commercial production at any time.

Byproduct uranium results from the processing of other mineral resources. Some U_3O_8 is recovered during copper and beryllium-ore-processing operations, but the primary source at present is recovery from phosphoric acid production for fertilizer. In 1980, five companies produced uranium as a by-product of wet-process phosphoric acid production and three additional facilities were being constructed.[13] The annual production capacity of the five operating circuits was 1179 MT (1300 tons) in 1981; the three additional facilities will increase the production capacity to 1814 MT (2000 tons).[13] Production from phosphate operations was 1166 MT (1285 tons) in 1981.[12] Annual production is expected to peak at 5443 MT (6000 tons) in 1990, decreasing thereafter to approximately 4535 MT (5000 tons) in 2000 and to about 4173 MT (4600 tons) in 2025.[9] Uranium is present in most solutions produced by acid leaching of copper waste dumps. Although the concentration of uranium is only 2 to 15 ppm, a significant quantity could be recovered by treating major process streams from the larger copper mines in the western United States. Plants in Utah and Arizona now produce U_3O_8 by treating copper-leaching solutions, and the construction of similar facilities at other copper mines and plants could increase the uranium recovery capacity to about 453 MT (500 tons) to 907 MT (1000 tons) annually by the mid-1980s.[8] Byproduct production from the processing of beryllium and bauxite ores is expected to make a small, relatively insignificant contribution in the near term.[8]

<u>Comparison of uranium resources and production capabilities with uranium requirements</u>

After comparing the quantity of U_3O_8 required to satisfy projected reactor demand (Table 2.4) with the estimated domestic uranium resources (Table 2.5) and U_3O_8 production capabilities, the staff has formulated the following conclusions:

1. Currently known reserves and probable resources will be adequate to support installed reactor capacity through 2000 and the expected lifetime (40 years) of the reactors.

2. It is evident that there is and will be more production capability for U_3O_8 than will be needed during the 1980 decade. Cost factors and U_3O_8 price fluctuations will determine which mines and mills will be profitable. Production capability may, however, have to expand in the 1990s and after the turn of the century to satisfy increasing domestic demands.

As of January 1, 1982 domestic delivery commitments of U_3O_8 totaled 115,574 MT (127,400 tons) for the period from 1983-2000.[17]

2.2.1.5 Comparison of health effects of the uranium fuel cycle with those of the coal fuel cycle

Research conducted by the NRC[18] comparing the health effects associated with the coal fuel cycle (mining, processing, fuel transportation, power generation, and waste disposal) with those associated with the uranium fuel cycle (mining, milling, uranium enrichment, fuel preparation, fuel transportation, power generation, irradiated fuel transportation, and waste disposal) indicated that increases in the use of coal for power generation may increase the adverse health effects related to electric energy production. As defined by the study, health effects are stated in terms of "excess" mortality, morbidity (disease and illness), and injury among occupational workers and the general public, where "excess" implies illness and injury rates higher than normal and premature deaths. The estimated excess deaths per 0.8 GWe/year (i.e., per 1000-MWe power plant operating at 80% capacity for one year) were 0.47 for an all-nuclear economy (all electricity used within the nuclear fuel cycle is generated by nuclear power) and 1.1 to 5.4 if all the electricity used in the uranium fuel cycle (primarily for uranium enrichment and reactor operation) came from coal-fired plants. Excess deaths for the entire coal cycle varied from 15 to 120 per 0.8 GWe/year (Table 2.6).

Excess morbidity and injury rates for occupational workers and the general public resulting from normal operations and accidents in an all-nuclear cycle were estimated to be about 14 per 0.8 GWe/year, with injuries to miners from accidents (falls, cave-ins, and explosions) accounting for ten of these occurrences. If all the electrical power used in the uranium fuel cycle originated from coal-fired plants, these rates would increase to approximately 17 to 24 per 0.8 GWe/year. The estimated excess disease and injury rate for the coal cycle was 57 to 210 per 0.8 GWe/year. Coal-related illnesses among coal miners and the general public and injuries to miners account for the majority of non-fatal cases (Table 2.7).

Although the adverse health effects related to either the uranium fuel cycle or the coal fuel cycle represent small additional risks to the general public, the study concluded that ". . . the coal fuel cycle may be more harmful to man by factors of 4 to 260, depending on the effect being considered, for an all-nuclear economy, or factors of 3 to 22 with the assumption that all of the electricity used by the uranium fuel cycle comes from coal-powered plants . . . ." (ref. 18, p. 13). Additionally, ". . . the impact of transportation of coal is based on firm statistics; this impact alone is greater than the conservative estimates of health effects for the entire uranium fuel cycle (all-nuclear economy) and can reasonably be expected to worsen as more coal is shipped over greater distance . . ." (ref. 18, p. 13).

Table 2.6. Current energy source excess mortality summary per year per 0.8-GW(e)/year power plant

	Occupational		General public		Totals
	Accident	Disease	Accident	Disease	
		Nuclear fuel cycle			
All nuclear	0.22[a]	0.14[b]	0.05[c]	0.06[b]	0.47
With 100% of the electricity used in the fuel cycle produced by coal power (U.S. population for nuclear effects; regional population for coal effects)	0.24–0.25[a,d]	0.14–0.46[b,e]	0.10[c,f]	0.64–4.6[g]	1.1–5.4
		Coal fuel cycle			
Regional population	0.35–0.65[d]	0–7[e]	1.2[f]	13–110[g]	15–120
Ratio of coal to nuclear:				(All nuclear)	32–260[h]
				(With coal power)	14–22[h]

[a]Primarily fatal nonradiological accidents, such as falls and explosions.

[b]Primarily fatal radiogenic cancers and leukemias from normal operations at mines, mills, power plants, and reprocessing plants.

[c]Primarily fatal transportation accidents (Table S-4, 10 CFR Part 51) and serious nuclear accidents.

[d]Primarily fatal mining accidents, such as cave-ins, fires, and explosions.

[e]Primarily pneumoconiosis and related respiratory diseases leading to respiratory failure in coal workers.

[f]Primarily members of the general public killed at rail crossings by coal trains.

[g]Primarily respiratory failure among the sick and elderly from combustion products from power plants but includes deaths from waste coal bank fires.

[h]100% of all electricity used by the nuclear fuel cycle produced by coal power; amounts to 45 MWe per 0.8 GW(e)/year.

Source: R. L. Gotchy, *Health Effects Attributable to Coal and Nuclear Fuel Cycle Alternatives*, Report NUREG-0332, Division of Site Safety and Environmental Analysis, Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission, September 1977.

2.2.2 Solar, geothermal, and synthetic fuels

Estimates reported in *The National Energy Outlook*[4] indicate that solar and geothermal sources will each supply about 1% of U.S. energy requirements by 1985 and about 2% by 1990. Supplies of synthetic gas and oil derived from coal will probably not exceed 1% of U.S. energy requirements as of the year 1990. These projections are based on many considerations. The technology exists in all cases but not in a commerically useful form. The potential for proving these technologies on a commercial scale is great, but timely development will require a favorable market as well as government incentives. A maximum of 6% of projected 1990 energy requirements is expected to be derived from solar, geothermal, and synthetic fuel resources combined.

The National Energy Plan[1] does not set specific goals for increased use of synthetic fuels or geothermal energy but does state that, as a possible goal, solar energy will be used in 2.5 million homes by 1985.

2.2.3 Energy conservation

The cornerstone of *The National Energy Plan* is conservation, the cleanest and cheapest way to relieve the energy shortage:

> If vigorous conservation measures are not undertaken and present trends continue, energy demand is projected to increase by more than 30% between now [1977] and 1985.[1]

Per capita energy used in the United States is twice that of other industrial countries. It is apparent that reductions in total energy demand can be achieved in all major uses. The plan lists five types of consumers as being prime targets for energy conservation: (1) transportation, (2) buildings (including residences), (3) appliances, (4) industry, and (5) industries and utilities using cogeneration of electricity and low-grade heat.

Part of the plan focuses on the use of all possible governmental means (tax reduction, incentives, direct subsidy, legislation, and regulation) to change the relationship between energy production and energy demand. Actions that improve the thermal efficiency of automobiles, homes, and office buildings would have the greatest conserving effect. However, in the case of electrical energy, demand is expected to increase (during the next decade) at a rate about twice as great as that for total energy.[3] It will be more difficult to conserve electrical energy because it will probably be a viable alternative for oil and gas use in residential heating and for some industrial applications. Therefore, conservation will not materially change the need for increased dependence on coal and uranium as fuels for generating electric power during the next decade.

Table 2.7. Current energy source summary of excess morbidity and injury per 0.8-GW(e)/year power plant

	Occupational		General public		Totals
	Morbidity	Injury	Morbidity	Injury	
	Nuclear fuel cycle				
All nuclear	0.84[a]	12[b]	0.78[c]	0.1[d]	14
With 100% of electricity used by the fuel cycle produced by coal power (U.S. population for nuclear effects; regional population for coal effects)	1.7–4.1[e]	13–14[b]	1.3–5.3[f]	0.55[g]	17–24
	Coal fuel cycle				
Regional population	20–70[e]	17–34[h]	10–100[f]	10[g]	57–210
Ratio of coal to nuclear:				(All nuclear)	4.1–15[i]
				(With coal power)	3.4–8.8[i]

[a]Primarily nonfatal cancers and thyroid nodules.

[b]Primarily nonfatal injuries associated with accidents in uranium mines, such as rock falls and explosions.

[c]Primarily nonfatal cancers, thyroid nodules, genetically related diseases, and nonfatal illnesses following high radiation doses, such as radiation thyroiditis, prodromal vomiting, and temporary sterility.

[d]Transportation-related injuries from Table S-4, 10 CFR Part 51.

[e]Primarily nonfatal diseases associated with coal mining, such as pneumoconiosis, bronchitis, and emphysema.

[f]Primarily respiratory diseases among adults and children from sulfur emissions from coal-fired power plants but includes waste coal bank fires.

[g]Primarily injuries to coal miners from cave-ins, fires, and explosions.

[h]Primarily nonfatal injuries among members of the general public from collisions with coal trains at railroad crossings.

[i]100% of all electricity used by the nuclear fuel cycle produced by coal power; amounts to 45 MWe per 0.8 GW(e)/year.

Source: R. L. Gotchy, *Health Effects Attributable to Coal and Nuclear Fuel Cycle Alternatives*, Report NUREG-0332, Division of Site Safety and Environmental Analysis, Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission, September 1977.

2.2.4 Evaluation of alternative energy sources

To solve our nation's intensifying and formidable energy supply and demand problems will require rapid and extensive expansions in the production and use of all practical energy forms and resources — along with the setting and meeting of adequate energy conservation goals. *The National Energy Plan* clearly states, and it is becoming increasingly clear, that both coal and nuclear electrical generation facilities will be needed to meet U.S. energy requirements through the year 2000, even if the conservation goals of the plan are met.[1] (The relative amounts of each energy source used will depend on economic and regional environmental considerations.) Therefore, it appears that increased use of the nonnuclear energy sources discussed above will not lessen the need for the uranium to be recovered and processed by the proposed solution-mining project (and by similar ventures) if the project is conducted within acceptable, suitable constraints required to protect the environment and the public.

2.3 ALTERNATIVES IF URANIUM ORE IS MINED AND REFINED ON THE SITE

This section describes the applicant's proposal along with alternative methods for uranium recovery from the available ore source and compares the potential environmental effects of the various recovery operations.

2.3.1 Summary of the proposed activity

The applicant proposes to construct an in situ leaching uranium mine and recovery plant in Converse County, Wyoming, about 12 km (7.5 miles) by air northeast of the town of Glenrock and about 40 km (25 miles) by air east of Casper. The proposed permit site consists of about 308 ha (760 acres) and contains the ore body, mining facilities, and sufficient area for necessary environmental monitoring installations. The permit area is a contiguous tract of land within Township 34 North (T34N), Range 74 West (R74W) of the Six Principal Meridian, Converse County, Wyoming (Fig. 2.1).

The mineralized ore body is located within two geologic intervals approximately 76 m (250 ft) and approximately 107 m (350 ft) below the land surface. The proposed operation at the Teton site will recover approximately 1.04 x 10^6 kg (2.3 x 10^6 lb) of U_3O_8 from about 32 ha (80 acres) of the ore body over an estimated eight-year period of active mining.

The project should last about 11 years (allowing time for groundwater restoration, plant decommissioning, and surface reclamation). The project will be covered by a Reclamation Performance Bond with the state of Wyoming in keeping with the requirements of Wyoming law.

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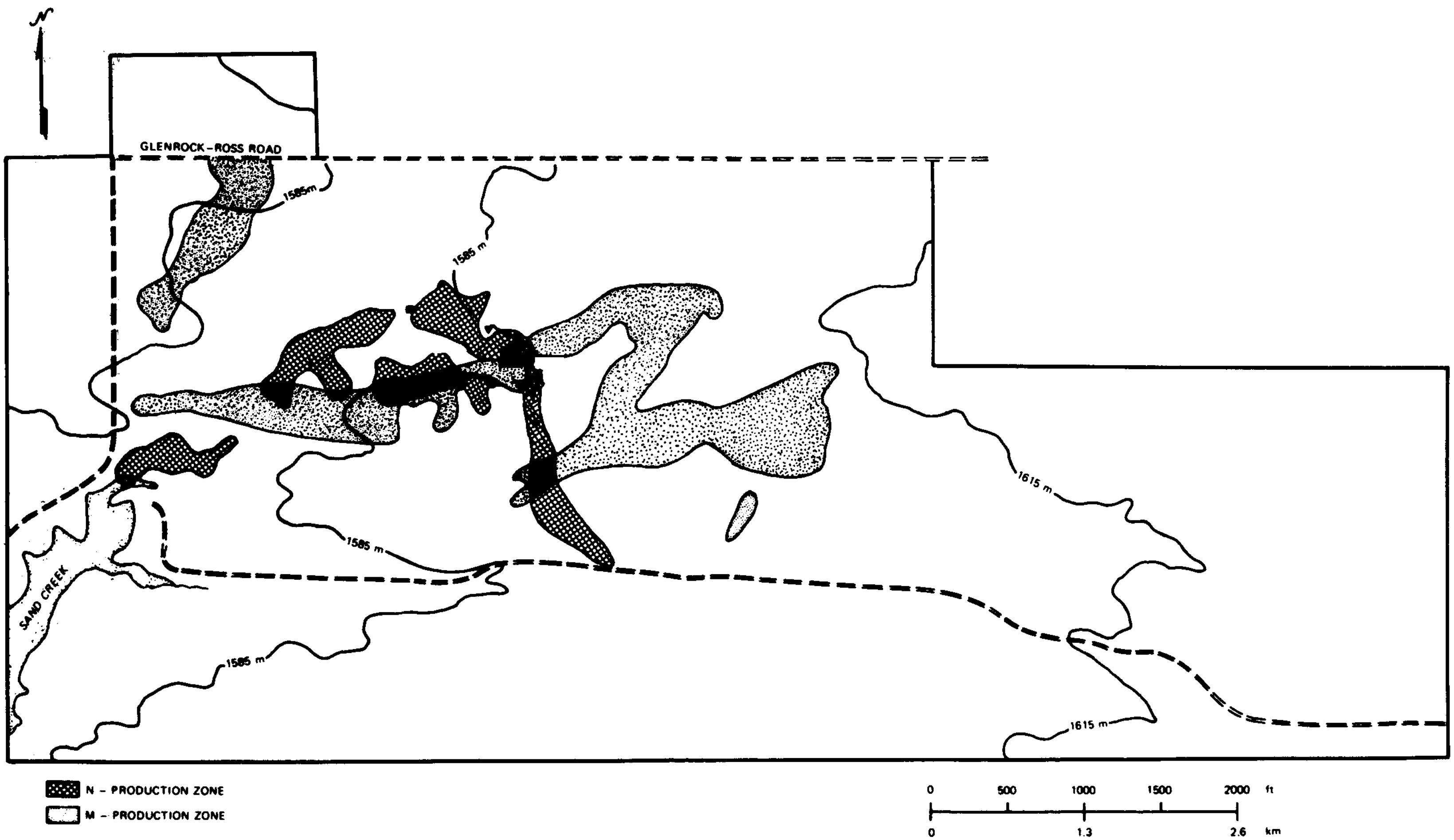

Fig. 2.1. Outline of the uranium ore body at the Teton-Nedco project site.

Using state-of-the-art extraction technology, the commercial processing plant will recover the uranium from a sodium bicarbonate/carbonate lixiviant. Operating plans call for the commercial plant to circulate up to 7571 L/min (2000 gpm) when the mining operation and groundwater restoration are concurrent. The expected annual U_3O_8 production will be approximately 1.29 x 10^5 kg (285 x 10^3 lb). Most of the resulting barren (uranium-depleted) lixiviant will be refortified with carbonate and oxidant (oxygen or hydrogen peroxide) and recycled to the ore zone. A small amount of barren lixiviant will be withdrawn from circulation and impounded in an evaporation pond after treatment, which means that withdrawal from the production wells will be slightly greater than injection. This minimizes the potential for the spread of leach solution out of the ore zone.

Upon completion of leaching activities, the water within the ore horizon and surrounding areas will be restored to baseline levels on a parameter by parameter basis. Individual groundwater parameters that can not be returned to baseline by reasonable efforts will at least be returned to levels commensurate with the groundwater's highest potential premining used based on Wyoming drinking water and livestock standards. This restoration will be performed by withdrawal of lixivant-contaminated water, treatment of the recovered solution to acceptable quality by physical means, and reinjection of the treated water into the ore zone. Successful restoration by these methods has been demonstrated at the R&D facility (see Sect. 4.3.2 and Appendix F). Both leaching and restoration activities will generate solid and liquid wastes, which will be impounded in ponds. The waste ponds will have an impermeable Hypalon liner (or similar material) to contain the liquid effluent. A leak-detection system will be installed to reveal possible liner failure so that mitigating measures can be implemented if needed.

Reclamation procedures for site surface areas will meet applicable NRC and state requirements. The objective of the surface reclamation efforts is to return the disturbed lands to a quality equal to or better than that of premining conditions. All structures, foundations, and equipment will be removed from the processing plant and well field areas. Building materials and soils showing radioactive contamination will be disposed of in the same manner as other solid radioactive wastes at a licensed tailings disposal facility. All affected surface areas will be reclaimed. The applicant's proposed reclamation procedures and the staff's evaluation are discussed in Sect. 2.10.3.5.

2.3.2 Description of the ore body

2.3.2.1 Physical shape and area

Although the applicant is leasing a 308-ha (760-acre) project site, the ore body to be mined by the in situ solution mining method lies beneath approximately 32 ha (80 acres) only. The applicant expects to produce approximately 1.04 x 10^6 kg (2.3 x 10^6 lb) of uranium (as U_3O_8) from the known reserves at the site (ER, p. 3).

The host rock is the upper portion of the Fort Union formation of Paleocene age. The ore lies within two separate sand units designated by the applicant as the N and M. The N sand lies above the M sand at a depth of 67 m to 82 m (220 to 270 ft) beneath land surface. The ore-bearing portion of the unit ranges in thickness from 1.5 m to 6.1 m (5 to 20 ft) within the 15-m (50-ft) thick sand. Approximately 30 m (100 ft) of claystone separates the N sand from the uppermost water-saturated sand unit designated as the O aquifer. The N sand contains 26% of the mineable uranium (ER, p. 35).

The M sand unit lies at a depth of 98 m to 119 m (320 to 390 ft) beneath land surface and is separated from the N sand unit by approximately 15 m to 23 m (50 to 75 ft) of interbedded claystone and siltstone. The mineralized zone occupies a thickness of 1.5 to 6.1 m (5 to 20 ft) within the 15-m to 20-m (50- to 65-ft) thick sand unit. There are approximately 18 m to 21 m (60 to 70 ft) of claystone separating the M sand from the next lower sand, which is designated as the basal sand unit. The M sand is the principal ore-bearing unit under the project area and contains 74% of the mineable ore (ER, p. 36).

2.3.2.2 Ore genesis

Roll-type uranium deposits are generally associated with fluvial sandstones and conglomerates with the uranium concentrated by an oxidizing liquid front moving down the hydrologic gradient through the reducing host zone sands. Uranium is precipitated along the interface between the oxidizing and reducing sides of the front.[19]

Late in the Paleocene epoch, the Laramide Orgeny uplifted the land masses surrounding the Powder River Basin exposing granite basement rocks to weathering and erosion. Channel and stream-bank deposits accumulated as subsidence in the southern portion of the basin accompanied the uplift. A thick mass of tuffaceous sediments was deposited in the basin due to northward tilting and deep weathering with minor erosion late in the Eocene epoch and continued subsidence in the late Oligocene through the Pliocene epochs. The entire region was uplifted several thousand meters late in the Pliocene epoch (ER, p. 19).

Uranium entered the groundwater of the basin through weathering of the Tertiary sediments and/or the Precambrian granites exposed in the adjoining mountainous areas. Uranium ions, carried in oxidizing host solutions, migrated down dip until reducing conditions were encountered and the uranium precipitated. Accumulation of uranium in the ore-bearing sands of the Leuenberger site probably resulted from a continual process of migration, dissolution, and secretion of uranyl ions in Paleocene channel deposits since late Tertiary time (ER, p. 19).

2.3.3 Mining alternatives

2.3.3.1 Conventional mining methods

The selection of a mining technique to recover a mineral resource is based on several complex and interrelated factors: (1) the spatial characteristics of the deposit (size, shape, and depth); (2) physical (or mechanical) properties of the mineral deposit and surrounding geologic structure; (3) groundwater and surface-water conditions; (4) economic factors including ore grade, comparative mining costs, and desired production rates (uranium mining and resource development account for about 40% of the costs for producing uranium concentrates);[20] and (5) environmental factors such as preservation and reclamation of the environment and the prevention of air and water pollution. The two most commonly used methods for mining uranium deposits are open-pit (surface mining) and underground mining. Other mining methods, among which solution mining is the most advanced, are in the developmental state.

Open-pit mining

Although relatively deep [>150-m (500-ft)] ore bodies have been surface mined, open-pit mining is normally used to extract ore from comparatively large, shallow ore deposits covered with less than 90 m (300 ft) of loosely consolidated soil or detritus[20] (compared with the mining of other minerals, the ratio of overburden to uranium ore is unusually large, ranging from about 8:1 to 35:1).[21] The maximum mining depth and ore cut-off grade are determined by economic factors (i.e., deeper mines and lower grade ores become uneconomical when the costs of mining and milling plus a reasonable profit exceed the revenues from the sale of the yellowcake product). To recover the uranium, the extracted ore must be processed in a mill (Sect. 2.3.4.1). In 1978, surface mining contributed about 55% of the 12.5×10^6 MT (13.8×10^6 tons) of uranium ore produced in the United States.[9] Surface-mined ores accounted for about 46% of the total annual uranium concentrate production, estimated at 16,774 MT (18,490 tons) of U_3O_8.[9]

Surface mining involves the creation of a pit (or pits) by the excavation of the overburden and topsoil overlying the deposits to permit ore extraction. Equipment used for stripping overburden includes tractors with rippers, rubber-tired scrapers, and tractor pushers; diesel-powered shovels; and large truck fleets.[22] For the removal of ore and waste from the ore zone, bulldozers, front-end loaders, diesel shovels, draglines, and backhoes are used (drilling and blasting usually are not necessary). The size of the operation often determines which equipment should be used (e.g., backhoes are generally more economical for digging and loading ore from some small ore deposits).[21] Because groundwater inflow is a problem in many open-pit mines, a trench may be dug around

the periphery of the pit floor to collect groundwater drainage.[21] The water is pumped from the mine and may be used for milling processes or discharged to the surface after treatment, if necessary.

Many alternatives exist for the reclamation of uranium surface mines. Generally, overburden and topsoil are stored in dumps during mining, the overburden being used to refill the pit (perhaps partially). The surface is shaped to a rolling topography, the slopes ranging from 0 to 30%, and salvaged topsoil is then distributed over the contoured surface. The restored surfaces are revegetated with appropriate plant species, and, if necessary, fertilizers and soil amendments are used to ensure plant growth. Precautions are taken to stabilize the soil against erosion and to provide watershed protection.

The environmental impacts associated with uranium open-pit mining operations are well documented.[4,21,23] Compared with other commerically used mining techniques, open-pit mining disturbs a much larger surface area. Overburden dumps and pits remain after mining operations are completed, and, where mining has occurred, the geologic formations are completely and permanently altered. Because conventional milling methods must be used to process the ore, measures to alleviate the short- and long-term environmental impacts associated with the disposal of mill tailings must be determined and evaluated.

Underground mining

Underground mining is the method generally used for deep, relatively high-grade ore deposits in structurally stable host rock. In 1978, roughly 45% of the total uranium ore extracted came from underground mines; however, because the average grade of ores mined underground was higher than surface-mined ores, their milling accounted for about 48% of the total annual U_3O_8 production.[9]

Because of varying ore-body characteristics (size, shape, depth, and ore grade), many alternative underground mining techniques have evolved.[20] Simple adits or inclined entries driven into a canyon wall or sloping ground are sometimes used to reach small ore deposits.[21] Vertical mine shafts and horizontal tunnels are usually needed to mine the larger ore deposits; some of these ore bodies are about 1 km long, a few hundred meters wide, 2 to 30 m (5 to 100 ft) thick, and a few hundred meters below ground [up to 427 m (1400 ft)].[21] Typically, the shaft is circular, compartmented, concrete lined, and up to 4.3 m (14 ft) in diameter.[22] The mining method selected for each ore body depends on the stability of the ground, the size and shape of the ore zone, and the cost of extraction. Depending on ground stability or the permanency of the tunnel, steel plates, timber, or concrete is used to support tunnels extending from the shaft.[21] The ore is drilled, blasted, and often transported by slushers to the ore pass. Underground haulage may be either by electric or diesel locomotive or by trackless, rubber-tired equipment.[22] New tunnels are driven until the ore deposit is depleted.

Groundwater intrusion is a problem with underground mining, and dewatering is often required. The rate of water pumped from mines may range from 0.76 to 11 m^3/min (200 to 3000 gpm).[21] The water is frequently used as process water in a uranium mill.

Mines are required to have proper ventilation to prevent the accumulation of radon-222 (a uranium daughter) to concentrations hazardous to the health of the miners.[21] Ventilation holes, typically 0.9 to 1.8 m (3 to 6 ft) in diameter, are drilled to connect with the underground workings. A large fan installed at the top of the hole on the surface exhausts the mine air entering the shaft.

After mining operations have ceased, the equipment and buildings at the mine shaft and the mining equipment are removed. Air shafts and the mine shaft are sealed (usually with concrete), covered with topsoil, and the area is revegetated with appropriate plant species to stabilize the soil.

Because no pits are created, underground mining disturbs significantly less surface area than comparable surface mines; however, because conventional milling procedures must be used to recover the uranium, related tailings disposal problems and methods of solution are the same as for surface mining.

2.3.3.2 <u>In situ leaching with acidic or alkaline lixiviants</u>

In situ leaching is a solution-mining method* only recently used for uranium extraction on a commercial scale and is a potential addition to the list of conventional methods being used. Because the technology for solution mining of uranium is relatively new and is still in the development stage, considerable variation exists from one operation to another.[24] Therefore, both operational and environmental considerations are site specific.

Generically, the mineral sought is dissolved from its host source in situ and extracted as a liquid, leaving the solid host material in its natural position. In situ leaching of uranium ore deposits normally involves

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*Solution mining is a general term describing the extraction of minerals in liquid form. The solution may contain only the mineral sought from the natural source (e.g., salt or sulfur) or may include other materials such as excess chemicals that have been added to aid in the dissolution of the resource from its source host, reaction byproducts, and other materials in the mineral deposit dissolved in the process.

(1) the introduction, through injection wells, of a leach solution or lixiviant (usually either an acidic or basic oxidizing solution) into the ore body to complex the contained uranium; (2) mobilization of the uranium from the host material via creation of a soluble complex salt; (3) removal, through production wells, of the complexed uranium-bearing solution; and (4) recovery of the solubilized uranium by conventional extraction operations. Therefore, although the chemical technology is essentially conventional, the customary ore extraction, transportation, storage, crushing, and grinding operations are eliminated. Solid wastes that require controlled disposal are generated; however, the volume produced is much less than that created by conventional milling. The disposal of waste materials and potential contamination of aquifers are the major environmental concerns and require careful control.

In situ leaching is normally used to mine relatively small, isolated, low-grade ore bodies that cannot be developed economically by conventional techniques; however, not all of the ore deposits possessing these characteristics can be successfully leached in situ. The following additional criteria must be satisfied:

1. The ore must be located in a saturated stratum below the static water table.

2. The ore body must possess suitable mineralogic and hydraulic properties (i.e., adequate permeability and amenability to chemical leaching).

3. The ore deposit must be extensive enough to justify the cost of uranium recovery.

4. Because leachate loss is both economically and environmentally unsound, the capability to retrieve as much of the acidic or alkaline leach solution as possible is necessary. Therefore, the ore zone must be generally horizontal and be confined by rock layers whose properties and continuity make the layers virtually impermeable, such as shales, siltstones, or mudstones. To select well locations and the inflow-effluent rates, the direction and velocity of the regional water flow should also be known.[21]

In situ leaching of uranium ore is usually carried out by drilling inflow wells into the ore body either upstream of (based on the direction of groundwater flow) or in a symmetrical pattern around the recovery wells. Selection of location and spacing of wells is based on the fact that the flow between wells and within an aquifer can be controlled by varying inflow-effluent rates, by the spacing between wells, and by properly aligning wells at specific angles to the direction of groundwater flow.[21] Salt solutions of ions, such as sulfate, bicarbonate, and

carbonate, which are known to form stable aqueous complexes with hexavalent uranium, are pumped to the inflow wells; simultaneously, a slightly greater volume of liquid is withdrawn from the production wells. An oxidizing agent such as oxygen (as pure O_2 or as air), hydrogen peroxide, or sodium chlorate may be added to increase leaching efficiency. The inflow of solution is continued until the leach zone is depleted, as is indicated by a decrease in uranium concentration in the leachate. (Alternative leaching solutions are discussed in Sect. 2.3.9.1.)

2.3.4 Processing alternatives

2.3.4.1 Conventional uranium milling processes

If the ore deposits that the applicant is proposing to process by in situ leaching were to be mined using either open-pit or underground methods, the ore would probably be transported by truck to and processed at an existing conventional uranium mill. (New mill facilities could be erected and placed into operation, or the ore could be heap leached; however, the probability that these processing alternatives would be implemented is low.)

Uranium concentrates are conventionally produced by the milling of uranium ore via the following procedure: (1) ore preparation (involving primarily the crushing and grinding of the ore), (2) leaching, (3) separation of pregnant leach liquids from waste solids (tailings), (4) concentration and purification of the uranium by extraction from the pregnant solution, (5) precipitation of the uranium from the extract solution, and (6) drying and packaging. The specific manner in which each of these steps, singly or in combination, is done varies from mill to mill and depends on differing ore characteristics. Normally, process decisions are based on overall economic considerations, including costs of controlling chemical and radiological releases to air, water, and land.

Crushing and grinding of ore are needed to reduce overall particle size to ensure sufficient contact with the uranium-dissolving reagent. Conventional crushing equipment usually reduces the size of the ore particles to less than 1.9 cm (0.75 in.). Grinding is usually accomplished by rod or ball mill, the ore being ground to approximately 28 mesh for acid leaching or to approximately 200 mesh for alkaline leaching.[21] Semiautogenous grinding, which minimizes dust problems and replaces the above processes, is being used in most new facilities.

The leaching method chosen for removal of the uranium from the ground ore depends on the chemical properties of the ore. Ores containing low levels of basic materials (primarily lime) are usually leached with

sulfuric acid. An alkaline leach reagent (normally sodium carbonate/bicarbonate solution) is often used when the lime content of the ore is high. Acid may also be used to leach ore of this type; however, because larger quantities of acid would be required, process costs would be increased significantly.

The separation of the pregnant leach solution (which contains over 90% of the uranium in the ore) from waste solids is usually done by thickening or by filtration. The majority of the acid-leaching mills in the United States use countercurrent decantation in thickeners for liquid-solid separation.[25]

Concentration and purification of the uranium from the pregnant leach solution are necessary to produce high-grade uranium concentrates and are usually accomplished by either solvent extraction or by ion exchange processes. The methods are similar in that both involve ion interchange between the leach liquor and either a solid resin (resin ion exchange) or a liquid organic solvent (solvent extraction).

The milling process generally concludes with the recovery of the uranium from solution by chemical precipitation. When acid-leaching methods are used, the uranium is precipitated by neutralization with a base such as ammonia, lime, magnesia, or hydrogen peroxide.[25] When alkaline leach processes are used, the uranium is normally precipitated as a sodium diuranate by adding caustic to clarified carbonate/bicarbonate solutions to increase the pH to approximately 12 (ref. 25). The precipitate is then dewatered, dried, and packaged for shipment.

Because the solution-mining project proposed by the applicant involves leaching the ore in situ, the crushing and grinding steps are eliminated and no tailings are generated.

2.3.4.2 Unconventional uranium milling processes

Heap leaching

The heap-leaching process consists of leaching the ore in a static or semistatic condition, either by gravitational flow through an open pile or by flooding a confined ore pile.[25] This technique can be used to profitably treat low-grade ore dumps or to process ore from small deposits located long distances from conventional milling facilities.[25] Heap leaching does not require a large capital expenditure for equipment, and manpower requirements are minimal.[21] Because shipping a high-grade pregnant solution or a crude bulk precipitate from a point near a mine site is more economical than hauling low-grade ore to a mill, heap leaching is often economically well suited for processing ore from remote mining operations.

A variety of lixiviants has been used for heap leaching: water, ferric chloride, ferric sulfate, alkali carbonate, and sulfuric acid. As of 1971, all domestic heap-leaching operations used acidic solutions.[25] Natural heap leaching with water, a variant of the bacterial-leaching concept, has been used in foreign countries.

The uranium-enriched solutions collected from a pile can be processed at the leaching site by ion exchange or solvent extraction, and the uranium can be precipitated by sodium carbonate or ammonia, the final precipitated-slurry product being shipped to a processing facility. In cases where the dumps are reasonably near a mill, it is common practice to use acid solutions from the mill circuit for the heap-leaching operation, returning the enriched solutions to the mill circuit for processing.[25] Operations are terminated and the pile is reclaimed when the uranium recovery no longer justifies the pumping of leaching solution through it or when a specified low limit of uranium solution grade is reached.

2.3.5 Evaluation of mining and processing alternatives

Although either surface or underground mining could be used to extract the proposed ore to be processed by in situ leaching, the depth, size, and shape of the deposits and the relatively low average ore grade are such that use of these mining methods would not be economically justified. For example, to surface mine the deposits, approximately 41 m^3 of overburden would have to be removed for each kilogram of yellowcake produced (24.5 yd^3/lb of U_3O_8). The cost for removing a cubic meter of earth is about \$0.98/m^3 (\$0.75/yd^3) (ref. 14). Therefore, the staff estimates that the total cost of overburden removal alone (excluding ore extraction, transportation, milling, and waste disposal costs) would be approximately \$40/kg (\$18/lb) of uranium. Unless the price of yellowcake rises substantially and rapidly, surface mining of this and similar ore deposits is not economically feasible. Underground mining would be even more expensive.

Because heap leaching requires the conventional mining of ore, the methods are eliminated as not economically feasible. Alkaline or acid in situ leaching might be economically and environmentally acceptable if adequate controls and constraints are stipulated and used.

The applicant has proposed to use solution-mining techniques to mine the Teton project ore deposits primarily for economic reasons. A significant advantage of this decision is that the environmental impacts associated with in situ leaching of uranium are generally much less severe than the impacts associated with conventional open-pit and underground mining. The in situ leaching method has several significant environmental advantages:

1. Significantly less surface area is disturbed than in surface mining, and the degree of disruption is much less.

2. No mill tailings are produced, and the volume of solid wastes is reduced significantly. The gross quantity of solid wastes produced by in situ leaching is generally less than 1% of that produced by conventional milling methods [more than 948 kg (2090 lb) of tailings usually result from processing each metric ton (2200 lb) of ore].

3. Because no ore and overburden stockpiles, or tailings pile(s), are created and the crushing and grinding ore-processing operations are not needed, the air pollution problems caused by windblown dusts from these sources are eliminated.

4. The tailings produced by conventional mills contain essentially all of the radium-226 originally present in the ore. By comparison, less than 5% of the radium in an ore body is brought to the surface when in situ leaching methods are used. Consequently, operating personnel are not exposed to the radionuclides present in and emanating from the ore and tailings, and the potential for radiation exposure is significantly less than that associated with conventional mining and milling.

5. By removing the solid wastes from the site to a licensed waste disposal site and otherwise restricting them from contaminating the surface and subsurface environment, the entire mine site can be returned to unrestricted use within a relatively short time.

6. Solution mining results in significantly less water consumption than conventional mining and milling.

7. Socioeconomic advantages of in situ leaching include
   - ability to mine a lower grade ore,
   - a minimum of capital investment,
   - less risk to the miner,
   - shorter lead time before production begins, and
   - lower manpower requirements.

The primary disadvantage of in situ leaching of uranium is the potential for groundwater contamination. This, however, does not imply that conventional uranium mining necessarily has an advantage in regard to groundwater pollution. On the contrary, in situ leaching will have a less severe impact on groundwater quality than does conventional mining. Nevertheless, excursions of leach solution from the mining zones have

the potential to enter surface water and to contaminate nearby well water. Therefore, to confine the leach solution and mobilized ore zone elements to the mining zone, the operator must maintain a proper balance between injection and production. In the event of an excursion, monitor wells must be adequately spaced and screened to detect the advancing contaminant plume. These wells can be properly placed only if the hydrogeologic characteristics of the aquifer are adequately known. If an excursion is detected, the operator has the choice of implementing one or more methods, such as stopping the entire operation and then pumping all wells, to reduce its impact on the groundwater. However, some of the contaminants periodically may escape the influence of the pumping wells and will travel horizontally in the direction of the groundwater flow. Such impacts are unavoidable and, in most cases, correctable or negligible with monitoring and proper well-field pumping methods. R&D operations conducted at the site resulted in no excursions and demonstrated that groundwater can be restored.

2.3.6 Mining and milling waste disposal alternatives

2.3.6.1 In situ solution-mining wastes

As stated in Sect. 2.3.5, no mill tailings (leached ore) are brought to the surface during in situ solution mining. Solution mining does produce contaminated solid wastes when the soluble constituents are precipitated from the recovery-plant bleed and aquifer restoration waste streams during evaporation or treatment. These solid wastes, typically less than 1% of the wastes produced by other mining and milling methods, must be disposed of by using the criteria for mill tailings disposal discussed below.

The preferred disposal method, proposed by the applicant, is to transfer these wastes to an active mill tailings disposal site or other licensed waste disposal facility in order to return the site to unrestricted use and minimize the number of final disposal sites for which long-term surveillance must be provided. This method will be required by license condition.

2.3.6.2 Mill tailings disposal

All other uranium mining and milling methods produce about 1 t (1.1 tons) of tailings for each metric ton (1.1 tons) of ore mined.

Objectives to be attained in tailings disposal programs

A satisfactory tailings disposal program must attain the following objectives:

1. reduce or eliminate airborne radioactive emissions (radon emissions are of primary concern because of the ease of dispersion of this inert gas),

2. reduce or eliminate impacts on groundwater, and

3. ensure long-term stability and isolation of the tailings without the need for continued active maintenance.

Numerous strategies for attaining these objectives have been suggested. For purposes of discussion, elements of these proposed strategies may be classified into four categories:

1. preparation of tailings for disposal (some methods involve changes in mill operations),

2. location of the tailings disposal area,

3. preparation of the tailings disposal area, and

4. stabilization and covering of the tailings.

Various tailings disposal programs that, when properly implemented, will meet the above objectives have been a topic of NRC study.[14]

2.3.7 Uranium extraction siting alternatives

2.3.7.1 In situ siting alternatives

The injection and production well locations limit the locations of the concentration, purification, and precipitation processing steps to locations within practical and economic pumping distances from the producing well field. The necessity for a suitable site for the evaporation pond may further limit flexibility in plant location.

2.3.7.2 Mill siting alternatives

The most important factor to be considered during the mill site-selection process is its close proximity to an optimal tailings disposal location. In this regard, the selection of a mill site is considered by the staff to be subordinate to, and dependent upon, the selection of a site for long-term disposal of the tailings wastes produced during mill operation. Other factors considered in evaluating the siting of the mill are as follows:

1. proximity to producing mines and known ore bodies, for decreasing the impacts associated with ore transport;

2. remoteness from populated areas;

3. availability of housing and other services to employees; and

4. nonexistence of unique habitats that might support protected, threatened, or endangered wildlife species.

The applicant did not propose conventional mining and milling as a viable alternative. The staff agrees that conventional methods are not economically viable for resource recovery from this ore body.

2.3.8 The alternative of processing in an existing mill

In Sect. 2.3.5 the staff has concluded that surface mining this ore body is not economically feasible. Underground mining is even more costly.

The staff estimates that transportation to the nearest operating uranium mill would cost an additional \$4.4 to \$6.4/kg (\$2 to \$14/lb) of U_3O_8 produced. This alternative is not an economically viable option.

2.3.9 Alternatives specific to in situ leaching

2.3.9.1 Alternative lixiviants and oxidants

The ideal lixiviant for in situ leaching will oxidize the uranium, complex the uranium to maintain it in solution, and minimally react with the nonuranium constituents of the host formation.[21] However, ". . . no lixiviant is entirely inert to the other minerals commonly associated with sedimentary uranium deposits . . . therefore, lixiviant agents and concentrations must be adapted to each ore body to assure maximum uranium recovery while minimizing undesirable reactions . . ." (ref. 26, p. 11). Salt solutions of ions, such as bicarbonate, carbonate, or sulfate, which form stable aqueous complexes with hexavalent (or soluble) uranium, are the most commonly used lixiviants. The leaching solution may be either acidic or basic, depending primarily on the mineralogy of the ore deposits.

Acidic lixiviants are best suited for low-alkaline (low-carbonate) ore deposits. However, acidic solutions are usually less selective for uranium (i.e., they tend to dissolve other trace minerals present in the ore such as aluminum, iron, copper, zinc, zirconium, selenium, arsenic, vanadium, and molybdenum). Excessive precipitation of calcium sulfate ($CaSO_4$) may also cause plugging of the leaching channels.[25] A solution containing sulfuric acid (H_2SO_4) is the most commonly used acidic lixiviant. Nitric acid (HNO_3) or hydrochloric acid (HCl) might also be used; however, these reagents are relatively expensive.[25]

Basic lixiviants are preferred for the leaching of high-carbonate ores because such ores will neutralize substantial quantities of an acidic lixiviant, increasing operating costs. The use of an alkaline leach solution may result in a lower uranium recovery rate than if an acidic lixiviant were used; however, lower concentrations of unwanted nonuranium ore constituents are produced. Typical alkaline solutions contain $NaCO_3$, $NaHCO_3$, or $(NH_4)HCO_3$.

Because oxidation ultimately controls the uranium recovery efficiency, oxidizing agents such as air, oxygen (O_2), hydrogen peroxide (H_2O_2), sodium chlorate ($NaClO_3$), sodium hypochlorite (NaOCl), and/or potassium permanganate ($KMnO_4$) may be injected along with the lixiviant to increase leaching effectiveness (or they may be generated within the ore zone through the actions of the lixiviant on associated nonuranium minerals).[21] For the project, the intended primary oxidizer will be oxygen with hydrogen peroxide used as a second choice.

2.3.9.2 Alternative aquifer restoration methods

After cessation of leaching operations, procedures must be implemented to reestablish the quality of affected groundwater to levels commensurate with premining levels. Restoration is accomplished by reducing, via removal or immobilization of unwanted chemical species, the concentration of toxic contaminants remaining in the aquifer to levels such that the water is returned to premining potential use. Several alternative restoration methods exist; however, because application of these techniques to full-scale commercial operations is limited, groundwater restoration technology is still in the developmental stage. Preliminary results based on experimental pilot-scale projects indicate that restoration of all species to near baseline levels and/or drinking water levels is achievable.

Natural restoration

Natural restoration is a passive or "no-action" aquifer cleanup alternative that relies on the innate capacity of typical uranium ore-bearing strata and uncontaminated groundwater to trap the environmentally objectionable chemical elements solubilized by leaching; that is, naturally initiated geochemical mechanisms — such as reprecipitation, ion exchange (usually with clay material), adsorption, and reduction — may be capable of purging the affected area of polluting elements. ". . . The concept of natural groundwater quality restoration may have particular merit in uranium leaching . . ." (ref. 26, p. 76). Reprecipitation and ion exchange mechanisms — which tend to immobilize CO_3, SO_4, NH_4, Fe, Mn, U, and V — and adsorption, which is effective in removing common heavy metal trace elements, can purge significant amounts of contaminating ions." Additionally, ". . . Migration of contaminated waters outside the immediate mining-affected area will bring the dissolved metal complexes into contact with reduced and less altered rock where reduction and precipitation of dissolved chemical species are likely to occur . . . [T]hese reactions are analogous to reactions responsible for the deposition of ore and associated minerals [and have] been observed where uranium-bearing lixiviants have come into contact with reduced sandstone in the periphery of a producing well field . . ." (ref. 26, p. 60).

Although it is possible that aquifers contaminated by in situ uranium leaching operations can be naturally restored, it is very difficult to

predict before commencement of operations when and if (or to what extent) groundwater pollutants can be reduced to acceptable levels; therefore, in-depth, site-specific analyses would have to be performed before this no-action alternative could be justified. Because few experimentally obtained results are available, the NRC has heretofore required and will continue to require the implementation of active restorative means, such as clean water circulation, to ensure compliance.

Groundwater sweeping

Groundwater sweeping consists of the extended withdrawal of water from the ore zone aquifer. The water withdrawal induces the flow of uncontaminated water into the leach field from the surrounding areas of the ore zone aquifer. By the optimal selection of withdrawal well locations, contaminants will be swept toward the withdrawal wells and thus removed from the aquifer. The amount of water withdrawn during groundwater sweep restoration is a function of the hydrologic and chemical properties of the affected area. Substantial improvements in water quality are usually noted after the withdrawal of one or two pore volumes of water. The term *pore volume* refers to the amount of groundwater in the leach field: 1 pore volume = area of well field x average affected aquifer thickness x porosity/100%. For all mining units of the proposed Teton project, the affected volume is approximately

(28.4 ha) x (10.6 m average affected thickness) x (25%) = 754,988 m^3,

or

(80 acres) x (35 ft average affected thickness) x (25%) = 700 acre-ft.

When one or two pore volumes of water have been withdrawn, the effects of mixing the incoming groundwater with the residual lixiviant become prominent and the contaminant concentrations decrease more slowly toward baseline levels. Complicating factors arise, such as cation desorption from clays and feldspars (ammonium ion from ammonium bicarbonate lixiviants[25] or hydrogen ion from acid lixiviants[27]) or the persistent concentrations of toxic trace elements in excess of allowable levels. Therefore, five to ten or more pore volumes could be withdrawn to accomplish final restoration.

At this point, it is impossible to estimate accurately the required number of pore volumes that would be needed to restore the proposed mining units by groundwater sweeping alone. At the R&D facility, the feasability of restoring the groundwater using a combination groundwater sweep and clean water recirculation was demonstrated. Based on the proposed time table of eight years of mining and nine years of restoration and on the R&D test data for a combination groundwater weep and clean water recirculation, the projected total water to be pumped from the ore zone and discharged to the evaporation ponds for restoration of the proposed commercial scale mine is about 7.96×10^5 m^3 (645 acre-ft).

Clean water recirculation

Clean water recirculation involves the withdrawal of contaminated water from the ore zone aquifer, physical and/or chemical treatment of the water to reduce the dissolved solids and toxic contaminant content, and reinjection of treated water into the ore zone aquifer. This recirculation will sweep contaminants toward the production wells, where they are withdrawn and removed from solution.

Therefore, clean water recirculation is similar to groundwater sweeping in that both methods use flows of uncontaminated water to cleanse and stabilize the affected areas of the ore zone aquifer. However, the use of water treatment and recycle may greatly reduce the water consumption of clean water recirculation relative to that of groundwater sweeping. Some forms of chemical restoration, which will be discussed below, may also be applied to clean water recirculation to facilitate restoration and offer further reductions in water consumption.

Several alternative water treatment processes exist for the separation of contaminants from restoration streams. Where the general dissolved solids content of the water must be decreased, the processes of reverse osmosis, electrodialysis, distillation, ion exchange, or freeze separation may be employed. In cases where control of specific contaminants is desirable, chemical precipitation, ion exchange, and carbon adsorption may be employed. The performance characteristics and costs of each of these alternatives are addressed below. The cost data are drawn from a U.S. Bureau of Mines (USBM) study of groundwater restoration technology,[30] and costs are updated to January 1982.

General techniques for reduction of total dissolved solids (TDS)

1. Reverse osmosis (RO). This technology is receiving much attention in the in situ leaching industry as a prime salt removal/water purification process; RO employs a polymeric membrane that is permeable to water but relatively impermeable to salts. By exerting a pressure of several hundred pounds per square inch across the membrane, water will migrate through the membrane, leaving the salts in a concentrated brine. The product stream is low in total dissolved solids (TDS) and contains from 70 to 90% of the water in the feed. The brine containing almost all of the salts and 10 to 30% of the water in the feed is discharged to an evaporation pond for disposal. Equipment for RO is commercially available for in situ leach restoration activities. The estimated total cost (January 1982 dollars) is \$0.35 per 1000 L (\$1.33 per 1000 gal).[30]

2. Electrodialysis (ED). Like RO, ED is a membrane process used in water desalting and chemical recovery. Electrodialysis involves two selective membranes that sandwich the stream to be treated. As an electric current flows through the membranes and water stream, the contaminant ions from the stream pass through the membranes into waste stream compartments. A single ED unit [818 m^3/d (150 gpm)]

will remove from 20 to 50% of the salt content from the solution.[30] By adding multiple stages, salt removal in excess of 90% is possible[31] with a loss of less than 10% of the feedwater to the brine.[32] Although some redesign may be required, commercial ED equipment is available for application to restoration activities.[30] From the USBM study, the total cost of ED treatment is estimated to be $0.48 per 1000 L ($1.81 per 1000 gal). However, for large-scale operations at high TDS levels, the cost advantage of RO technology vanishes.[31,32] Therefore, more extensive study may be required to define the relative merits of ED and RO in a given situation.

3. Distillation. Distillation is widely used in the commercial desalination of brackish and saline waters. Among the many variations available, multistage flash evaporation and vapor compression evaporation appear most suitable for use in restoration. Evaporation is an energy-intensive process, basically requiring 2321 kWh of heat to vaporize 3800 L (1000 gal) of water. However, multistage flash evaporation or vapor compression evaporation reduces the overall energy requirement.

   Multistage flash evaporation units have a series of flash evaporator stages that operate at progressively lower pressures and boiling points. Heated water is allowed to partially vaporize and cool in a flash chamber. The salts stay in the liquid and pass on to the next chamber. The lower pressures and boiling temperatures of each succeeding chamber allow additional evaporation of water from the brine. The steam vapor from each flash stage is conducted to heat exchangers, where it gives up heat to the feedwater. Thus the heat is used over and over. This configuration reduces the heat requirement to the range of 24 to 111 kWh per 1000 L (90 to 420 kWh per 1000 gal).[31]

   The vapor compression evaporator operates by compressing the steam vapor from an evaporation chamber to a higher pressure (raising the temperature) so that the heat in the vapor may be used to boil more water. This heat recycling reduces the energy requirement (mainly in the form of electricity) to the range of 7 to 24 kWh per 1000 L (26 to 90 kWh per 1000 gal).[31]

   The distillation processes examined above are capable of producing a very low TDS restoration stream containing over 90% of the water in the feed solution. The salts are concentrated in a waste brine, which is discharged to an evaporation pond for disposal. Both types of systems may be assembled from commercially available equipment. Portable skid-mounted vapor compression evaporation units have been used by the U.S. military for production of potable water at remote bases.[33] Diesel- or gasoline-powered units based on this technology may be attractive for use at remote in situ leaching projects where no electric service is available.

Recent cost increases in fuels and construction materials make projection of distillation treatment costs difficult. A recent study of a facility to treat 0.22 m^3/s (5×10^6 gal/d) of acid mine drainage by multistage flash evaporation cited operating costs of $1.57 per 1000 L ($5.94 per 1000 gal).[30] Total costs would exceed that figure. Vapor compression evaporation would also be expensive.[32,33] The staff considers evaporation energy intensive and uneconomic compared with other alternatives.

4. Ion exchange (IX). Contaminants and TDS may be removed from restoration streams by IX. Although nearly complete removal of TDS is possible with this technology, costs and water consumption are excessive for feed TDS concentrations greater than 350 to 500 ppm.[30] A preliminary design examining IX treatment of 2390 ppm restoration water indicated that spent regeneration brine and resin wash waste flows would be greater than 30% of the treated water flow.[34] In addition to the recovered dissolved solids and contaminants, the regeneration wastes would contain high concentrations of elution chemicals. Therefore, use of IX processes for TDS and contaminants may greatly increase evaporation pond and solid waste storage requirements relative to the other technologies previously discussed. The total cost of IX treatment under the USBM study conditions is estimated to be $1.06 per 1000 L ($4.03 per 1000 gal).[30] The increases in wastes and high costs make this alternative undesirable.

5. Freeze separation. When an aqueous solution partially freezes, the stream separates into two phases: (1) a solid ice that is nearly pure water and (2) a brine that contains nearly all of the dissolved solids in the feed. These two phases may be mechanically separated into a pure water stream (after melting) and a brine.

   Freeze separation is in the developmental stage and has not been applied specifically to restoration water treatment. Freeze separation is claimed to have potential for low costs, high water recovery, and effective contaminant rejection.[30,31] As with ED, the treatment costs for this system are strongly affected by the size or scale of the operation but are believed to be comparable to those of RO.[30] Further development is necessary to define the merits of freeze separation.

   At this time, only RO or ED are the best and only reliable cost-effective methods.

Techniques for specific contaminant removal

1. Chemical precipitation. Concentrations of chemicals (Ca, Mg, SO_4, and CO_3) and hazardous trace metals and radionuclides (radium, uranium, and thorium) may be reduced in solutions by means of lime precipitation. Very soluble ionic species, such as chloride, ammonium, and sodium, are essentially unaffected by the process.

Although significant reductions in TDS may be achieved, lime precipitation treatment alone is generally insufficient to achieve restoration goals. Therefore, precipitation treatment is usually teamed with general TDS removal systems (RO, ED, IX, distillation, etc.). Lime-based precipitation and softening pretreatment of RO and ED feed streams may be required to prevent fouling of membrane surfaces by sparingly soluble salts ($CaSO_4$, $CaCO_3$, etc.). Distillation, IX, and freeze precipitation units can be operated without chemical precipitation pretreatment.

Chemical precipitation uses the principles of super saturation and pH control to remove hardness ions and trace elements. The addition of lime [either as CaO or $Ca(OH)_2$] will increase the pH of the water stream. The added calcium ion will induce the precipitation of $CaSO_4$, $CaCO_3$, and other hardness-forming compounds. Some of the dissolved radium and barium will coprecipitate with the calcium. The increase in pH will cause the precipitation of such trace contaminants as arsenic, cadmium, iron, lead, manganese, mercury, selenium, silicon, silver, thorium, and zinc. Contaminants such as chromium, copper, molybdenum, uranium, and vanadium form soluble complexes or are otherwise soluble at high pH and may be only partially removed by lime precipitation.[26,35,36] The solid precipitate produced by this technique consists mainly of insoluble calcium salts but contains toxic trace contaminants and radionuclides. Therefore, the wastes must be isolated from the environment in some form of long-term disposal impoundment.

2. Ion exchange (IX). Specific contaminants may be removed from restoration wastes by IX or solvent extraction techniques. This is possible for contaminants such as uranium, vanadium, and molybdenum, which have a strong affinity for weak base anion exchange resins. Because general TDS removal is not being attempted, the water consumption and chemical costs of this alternative are not excessive. The recovery of additional uranium and valuable by-product metals may offset the added cost of the system.

3. Carbon adsorption. Activated carbon is commonly used in water treatment processes to adsorb trace elements. This technique has been used to control molybdenum[37] and vanadium[38] contamination of elution systems of uranium recovery processes employed at in situ leaching facilities. When used in conjunction with lime precipitation, carbon adsorption can achieve reductions in arsenic, selenium, and vanadium concentrations by greater than 90% in industrial wastewater.[36]

Chemical restoration

To facilitate restoration by natural groundwater sweeping or clean water recirculation methods, the addition of specific chemical agents may be beneficial. The function of possible additives includes chemical reduction and stabilization, neutralization, and elution of contaminants from clays and other ion exchangers.

Hydrogen sulfide and sodium sulfide have been identified[26,30] as potentially effective reducing agents. Anaerobic bacteria may also be used to establish reducing conditions in an aquifer.[30] The successful application of reducing agents may result in the transformation of soluble, highly oxidized uranium, vanadium, and other toxic contaminants to insoluble reduced forms. Concentrations of major cations and anions (sodium, calcium, magnesium, sulfate, bicarbonate, carbonate, chloride) are not significantly affected by this treatment.[26] However, the injection of reducing agents has not yet been successfully applied to uranium in situ leach restoration.

Neutralization may be a useful step in the restoration of acid-leached aquifers. The injection of sodium hydroxide would result in the desorption and neutralization of acidic hydrogen ions adsorbed on clays and feldspars. The resulting shift in the pH of the aquifer would lead to the precipitation of acid-soluble, heavy-metal contaminants.[27]

Attempts have been made to remove adsorbed ammonium ion from clays through the use of saline solutions of sodium, calcium, and/or magnesium. The concentrated calcium and magnesium salts force the ammonium off the ion exchange sites of the clays. The desorbed ammonia is then withdrawn from the aquifer and removed from solution.

Because the proposed lixiviant for the Teton project is of the sodium carbonate/bicarbonate type, ion adsorption by clays is not expected to affect restoration. The restoration of the R&D plot showed no particular need for chemical-reducing agents. However, it is possible that conditions in the commercial mining units may make the use of a reducing agent necessary. Details and evaluations of the applicant's proposed commercial scale groundwater restoration and R&D restoration programs are discussed in Sects. 2.3.10.3 and 4.3.2 and Appendix F.

2.3.10 Details of the applicant's proposed operation

2.3.10.1 Well field

Well field design and operation

Teton Exploration Drilling Company intends to employ a conventional five-spot well pattern (or an equivalent, staggered line drive pattern) comprised of four injection wells surrounding one central recovery well. The five wells are collectively termed a production cell. The cell dimensions are anticipated to be approximately 15 m (50 ft) by 30 m (100 ft) in the M zone and approximately 18 m (60 ft) by 37 m (120 ft) in the N zone, with the respective recovery wells centrally located within these rectangular cells. All wells will have the capability of acting as either injection or recovery wells to enable well field flow reversal to take advantage of the flow-path alterations and improved oxidation potential. In addition, interchangeable wells will facilitate groundwater restoration. During operation, leach solution will flow from the injection wells to the recovery wells, with about 0.5% more

water being recovered than injected, creating an overall negative hydraulic stress in the well field areas. Under this stress, the overall groundwater movement will be toward the well field areas. The average production per recovery well will be about 136 m^3/d (25 gpm). The injection rates will vary with the hydrology and the geometrical configuration of the well field but will be about 0.5% less than recovery-well flow rates. Injection pressures are expected to operate at 0.69 MPa (100 psi) or less. This injection pressure is in the same range as other in situ mining operations in the state.[34,38] The staff estimates that 0.014 MPa/m (0.63 psi/ft) of well depth is the minimum pressure that could initiate hydraulic fractures (value based on lithostatic pressure only). This estimate is conservative; actual pressures required for fracturing will exceed this value. However, the applicant will monitor injection wellhead pressures to ensure that this value is not exceeded during production.

The production cells will be distributed over six areas in the M zone and two in the N zone of the mine ore body, with each area constituting a separate mining unit (Figs. 2.2 and 2.3). The R&D well fields for the N and M ore zones are located in the area where mining units I and VII overlap (Fig. 2.1). Each mining unit will consist of a reserve block of approximately 12 to 13% of the total recoverable U_3O_8. Each mining unit is dedicated to only one ore zone and is anticipated to operate at between 6540 and 8175 m^3/d (1200 and 1500 gpm). No injection or recovery well will simultaneously communicate with M and N zone sands. The M sand will be mined first. Mining the six M zone and two N zone units will take an estimated 6.5 and 1.5 years, respectively, totaling eight years of active mining.

The proposed mining schedule for each of the mining units is tabulated in Table 2.8, along with the anticipated groundwater restoration schedule. Figures 2.2 and 2.3 show the details of the Leuenberger in situ uranium mining plans for M and N production zones respectively. For example,

Table 2.8. Teton proposed mining and reclamation schedule

Mining unit	Mining years after commencement	Reclamation years after commencement
I	0–1.5	1.5–2.5
II	0.5–2.0	2.5–3.5
III	1.5–3.5	3.5–4.5
IV	2.5–4.5	4.5–5.5
V	3.5–5.5	5.5–6.5
VI	5.0–6.5	6.5–7.5
VII	6.0–7.5	7.5–9.0
VIII	6.5–8.0	9.0–10.5
Site decommissioning		10.5–11.0

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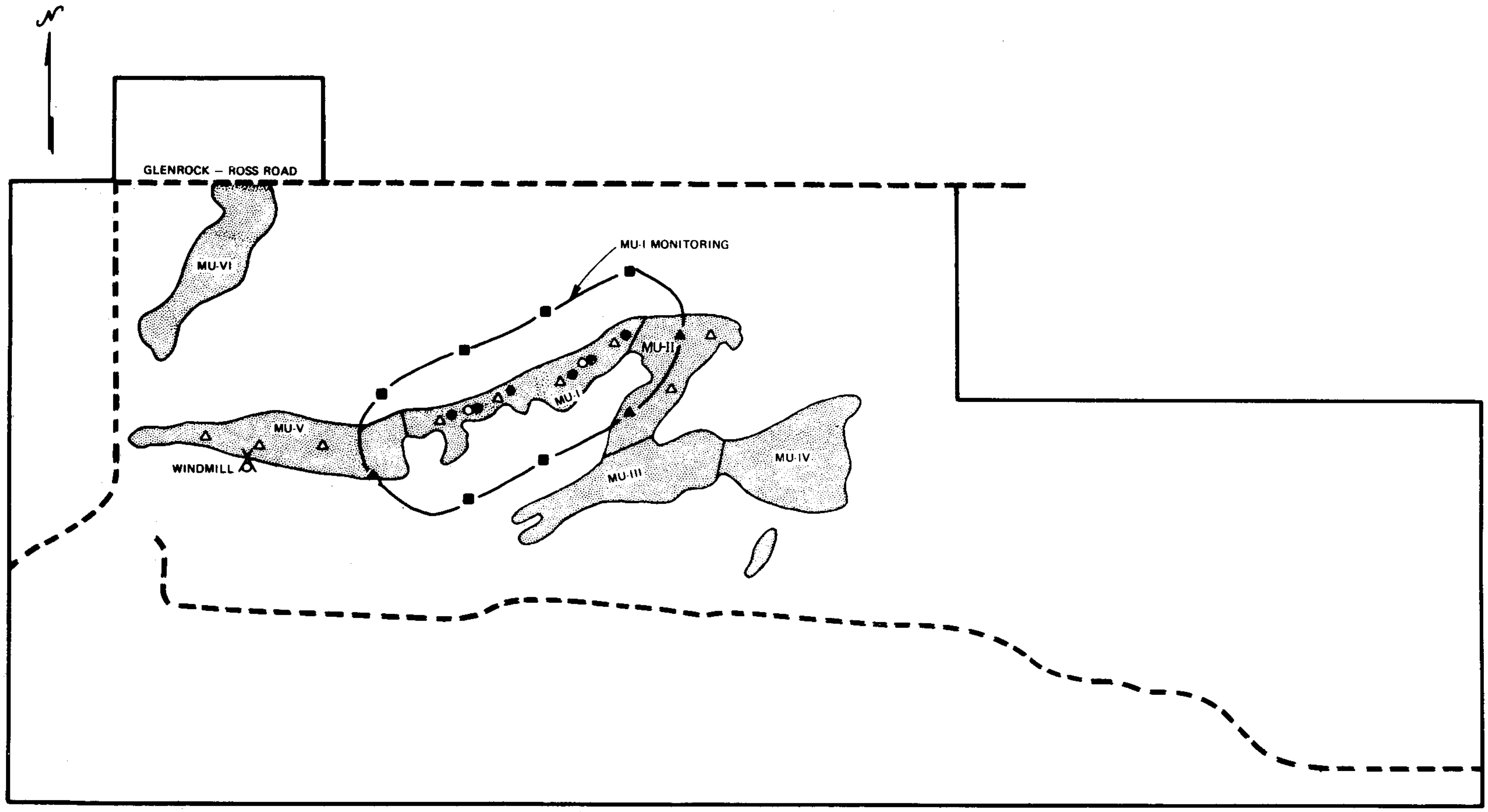

■ PROPOSED LOCATION OF MU-I MONITOR RING WELL
▲ M AQUIFER MONITOR WELL USED TO ESTABLISH BASELINE FOR RESTORATION
△ M AQUIFER WELL USED TO ESTABLISH BASELINE FOR RESTORATION
● N AQUIFER MONITOR WELL
○ O AQUIFER MONITOR WELL
● BASAL AQUIFER MONITOR WELL
M PRODUCTION ZONE

PROPOSED SCHEDULE

	MINING AFTER COMMENCEMENT (yr)	RECLAMATION AFTER COMMENCEMENT (yr)
MU-I	0–1.5	1.5–2.5
MU-II	0.5 – 2	2.5–3.5
MU-III	1.5–3.5	3.5–4.5
MU-IV	2.5–4.5	4.5–5.5
MU-V	3.5–5.5	5.5–6.5
MU-VI	5–6.5	6.5–7.5

0 1000 2000 ft
0 0.2 0.3 0.4 0.5 km

Fig. 2.2. In situ uranium mining plan for the M production zone of the Teton-Nedco project site.

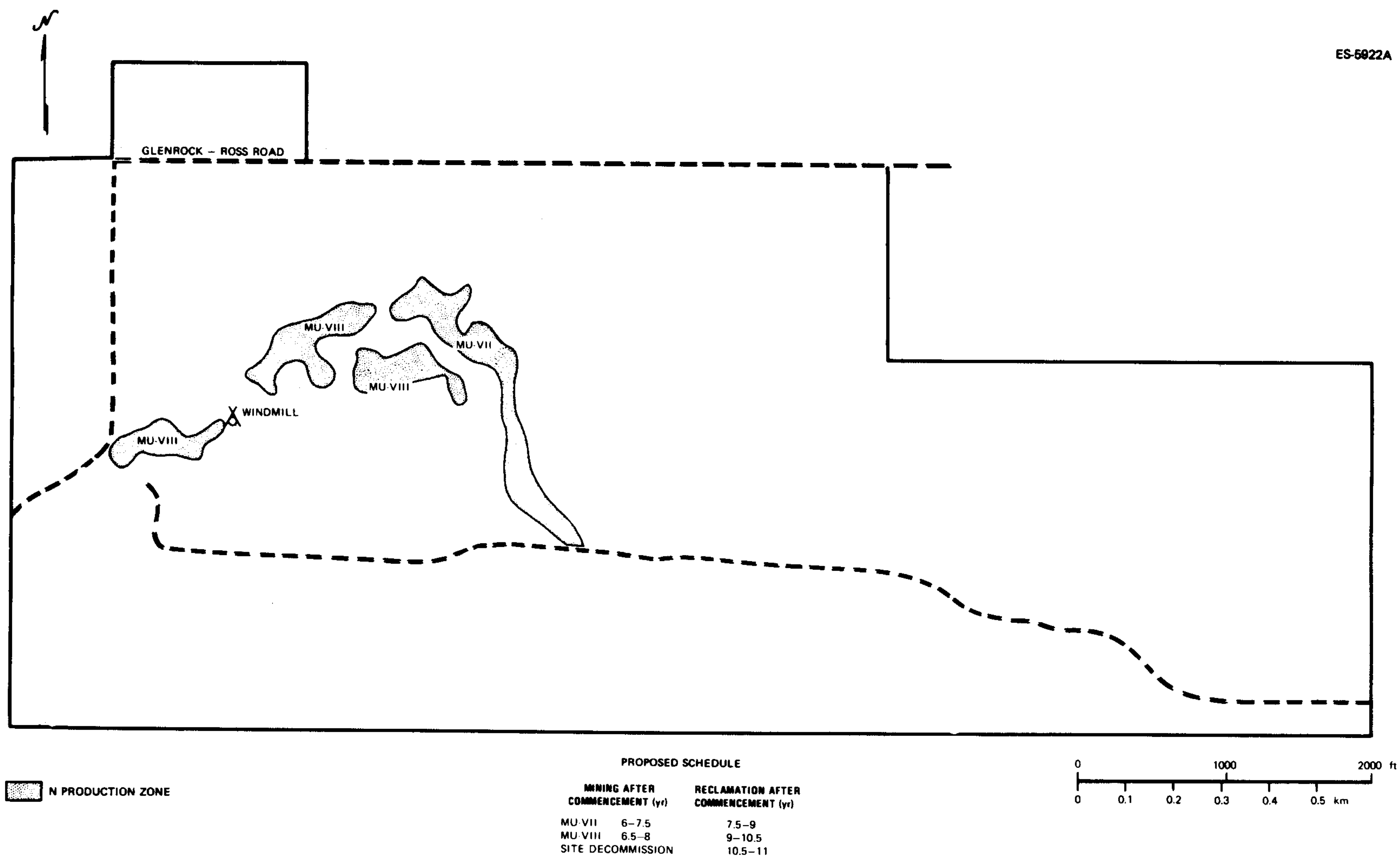

Fig. 2.3. In situ uranium mining plan for the N production zone of the Teton-Nedco project site.

Mining Unit I will be used to mine the first M production zone and will consist of approximately 170 wells and will cover about 3.2 ha (8 acres). Figure 2.4 shows the well field layout and piping used, for example, in Mining Unit I. The pregnant leach solution pumping rate from the entire first mining unit, when operational, will be about 6540 to 8175 m^3/d (1200 to 1500 gpm).

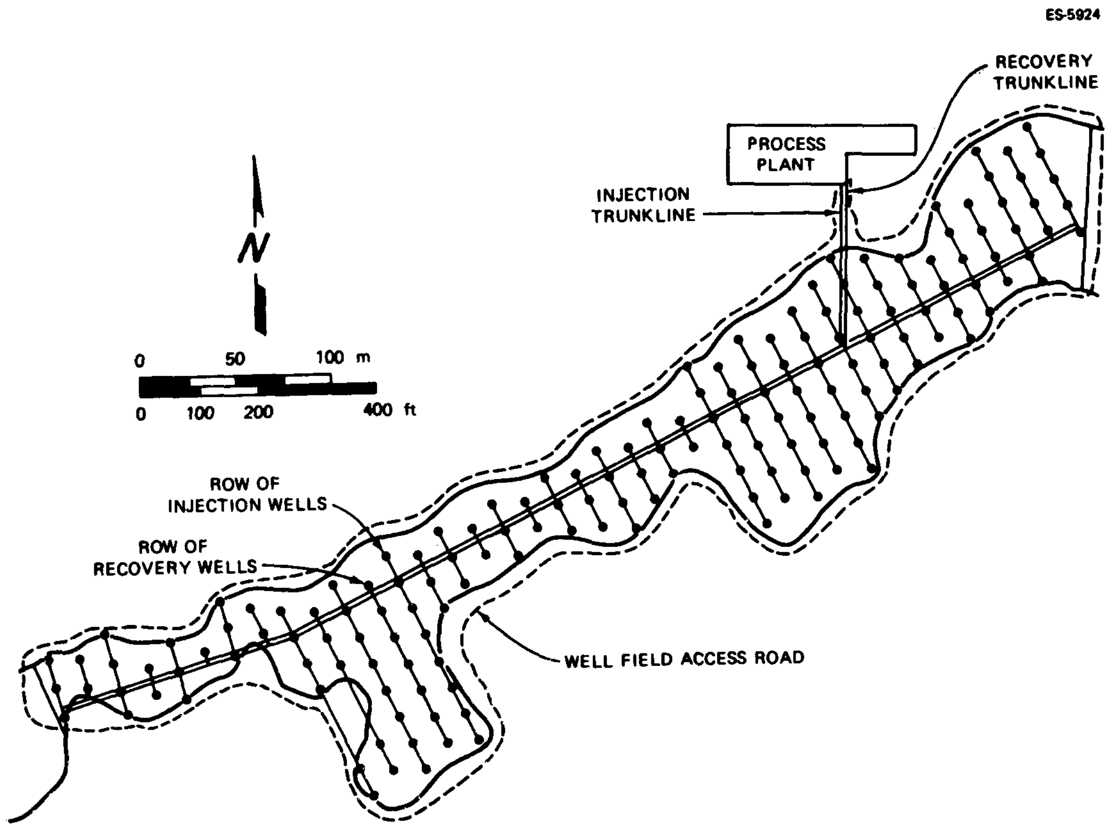

Fig. 2.4. Typical well field layout for mining unit I at the Teton-Nedco project site.

Each line of injection and recovery wells will be connected to injection and recovery manifold lines respectively. These pipe lines will be plumbed to a trunk line to carry solutions to and from the process plant. All well field piping will be either polyvinyl chloride (PVC), high-density polyethylene, or fiberglass and will be encased in heat-traced insulation. The piping will be installed flush with ground level for accessibility and safety.

M zone wells that intersect with the N production zone areas may be cemented off above the M zone after M zone mining and groundwater restoration. These wells may be utilized later in the N zone mining phase by underreaming the casing and resetting the screen.

Although the total number of production and injection wells required to solution mine the Teton ore body will depend on local hydrologic conditions and estimates from final results of the R&D operation, the staff estimates that about 1020 wells will be needed for the presently defined ore body. This estimate is based on 170 wells to mine the M zone of Mining Unit I. In addition, drilling and completion of about 120 monitor wells to detect possible lateral and vertical excursions are proposed. Excursion monitor wells will be placed as described in Sect. 4.4.2.5. Monitor wells for the N production zone will be open to the N aquifer, and monitor wells for the M production zone will be open to the M aquifer.

Well construction

The Teton well construction method will allow injection and recovery wells to be interchanged by drilling and completing injection and recovery wells to the same specifications. Figure 2.5 shows the anticipated design for injection and recovery well completion. Each injection and recovery well will initially be drilled through the target ore sand to the top of the underlying claystone. The hole will then be geophysically logged and the ore interval(s) selected. Each well will then be reamed down to the top of the selected ore interval to a size large enough to readily accept surface casing. After the casing has been set, the well casing annulus will be cemented in place to ensure that the production zone is hydraulically sealed from overlying horizons. After the cement has set, the target ore interval will be underreamed with a blade-type underreaming tool. Screen will be telescoped through the casing and set with the use of blank casing and screen packers so that only the sand containing economic mineralization will be leached. The well will be developed before leach solution injection and recovery.

Wells will first be drilled with heavy drill collars that apply weight directly to the drilling bit. This pilot hole will be drilled as straight as possible. The hole will then be enlarged in diameter from 12.7 to 15.3 cm (5 to 6 in.) with a larger drilling bit.

After the larger diameter hole is finished, a 10.9- to 11.4-cm (4.3- to 4.5-in.) casing will be emplaced in the hole. The casing will be constructed of PVC or fiberglass and joined with glue, mechanical connections, or thread-type joints. A minimum of three centralizers will be used to maintain the casing in the center of the hole. The first centralizer will be located at the bottom of the casing string.

Once the casing run is complete, water will be circulated through the annulus to ensure that cement can be returned to the surface. With circulation established, the cement slurry will be introduced into the casing by pumping. A predetermined volume of cement slurry will be pumped to fill the entire annular area. The cement will be a light slurry, with bentonite or a mud product added to stop the cement from settling. Calcium chloride may be added to speed the set time. The cement volume will then be displaced out of the casing and into the annulus by chasing it with a

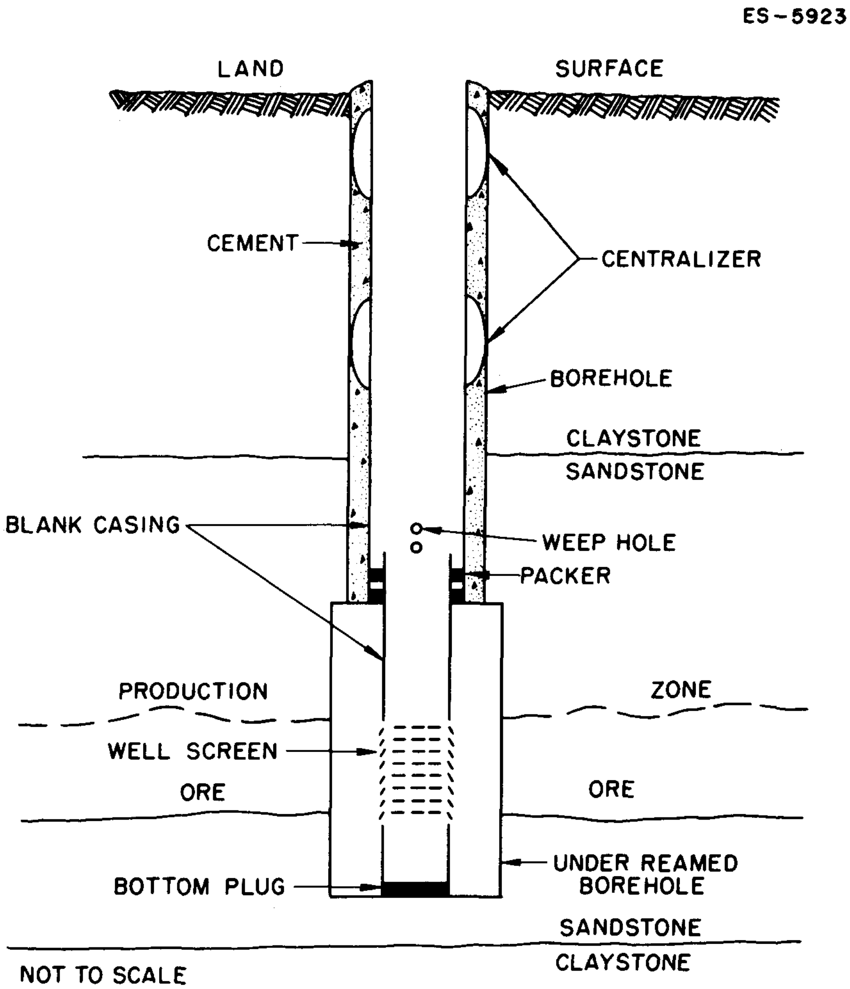

Fig. 2.5. Schematic of a typical injection and recovery well completion at the Teton-Nedco project site.

rubber washdown plug and water. When the plug reaches the bottom of the casing, the pressure in the system rises, thus indicating that all the cement is displaced. The pressure will not be bled off until the cement has set, and the casing will be securely held down at the surface to prevent the casing from floating while the cement sets. After the cement has set, which usually takes 12 h, the well will be drilled out past the bottom of the casing and through the zone host sandstone. The hole extension will be drilled with a non-clogging drill mud.

A screen assembly, consisting of a blank tail piece, screen, and blank riser pipe connected to a packer, will then be run into the well. The screen assembly will be less than 10.3 cm (4 in.) in diameter and will have a packer that is compatible with the inside diameter of the casing. The screen assembly will be emplaced at the bottom of the well with a stringer rod equipped with jets to wash the ore body sandstone from the screen openings.

For completion, the final well cleanup will be accomplished by using the stringer rod in combination with washing and air-bubbling cycles. The pressure will be increased gradually and the stringer rod run up and down throughout the screen-opening interval. This operation will be continued until only clean, sand-free water is circulated to the surface. Upon completion, the applicant will use high-pressure packer tests to check well integrity.[34]

Mechanical integrity

Before well operation, a field test will be conducted to demonstrate the mechanical integrity of the well casing. This mechanical test will be performed by packer test as recommended by the U.S. Department of the Interior.[39] The test consists of placement of two packers — first, within the casing and above the well screen, and second, below the wellhead. Then the packers are inflated and pressurized. The pressure rating of the casing will not be exceeded by predetermined setting of the wellhead pressure.

The well will be shut in after successful pressurization and the pressure readings recorded every 30 s for 10 min. If the pressure remains constant during this time, then the well will be acceptable for injection. If the mechanical integrity test fails, then the well casing will be checked for cracks or holes via downhole television or other methods. If possible, the well will be repaired and the packer test will be repeated. If any well casing leakage cannot be repaired or corrected, the well will be plugged and reclaimed as described in Sect. 2.3.10.5.[40]

The staff considers the applicant's proposed packer test procedures adequate for determining the mechanical integrity of production and injection well casings.

Results of the packer test will be reported to the NRC as a condition of the license. Mechanical integrity tests will be repeated every five years for wells still in use.[40]

Well abandonment

Production, injection, and monitor wells will be properly abandoned after the completion of groundwater restoration of a given mining unit. Abandonment of wells is accomplished by filling with a bentonite slurry and capping with cement below the surface to within approximately 0.6 m (2 ft) of the surface. The well casing at a depth of 0.6 m (2 ft) below the land surface will be cut off and removed, and the hole will be backfilled to the surface.

Any wells not abandoned in this manner will remain as water wells, and permits will be issued by the Wyoming state engineer. The engineer will be given the location of the well field areas and the range of depths of the production zones during site decommissioning.[40]

Well abandonment procedures will be in compliance with Wyoming statute W.S. 35-11.401 and W.S. 35-11.404 and the provisions of Chapter XV of the Wyoming Department of Environmental Quality Land Quality Division rules and regulations as amended in 1980.[41]

2.3.10.2 Recovery plant

Construction and appearance

The surface area affected by the proposed operation will be contained within the 308-ha (760-acre) permit area and will constitute a total of approximately 48.6 ha (120 acres). The significant surface features associated with the proposed Leuenberger in situ uranium mining operation are tabulated in Table 2.9.

Table 2.9. Affected surface area for Leuenberger operation

Description	Total affected area [ha (acres)]
Well field area	32.4 (80.0)
Processing plant	0.2 (0.6)
Solar evaporation ponds	11.6 (28.6)
Parking lot, auxiliary building, access roads, pipelines, etc.	4.4 (10.8)
Total	48.6 (120.0)

The processing plant facility for the proposed commercial operation will include the present 30-m-long by 15-m-wide structure (100 ft by 50 ft) used for R&D plus a proposed addition to the existing pilot operation approximately 61 m (200 ft) long by 30 m (100 ft) wide, with 7-m (24-ft) eaves and a 9-m (30-ft) center peak. An additional office expansion occupying 209 m^2 (2250 ft^2) will be added.

The processing plant will require a concrete foundation and will be enclosed for winter operation The plant foundation will be approximately 2532 m^2 (27,250 ft^2) and occupy 0.25 ha (0.63 acres). A parking lot, truck access, fuel storage tank, pipelines, chemical storage areas, auxiliary tool sheds, storage compounds, and access roads will constitute

the balance of surface disturbance at the Leuenberger site. The future layout of the expanded plant building and other existing and planned plant area facilities is given in Fig. 2.6.

Electric utility service will be used to operate the commercial plant, and diesel generators will provide an emergency source of power. Berms will be established around the existing diesel fuel, process chemical, and solution storage tanks. Salvageable topsoil as identified in the Surface Reclamation Plan will be stockpiled and seeded before plant construction.

Uranium recovery process

The uranium recovery plant will use standard concentration and purification processes. Projected from pilot-plant test results, the expected uranium concentration in the pregnant liquor will average about 50 ppm of U_3O_8 but may vary from 50 to 85 ppm. Ion exchange resins function acceptably under these conditions and will be used in the process. The process plant will have a maximum flow capacity of 8176 m^3/d (1500 gpm) for the mining operation.

Recovery plants using resin ion exchange columns are organized into three sequential units: the leaching circuit, the elution/precipitation circuit, and product preparation area. To simplify plant operation and eliminate atmospheric releases of uranium concentrates, the yellowcake product will not be dried but will instead be shipped as an aqueous concentrated slurry. Because the leaching circuit includes the well field and the ore body, which lie outside the boundaries of the plant complex proper, it presents a greater potential for environmental effects than the other plant circuits (Fig. 2.7).

Leaching circuit

In situ leaching of uranium requires the circulation of a lixiviant that will oxidize the uranium to a soluble state and form stable uranium ion complexes easily recovered from the ore body. The Teton project will use a lixiviant consisting of sodium carbonate (Na_2CO_3) and sodium bicarbonate ($NaHCO_3$) and oxygen or hydrogen peroxide (H_2O_2) in water. Sodium carbonate/bicarbonate is used as a leach solution because of its selectivity for uranium and minor reaction with the gangue minerals. The pilot test was operated with sodium bicarbonate concentrations, apparently at about 2 g/L, and the commercial plant is expected to operate in the same range. On injection into the ore zone, the dissolved oxygen (250-400 ppm) reacts with the uranium minerals and brings the uranium to the U^{+6} oxidation state.

The uranium complexes with carbonate to give an uranyldicarbonate ion $[UO_2(CO_3)_2^{-2}]$ and an uranyltricarbonate ion $[UO_2(CO_3)_3^{-4}]$, which are soluble and readily recovered from the ore zone. When the ore minerals are disrupted by leaching, a small portion of the radium content will

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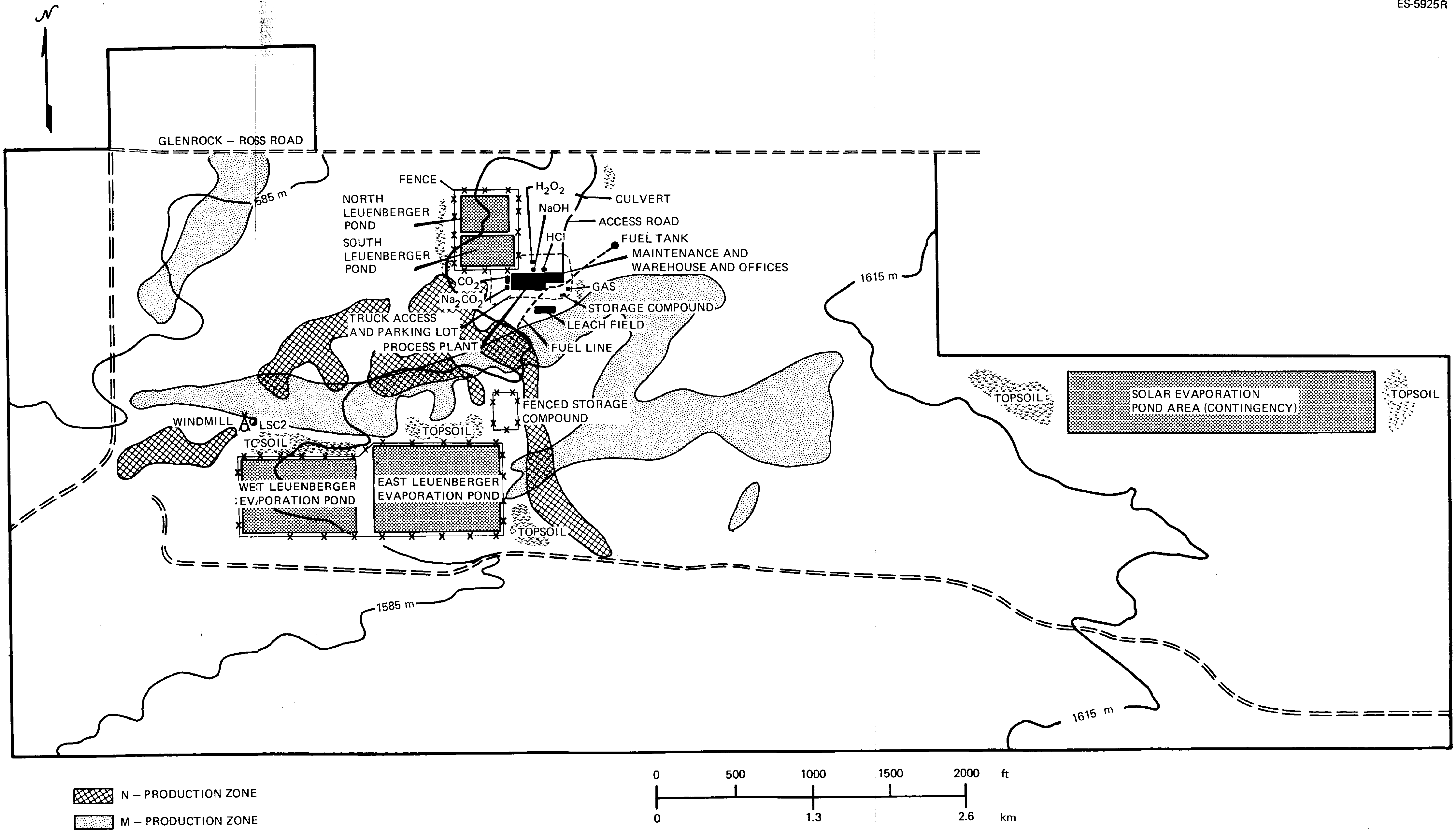

Fig. 2.6. Teton-Nedco site facility layout.

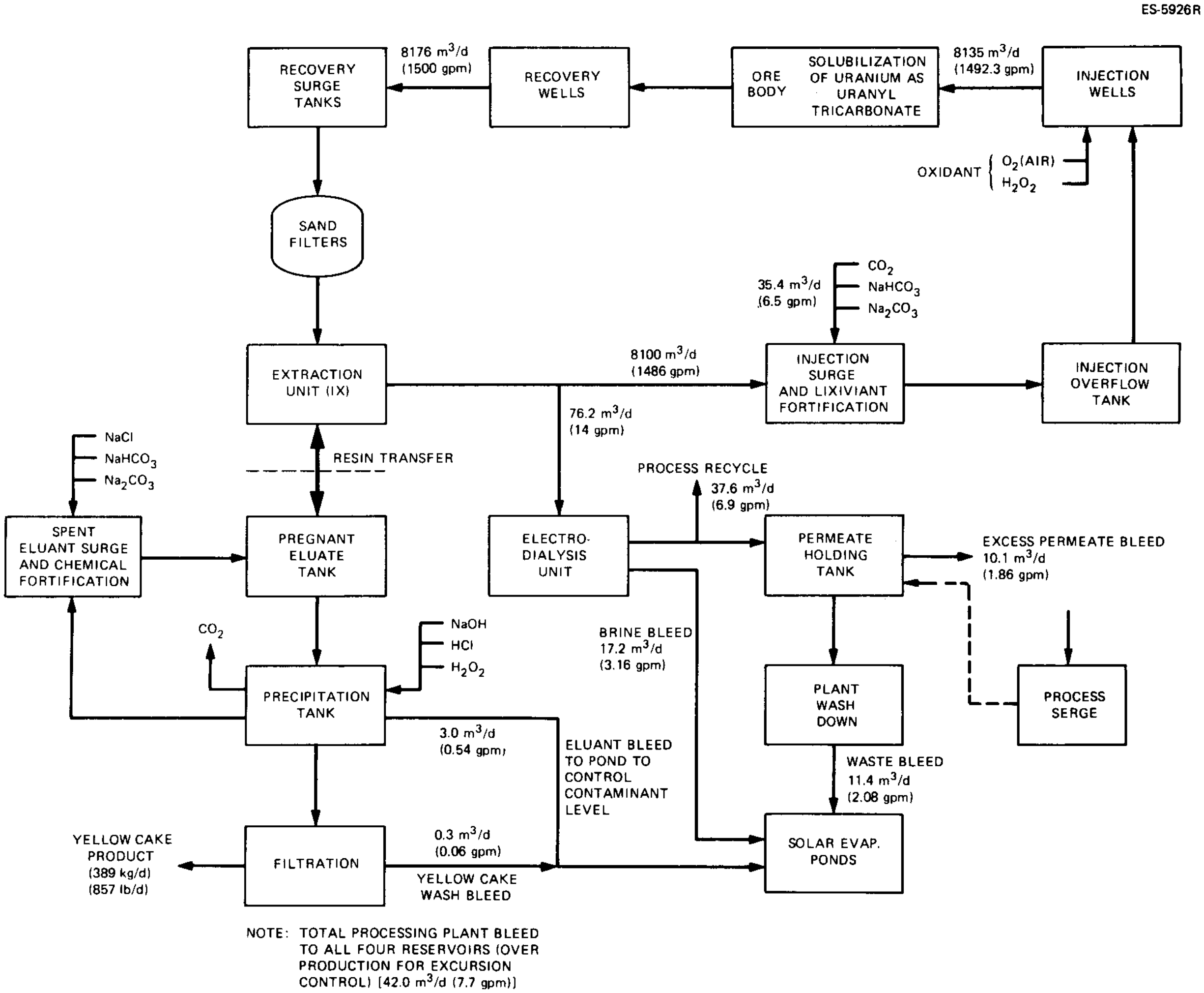

Fig. 2.7. Uranium recovery process flow sheet for the Teton-Nedco facility.

also be dissolved. Depending on site conditions, contaminants such as arsenic, barium, fluoride, lead, selenium, vanadium, and zinc may also be oxidized and mobilized.[42] However, the results of the pilot-scale test at this site do not show any major changes in trace element mobilization during leaching.[43]

At design capacity flow of 5678 L/min (1500 gpm), approximately 120 injection and 60 production wells would be in operation. The lixiviant output of these wells would be collected and pumped to the central recovery plant. The dissolution and complexing of uranium occur as the lixiviant flows through the ore body from the injection wells to the production wells. The lixiviant would be circulated through the ore zone as long as uranium extraction is economically feasible.

The uranium-bearing solution, or pregnant lixiviant, is directed to the ion exchange tanks. As the solution passes through the tanks, the ion exchange resin beads in the tanks preferentially absorb the uranyldicarbonate and/or uranyltricarbonate from the solution and release the

chloride ion back into the solution. The barren lixiviant leaving the tanks may contain less than 1 ppm of uranium. To remove the uranium from the resin and to make it available again for extraction, Teton will either transfer the resin to a separate elution tank or isolate the vessel containing the resin and perform in-place elution. The resin will be eluted by conventional means.

To control the spread of lixiviant from the ore zone, a leach-circuit average bleed of approximately 0.5% of recovery flow or 29.1 L/min (7.7 gpm) at the design flow rate is taken. The clean permeate would be utilized for process makeup water and, with the possible addition of a coprecipitation circuit to remove any remaining trace of radiometric constituents, would be utilized for plant washdown. The bleed stream maintains a hydraulic gradient toward the operating well field areas, thus minimizing leach-solution excursion potential. This gradient will result in a constant inflow of groundwater from the area surrounding the well fields.

The barren lixiviant is recycled, enters the injection surge tank, and is monitored for both pH (average approximately 6.5) and bicarbonate levels. Carbon dioxide and/or sodium carbonate/bicarbonate will be added as necessary to restore the lixiviant to its original strength. The solution is returned to the well field, where the oxidant (O_2 gas and/or H_2O_2) is added just before reinjection of the lixiviant into the ore zone. The leaching efficiency of uranium recovery in the mineralized ore zone is anticipated to be 65 to 80%.[44]

Elution/precipitation circuit

Teton will use a conventional batch-type elution system. The IX resin will adsorb uranium from mined solution until the IX resin is exhausted or fully loaded with uranium. The elution circuit purpose is to strip the uranium from the resin. The resin is then conditioned for reuse in the adsorption circuit. The applicant has estimated that the recovery of uranium from the IX circuit is 99+% efficient.

In the elution circuit, uranyldicarbonate/uranyltricarbonate is removed from the loaded resin by a chloride or sulfate ion solution. The solution to be utilized will be either 1.5 N sodium chloride or sodium sulphate and 0.5 N sodium carbonate.

A portion of the soluble uranium liquor will be diverted to decompose the carbonate present in the solution by evolving carbon dioxide gas. Hydrogen peroxide will be added to effect precipitation of the uranium as uranium peroxide. The uranium-depleted supernate will be reused in future elutions with the possible addition of sodium chloride or sodium sulfate and sodium carbonate as needed for reconstitution. A small portion of the supernate will be discharged to the brine pond at approximately 2 L/min (0.54 gpm) during process equilibrium. Additional bleed of the elution circuit may be required periodically to minimize impurities such as SO_4, Cl^-, V, and Mo, which could affect product purity.[40]

After precipitation, the yellowcake product is withdrawn to the product preparation area.

Product preparation area

The yellowcake (precipitated uranium, U_3O_8) from the elution/precipitation circuit will be washed to remove adsorbed contaminants and then dewatered to a thickened slurry. This slurry will be stored in tanks within the plant building prior to shipment. Because all uranium will be in a wet slurry, dust releases and hazards associated with yellowcake drying will be eliminated. Onsite inventory of U_3O_8 will typically be 22,679 kg (50,000 lb). The maximum weight of U_3O_8 maintained onsite in the event of inclement weather or other interruptions in product delivery will be 90,718 kg (200,000 lb).

Yellowcake drying equipment employed in conventional product preparation operations will not be used by the applicant. The yellowcake product from the Teton project will be stored and shipped as a slurry (50% U_3O_8 by weight) in approved drums. The yellowcake slurry will be transported in approved trailers to licensed facilities for further processing.

2.3.10.3 Proposed aquifer restoration program

Teton proposes to accomplish restoration through a combination of groundwater sweeping and clean water circulation which was demonstrated feasible at the R&D facility (see Sect. 4.3.2 and Appendix F). Aquifer restoration will be a continuous operation both during and after mining. The applicant will restore the well field aquifer to a quality for use equal to and consistent with the uses for which the water was suitable before mining, pursuant to Wyoming Statute W.S. 35-11.103f(iii) and applicable regulations. The water quality criteria to be used for groundwater restoration is prescribed and approved by the Wyoming DEQ and the NRC (Sect. 4.3.1).

The Mine Plan and Groundwater Restoration Plan are highly interdependent. The groundwater restoration program will normally commence about 1.5 to 2 years after a mining unit is first operating. As presently anticipated, the initial mining unit will be mined through the injection and recovery of leach solution at a circulation rate up to 5678 L/min (1500 gpm) for about six months before start-up of the second mining unit. The initial mining unit will be allowed to soak with no injection or recovery for about six months. During the next six months, the initial mining unit will be mined again by the injection and recovery of leach solution with reversed well field flow. During well field reversal, the old injection wells are used as recovery wells and vice versa. At the same time, Mining Unit II will be left to soak.

After this six-month period, the solutions in Mining Unit I will be sent to the process plant at a rate of 1893 L/min (500 gpm) for uranium extraction and chemical refortification, and groundwater from Mining Unit III will be transferred to Mining Unit I. Refortified solutions will be injected into Mining Unit III, which will be allowed to soak for

approximately four months in preparation for active leach-solution circulation and uranium recovery. Mining Unit I will be put on the restoration circuit at a rate of up to 757 L/min (200 gpm) after the water transfer from Mining Unit III. The transfer stage denotes the beginning of mining for one unit and groundwater restoration for the previous unit. Complete transfer will take approximately two months. Groundwater restoration, including transfer, should be achieved within 12 months for each mining unit.[40] Mining in unit IV shall not commence until the restoration of unit I has been demonstrated by the applicant and approved by the NRC.

This mining and groundwater restoration sequence will continue with the transfer of clean water from Mining Unit IV to Mining Unit II; the soaking and mining sequence will begin between Mining Units III and IV. This proposed plan will be followed throughout the operation. The anticipated time schedule showing the duration of mining and groundwater restoration for each mining unit is illustrated in Table 2.8. Water transfer will not be possible for the last two mining units because no new mining units will be brought on-line. Present plans call for straight groundwater circulation through an ED unit to effect groundwater restoration for these two mining units.[40]

The restoration circuit includes an ED unit where groundwater undergoing restoration is passed through the unit to improve the water quality. Approximately 80% of this water will be returned to the well field undergoing restoration as clean water permeate, and 20% will be sent to the brine pond for solar evaporation. The clean water permeate reinjected into the well field (80% of pumpage) will require a 20% addition from groundwater outside the well field areas or from groundwater in previously restored mining units.[40] The pilot-scale restoration program in the N zone required the recirculation of 18.22 pore volumes through the leached zone while removing 42.34 pore volumes for a net sweep of 24.12 pore volumes of untreated water (ER, Appendix D-6.5). Commercial-scale restoration, however, will use an ED unit to clean the water and remove only 20% as brine to be placed in the evaporation ponds. Data from the pilot-scale restoration program in the M zone, where an ED unit was used, indicate a significant reduction of water used compared with restoration of the N zone.

The design capacity of the ED unit for initial mining unit waste stream treatment is 757 L/min (200 gpm). Additional ED units will be installed by the applicant if necessary to speed up aquifer restoration.

Clean water recirculation will continue until restoration sampling indicates that the water quality in the affected aquifer meets established restoration criteria. To preserve potential water use, restoration criteria will be as close to baseline as reasonably achievable on a parameter-by-parameter basis (Sect. 4.3.1).

Postrestoration monitoring will be conducted to ensure the stability of the restored-water quality. A description of the monitoring program is in Sect. 4.4. If stable restoration has not been obtained, recirculation may be resumed as necessary. Once stable conditions are established, the well field will be decommissioned as described in Sect. 2.3.10.5.

2.3.10.4 Effluents and waste management

Atmospheric emissions and liquid and solid wastes will be generated by the operation of the Teton project. Because of the generally small scale of this operation, the magnitude of effluent emissions and waste generation will also be small, thus minimizing offsite impacts resulting from the operation (Sect. 4). A summary of the atmospheric emissions, liquid wastes, solid wastes, and proposed methods of control and management for each follows.

Atmospheric emissions

Radiological emissions. The only significant radiological atmospheric emission is that of radon-222. The radon will be released where lixiviant solutions are exposed to the atmosphere, such as at process surge tanks, ion exchange columns, or solar evaporation ponds. If the radon-222 baseline concentration is 50,000 pCi/L with a maximum flow of 7571 L/min (2000 gpm) [5678 L/min (1500 gpm) leach-circuit flow and 1893 L/min (500 gpm) restoration flow], the staff estimates the radon release per plant operating year to be 627 Ci/year. The applicant, using very limited pilot-plant data, estimated 72 Ci/year. The basic difference in the results is due to the staff's assumption that all radon-222 was released from solution.

Radiological atmospheric emission will be controlled by ventilation systems for all open process tanks. The systems will consist of 25.4-cm-diam (10-in.) heat duct piping where fresh air will be circulated across the top of each tank to be ultimately vented to the outside atmosphere. Fresh air will be drawn from outside the plant and controlled with flues installed near the air intake. High-volume exhaust fans will circulate the fresh air across the tops of the tanks and draw the gases and fumes to outside vents placed on the south sides of the buildings and above roof levels. A separate ventilation system will be used for each of the three functional areas within the process plant: ion exchange, elution/precipitation, and ED restoration (ER, Fig. 4-1).

The plant ventilation system is designed to circulate air within the process plant work area at the rate of two plant air-volume changes per hour [33,985 m^3/h (1.2×10^6 ft^3/h)]. The work area includes the three functional areas within the process plant. The ventilation system will consist of fresh-air intake louvers, wall fans, and convection vents in the roof of the plant.

Nonradioactive atmospheric emission. The principal nonradioactive atmospheric emissions from the Teton project will be suspended particulates and gaseous pollutants from the exhausts of vehicles and dusts from dirt road traffic. The exhaust emissions will result from the sources listed in Table 2.10. The primary source of pollutants will be the four 400-hp diesel engines on the drill rigs and two diesel-powered water trucks.[45] A rough approximation of the emissions from this diesel equipment is indicated by the source terms that the staff obtained for 400-hp diesel engines.[47,48] The source terms per engine

Table 2.10. Estimated equipment needs

Type and number	Fuel type	Estimated h/year	Purpose
Shallow-hole, truck-mounted drill rig, 4	Diesel #2	1200 each	Wellfield installation
2800-gal water truck, 2	Diesel #2	1200 each	Wellfield installation
Backhoes, 2	Diesel #2	400 each	Wellfield installation and maintenance
Small truck, 1	Gasoline	300	Well service and maintenance
Light truck (pickup), 6	Gasoline	1095 each	Routine operator duties
Plant forklift, 1	Propane	300	Loading and unloading process materials and supplies
Backup generator, 2	Diesel #2	No estimate	Backup for process plant and wellfield area

Source: ER, Response 1, Effluents and Waste Management; R. Kroodsma, ORNL, personal communication with Dick Appel, Teton-Nedco, Feb. 23 1982.

are: SO_x, 0.1 g/s; NO_x, 1.56 g/s; hydrocarbons, 0.12 g/s; carbon monoxide, 0.34 g/s; particulates, 0.11 g/s; and aldehydes, 0.02 g/s. Dust emissions from wind erosion and operations will be minimized through prompt reclamation of affected areas and establishment of vegetative cover on soil stockpiles. Dust releases resulting from project-related traffic should be small because of the low volume of traffic.

Other nonradiological gases are CO_2 gas and HCL-H_2O_2 fumes from the elution/precipitation circuit, but these gases are of low concentration and are environmentally insignificant.

Liquid wastes

Liquid wastes from the operation of the proposed project include the processing plant bleed stream, restoration waste brine, well-cleaning wastes, and office and personnel facility sanitary wastes. A water balance for the Leuenberger site is presented in Fig. 2.8.

The processing plant bleed stream will have an estimated flow of 42.0 m^3/d (7.7 gpm). This figure includes plant wash bleed [11.3 m^3/d (2.08 gpm)], eluant bleed [2.9 m^3/d (0.54 gpm)], yellowcake wash water [0.3 m^3/d (0.06 gpm)], brine bleed [17.2 m^3/d (3.16 gpm)], and an excess permeate bleed of 10.1 m^3/d (1.86 gpm).

The overproduction bleed will be directed to an ED unit to concentrate the waste (brine). Twenty to twenty-five percent of the brine is diverged to the holding ponds while the remaining volume (75-80%) is retained for later process use or stored as clean water permeate.

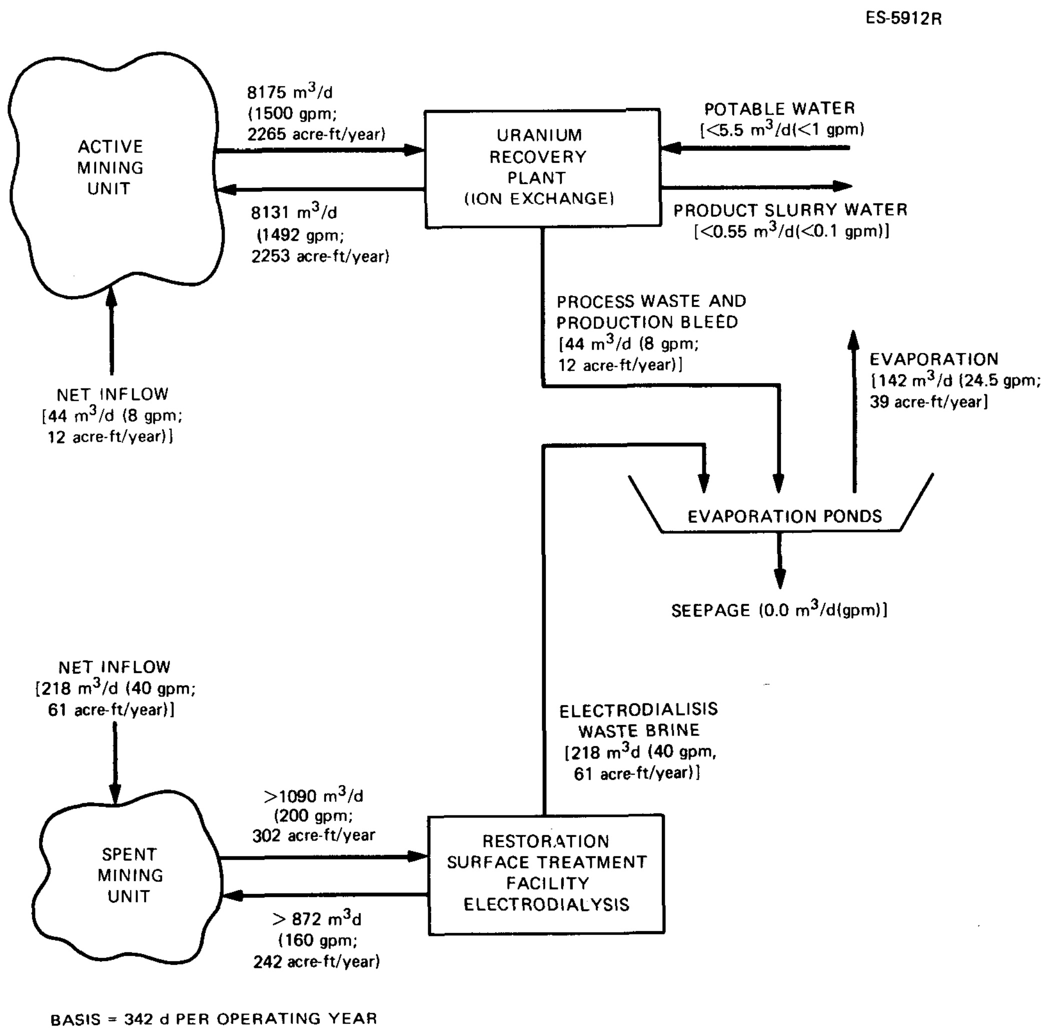

Fig. 2.8. Water balance for the Teton-Nedco project based on 80% efficiency of the electrodialysis unit.

Table 2.11. Expected chemical composition of water in Leuenberger ponds

All values are in mg/L unless otherwise indicated

Major source (anticipated pond)	Process bleed brine and restoration brine (East and West ponds)
U_3O_8	1.2
Chloride	430
HCO_3	6,500
SO_4	1,800
Calcium	900
Magnesium	220
Sodium	1,850
Potassium	150
^{226}Ra, pCi/L	750
Total dissolved solids	11,800

Source: ER, p. D-6.288.

The processing plant bleed, restoration waste brine, and well-cleaning waste will be impounded in evaporation ponds to prevent liquid discharge to surface water or shallow groundwater systems. The evaporation area required to evaporate the total wastewater production of 8.9×10^4 m^3 (73 acre-ft) per year, starting the second year of operation, at a net evaporation rate of 0.81 m (32 in.) per year, is about 8.3 ha (20.5 acres). The applicant plans to use four solar evaporation ponds with a total area of 6.0 ha (14.8 acres) and 2.6×10^5 m^3 (214 acre-ft) of capacity. Thus the applicant may run out of pond capacity by the ninth year of operation. The locations of these ponds are shown on the Site Facility Layout Map (Fig. 2.6) and are labeled as the North, South, East, and West Leuenberger ponds. An area east of these ponds has been designated for contingency ponds. The North and South Leuenberger ponds have been constructed under the R&D license in conjunction with the present ongoing research and development phase of the Leuenberger operation.[41] The evaporation pond system will have adequate reserve capacity maintained to provide alternate temporary storage of pond contents in the event of leakage from an operating pond and will maintain at least 0.6 m (2 ft) of freeboard under normal operating conditions to prevent spillover during a probable maximum rainstorm. The East and West ponds will not be located in or across drainages, and there will be no surface discharge from them. The engineering design and method of these two evaporation pond constructions will be similar to the ponds (North and South) built for the R&D project. The proposed construction of the East pond is shown in Fig. 2.9.

The North and South Leuenberger ponds have 0.8-mm (30-mil) Hypalon liners and separate leak-detection systems. The PVC pipes used for the leak-detection systems are slotted on the upper half and buried approximately 30 cm (12 in.) beneath the finished bottom grade of the pond. The pipes are bedded in free-draining gravel and sloped to the lowest elevation of the leak-detection system. The pipes are connected to vertical standpipes, which lead to the surface, and are approximately 13 cm (5 in.) in diameter with a removable cap placed at the top.[42]

The East and West Leuenberger ponds will be lined with Hypalon or equivalent material. Leak-detection systems will be installed. These systems will be connected to nonperforated pipe that will extend through the sides of the berm at the lowest point of the leak-detection system; each will be fitted with a cap, valve, and standpipe. Leak-detection systems will be designed, built, and monitored to conform with criteria in the Staff Technical Position Paper, WM-8101, "Design, Installation, and Operation of Natural and Synthetic Liners at Uranium Recovery Facilities," and the ponds will be designed and constructed to conform to the criteria presented in U.S. Nuclear Regulatory Commission Regulatory Guide 3.11, "Design, Construction, and Inspection of Embankment Retention Systems for Uranium Mills." In the event of a leak, the cap can be removed and a sample of water in the detection system can easily be retrieved by opening the valve without using a pump or grab sampler. The system can be drained, if desired, by keeping the valve open and circulating the drained fluid back to the pond.[42]

If liquid is present in a standpipe, it will be analyzed to determine from its composition if liner failure has occurred. If failure is confirmed, the liquid in the failed pond will be pumped to adjacent ponds and the damaged liner section will be repaired.

As planned, the East Leuenberger pond (Fig. 2.9) will be constructed during the first year of operation. The West Leuenberger pond will not be needed until the fourth year, during groundwater restoration. It is expected that construction of the West Leuenberger pond will begin during the third year of the project.

Sanitary wastes from the office and personnel facilities will be disposed of by a state-approved septic tank and leach-field system (Fig. 2.6).

Solid wastes

Solid wastes to be produced by the project include construction and operation refuse, well-construction wastes, process solid wastes, and evaporation pond residues. Construction refuse will be comprised of building material scrap and other nonradioactive wastes. Approximately 720 m^3 (943 yd^3) of these wastes will be generated during the first year of the project.[46] Operation refuse will probably be generated at a lower rate per year during the mining and restoration phases of the project. Trash generated in the office facilities and personnel quarters

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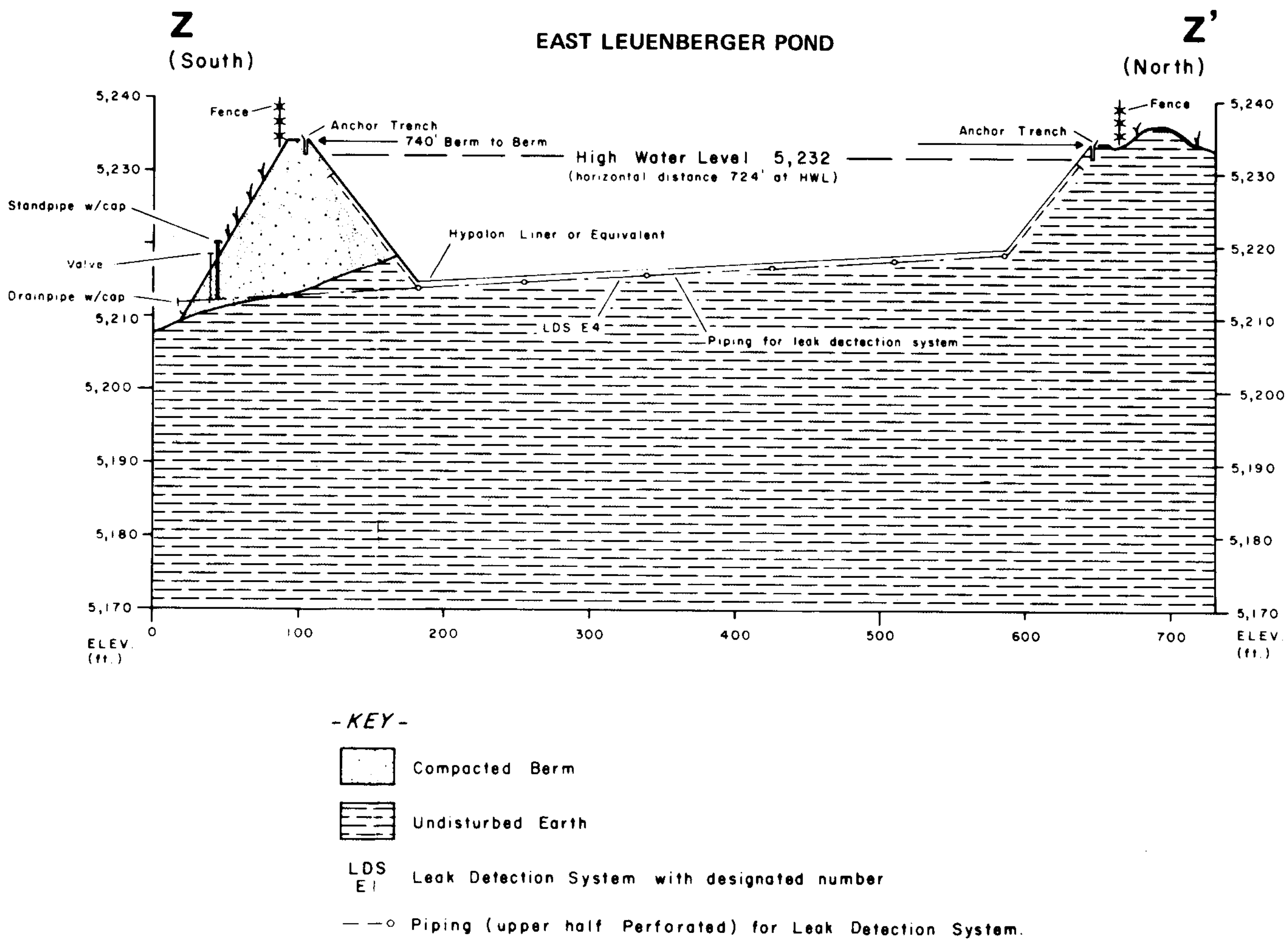

Fig. 2.9. Design plan for north and south reservoirs at the Teton-Nedco site.

and uncontaminated, worn process equipment will constitute the major portion of this waste. All construction, operation, and other nonradioactive wastes will be disposed of in a manner approved by the Wyoming Department of Environmental Quality.

Well-construction waste includes drill cuttings, spent drilling mud, worn equipment, and pipe scrap. Equipment and scrap materials will be disposed of as construction refuse. Spent drilling mud and drill cuttings will be placed in the mud pits excavated in connection with well-drilling activities. Based on boreholes of 15.3 cm (6 in.) diameter and a maximum average depth of 107 m (350 ft), the amount of drill cuttings per well will be 1.95 m^3 (2.55 yd^3). Construction of 1140 wells — which includes injection, recovery, and monitoring wells — will result in production of about 2219 m^3 (2907 yd^3) of wastes. Less than 3.6% of these wastes would be from the ore zone (0.06 to 0.1% U_3O_8). The average radium concentration caused by the presence of ore zone cuttings and a mean background level of radium-226 in the soil of 0.65 pCi/g (ER, Table D-10.2), will be about 8.4 pCi/g. This level of radiation will be reduced somewhat by the addition of drilling mud. Topsoil removed during pit excavation will be used to cover the pits. The size of each pit will be about 2.3 m^2 (25 ft^2). The staff concluded that this method of disposal of drill cuttings is acceptable because (1) the radiation level of 8.4 pCi/g is well below the standard for subsurface soils (15 pCi/g above background), (2) is within twice the range of background radiation levels found in mineralized areas of the West, and (3) the drill cuttings will be covered with several feet of soil. Although the value of 8.4 pCi/g is an estimated average, and it is realized that the radium-226 will not be uniformly distributed, the staff does not feel verification sampling is necessary because the standard allows averaging over an area of 100 m^2.

Process solid wastes will include spent ion exchange resins; sediments removed from surge tanks and filters; and contaminated, worn equipment. These low-level radioactive wastes — with the exception of work equipment, parts, or other hardware — will be barreled for disposal in a licensed disposal facility.

The recovery-plant bleed and the average restoration waste brine will have TDS contents of an average 11,800 mg/L. The further concentration of these streams by evaporation in the ponds will result in the formation of solid residues. Each of the chemical species present in the liquid wastes (Table 2.11) will be present in the residue in a relatively leachable form. Based on the projected waste flow rates, 4.8×10^9 g (5291 tons) of soluble solid wastes will accumulate in the ponds over the life of the operation.[42]

Environmental isolation of the wastes is necessary because of their chemical and radionuclide content. During the operational phase of the project, the presence of a water layer over the precipitated solids and the use of an artificial liner to eliminate seepage are sufficient to isolate the solids. However, adequate long-term isolation is necessary after project closure. The applicant proposes offsite final disposal of this solid waste at a licensed tailings disposal facility.

2.3.10.5 Surface reclamation and decommissioning

Teton-Nedco, in accordance with NRC and Wyoming DEQ regulations, proposes to decommission the Teton project facilities and to restore affected portions of the permit area to their original use (wildlife and livestock grazing) or to an alternative use that can be justified and that is acceptable to the state and the landowner. The goal of surface reclamation will be to return the disturbed lands to equal or better vegetative quality than that of premining conditions.

The applicant will secure a Reclamation Performance Bond to ensure the availability of funds to complete restoration and reclamation and to satisfy bonding requirements of the state of Wyoming. The bond will be filed with the Wyoming DEQ. NRC also requires that financial surety be provided to ensure the availability of adequate funds for site decommissioning, decontamination, reclamation, and groundwater restoration. Before commencement of any authorized commercial mining operation, the NRC staff will independently review the terms, conditions, amounts, and forms of the surety arrangements to determine the extent to which those arrangements satisfy existing NRC regulations and any additional surety arrangements required as part of the license conditions. The NRC will not require duplication of surety coverage to be provided under bonding arrangements with the state of Wyoming. The staff will require that surety arrangements be reviewed and/or revised annually to account for current costs and project status factors. The applicant's preliminary decommissioning and reclamation plan will be submitted to the NRC and Wyoming DEQ and will serve as the basis for Wyoming bonding requirements of the project.

Reclamation will occur in stages throughout the life of the project (Figs. 2.2 and 2.3). Reclamation of each mining unit will commence soon after groundwater restoration and will continue for about one year. Injection and recovery wells will be filled with a bentonite slurry and capped with a cement plug. The well casings will be cut off at least 60 cm (2 ft) below the land surface. Wells not reclaimed in this manner will be left unplugged as water wells and will be permitted by the Wyoming state engineer. Disturbed areas with topsoils left in place in the well fields, outside storage areas, trunklines, and access routes will be seeded periodically to maintain good vegetative cover during project operation and will be prepared and reseeded after abandonment. After well completion, fluids will be allowed to evaporate from the mud pits from which topsoils had been removed and stored before well installation. The pits then will be backfilled, covered with topsoil, and seeded.

On completion of operations, water from the North and South Leuenberger ponds (Fig. 2.9) will either be transferred to the East and West Leuenberger ponds or will be treated and used for groundwater restoration. No major amounts of evaporative salts are expected to exist in the north and south ponds. A salt layer of an estimated 12 cm (0.4 ft) will exist in the bottom of the east and west ponds. This salt layer and the pond liners will be removed and transported to a licensed disposal facility.

The processing plant and buildings, tanks, and equipment will be disassembled and removed from the site. Miscellaneous debris and the process building foundation will be deposited in the area once occupied by the evaporation ponds unless they are significantly contaminated by radioactivity. All topsoil will be removed from the face of the evaporation pond berms, the ponds will be regraded, the topsoil will be replaced, and the area will be reseeded. All other disturbed areas will also be covered with topsoil and reseeded. Vegetation cover and biomass will be measured on the reclaimed areas and compared with baseline data (ER, Appendix D-8) to evaluate reclamation success and to determine bond release with the Wyoming DEQ. Natural contours will be restored in certain areas. A minimum of recontouring will be necessary, however, because no major changes in topography will result from the proposed mining operation.

2.3.11 Staff evaluation of the proposed operation and alternatives

Although the 1981 supply of uranium was greater than demand, the staff considers that the eventual need for additional uranium production is demonstrated in Sect. 2.2 and that favorable licensing action is in the public interest, subject to appropriate conditions to appropriately restrict or minimize environmental and other impacts.

The staff believes that conventional mining and milling are not economically viable for recovering uranium from this ore body at present or in the foreseeable future, as discussed in Sect. 2.3.

The staff concurs with the applicant's choice of in situ leaching to extract uranium at this site because the following geologic and hydraulic conditions exist at the site:

1. The ore is located in a saturation stratum below the static water table.
2. The ore is amenable to chemical leaching.
3. The ore body is extensive enough to be economically mined.
4. The host zone rock is adequately confined by continuous layers of impermeable mudstone, shale, or siltstone.

The staff has carefully studied available restoration data from the pilot project performed by the applicant and believes that the ore-bearing aquifer can be restored to a condition of potential use equal to current baseline conditions (see Sect. 4.3).

The waste disposal and ground restoration plans are acceptable, subject to the regulations of the Wyoming DEQ and the U.S. Environmental Protection Agency (EPA).

The staff concludes that the adverse environmental impacts and costs are such that the use of the mitigating measures planned by the applicant and specified by the regulatory agencies involved will keep long- and short-term adverse impacts at minimal levels.

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3. THE EXISTING ENVIRONMENT

3.1 CLIMATE

3.1.1 General influences

The climate of east-central Wyoming is dominated by low- and high-pressure centers and their attendant frontal systems that migrate easterly through the area throughout the year. The major topographical influences on atmospheric flow in this region are the north-south trending mountain ranges in the west-central portion of the state that tend to block many of the storm systems. The climate is semiarid and the seasons are distinct, with mild summers and harsh winters. Spring and fall are transition seasons, with warm days and cold nights. Heavy snowfalls can be expected during both these seasons.[1] Terrain in the project region is rolling and hilly with relatively minor elevation differences; thus, weather conditions are fairly similar throughout the region at a given time.

3.1.2 Winds

The prevailing wind direction is westerly to southwesterly, and the speeds are quite high. Characteristics of wind speed and direction, abstracted from meteorological records for Casper, Wyoming, are presented in Table 3.1. From evaluation of local meteorological patterns, the staff concluded that the Casper data are representative of the site (Fig. 3.1). Strong winds are fairly frequent; the strongest recorded wind speed was 130 km/h (81 mph) from the southwest and occurred in March 1956.[2]

The local topography strongly influences micrometeorological conditions at the site. The dilution of airborne contaminants resulting from normal operating releases will be determined largely by small-scale turbulence in the local area combined with the prevailing wind and with the mode of release (ground-level or elevated).

3.1.3 Precipitation

The mean, maximum, and minimum precipitation and snowfall at Casper, Wyoming,[3] approximately 56 km (35 miles) west-southwest of the proposed mill site, are given in Table 3.2 for the period 1941-1975. The area has an average annual precipitation of about 0.3 m (12 in.) and potential annual evaporation of about 1.1 m (44 in.). More than 50% of the annual precipitation is received during the months of April, May, June, and July. Late spring and summer precipitation is normally derived from scattered thunderstorms; the land area affected and amounts of rain falling during such storms are extremely variable.

Table 3.1. Joint frequency of annual average wind speed and direction for Casper, Wyoming, 1966–1975[a]

Direction	Frequency (%) for specified speed range (mph)[b]						
	0–3	4–6	7–10	11–16	17–21	>21	Total
North	0.4	1.5	1.4	0.8	0.3	0.1	4.5
North-northeast	0.4	1.9	2.2	2.1	0.6	0.1	7.3
Northeast	0.2	1.0	1.4	1.0	0.2	0.1	3.9
East-northeast	0.2	0.9	1.1	0.6	0.1	0.0	2.9
East	0.4	1.3	1.7	1.2	0.2	0.1	4.9
East-southeast	0.2	0.7	0.7	0.4	0.1	0.0	2.1
Southeast	0.2	0.6	0.5	0.2	0.0	0.0	1.5
South-southeast	0.2	0.7	0.4	0.1	0.0	0.0	1.4
South	0.2	0.7	0.4	0.3	0.1	0.0	1.7
South-southwest	0.2	0.9	1.8	4.5	4.3	2.4	14.1
Southwest	0.2	0.9	2.8	6.3	4.5	2.1	16.8
West-southwest	0.4	1.7	5.2	4.8	2.0	0.9	15.0
West	0.8	2.9	4.5	2.8	1.0	0.6	12.6
West-northwest	0.3	1.3	1.0	0.9	0.3	0.1	3.9
Northwest	0.2	1.1	1.0	0.5	0.2	0.0	3.0
North-northwest	0.4	1.8	1.3	0.6	0.2	0.1	4.5
Total	4.9	19.9	27.4	27.1	14.1	6.6	

[a] A 2.2% calm is distributed in the table.
[b] To convert from miles per hour to kilometers per hour, multiply by 1.609.
Source: Directorate of Licensing, U.S. Nuclear Regulatory Commission, *Final Environmental Statement Related to Operation of Bear Creek Project*, Docket No. 40-8452, June 1977, Table 2.1.

3.1.4 Storms

Winter storms with their attendant snowfall, low temperatures, and high winds are common. Summer thunderstorms, occasionally spawning tornadoes, are frequent in spring and summer. These tornadoes tend to be notably less destructive than those occurring farther east. Five tornadoes have been reported within 80 km (50 miles) of the site since 1950.[4]

3.2 AIR QUALITY

The Teton-Nedco site is in the Casper Intrastate Air Quality Control Region. Air quality in this region is better than the national standards (40 CFR Part 81). There is no nonradiological air quality monitoring other than for particulates at the Teton site. Particulate data were collected at the site from October 1979 through June 1980 on 44 days. The mean concentration was 20 $\mu g/m^3$. For the period April through June

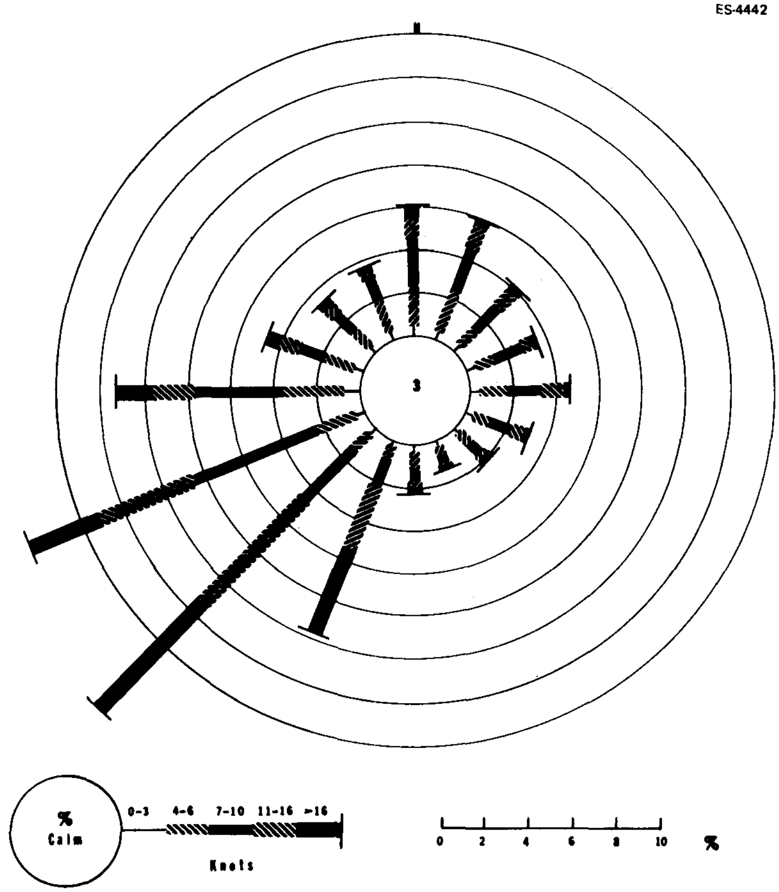

Fig. 3.1. Five-year average (1967-1971) wind rose for Casper, Wyoming.

1980, the mean concentration was 29 μg/m³. Although sampling for the period July through September was not reported in the ER, it would be expected that particulate concentrations would be higher at this time (the summer and fall dry seasons).

Ambient air quality data gathered at the three monitoring stations closest to the site are presented in Table 3.3. Air quality at the site is probably similar to that at the Irene Ranch and Willson Ranch stations, for which the setting is rural and the air quality is high. Air quality is lower in the city of Casper, where the annual standard for total suspended particulates (TSP) was exceeded in 1978. As indicated by the monitoring data, air quality at the site is probably well within the state and federal standards. No data are presented for carbon monoxide or hydrocarbons. However, their concentrations at the site are probably well below the standards or guidelines.

Table 3.2. Mean, maximum, and minimum total precipitation and snowfall for Casper, Wyoming

All values are in cm (in.)

	Total precipitation			Snowfall	
	Mean	Maximum	Minimum	Mean	Maximum
January	1.27 (0.50)	2.51 (0.99)	Trace	22.9 (9.0)	48.8 (19.2)
February	1.27 (0.50)	2.57 (1.01)	0.38 (0.15)	24.6 (9.7)	60.5 (23.8)
March	2.29 (0.90)	6.17 (2.43)	0.64 (0.25)	36.1 (14.2)	83.6 (32.9)
April	3.68 (1.45)	9.81 (3.86)	0.51 (0.20)	34.8 (13.7)	143.1 (56.3)
May	4.95 (1.95)	14.19 (5.59)	0.76 (0.30)	4.3 (1.7)	60.7 (23.9)
June	3.68 (1.45)	9.53 (3.75)	0.08 (0.03)	0.76 (0.3)	7.6 (3.0)
July	2.41 (0.95)	7.75 (3.05)	0.28 (0.11)	0.0 (0.0)	0.0 (0.0)
August	1.39 (0.55)	3.86 (1.52)	0.05 (0.02)	Trace	Trace
September	2.16 (0.85)	8.33 (3.28)	0.18 (0.07)	2.3 (0.9)	22.4 (8.8)
October	2.29 (0.90)	6.32 (2.49)	Trace	11.9 (4.7)	33.3 (13.1)
November	1.78 (0.70)	3.31 (1.30)	0.18 (0.07)	23.4 (9.2)	50.5 (19.9)
December	1.27 (0.50)	2.64 (1.04)	0.08 (0.03)	22.4 (8.8)	45.2 (17.8)
Annual	28.45 (11.20)	41.25 (16.24)[a]	18.64 (7.34)[b]	183.4 (72.2)	296.7 (116.8)[c]

[a] Data are for the year 1941.
[b] Data are for the year 1960.
[c] Data are for the years 1972 and 1973.
Source: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, *Local Climatological Data, 1975, Lander, Wyoming*, 1976. Base data are from 1975 summary of local climatological data, Casper, Wyoming.

Table 3.3. Summary of air quality data for the Teton-Nedco region, 1978 (particulates) and 1979 (SO_x and NO_x)

Parameter ($\mu g/m^3$)	Air quality standards[a]	Wyoming Department of Environmental Quality data		
		Casper, 48 km WSW[b]	Irene Ranch, 85 km NE[b]	Willson Ranch, 105 km E[b]
Sulfur dioxide				
24-h maximum	260	48	5	2
Annual average	80	1.2	0.6	0.1
TSP[c]				
24-h maximum	150	179	118	
Annual average	60	64	19	
Nitrogen dioxide				
24-h maximum		80	32	13
Annual average	100	33	6.5	3.6

[a] Secondary or primary, whichever is lower.
[b] Distance and direction from the site; the Willson Station is 8 km NW of Lusk.
[c] Total suspended particulates.

3.3 TOPOGRAPHY

The site (Fig. 1.1) is located in the southern portion of the Powder River Basin, which is in the unglaciated Missouri Plateau section of the Great Plateau section of the Great Plains physiographic province. Elevations on the site range from about 1573 m (5160 ft) at the west end of the site to 1640 m (5380 ft) at the east end of the site (ER, Fig. 3-1). The east end of the site is located on the crest of a broad, low ridge. An intermittent stream originates near the east end of the site, flows to the west, and has thus created a shallow draw passing from east to west through the southern half of the site. A second intermittent stream enters the northwestern part of the site and meets the above-mentioned stream at the site's west border. This stream has formed a shallow draw in the northwestern part of the site. The slopes on the site are predominantly gentle. The elevational change of 67 m (220 ft) from the east end to the west end of the site represents an average slope of about 2.4%. Slopes on the low ridges along the eastern and southern boundaries of the site average about 6%.

3.4 DEMOGRAPHY AND SOCIOECONOMIC PROFILE

The proposed project site is located within the boundaries of the applicant's 308-ha (760-acre) Leuenberger mine permit area, which is located south of State Highway 95 in the east-central portion of Converse County, by road approximately 16 km (10 miles) northeast of Glenrock; about 48 km (30 miles) east of Casper, the county seat for Natrona County; and approximately 43 km (27 miles) northwest of Douglas, the county seat for Converse County (see Fig. 3.2). The land in the immediate vicinity of the permit area is sparsely populated; and, although the site is in Converse County, portions of Natrona County are within a 32-km (20-mile) radius.

Because of their close proximity to the permit area and because they are the only communities within reasonable commuting distance that possess amenities such as schools, retail districts, medical care facilities, and utilities usually sought by in-migrants, the staff has concluded that Glenrock, Casper, and Douglas will absorb the majority of the socioeconomic impacts resulting from the proposed project. Therefore, the socioeconomic descriptions and impact analyses focus on these communities and the surrounding regions in Converse and Natrona counties.

3.4.1 Population

3.4.1.1 Converse County

According to the 1980 census, the population of Converse County was 14,069; a 136.9% higher count than the 5938 recorded in 1970 (Table 3.4). Converse County is dominated by Douglas and Glenrock. Both communities, primarily due to growth in the county's mineral extraction

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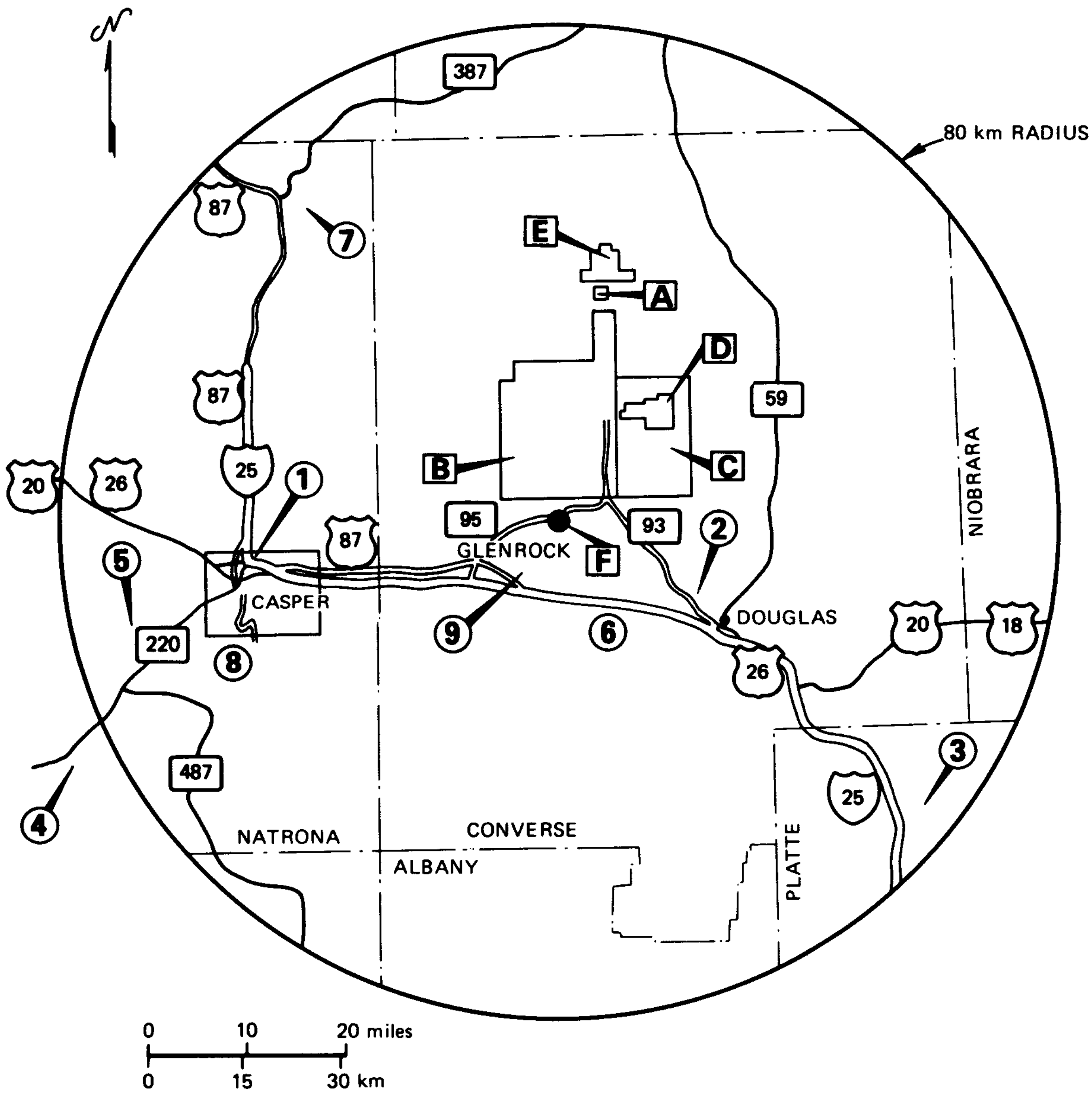

URANIUM MINING AREAS

A. PIONEER NUCLEAR
B. KERR McGREE NUCLEAR CORP.
C. UNITED NUCLEAR CORP.
D. EXXON MINERAL CO.
E. BEAR CREEK URANIUM CO.
F. LEUENBERGER SITE (TETON)

LOCATION OF POINTS OF INTEREST

1. FORT CASPAR
2. FORT FETTERMAN
3. GLENDO STATE PARK
4. ALCOVA RECREATION AREA
5. DAN SPEAR FISH HATCHERY
6. AYRES NATURAL BRIDGE
7. SALT CREEK OILFIELD – TEAPOT DOME
8. CASPER MOUNTAIN RECREATION AREA
9. DAVE JOHNSTON COAL POWER PLANT

Fig. 3.2. Population and activity centers within 80 km (50 miles) of the Teton-Nedco site.

Table 3.4. Population statistics for Converse and Natrona counties and major towns potentially impacted by the project

County, city, town, or census division	1980 population	1980 population distribution (percentage of county population)	1970 population	1970 population distribution (percentage of county population)	Population change 1970–1980	
					Total	Percentage
Converse County	14,069	100	5,938	100	8,131	136.9
Douglas	6,030	42.9	2,677	45.1	3,353	125.3
Glenrock	2,736	19.5	1,515	25.5	1,221	80.6
Natrona County	71,856	100	51,264	100	20,592	40.2
Casper	51,005	71	39,361	76.4	11,644	29.6
Mills	2,139	3	1,724	3.4	415	24.1
Evansville	2,652	3.7	832	1.6	1,820	218.8

Source: U.S. Department of Commerce, Bureau of the Census, *1980 Census of Population and Housing, Wyoming Final Population and Housing Unit Counts*, March 1981.

industry, experienced extensive population growth during the 1970-1980 decade. Douglas's population grew from 2677 in 1970 to 6030 in 1980, a 125.3% increase; Glenrock's population grew from 1515 in 1970 to 2736 in 1980, an 80.6% increase.

However, because of the recent decline in coal and uranium operations, Converse County's population is not expected to grow in the 1980s at the rate it has in the past decade (Table 3.5).

Table 3.5. Population projections for Converse County and for the Glenrock and Douglas urban areas

Geographical area	1985	1990	1992
Converse County	17,748	21,302	22,768
Glenrock	3,372	4,047	4,326
Douglas	7,632	9,160	9,790

Source: Converse County Planning Office, *Population Projections for Converse County and the Towns of Douglas and Glenrock*, Rev. February 1980.

3.4.1.2 Natrona County

In terms of population, Natrona County and Casper, with 1980 populations of 71,856 and 51,005, respectively, are the largest county and city in Wyoming. Casper, whose growth has been induced by expansions in the mineral extraction industry, is the major economic center in central Wyoming: offices for most of the state's major industrial companies are located in Casper. However, because of the slowdown in energy-related industrial expansions, the populations of Natrona County and Casper are not expected to continue their rapid growth over the next 7 years (Table 3.6).

Table 3.6. Population projections for Natrona County and Casper

Geographical area	1985	1990	1992
Natrona County	84,953[a]	99,244[a]	104,801[a]
Casper	60,317[a]	70,463[a]	74,409[b]

[a]D. M. Rud, Wyoming Housing Monitoring System, Wyoming Department of Economic Planning and Development Planning Division, Cheyenne, Wyoming, May, 1983.

[b]Staff-calculated estimates assuming Casper contains 71% of the county's population.

3.4.2 Housing

3.4.2.1 Converse County

Housing statistics for Converse County, Douglas, and Glenrock are presented in Tables 3.7 and 3.8. These statistics reveal the following important trends.

- To keep up with population growth in the late 1970s, residential housing stocks increased at a very rapid pace. Nearly 3100 housing units were added to Converse County's inventory during the 1970s — a 134% increase; Douglas's inventory grew from 1066 to 2338 (a 119% increase); and Glenrock's grew from 514 to 1044 (a 103% increase).

- The Converse County Health Department conducted a survey of the county's housing in 1981 and counted a total of 3658 housing units in Glenrock and Douglas (Table 3.8). Of this total, 59% (2158 units) were single-family units, 14% (515 units) were multifamily units, and 27% (985 units) were mobile homes.

According to the Converse County Planning Office[5] the Glenrock housing vacancy rate had, as of September 1981, risen to approximately 8% because of layoffs in the local uranium industry. (By the end of 1982 the county's vacancy rate had risen to 17.5%.) Very little new construction occurred in the Glenrock area in 1981; however, 178 zoned, fully developed (i.e.,

Table 3.7. Housing counts for the cities, towns, and census divisions in Converse and Natrona counties

County, city, town, or census division	1980 housing count[a]	1980 housing count distribution (percentage of county total)	1970 housing count	1970 housing count distribution (percentage of county total)	Housing change 1970 to 1980	
					Total	Percentage
Converse County	5,350	100.0	2,291	100.0	3,059	133.5
Douglas (division)	3,640	68.0				
Douglas (town)	2,338	43.7	1,066	46.5	1,272	119.3
Lost Springs (town)	3	0.0	2	0.0	1	50.0
Glenrock (division)	1,710	32.0	710	31.0	1,000	140.8
Glenrock (town)	1,044	19.5	514	22.4	530	103.1
Natrona County	28,493	100.0	17,324	100.0	11,169	64.5
Casper (division)	22,484	78.9				
Casper (city)	19,770	69.4	13,369	77.2	6,401	47.9
Mills (town)	895	3.1	580	3.4	315	54.3
Casper North (division)	1,498	5.3				
Casper (city)	5	0.0				
Edgerton (town)	205	0.7	140	0.8	65	46.4
Midwest (town)	253	0.9				
Casper South (division)	2,384	8.4				
Casper (city)	481	1.7				
Evansville (town)	890	3.1	262	1.5	628	239.7

[a]Final count.

Source: U.S. Department of Commerce, Bureau of the Census, *1980 Census of Population and Housing, Wyoming Final Population and Housing Unit Counts*, March 1981.

Table 3.8. Housing counts by housing type for Glenrock and Douglas, 1981

Housing type	Glenrock[a]		Douglas[b]	
	Number of units	Distribution (%)	Number of units	Distribution (%)
Single-family	636	59.8	1522	58.7
Multifamily	234	22.0	281	10.8
Mobile homes	194	18.2	791	30.5
Total	1064	100.0	2594	100.0

[a]M. Sceirz, Douglas/Converse County Planner, Converse County Planning Office, personal communication, Sept. 18, 1981.

[b]C. L. Higgins, Deputy Health Officer, Converse County Health Department, written communication, Oct. 19, 1981.

roads, curbs, and sewer, water, and telephone lines have been installed) single-family plots are available for future development. A 695-m^2 (7500-ft^2), 45-plot mobile home park has also been developed to accommodate future housing demand increases.

Housing in the Glenrock-Douglas area is relatively expensive. As of 1980, the estimated cost of a new 102-m^2 (1100-ft^2) three-bedroom home with an unfinished basement and one-car garage was approximately $70,000.[6,7] The average monthly rental for a three-bedroom home ranged from approximately $450 to $550: the average monthly rental for a one- to three-bedroom apartment was approximately $300-375.[6,7]

3.4.2.2 Natrona County

Natrona County and Casper — like Converse County, Douglas, and Glenrock — have significantly increased their housing stocks over the last ten years because of population increases induced by energy developments. The county's inventory increased by about 65% (11,169 units) during the 1970s, and Casper's inventory increased by about 6900 units — an increase of approximately 50% (Table 3.7). The vast majority of the county's housing is located in the city of Casper and within the urban fringe surrounding the city. A housing survey conducted in 1980 (Table 3.9) indicated that most of the housing in the Casper area (approximately 58%) was owner-occupied, single-family housing units. Rental multifamily units (approximately 19%) and owner-occupied mobile homes (approximately 11%) were the next two largest categories.[8] Despite this predominance of single-family units, the survey revealed that there was a considerable unmet demand for affordable single-family units.* That is, many households currently residing in mobile homes and rental properties preferred to live in single-family housing but could not afford to acquire single-family units. It was estimated that when housing preferences are accounted for, as many as 6300 single-family units could be needed in the Casper area by 1984 (Table 3.9).

3.4.3 Employment

Wyoming has historically recorded low unemployment rates (Table 3.10): the 1979 (2.7%) and 1978 (3.3%) rates were the lowest and fourth lowest, respectively, among the states (by comparison, the national rates were 5.8% in 1979 and 6.0% in 1978). Over the past few years unemployment rates of Converse and Natrona counties have been even lower than the

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*Owner-occupied, single-family units are too expensive for the majority of Casper households. The cost of a new three-bedroom 102 m^2 (1100 ft^2) home with an unfinished basement and a one-car garage is about $95,000.[9] By comparison, the average monthly rental for a three-bedroom home is about $380, and the average monthly rental for a one- to three-bedroom apartment is approximately $250.[9]

Table 3.9. Summary of the 1980–1984 housing market for Casper, Wyoming, by housing category

Housing category	1980 supply	1984 demand[a]	Excess (or shortage)
Owner-occupied single-family housing	14,634	20,937	(6,303)
Rental single-family housing	2,230	1,837	(393)
Owner-occupied multifamily housing	390	506	(116)
Rental multifamily housing	4,669	2,517	2,152
Owner-occupied mobile homes	2,753	2,343	410
Rental mobile homes	433	286	147
Total/net	25,109	28,426	(4,103)

[a]The housing demand estimates are for "preferred" housing; that is, the estimates contain housing demands by households who would prefer — if financially feasible — to move into different types of housing.

Source: Mobius, Inc., Stuart/Nichols, *Housing for the Eighties, A Matter of Choice*, a study prepared for the Casper City Council and the City of Casper Housing and Community Development Office, September 1980.

state's, declining to 2.1 and 2.2%, respectively, in 1979. However, by March 1983, the counties' rates had climbed to 11.6 and 12.5%; similarly, the state rate had increased to 10.9%.[10] Although undesirable, these increased percentages were not compatible with national trends and were still considerably below the nation's recessionary rates (7 to 8%). However, in January 1983 Wyoming's unemployment rate of 9.9% is approaching the national rate of 10.2%. The relatively high unemployment rate for Converse County was a sudden development [the county's rate was 2.4% in September 1980 and has been as low as 1.6% (November 1979)] and essentially resulted from layoffs in the local uranium mining/processing industry.[11] These layoffs were caused by the current softness in the yellowcake market.

As illustrated in Table 3.11, the economy of the impacted region is dominated by four industries: mining, construction, trade, and services. In 1979, these industries accounted for about 84% of Converse County's employment and 85% of Natrona County's. Mining is, by far, the major employment sector in Converse County and accounted for nearly 36% of the county's employment in 1979. Trade (wholesale and retail) and services, employing 27.3% and 22.3%, respectively, of those working in 1979, are the largest industries in Natrona County; mining is a close third at 19.7%. The emphasis on trade and services is due to Casper's importance as a trade center for east-central Wyoming. The employment data in-

Table 3.10. Labor force and unemployment estimates for Wyoming, Converse, and Natrona counties, with national unemployment estimates for selected years in the 1970s and for February 1980 and February 1981

Year	National unemployment rate(%)	Wyoming[a]			Converse County[a]			Natrona County[a]		
		Civilian labor force	Unemployed	Unemployment rate (%)	Civilian labor force	Unemployed	Unemployment rate (%)	Civilian labor force	Unemployed	Unemployment rate (%)
1970	4.9[b]	142,790	6,290	4.4	2,600	110	4.2	22,310	910	4.1
1975	8.5[b]	165,869	6,981	4.2	3,942	116	2.9	26,200	936	3.6
1979	5.8[b]	223,000	6,000	2.8	6,713	141	2.1	38,161	831	2.2
1980 (Feb.)	7.9[b]	214,188	8,813	4.0	6,981	212	3.0	36,560	1,063	2.9
1981 (Feb.)	7.6[b]	220,967	12,052	4.1	7,686	370	3.5[c]	37,315	1,443	3.3[c]
1982 (June)	9.5			5.2			5.0			NA
1983 (Jan.)[d]	10.2			9.9			NA			NA
Change, % (1970-1981)		+54.8	+91.6		+195.6	+236.4		+67.3	+58.6	

[a]Wyoming Employment Security Commission, Research and Analysis Section, *Wyoming Annual Average Labor Force, 1970-1979*, Casper, Wyo., undated; *Wyoming Employment Security Commission Pocket Data Card, February 1981*. The 1970 data were based on the number of jobs at place of work. The 1975 and subsequent data were based on the number of workers and place of residence and were benchmarked to current population survey data from the Bureau of Labor Statistics.

[b]U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States*, 103d Edition: 1982-83, Tables 656, 657.

[c]Yearly average from *Wyoming Income and Employment Report*, Division of Research and Statistics, Cheyenne, Wyoming, June 1982.

[d]Employment and earnings from U.S. Department of Labor, Bureau of Labor Statistics, March 1983.

Table 3.11. Employment statistics and projections for Wyoming, Converse, and Natrona counties for 1981 and 1983

Industrial classification	Wyoming					Converse County					Natrona County				
	Average employment level[a]		Employment distribution (%)[a]		Employment increase 1978-1983 (%)	Average employment level[a]		Employment distribution (%)[a]		Employment increase 1981-1983 (%)	Average employment level[a]		Employment distribution (%)[a]		Employment increase 1981-1983 (%)
	1981	1983	1981	1983		1981	1983	1981	1983		1981	1983	1981	1983	
Mining	37,261	41,805	14.3	15.0	12.2	2,313	2,626	29.7	30.9	13.5	7,281	7,921	17.2	17.5	8.8
Construction	23,168	25,625	8.9	9.2	10.6	626	683	8.0	8.0	9.1	3,772	4,146	8.9	9.2	9.9
Manufacturing	10,047	10,462	3.8	3.7	4.1	80	88	1.0	1.0	10.0	1,801	1,821	4.2	4.0	1.1
Transportation, commerce, and utilities	16,860	18,002	6.5	6.5	6.8	426	436	5.5	5.1	2.3	2,685	2,854	6.3	6.3	6.3
Trade	46,529	50,178	17.8	18.0	7.8	1,168	1,289	15.0	15.2	10.4	9,992	10,790	23.6	23.8	8.0
Agriculture	16,428	16,579	6.3	5.9	0.9	570	570	7.3	6.7	0.0	579	579	1.4	1.3	0.0
Nonfarm Proprietors	21,256	22,507	8.1	8.1	5.9	841	920	10.8	10.8	9.4	3,193	3,385	7.5	7.5	6.0
Finance, insurance, and real estate	7,643	8,293	2.9	3.0	8.5	178	195	2.3	2.3	9.6	1,666	1,801	3.9	4.0	8.1
Services, agriculture, forestry, and fishing	31,889	33,651	12.2	12.1	5.5	459	491	5.9	5.8	7.0	5,867	6,235	13.8	13.8	6.3
Government	50,255	51,891	19.2	18.6	3.3	1,123	1,197	14.4	14.1	6.6	5,585	5,720	13.2	12.6	2.4
Total	261,340	278,997	100.0	100.0	6.8	7,781	8,500	100.0	100.0	9.2	42,423	45,257	100.0	100.0	6.7

[a]Projections

Source: Wyoming Population and Employment Forecast Report Division of Research and Statistics, Cheyenne Wyoming, July 1982.

Table 3.11 also indicate that, except for the services sector, Natrona County's economy has remained fairly stable over the past few years. However, 1983 unemployment data in Table 3.10 indicate a high unemployment rate in Wyoming. This recent development almost certainly impacts Natrona County also.

3.4.4 Economics

3.4.4.1 Regional economic base

Overview

The "basic" industries of a region are those that involve either the exportation of goods and services to points outside the defined region or the marketing of goods and services to buyers who came from outside the region's boundaries. Therefore, the definition of an appropriate region is very important in economic base analyses. For this study, the basic region was considered to include Converse and Natrona counties. This choice was a judgmental decision of the staff and was based on the belief that the vast majority of the socioeconomic impacts related to the proposed solution mining project will occur in the defined region.

As indicated in Sect. 3.4.4, the mineral extraction industry is, by far, the most important basic industry in the two-county region. Agriculture is the second most important basic industry. The manufacturing sector, while expanding, serves a limited role.

Converse County

The primary basic industries in Converse County are the mineral extraction industry (coal, uranium, and oil) and agriculture. The developments of the Big Muddy Field near Glenrock in 1916, the South Glenrock Field in 1950, and the Shawnee Flat Top Field on the western edge of the county have made Converse County a major oil producer. The presence of large coal deposits at the Shawnee Basin Fields led to the construction of Pacific Power and Light's Dave Johnston coal-fired electric generation facility near Glenrock. Discoveries in the Powder River Basin, north of Glenrock, have made uranium mining/processing an important industry, with several major energy companies (such as Exxon and Kerr-McGee) owning and operating mining and/or milling facilities.

Natrona County

Natrona County, like Converse County, is heavily dependent on the petroleum industry, the mining industry, and agriculture. The petroleum extraction industry has been especially important to the growth and development of Casper. In 1916, discoveries of oil in large quantities in the Salt Creek field north of Casper spurred a major economic boom. The oil

industry continued to prosper in the post-World war II periods when three major oil refineries and a gas processing plant were constructed in Casper. Currently, four interstate pipelines either originate in or pass through Casper. Since Casper became a major shipping point for petroleum products, the petroleum industry stimulated the development of Casper as a regional trade, transportation, and service center in central Wyoming. Other energy-related developments, such as the growth of the uranium processing and mining industry, have induced further economic expansion.

3.4.4.2 Income

Comparative descriptive statistics indicate that the per capita income estimates for Wyoming and for Converse and Natrona counties have, with few exceptions (Table 3.12), been higher than national averages. For example, Wyoming's per capita income was estimated to be $10,875 in 1980, ranking the state 6th in this earnings category. Additionally, the state's per capita income has increased at a faster rate than the national average: the state ranked 26th in earnings in 1970, 12th in 1975, and 2nd in 1978.[12] In turn, Converse and Natrona counties have recorded relatively high earnings levels within the state of Wyoming. In 1980, Natrona County's per capita income ranked first in the state ($14,072 – 48% higher than the national average and 29% above the state average). Converse County's incomes have consistently been lower than Natrona's average but about the state's average.

The average annual wages earned in 1979 by employees in major industrial classifications are summarized in Table 3.13 and should be reasonably indicative of wages in the Converse/Natrona labor market area.

3.4.4.3 Finance and taxes

The impacted region is served by numerous banks and savings and loan (S&L) associations. Most of these facilities are located in Casper and Douglas: there are eight banks and five S&L's (total assets approximately $1.3 billion) in Casper and three banks (total assets approximately $79 million as of January 1, 1980) and two S&L's in Douglas.[6,9] There is one bank in Glenrock with approximately $12 million in deposits.[7]

The primary sources of income for the cities and counties are mineral tax revenues (from severance and ad valorem taxes), residential and commercial property tax revenues, and sales tax revenues (tax and spending statistics for the counties and cities within the impacted region are summarized in Tables 3.14 and 3.15). The state of Wyoming levies no personal or corporate income taxes, no gross receipts taxes, and no excise taxes.

Table 3.12. Per capita personal income in current dollars for the United States, Wyoming, and Converse and Natrona counties for selected years

Geographical area	Per capita income ($)				Rank in state or nation		Increase 1975-1980 (%)
	1975	1978	1979	1980	1975	1980	
United States[a]	5,857	7,783	8,668	9,490			62.0
Wyoming[a,b]	6,114	8,572	9,798	9,096	12	6	77.7
Converse County[b]	6,381	8,722	10,242	8,048	12	7	72.6
Natrona County[b]	7,671	11,191	12,785	11,415	2	1	83.4

[a]U.S. Bureau of the Census, *Statistical Abstract of the United States: 1982-83,* 103rd ed., Washington, D.C., 1981, Table 705, p. 427.

[b]*Wyoming Income and Employment Report,* Division of Research and Statistics, Cheyenne, Wyoming, June 1982.

Table 3.13. Average wage statistics for Wyoming and for Converse and Natrona counties, 1979

Industrial classification	Wyoming		Converse County		Natrona County	
	Earnings ($)	Rank	Earnings ($)	Rank	Earnings ($)	Rank
Agriculture	8,761	9	11,217	5	10,519	9
Mining	22,132	1	22,477	1	21,801	1
Construction	17,184	2	14,803	3	17,773	4
Manufacturing	14,875	5	13,540	4	19,295	2
Transportation, commerce, and utilities	17,007	3	20,650	2	17,403	5
Wholesale trade	15,829	4	10,701	7	18,238	3
Retail trade	7,744	10	7,654	10	9,534	10
Finance, insurance, and real estate	12,101	6	11,016	6	13,795	6
Services	10,366	8	9,653	9	11,850	8
Government	11,974	7	10,002	8	13,114	7

Source: Wyoming Employment Security Commission, Research and Analysis Section, *Wyoming Annual Planning Information, 1981*, Casper, Wyo., undated.

Table 3.14. Converse County tax statistics for 1979–1981

Tax jurisdiction	Property tax levies and tax revenues						Assessed valuation[a]	
	1979 mill levies	1979 tax revenues ($)	1980 mill levies	1980 tax revenues ($)	1981 mill levies	1981 tax revenues ($)	1979 valuation ($)	1980 valuation ($)
Converse County		15,337,467[c]		16,772,055[d]		25,216,048[d]	227,652,444[b]	264,273,539[d]
Glenrock	86.608[b]	273,617[b]	75.516[d]	239,574[d]	97.320[b]	363,476[d]	3,159,254[b]	3,797,261[d]
Douglas	71.764[c]	697,632[c]	70.917[d]	642,592[d]	70.402[d]	708,961[d]	9,721,203[c]	10,531,384[d]

Sales tax rate (county, FY79): 4%[a,b]

Sales tax collected: $2,734,283[b]

Sales tax distributed to:

County: $ 481,184[b]
Glenrock: $ 419,085[b]
Douglas: $ 740,586[c]

		City ($)	School ($)
Bonded indebtedness (FY79):	Glenrock[b]	346,000	5,445,000
	Douglas[c]	232,000	6,620,000

[a]Ratio of assessed valuation to true value for 1979 was ~8–10%. 1979 minerals assessed valuation subject to severance and ad valorem taxes (based on 1978 production): $141,303,489. Source: Industrial Development Division, Department of Economic Planning and Development "Glenrock, Wyoming, 1980 Community Profile."

[b]Industrial Development Division, Department of Economic Planning and Development, "Glenrock, Wyoming, 1980 Community Profile."

[c]Industrial Development Division, Department of Economic Planning and Development, "Douglas, Wyoming, 1980 Community Profile."

[d]V. Reed, Converse County Tax Assessor's Office, personal communication, Sept. 29, 1981.

Table 3.15. Natrona County and Casper tax statistics for recent years

Year	Mill levies[b]					Assessed valuation[a,b] ($)	
	Casper	School	County	State	Total	Casper	Natrona County
1970	9.84	43.82	15.49	6.00	75.15	56,590,000	145,266,500
1975	8.00	36.70	14.75	14.67	74.12	60,653,100	213,447,600
1977	8.00	35.00	12.50	18.00	73.50	81,550,800	220,416,900
1978	8.00	35.00	12.85	18.00	73.85	89,869,000	227,024,800
1979	8.00	33.50	13.00	18.00	72.50	98,285,500	246,256,300

Property taxes levied in 1979[c]: Casper: $ 7,125,700
County: $16,824,735

Sales tax rate (county, FY79): 4%[c]

Sales tax collected:[c] $34,657,400

Sales tax revenue distributed back to:[c]

Casper: $13, 673,100
County: $ 2,941,910

[a]Ratio of assessed valuation to true value for 1979 was ~8–10%. 1979 minerals assessed valuation subject to severance and ad valorem taxes (based on 1978 production): $66,342,200. Source: Industrial Development Division, Department of Economic Planning and Development, *Casper, Wyoming, 1980 Community Profile,* undated.

[b]Casper Area Chamber of Commerce, *Casper, Wyoming Area Development Statistics,* undated.

[c]Industrial Development Division, Department of Economic Planning and Development, *Casper, Wyoming, 1980 Community Profile,* undated.

3.4.4.4 Community services and public facilities

Education

Converse County. Converse County is divided into two school districts: District 1 in Douglas and District 2 in Glenrock. Statistics for these school districts are presented in Tables 3.16 and 3.17. There is additional enrollment capacity in all of the District 1 schools; there is deficient capacity in the middle and elementary schools in District 2. To alleviate overcrowding in the District 2 elementary schools, the middle school is now accommodating grades 5-8 instead of grades 6-8. Bids have been let for a new elementary school: plans are for this new school to be in operation in about two years (1983 school year).[13] When the new elementary school is completed, the fifth grade will be transferred from the middle school. Both school districts have new high schools; the Glenrock middle school is now located in the old Glenrock high school building.

Table 3.16. Public school statistics for Converse County, District 1 (Douglas area), as of Sept. 15, 1981

Schools[a]	Number of schools	Number of students enrolled	Enrollment capacity
High school (9–12)	1	556	900
Middle school (6–8)	1	474	750
Elementary (K–5)	3	1038	1350
Rural schools	8	74	
Total	13	2142	~3000

[a]Total certified teachers and administrators: 169.

Source: L. Harkless, Secretary for the Superintendent, Converse County School District 1, personal communication, Sept. 29, 1981.

Table 3.17. Public school statistics for Converse County, District 2 (Glenrock area), as of Sept. 15, 1981

Schools	Number of schools	Number of teachers	Number of students enrolled	Enrollment capacity
High school (9–12)	1	22	346	500
Middle school (5–8)	1	26	424	400
Elementary (K–4)	1	30	533	500
Total	3	78	1303	1400

Source: G. Stillwell, Secretary for the Superintendent, Converse County School District 2, personal communication, Sept. 29, 1981.

Natrona County. Statistics for the Natrona County school district are summarized in Table 3.18. As of September 1980, there were 36 schools in the district (most of these schools are located in Casper), 935 certified teachers were employed, and 14,112 students were enrolled.[10,14] The elementary school pupil/teacher ratio was about 25:1; the secondary school ratio was approximately 28:1. Elementary school enrollment increased by 400 for the 1980-1981 school year; therefore, some overcrowding existed in some of the elementary schools. In the past, overcrowding has been corrected by student busing and via the utilization of portable classrooms.

Table 3.18. Public school statistics for Natrona County, District 1, as of Sept. 15, 1980

School	Number of schools	Grades	Number of students enrolled
Elementary	28	K–8	8,106
Junior high	3	7–9	2,868
CY		7–9	812
Dean Morgan		7–9	1,167
East		7–9	889
High school	3	7–12	3,072
Midwest		7–12	139
Kelly Walsh		10–12	1,253
Natrona County		10–12	1,680
Special education	2		66
A. J. Woods			37
Roosevelt Center		7–12	29
Total	36	K-12	14,112

Source: State Department of Education, Planning Services Unit, "Fall Enrollment by School, as of September 15, 1980, District No. 1, Natrona County," Cheyenne, Wyo.

In addition to the above public schools, the Wyoming State Children's Home, the Wyoming School for the Deaf, Casper Junior College, and the University of Wyoming, Casper Branch, are located in Casper.

Medical services

Converse County. Currently, there are two doctors, one dentist, and a diagnostic and treatment center located in Glenrock.[15] The nearest commercial hospitals are located in Casper and Douglas, approximately 40 km (25 miles) and 35 km (22 miles) distant respectively. As of July

1981, there were three doctors (one new doctor expected), three dentists, one chiropractor, two optometrists, a commercial hospital, a nursing home, a physical therapy clinic, a mental health center, and a vocational rehabilitation facility located in Douglas. The hospital, Converse County Memorial Hospital, is a 32-bed facility; the occupancy rate is about 60%. Construction of a new 44-bed hospital facility is expected to commence in 1981 with completion expected in 1983. The Michael Manor Nursing Home is a 58-bed facility with a 95% occupancy rate.

Natrona County. There are 91 doctors, 45 dentists, a commercial hospital, three nursing homes, and several clinics located in Casper. The Memorial Hospital of Natrona County is a 282-bed facility; its occupancy rate is about 60%. There are 327 beds in the three nursing homes.[9]

Fire and police protection

Converse County. Glenrock's fire department, a 25-man volunteer unit, has two 3785-L/min (1000-gpm) pumpers and provides fire protection for areas within and outside the Glenrock city limits. Glenrock has equipment-sharing agreements with private companies in the area to control grass fires.[15] On a scale of 1 (best) to 10 (worst), Glenrock's fire insurance rating is 8. Glenrock's police department provides 24-h protection and consists of the police chief, two sergeants, six officers, and four dispatchers. The Converse County Rural Fire Control Association maintains over 30 mobile fire units located on ranches and in settlements.

Douglas's fire protection force consists of 30 volunteers; equipment includes two fire engines.[16] Douglas's fire insurance rating is 7. Police protection in Douglas is provided by a 12-man force (excluding dispatchers and administrative personnel) headed by a chief of police.

Natrona County. Casper has a 117-member police force; the Natrona County Sheriff's Department consists of 63 personnel.[9] The Casper Fire Department currently operates six fire stations, and sites have been selected for the construction of two additional stations.[17] As of October 1980, the Casper department consisted of 95 full-time firemen, and Casper's fire insurance rating was 4. The Natrona County Fire Department maintains a station at Mills, 5 km (3 miles) west of Casper. Other county fire-fighting equipment is located on ranches and settlements.

Water systems

Converse County. Glenrock obtains water from a system of wells consisting of a well field (four wells), a well gallery, and four additional wells. The pumping capacity of the wells is approximately 5.7×10^6 L/d (1.5×10^6 gpd), the storage capacity is approximately 6.1×10^6 L/d (1.6×10^6 gpd), and the average usage during the summer months is approximately 4.9×10^6 L/d (1.3×10^6 gpd).[15] A grant-funded exploratory study is now being conducted, and additional wells may be drilled in the spring of 1982. Douglas's water is obtained from the North Platte River

and a mountain spring. Douglas's water system is sufficiently sized for a population of approximately 12,000.[18]

Natrona County. The city of Casper obtains water from two sources. Approximately one-half of the water is drawn from the Platte River, and the remainder comes from 20 shallow wells near the river. The production capacity of these sources is about 1.44×10^8 L/d (3.8×10^7 gpd); peak demand has reached 1.33×10^8 L/d (3.5×10^7 gpd).[19] Various reservoirs around the city total 7.6×10^7 L (2×10^7 gal) in storage capacity. The water treatment plant has facilities for filtration and chlorination. Platte River water requires filtration; well water does not. The design capacity of the treatment plant is approximately 9.1×10^7 L/d (2.4×10^7 gpd); present flow averages 4.5×10^7 L/d (1.2×10^7 gpd).

Sewerage systems

Converse County. Glenrock's sewerage system is a six-cell lagoon treatment system [three cells serve the western portion of Glenrock (System A); three cells serve the eastern portion (System B)]. The system was upgraded during the past few years and is sufficiently sized for a population of approximately 8000.[20] An EPA 201 wastewater study is currently being conducted for possible further upgrading. Douglas's sewerage system is an insufficiently sized lagoon treatment system. Douglas is now in Phase II of EPA 208 funded project to upgrade its sewerage system.[18]

Natrona County. Casper utilizes an activated sludge system and chlorination to treat sewage. The design capacity of the treatment plant is 24.6×10^6 L/d (6.5×10^6 gpd); current average flow is 20.8×10^6 L/d 5.5×10^6 gpd) and peak flow is approximately 22.7×10^6 L/d (6×10^6 gpd). The sludge is dried, ground, and used as a soil conditioner in city parks. The condition of the primary treatment section of the plant is poor; the secondary facilities are in good condition. Most of the main sewers are loaded to capacity; $7.5 million has been targeted for improvement of a major trunk sewer — it is anticipated that a $4 million expansion of this sewer will be completed in 1982. An EPA 201 facilities plan study for the entire Casper system is nearing completion.

Utilities

The primary supplier of electricity in the Converse/Natrona County area is the Pacific Power and Light Company. Pacific Power, which operates the Dave Johnston coal-fired steam generating facility in Converse County, sells power on a retail basis and on a wholesale basis to local distributors. The primary supplier of natural gas in the area is the Kansas-Nebraska Natural Gas Company.

Transportation

The impacted region is served by two airports. Limited air service is provided at the Converse County Airport, located in the southeastern

sector of Douglas. This county facility has a 1544-m (5066-ft) asphalt runway and can accommodate small jet aircraft; major repair facilities are also available. The nearest commercial air facility is the Natrona County International Airport, located approximately 13 km (8 miles) northwest of Casper. This airport is an asphalt-surfaced, four-runway facility that is served by four commercial airlines (Western, Frontier, Continental, and Big Sky); general aviation services are also offered. Daily commercial flights are available to Boise, Idaho; Butte, Missoula, and Billings, Montana; Denver, Colorado; Rapid City, South Dakota; Salt Lake City, Utah; and Riverton, Wyoming. During July 1979 the Natrona airport accommodated 6750 landings.

The Burling-Northern and the Chicago and Northwestern railroad companies operate east-west lines passing through Casper, Glenrock, and Douglas. The impacted region is served by numerous motor freight carriers. Glenrock and Douglas are served by four motor freight carriers, Casper by six. Bus service for the region is provided by Trailways, Inc.

The major movement of vehicular traffic through Converse County is east-west on Interstate 25 and U.S. routes 20/26/87 (Fig. 3.2). The Leuenberger site is located south of State Highway 95. Highway 95 interconnects Glenrock and Orpha and eventually connects Orpha to Interstate 25 approximately 0.6 km (1 mile) southwest of Douglas.

Recreation

Overview. There are two major types of recreational facilities within the area impacted by the proposed project: (1) resource-oriented recreational outlets (e.g., hunting, fishing, camping, hiking, and skiing) and (2) user-oriented facilities requiring substantial development (e.g., community recreation centers, municipal parks, swimming pools, golf courses, and tennis courts). Resource-oriented recreational activities and facilities are, by far, the dominant sources of recreation in the Converse/Natrona County region.

Converse County. Converse County offers a wide variety of outdoor recreational activities for tourists and residents. Hunting, particularly for big and upland game, is an especially important pastime. Water sports such as skiing, boating, canoeing, and fishing are popular in the public-use areas designated by the state and counties along the North Platte River and its major irrigation water bodies, such as Alcova Lake and Glendo Reservoir. Although no state parks are located within the county, about one-fourth of Medicine Bow National Forest is situated south of the Leuenberger site in the southwestern corner of the county. Laramie Peak (located in the national forest), Ayres Natural Bridge, Jackalope Plunge, and various camping and picnicking sites attract many tourists. Glendo State Park is located about 40 km (25 miles) southeast of Douglas at the Glendo Reservoir in Platte County.

Many visitors are attracted to the county for the annual Wyoming State Fair and to tour the Wyoming Pioneer Memorial Museum in Douglas. Fort Fetterman, a state historical site and museum located approximately 18 km (11 miles) northwest of Douglas, is also an important tourist attraction.

Several user-oriented facilities are located in Glenrock and Douglas. Glenrock has six public parks covering 41 ha (102 acres) and operates a swimming pool; two additional parks and an indoor recreation center are in the planning stage.[15] Douglas currently has three city parks with a fourth being planned. One of the existing parks is specifically equipped for children, and two parks have tennis courts. Douglas also has an 18-hole golf course, several ball fields, and an indoor community recreation facility. Indoor and outdoor swimming facilities are also available.

Natrona County. The Natrona County Parks Department administers park facilities that are primarily resource oriented. Included in these facilities are acreage on Casper Mountain, Pathfinder Reservoir, Alcova Lake, Gray Reef Reservoir, and Ponderosa Mountain. The Casper Department of Parks maintains an extensive urban parks system that has numerous ballfields, tennis courts, picnic areas, and other recreational facilities. Casper also has a community recreation department that administers various recreational activities. Cultural attractions in the Casper area include the Pioneer Museum, Fort Casper, Weiner Wildlife Museum, Central Wyoming Fair and Rodeo, Community Concert, Civic Symphony, Nicolaysen Art Museum, West Winds Art Gallery, and Goss Rock Museum.

3.5 LAND USE

3.5.1 Current land use and resources

The Converse County Land Use Plan designates the area in the vicinity of the site as an agricultural and mining area (ER, Appendix D-1). Lands in the region have been used primarily for domestic livestock grazing although a few areas in the vicinity of the site may have been tilled many years ago. During the growing season, the site could support about 0.75 head of cattle per hectare (ER, Sect. 2.2.2). Although there are a few areas in the region where irrigated crops (hay, barley, oats, and corn) are grown on the better soils, there are no row or grain crops adjacent to the site. Recreational activities in the region include camping, hunting (Sect. 3.9.1), picnicking, hiking, skiing, and snowmobiling. No areas near the site are particularly important for such activities.

Currently, the major portion of the land within the permit area is leased by Teton from the Smith Cattle Company and has been used for uranium exploration and for the Leuenberger in situ uranium mining R&D facility. Several other mining facilities are located in the region surrounding the site (Sect. 3.7.2, Fig. 3.2).

3.5.2 Historical, archaeological, and scenic values

Although several sites of potential historical significance occur in the region, all are at least several kilometers from the Teton site. Converse County was crossed by several early survey parties, by both the Oregon and Bozeman trails, and by the Pony Express routes. However, no known survey parties or historical trails passed within 6.7 km (4 miles) of the site (ER, Appendix D-2). Several sites in the region are enrolled in the National Register of Historic Places (NRHP), but none of these is within 8 km (5 miles) of the site. A local historian concluded that there were no features of historic value at the site (ER, Appendix D-2).

Personnel of the Office of the Wyoming State Archaeologist were engaged to conduct a cultural resource inventory on the proposed commercial permit area. Approximately 405 ha (1000 acres) were surveyed, and a total of three isolated artifacts and eight archaeological sites (ER, Fig. D-3.1) were found. Four of the eight archaeological sites are surface sites that will require no further work and are not considered eligible for nomination to the NRHP. These are located 40, 85, 125, and 225 m from the nearest area to be affected (ER, Fig. D-3.1 and D-7.1). The other four sites have the potential to have subsurface deposits. One of these is adjacent to an area to be affected and the others are 430, 535, and 590 m from the nearest affected areas. The Wyoming State Historic Preservation Officer (SHPO) recommends cultural clearance subject to applicable state and federal laws reflected by the following stipulations:

1. No surface disturbing activities are to take place in or around the boundaries of the four sites having potential for subsurface deposits.

2. Prior to any future disturbing activities in these site areas, the sites must be evaluated for NRHP eligibility.

3. If any archaeological materials are discovered during construction, work in the area must halt immediately and the SHPO office contacted. Work in the area may not resume until the archaeological materials have been evaluated and adequate measures for their protection taken.

In the event these stipulations are not followed, clearance will be void.[21]

The lands of the site are gently rolling and generally lack trees. Although the general region contains pleasing, open landscapes, there is no scenic feature at the site which is in any way unique or particularly valuable in comparison to the surrounding region.

3.6 WATER

3.6.1 Surface water

Flowing across eastern Wyoming, the North Platte River drains the southern Powder River Basin and passes approximately 6.7 km (4 miles) south of the Teton-Nedco solution mine. Surface waters draining the mine site [elevation 1585 m (5200 ft)] flow by means of Little Sand Creek and its unnamed tributary to Sand Creek, thence to the North Platte, entering about 8.3 km (5 miles) east of the Glenrock city limits [elevation 1524 m (5000 ft)]. The North Platte at this location drains an area of 35,048 km^2 (13,538 sq miles), of which 3037 km^2 (1173 sq miles) are probably noncontributing.[22] Its flow is regulated by three sizeable reservoirs located within 167 stream km (100 stream miles) to the southwest: Alcova [capacity 2.3 x 10^8 m^3 (184,300 acre-ft)]; Pathfinder [capacity 1.3 x 10^9 m^3 (1,016,000 acre-ft)], and Seminoe [capacity 1.3 x 10^9 m^3 (1,017,000 acre-ft)].[22] Some additional regulation occurs 1.6 km (1 mile) upstream of the mouth of Sand Creek at the Dave Johnston power plant storage pond [9.3 x 10^5 m^3 (755 acre-ft)]. The river's natural flow throughout this region is dominated by transbasin diversions, storage reservoirs, power development, diversions for irrigation, and return flow from irrigated areas.

Contributions of surface water to the North Platte River from the mine site are small because all tributaries in the vicinity of the site are ephemeral. Records for October 1977 to September 1978[22] reveal that, at its convergence with the North Platte River, Sand Creek discharged water only between mid-February and mid-August. During this period, mean monthly discharges exceeded 0.028 m^3/s (1 ft^3/s) during only May [0.31 m^3/s (11.1 ft^3/s)] and July [0.17 m^3/s (5.95 ft^3/s)].

Several kilometers east of the Sand Creek entry point, the North Platte swings south past the city of Douglas then southeast to Glendo, another major reservoir approximately 83 stream km (50 stream miles) from Teton-Nedco. The capacity of this reservoir is 9.7 x 10^8 m^3 (789,400 acre-ft), and its waters are used primarily for irrigation and power development.

The quality of water in the North Platte River near Glenrock is generally good, as evidenced by U.S. Geological Survey (USGS) analyses[22] and the presence of fish species characteristic of relatively clean water (Sect. 3.9.2). Water quality at the Teton-Nedco site is not as easily ascertained, however, because of the ephemeral nature of the waterways crossing the site. The applicant originally intended to sample the Little Sand Creek drainage channel at three points: (1) as it entered the permit area, (2) at a location within the permit area just upstream from the Smith windmill, and (3) as it exited the permit area. The latter location, a stock pond fed by the Smith windmill, is the only sampling site that contains water during periods of no precipitation. Attempts to sample the two upstream locations have been unsuccessful for two years because of the total absence of runoff. The stock pond, however, has been sampled; analyses for selected constituents are presented in Table 3.19. Of the trace metals assayed, several (barium, cadmium, chromium,

Table 3.19. Water quality data for stock pond on Little Sand Creek (below Smith windmill)

Chemical units are mg/L unless otherwise noted

Constituent	Date sampled				
	5/15/80	7/23/80	10/17/80	2/17/81	4/9/81
pH	7.89	9.2	8	7.8	8.3
Conductivity (S/cm)	2590	2775	6315	5700	4939
Total dissolved solids	3270	3721	8343	5694	4568
Common ions					
Ammonia (NH_3 as N)	2.80	<0.1	<0.1	<0.1	<0.1
Total nitrogen (NO_2/NO_3)	0.29	0.76	0.66	0.36	0.34
Bicarbonate (HCO_3)	454	83	229	233	362
Carbonate (CO_3)	0	29		19	30.4
Calcium (Ca)	480	299	425	226	336.9
Chloride (Cl)	39	53	135	132	70
Boron (B)	0.05	<0.25	0.44	0.33	0.66
Fluoride (F)	0.39	0.5	0.49	0.56	0.44
Magnesium (Mg)	73	238	683	100.5	320.5
Potassium (K)	19	23.3	42	29	25.8
Sodium (Na)	50	352	741	973	539
Sulfate (SO_4)	1808	2071	4816	340	2408
Trace metals					
Aluminum (Al)	0.20	0.74	0.18	0.09	0.30
Arsenic (As)	<0.005	<0.005	0.008	0.007	<0.005
Iron (Fe)	<0.05	0.45	0.2	0.07	0.22
Manganese (Mn)	0.45	0.16	0.34	0.80	0.09
Nickel (Ni)	<0.05	0.07	<0.05	<0.05	<0.05
Selenium (Se)	<0.005	<0.005	<0.005	0.005	<0.005
Radium-226 pCi/L (Ra-226)	16 ± .26	0.95	0.7		
Uranium (U)	<0.05	0.03	0.3		0.50

Source: ER, Table 2-14, p. 59, and Teton-Nedco supplement thereto (part of response to NRC letter dated June 11, 1981).

copper, lead, mercury, molybdenum, and vanadium) were either absent or present below the limits of detection on all sampling dates and have been excluded from the table. Water from the stock pond meets livestock water standards.

3.6.2 Groundwater

3.6.2.1 Regional flow system

Climate and geology are the major factors controlling the occurrence of groundwater within the Powder River Basin. The climate in the region is semiarid with a mean annual precipitation of 305 mm (12.0 in.). Precipitation supplies almost all the water for recharge to the Cenozoic rocks of the Powder River Basin; however, much of the water potentially available for recharge to aquifers is lost to the atmosphere from a high rate of evaporation equaling several times the precipitation. Discharge is primarily due to evaporation, seepage to springs and lakes, transpiration, and pumpage from wells. The small fluctuations in annual water level at observation wells indicates a balance between recharge and discharge within the region.

The Powder River Basin's thick sequence of sedimentary rocks contains numerous water-bearing zones. Water is under artesian pressure in many of these zones, and they may contain wells that flow at land surface. Most wells in the region were drilled for developing water supplies for domestic and stock uses. In the region of the Leuenberger site, the Fort Union and Wasatch formations have the greatest potential for groundwater development.[23]

3.6.2.2 Site-specific groundwater and aquifer characteristics

Interbedded among the shales of the upper portions of the Fort Union formation are a series of sandstone layers comprising the four principal aquifers of the Leuenberger site (Fig. 3.3). The N and M aquifers, to be directly effected by solution mining, lie between the basal aquifer below and the O aquifer above.

Water in the O aquifer is found in wells at a depth of from 0 to greater than 40 m (0 to >130 ft) below land surface. The water table intersects the land surface within the permit area along Little Sand Creek at approximately 1576 m (5170 ft) elevation. Groundwater flow in the aquifer is to the southwest following the slope of the ground surface. Over portions of the project area, the O aquifer interfingers with the underlying claystone unit dividing it into an O_2 unit and a confined O_1 unit below the interfingering shale. Water levels in the O_1 unit follow the same trend as those of the O_2 unit but at an elevation approximately 0.61 m (2 ft) lower (ER, pp. 37 and 38).

The O_2 aquifer serves as a source of domestic water for several residents in the section immediately north of the project site (ER, p. 38).

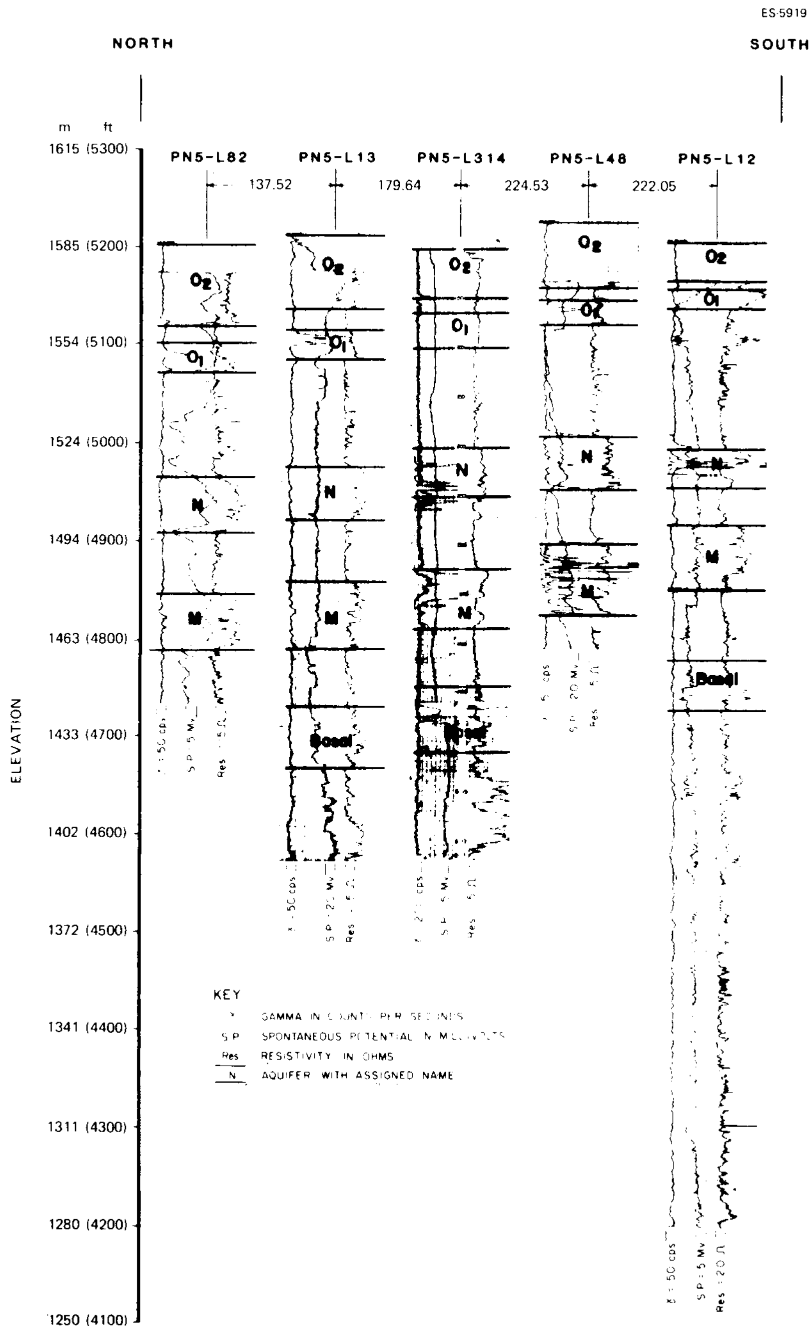

Fig. 3.3. Representative geophysical logs across the project site showing the series of sandstone layers comprising the four principal aquifers. Source: Adapted from ER, Fig. D-5.2.04.

Results from the applicant's O aquifer groundwater recovery test indicate that the O aquifer has a transmissivity of 7.7 m^2/d (620 gpd/ft). This value is consistent with transmissivities observed for other aquifers of the Fort Union formation in the area of the project site (ER, p. 38), and the staff concurs with the values calculated by the applicant.

Separated from the O aquifer by 30 m (100 ft) of claystone is the upper ore zone sand designated as the N aquifer. The potentiometric surface of the N aquifer has consistently remained 10.67 to 12.12 m (35 to 40 ft) below the water levels in the O aquifer. Groundwater in the N aquifer, under ambient conditions, moves in a northeasterly direction at a velocity of 0.8 m/year (2.5 ft/year).

The applicant conducted a single aquifer test in the N ore zone (Fig. 3.4). Aquifer test results, as interpreted by the applicant, indicate that the N aquifer is the more permeable of the ore-bearing sands with an average permeability of 0.6 m/d (1.9 ft/d). The transmissivity of the aquifer was calculated by the applicant to be 8.7 m^2/d (700 gpd/ft). The staff does not agree with the applicant's interpretation of the N ore zone aquifer test data. The staff believes that some of the water withdrawn during the test was derived from water released from storage in the confining layers and that the transmissivity and permeability of the N aquifer are approximately 3.73 m^2/d (300 gpd/ft) and 0.26 m/d (0.8 ft/d) respectively. A detailed discussion of the N #1 aquifer test is presented in Appendix B. During the N aquifer test, the applicant detected a negative hydraulic boundary attributable to the thinning of the aquifer in the southeastern portion of the project site.

A second ore-zone sand designated the M aquifer lies between the basal and N aquifers and is separated from the N aquifer by approximately 15.2 to 22.9 m (50 to 75 ft) of claystone. The potentiometric surface of the M aquifer follows the trend of the N aquifer but averages about 0.9 m (3 ft) lower in elevation.

Three M ore zone aquifer tests (Fig. 3.4) were conducted by the applicant. The highest permeability determined by the tests is 0.3 m/d. The average value of transmissivity was determined by the applicant to be 3.7 m^2/d (300 gpd/ft). Groundwater moves in the M aquifer to the northeast at a velocity of 0.4 m/year (1.23 ft/year). The staff concurs with the M ore aquifer parameters presented by the applicant. A detailed discussion of the three M ore zone aquifer tests are presented in Appendix B.

During one of the aquifer tests, the applicant reports observing a negative boundary in the M aquifer that appears to correspond with the rapid thinning of the M aquifer at the eastern edge of the ore deposit.

About 18.3 m (60 ft) of claystone separate the underlying basal aquifer from the M aquifer. The applicant's basal aquifer groundwater recovery tests yield approximate values of transmissivity of 6.7 to 1.5 m^2/d (540 to 120 gpd/ft) and permeabilities of 0.33 to 0.15 m/d (1.1 to 0.5 ft/d). The staff agrees with the basal aquifer characteristics

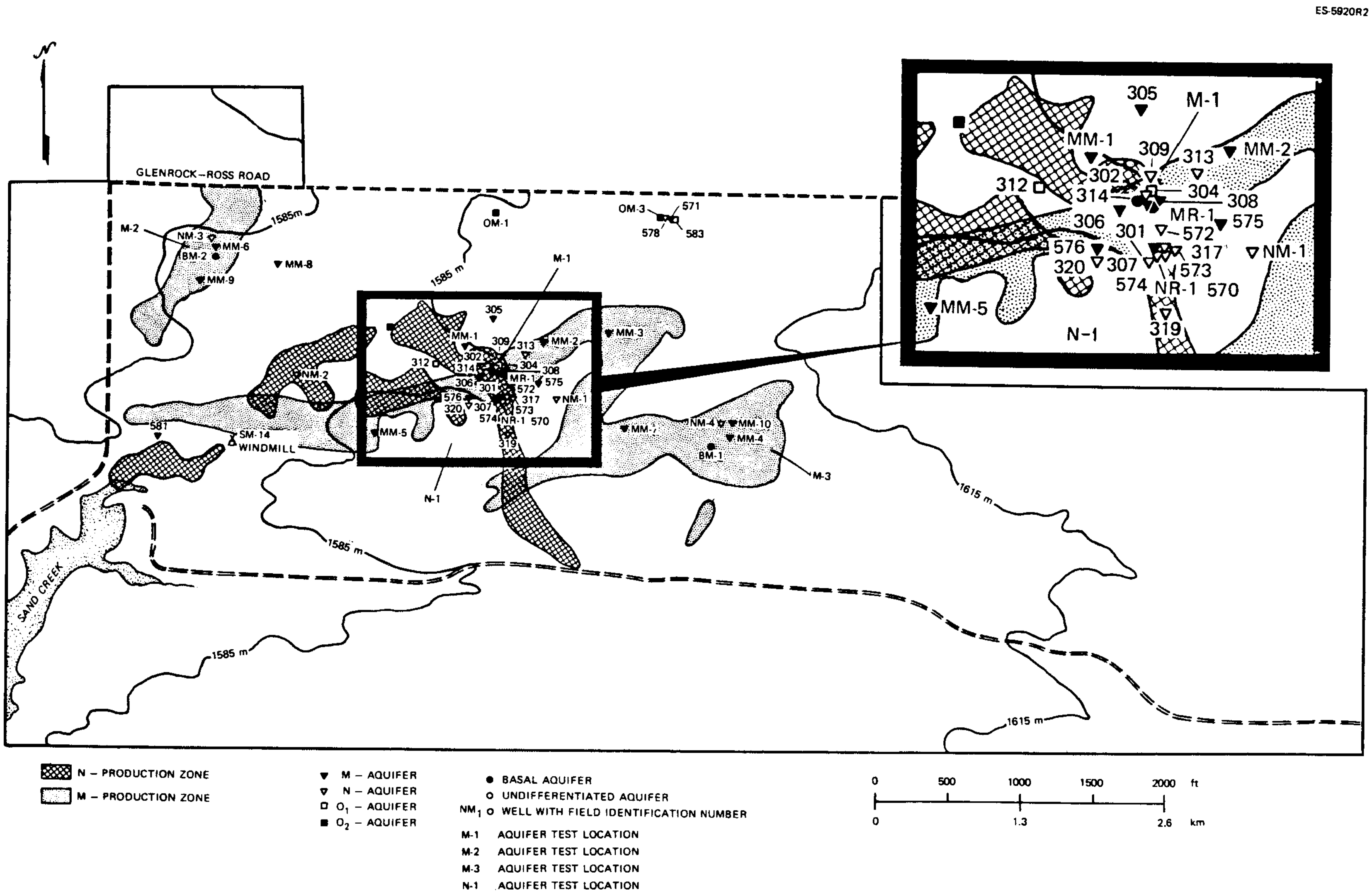

Fig. 3.4. Map of Teton project site showing locations of the four ore-zone aquifer tests.

calculated by the applicant and they are consistent with the parameters determined for other aquifers of the Fort Union Formation. The basal aquifer will serve as the source of fresh water for the site.

3.6.2.3 Hydraulic communication

At ambient conditions, the static head of the O aquifer is approximately 11 m (35 ft) higher than the static heads of the two ore zone sands (N and M aquifers), which indicates that the O aquifer is separate and distinct and that fluid migration between aquifers would normally occur in vertical downward directions.

Data from the applicant's four ore zone aquifer pumping tests (one in the N ore zone and three in the M ore zone) indicate that within area influenced by the tests there are no natural or manmade pathways (fractures, faults, abandoned boreholes, etc.) through the confining units for significant amounts of fluid to migrate between aquifers. This conclusion is further supported by the applicant's R and D test, where no vertical excursions were observed during the 13-month mining period. A detailed discussion and staff evaluation of the applicant's four aquifer tests is presented in Appendix B.

Before any proposed mining is conducted, the applicant will have to perform additional aquifer pumping tests, one in each mining unit, including Unit I, as described in Sect. 4.2 to verify confinement of the ore zones. These tests will be designed, with NRC approval, in part to supply data for a detailed evaluation of the hydraulic properties of the confining units.

3.6.2.4 Potentiometric surface

The static potentiometric elevations in wells that penetrate the O_2, N, and M aquifers were monitored periodically since the autumn of 1979. The potentiometric maps (Figs. 3.5, 3.6, and 3.7) show the average potentiometric surface of the O, N, and M aquifers for one year based on periodic water level measurements taken in 1980. The maps show that while water in the O_2 aquifer moves toward the southwest in response to the sloping land surface, water in the N and M aquifers moves down the direction of the formational dip or toward the northeast. The maps also indicate that the O aquifer is separate and distinct and that water levels in wells in the O aquifer are approximately 11 m (35 ft) higher than those of the underlying ore zones.

3.6.2.5 Site-specific groundwater quality

Baseline water quality of the M ore zone was determined by sampling six wells completed in the M ore zone within Mining Unit I between January 10, 1979, and April 19, 1981. The wells sampled were 301, 306, 307, 308, 575, and 576 (see Fig. 3.4). Average baseline values for an

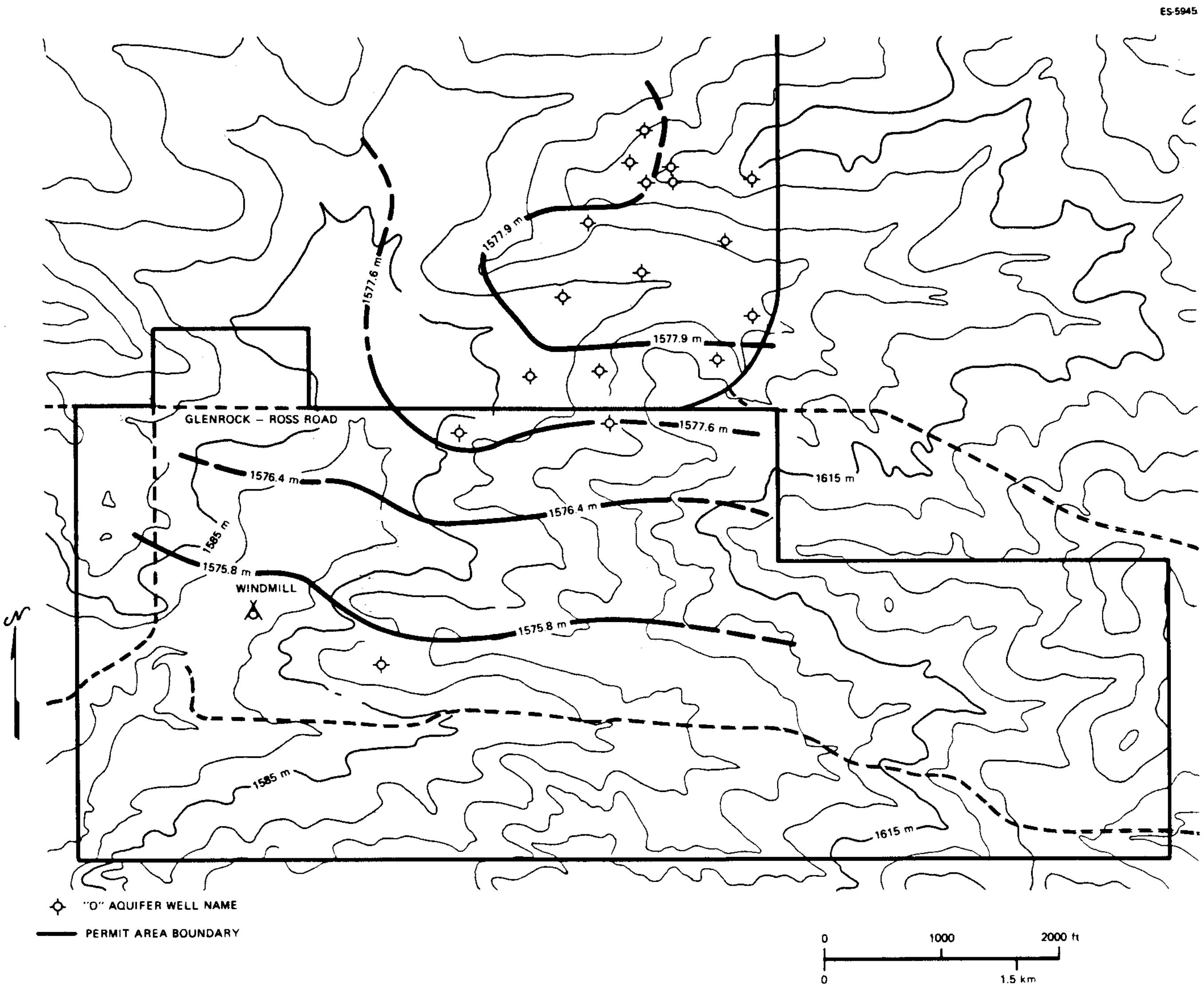

Fig. 3.5. Potentiometric map of the O aquifer. Source: Adapted from ER, Fig. 2-11.

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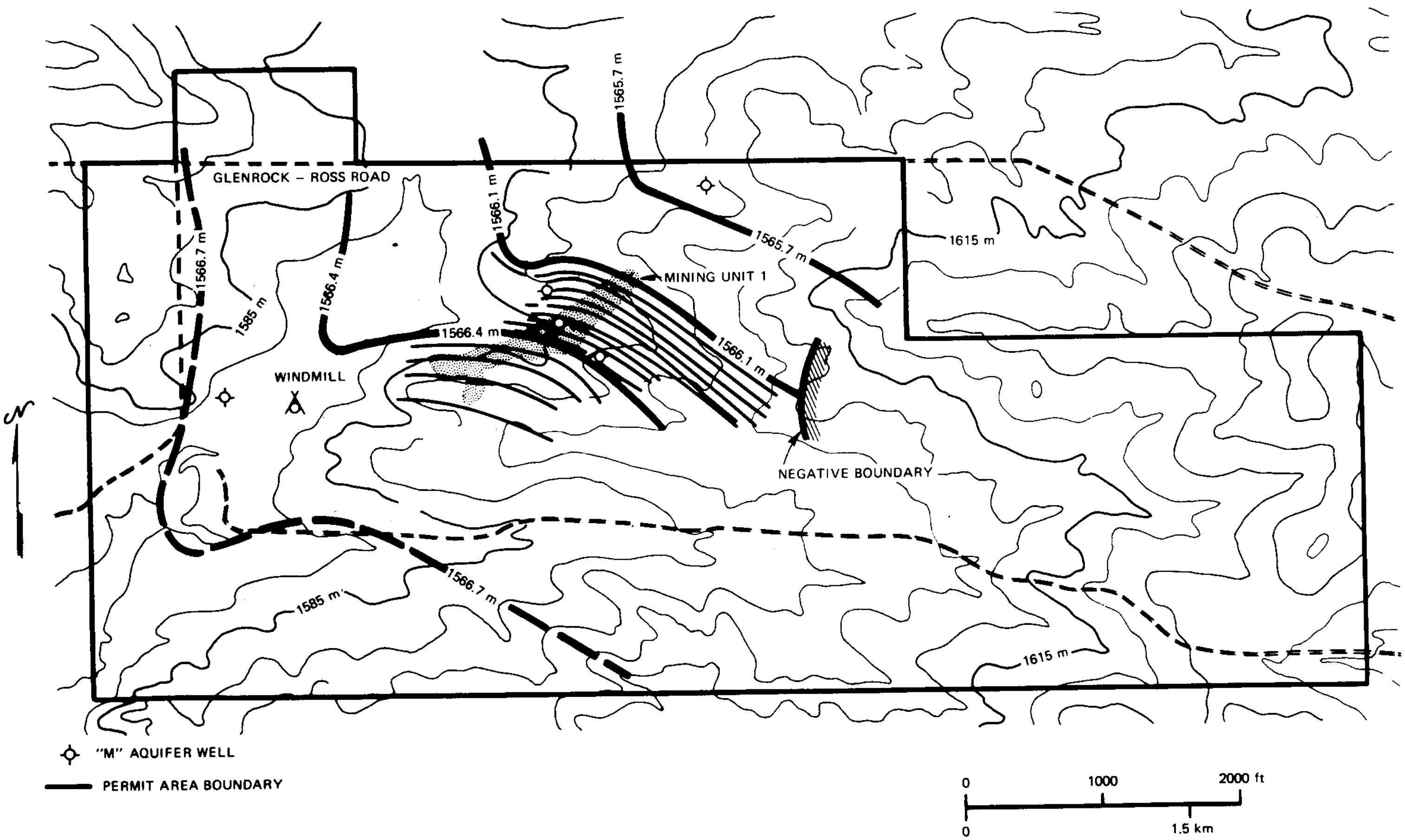

Fig. 3.6. Potentiometric map of the M aquifer. Source: Adapted from ER, Fig. 2-12.

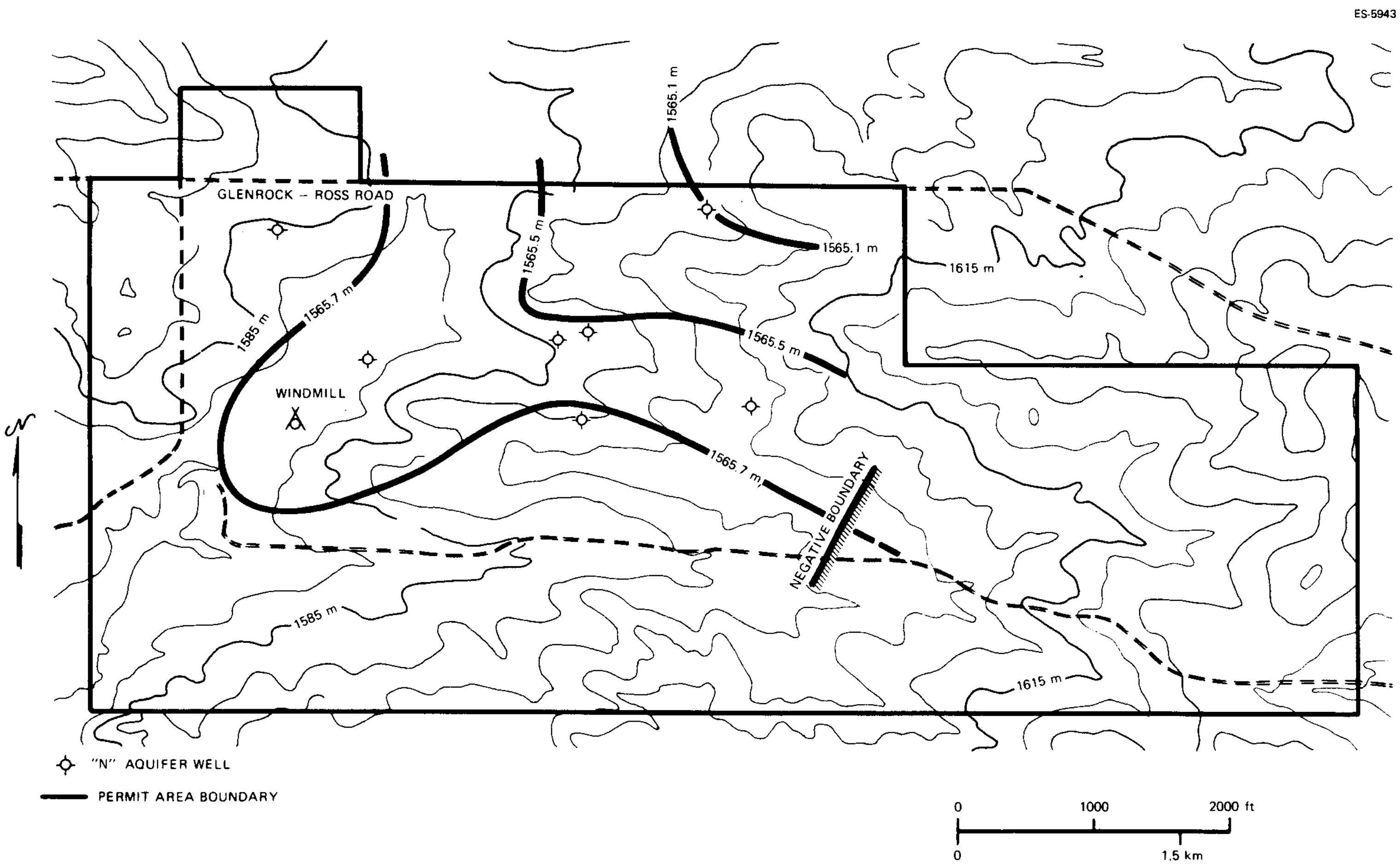

Fig. 3.7. Potentiometric map of the N aquifer. Source: Adapted from ER, Fig. 2-13.

indicator set of 36 groundwater quality indicator parameters were determined for each well sampled. Baseline values for each well listed in Table 3.20 are average values calculated from at least three separate samplings, except for well 308 where the value from only one sample is shown. The table also shows the composite mean of each parameter from all the wells. The composite mean baseline value for each parameter is compared to Wyoming drinking water and livestock standards in Table 4.1 (p. 4-6). The R&D data for the N ore zone indicates that the groundwater quality is similar to that found in the M ore zone.

As proposed by the applicant, additional premining water quality sampling will be performed in Mining Unit I and in all subsequent mining units by sampling a specified set of injection and recovery wells spaced evenly throughout the mining unit(s) at a minimum density of one well per two acres. This new data will be used to establish more representative baseline values for each mining unit (see Sect. 4.4.1.1). The same wells will be sampled as part of the postmining and postrestoration sampling programs (see Sect. 4.4.2.5).

Groundwater in the M and N ore zone sand of mining unit I does not meet drinking water standards because of its high radium-226 levels, which exceed the drinking water standard of 5 pCi/L. However, baseline averages for the other indicator parameters are within or very close to meeting drinking water standards (see Sect. 4.3, Tables 4.1 and 4.3). Therefore, the position of the NRC is that the quality of the water in the ore zone(s) be restored after mining to baseline. For this project, some improvement in a number of groundwater constituents may be expected. A detailed discussion of restoration criteria, restoration targets, and the applicant's R&D restoration tests are presented in Sect. 4.3 and Appendix F.

The groundwater quality of the O aquifer is similar to that of the ore zone aquifers except that radium-226 is below the 5 pCi/L standard. The O aquifer is the source of drinking water for residents living in the site vicinity. The basal aquifer contains potable water and will serve as the mining facility's source of fresh water (ER, p. 38).

3.6.2.6 Water use

The list of groundwater rights within 2 km (3 miles) of the project site supplied by the applicant indicates that there are 41 wells supplying water for stock and 20 supplying water for domestic use. The wells range in yield from 136 to 16 m^3/d (25 to 3 gpm). Some of these wells are not listed in the office of the Wyoming State Engineer and are therefore listed as unpermitted (ER, pp. D-6.1 to D-6.10).

Table 3.20. Data used to establish preliminary mean baseline values for mining unit I

(Unit in mg/L unless otherwise noted)

Parameter sample	Well number						Mean baseline
	301[a]	306[b]	307[c]	308[d]	575[e]	576[f]	
HCO_3^-	214.7	234	234	142	217	224	211
$CO_3^=$	0	0	0	0	0	0	0
Cl^-	2.3	6.0	6.7	8	8.8	8	6.6
$SO_4^=$	106.3	94.7	323	246	103	100	162
Anion equivalent	5.81	5.98	10.76	7.67	5.96	5.98	7.02
Ca^{++}	61.3	58.7	112	95	62.5	66	75.9
Mg^{++}	16	17.4	43.4	21	16.5	15.3	21.6
Na^+	26.7	29	26.3	22	27.5	28.6	26.7
K^+	7	8.3	10.2	10	9.4	8.5	8.9
Cation equivalent	5.74	5.86	10.62	7.68	5.95	6.04	6.98
−/+ balance	101.22	102.05	101.32	99.9	100.17	99.01	100.57
ΣTDS	434.3	448.1	755.6	544	444.7	450.4	512.7
Conductivity, μsemens/cm	NA[g]	463	812	715	476	476	588
TDS	330	341	700	197	350	350	378
pH unit	NA	7.85	8.04	8.04	7.5	7.63	7.8
U	<.005	0.15	<.10	0.072	<.10	<.10	0.10
Al	<.10	0.36	<.05	0.04	<.05	<.05	0.11
NH_4^+	1.18	0.12	0.15	<.10	0.12	<.10	0.30
As	<.005	0.007	<.005	<.005	0.006	<.005	0.006
Ba	<.50	<.40	0.12	0.05	<.50	<.50	<0.50
B	0.10	0.08	<.25	0.01	<.25	<.25	<0.25
Cd	<.005	<.02	<.05	0.002	<.01	<.01	<0.05
Cr	<.02	<.10	<.05	0.02	<.05	<.05	<0.10
Cu	<.01	<.09	<.05	<.01	<.05	<.05	<0.09
F	0.51	0.48	0.43	0.51	0.49	0.50	0.49
Fe	0.26	1.31	0.11	0.10	0.19	0.12	0.35
Pb	<.02	0.06	<.05	0.02	0.017	<.05	<0.05
Mn	0.05	0.08	0.053	0.04	<.20	0.055	0.08
Hg	<.001	<.001	0.003	<.0005	<.001	<.001	0.0013
Mo	<.02	<.50	<.10	<.05	<.10	<.10	<0.50
Ni	<.01	<.10	<.05	<.02	<.05	<.05	<0.10
NO_2/NO_3	0.013	0.45	0.10	<.05	0.16	0.11	0.15
Se	<.005	<.01	0.019	<.005	<.005	<.005	<0.01
V	<1.0	<.05	<.10	<.05	<.10	<.10	<1.0
Zn	0.026	<.05	<.05	0.03	<.05	<.05	<0.05
Radium-226 pci/L	420	562	6.67	102	7.41	20.96	186.5
Thorium-230 pci/L	NA	3.6	1.67	2.4	2.97	1.25	2.35
Gross A pci/L	NA	NA	NA	NA	NA	NA	NA
Gross B pci/L	NA	NA	NA	NA	NA	NA	NA

[a]Mean of 1/10/79, 1/10/79, and 2/16/79.
[b]Mean of 6/11/79, 6/11/79, and 5/13/80.
[c]Mean of 6/1/79, 10/10/80, and 1/14/81.
[d]5/31/79, one sampling.
[e]Mean of 2/29/79, 5/13/80, 7/16/80, 10/6/80, 1/13/81, and 4/6/81.
[f]Mean of 6/29/79, 5/13/80, 7/16/80, 1/4/81, and 4/6/81.
[g]Not available.
[h]Table 4.1 compares the mean baseline values to Wyoming Drinkwater and Livestock standards.

3.7 GEOLOGY, MINERAL RESOURCES, AND SEISMICITY

3.7.1 Geology

3.7.1.1 Regional geology

The project site is located in east central Wyoming in the southern portion of the Powder River Basin (Fig. 3.8). The Powder River Basin occupies approximately 30,000 km^2 (12,000 sq miles) and is bounded on the south by the Laramie Range, on the east by the Black Hills, and on the west by the Bighorn Mountains (ER, p. 16).

The Powder River Basin is an asymmetric syncline incorporating a sedimentary rock sequence ranging in age from Cambrian to Recent and having a maximum thickness of approximately 4573 m (15,000 ft) along its synclinal axis (Fig. 3.9). The sediments overlie a Precambian igneous and metamorphic basement rock complex (ER, p. 18). The structural axis projected to the surface from the Precambian basement is approximately parallel to the front of the Bighorn Mountains (Fig. 3.8). Pre-Tertiary strata along the east side of the Bighorn Mountains dip from 30° east to locally overturned. Toward the Powder River Basin, dip of Tertiary strata are generally less than 5° toward the structural axis; locally dips may be steeper along the limbs of small scale folds.[24] Readers interested in the geologic history of the Southern Powder River Basin are referred to Sharp and Gibbons, 1964 (ref. 25).

Solution mining of uranium at Teton Project will be confined to the Fort Union formation of Paleocene age. The formation consists of dark gray siltstones and claystone; buff to gray, fine- to coarse-grained channel sandstones; abundant fossils; and coal beds up to 37 m (120 ft) thick. These deposits suggest that the Fort Union formation was deposited in a swampy, forested lowland threaded by sluggish rivers. The source area for the Fort Union formation has not been clearly determined. The Laramie Range to the south, the Sweetwater Arch in Central Wyoming, and a site near the Bighorn Mountains have all been postulated as its source.[24]

3.7.1.2 Site geology

The stratigraphic unit outcropping at the site surface and containing the economic uranium mineralization for the Leuenberger site is the upper portion of the Paleocene Fort Union formation. The formation's uppermost layers are composed of interbedded fine- to coarse-grained sandstone, siltstone, claystone, subbituminous coal and lignite (ER, p. 28). A description of the typical lithology of the upper portion of the Fort Union Formation is shown in Table 3.21. Unit designations O, N, M, and basal sands are by the applicant.

Two separate mineralized zones, one in each of the N and M sands, exist at the project site (see Table 3.21). The upper N sand is approximately 15 m (50 ft) thick and lies at a depth of 61 m (200 ft) or more beneath the surface of the Leuenberger site. Approximately 30 m (100 ft) of claystone lies between the N sand and the uppermost O sand unit (ER, p. 35).

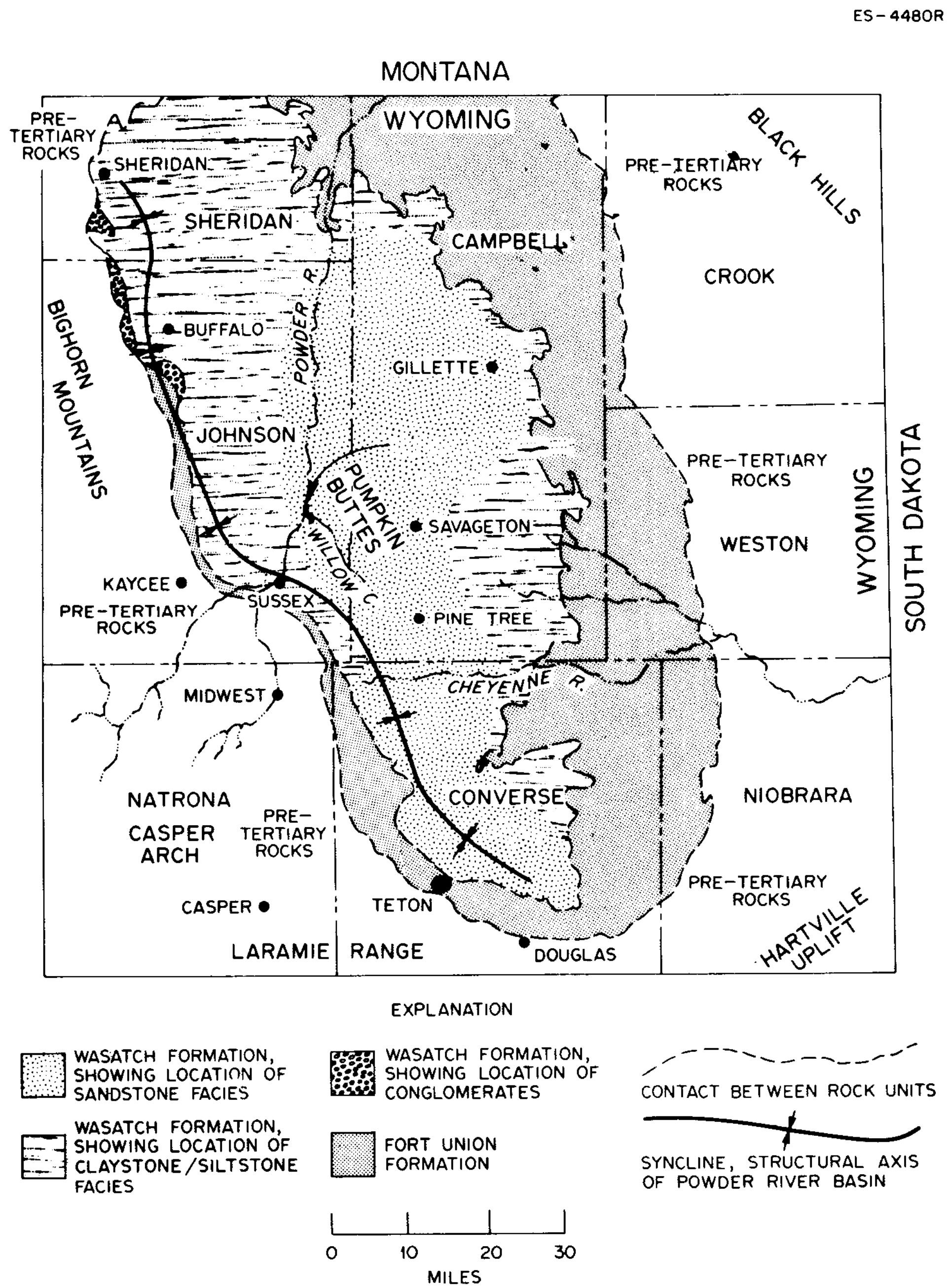

Fig. 3.8. Regional geology showing relationship to the Teton site. Modified from W. M. Sharp and A. B. Gibbon, *Geology and Uranium Deposits of the Southern Part of the Powder River Basin, Wyoming*, U.S. Geological Survey Bulletin No. 1147-D, 1954.

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Stratigraphic Column

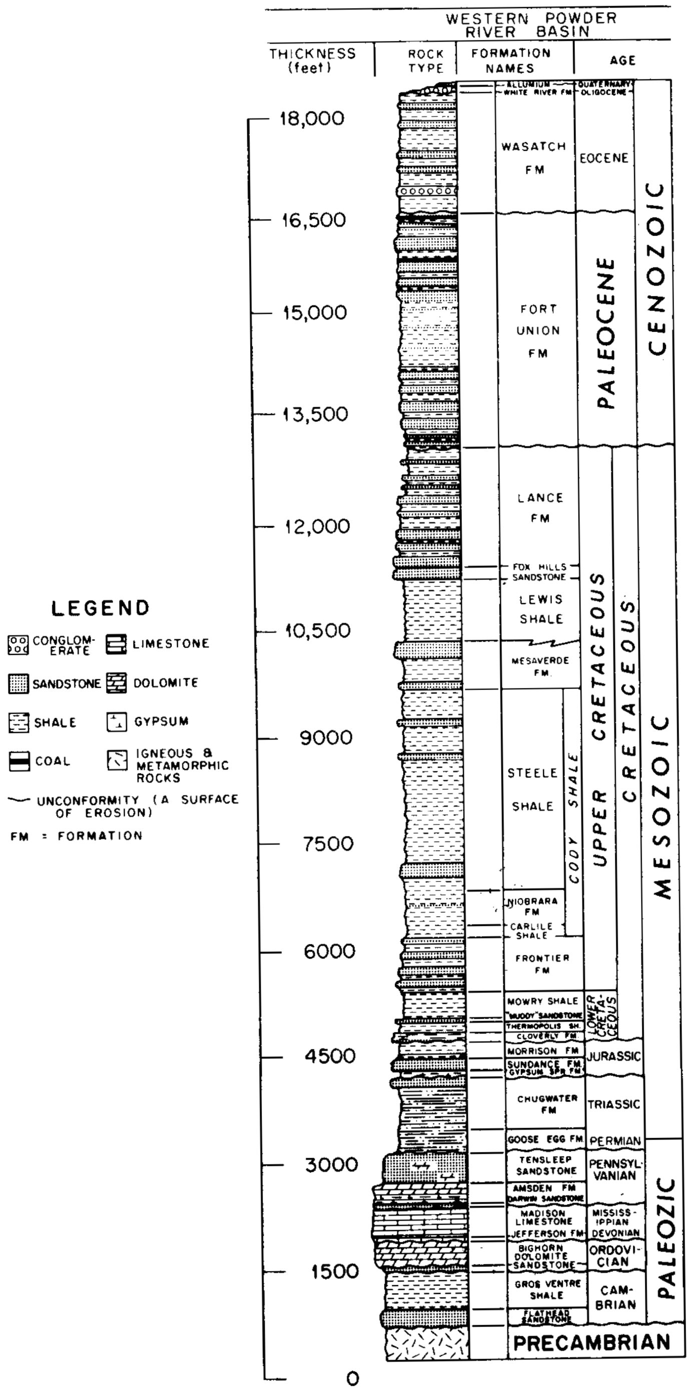

Fig. 3.9. Stratigraphic succession in the western Powder River Basin, Wyoming. Source: W. M. Sharp, E. J. McKay, F. A. McKeown, and A. M. White, *Geology and Uranium Deposits of the Pumpkin Buttes Area of the Powder River Basin, Wyoming*, U.S. Geol. Survey Bull. 1107-H, 1964.

Table 3.21. Typical vertical profile at Leuenberger site

Unit	Description[a]
O Sand	
O_2 sand member, thickness 50 ft to 100 ft	Oxidized to bleached-fine to coarse-grained sand with occasional limonite and hematite stringers, argillaceous in part. Contains small amounts of feldspar and chert. Grain shape subrounded to subangular. Color range very pale orange to grayish orange.
Clay member, thickness 10 ft to 30 ft	Clay, arenaceous in part, medium bluish gray. This clay member is generally absent in the southern portion of the permit area.
O_1 sand member, thickness 0 ft to 45 ft	Fine- to coarse-grained sand with limonite and hematite stringers, trace feldspar, chert, and lignite lanimae. Color grayish orange pink.
Clay below O sand, thickness 100 ft to 170 ft	Clay with sporadic interbeds of silt and very-fine-grained sand. Unit composed of various mixed layer clay minerals with significant amounts of montmorillonite. Color is medium gray.
N sand, thickness 0 ft to 60 ft	Fine- to coarse-grained sand with frequent intervals of shale pebble conglomerate in coarse-grained sand matrix. Also contains pebble units with rounded to subrounded chert, quartzite, and occasional granite pebbles imbedded in clay matrix, typically near base of unit. Fine-grained intervals generally interlaminated with silt and carbonaceous material. Coarse-grained units contain varying amounts of muscovite, biotite, chert fragments, plagioclase feldspar, and kaolinite. Color light gray to medium dark gray in unaltered areas and yellowish gray to dark yellow orange in altered areas.
Clay below N sand, thickness 60 ft to 160 ft	Clay with sporadic silt laminae, discontinuous fine-grained sand lenses and occasional carbonaceous laminae. Color medium gray to medium dark gray.

Table 3.21. (Continued)

Unit	Description[a]
M sand, thickness 0 ft to 70 ft	Fine- to coarse-grained sand with frequent intervals of shale pebble conglomerate in coarse-grained sand matrix. Fine grained intervals occasionally interlaminated with silt and carbonaceous material; with trace amounts of pyrite present in some areas. Coarse grained units typically contain small amount of muscovite, biotite, chert fragments, plagioclase feldspar, kaolinite and sporadic concentrated lignite laminae. Color light gray to medium dark gray in unaltered areas and yellowish gray to dark yellow-orange in altered areas.
Clay below M sand, thickness 50 ft to 60 ft	Clay with occasional sand breaks. Color medium gray to medium dark gray.
Basal sand, thickness 50 ft to 70 ft	Fine- to medium-grained sand and silt, very argillaceous in part with rare carbonaceous laminae. Sand typically quartzose with minor amounts of feldspar, chert, and muscovite. Middle of unit typically clay from 1 to 20 ft. Color medium light gray to medium dark gray.

[a]Color names taken from system described in National Bureau of Standards Research Paper RP 1239.

Separating the N sand from the lower ore-bearing M sand is approximately 15 to 23 m (50 to 75 ft) of interbedded claystone and siltstone. The M sand is approximately 15 to 20 m (50 to 65 ft) thick and lies at a depth of 98 m (320 ft) from the surface. This unit differs from the N sand in that there is generally less clay in the matrix and very few interbeds of claystone and coaly material present. The M sand is separated from the next lower basal sand unit by 18 to 21 m (60 to 70 ft) of claystone (ER, p. 36). The applicant's geologic cross sections constructed for the project area indicate that the N and M sand units are not continuous within the project boundaries (Figs. 3.10, 3.11, and 3.12).

No faulting at the Leuenberger site has been reported nor is any evident from geophysical log interpretations (ER, p. 63).

An independent staff evaluation of a representative set of geophysical logs indicated that the layers of interbedded clays and silts separating the O, M, N, and basal aquifers are uniform and continuous throughout the project area. Several representative geophysical logs are shown in Fig. 3.3.

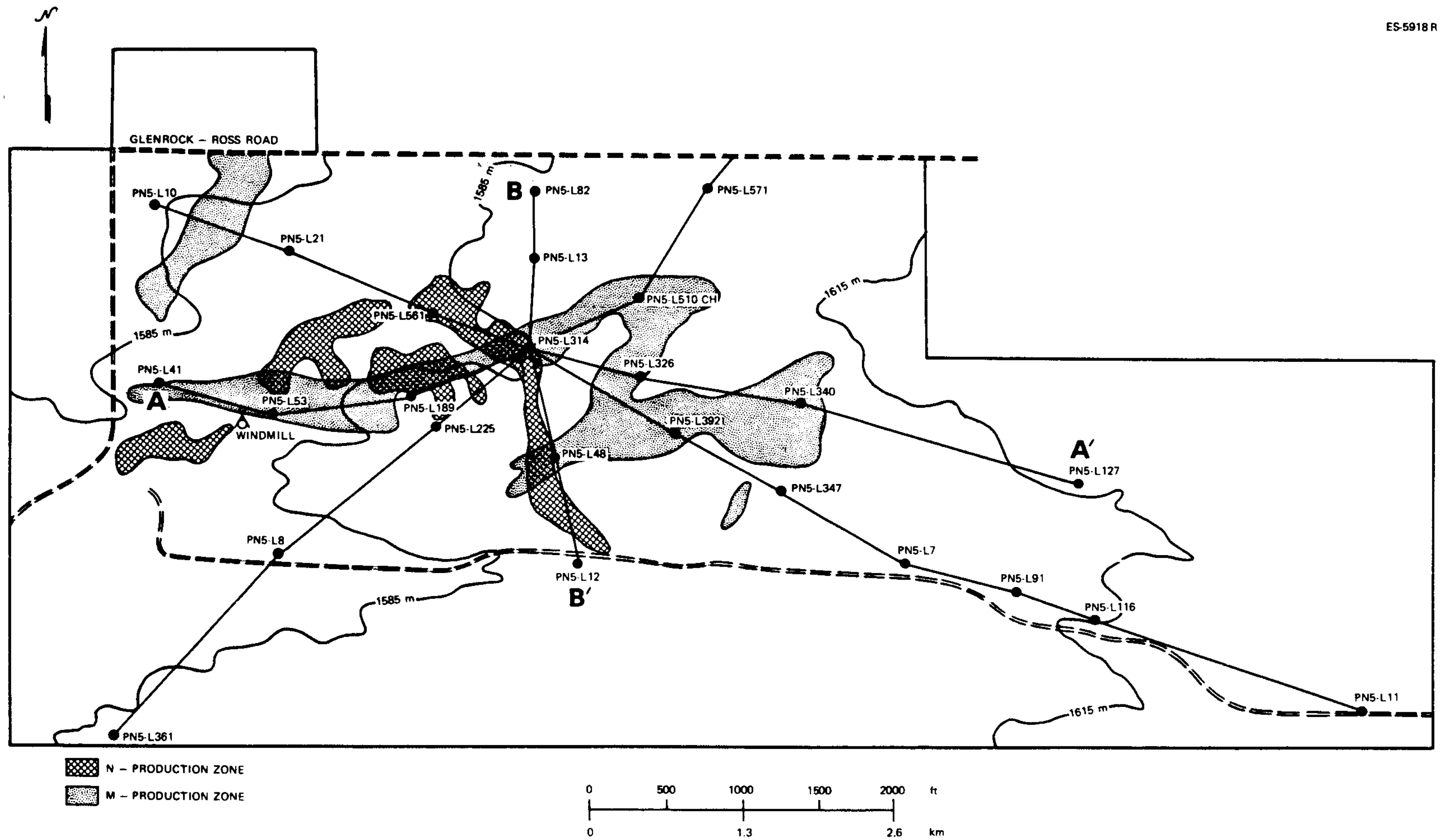

Fig. 3.10. Map of Teton project area showing outline of uranium ore bodies and locations of geologic cross sections A-A' and B-B'. Source: Adapted from ER, Fig. 2-10.

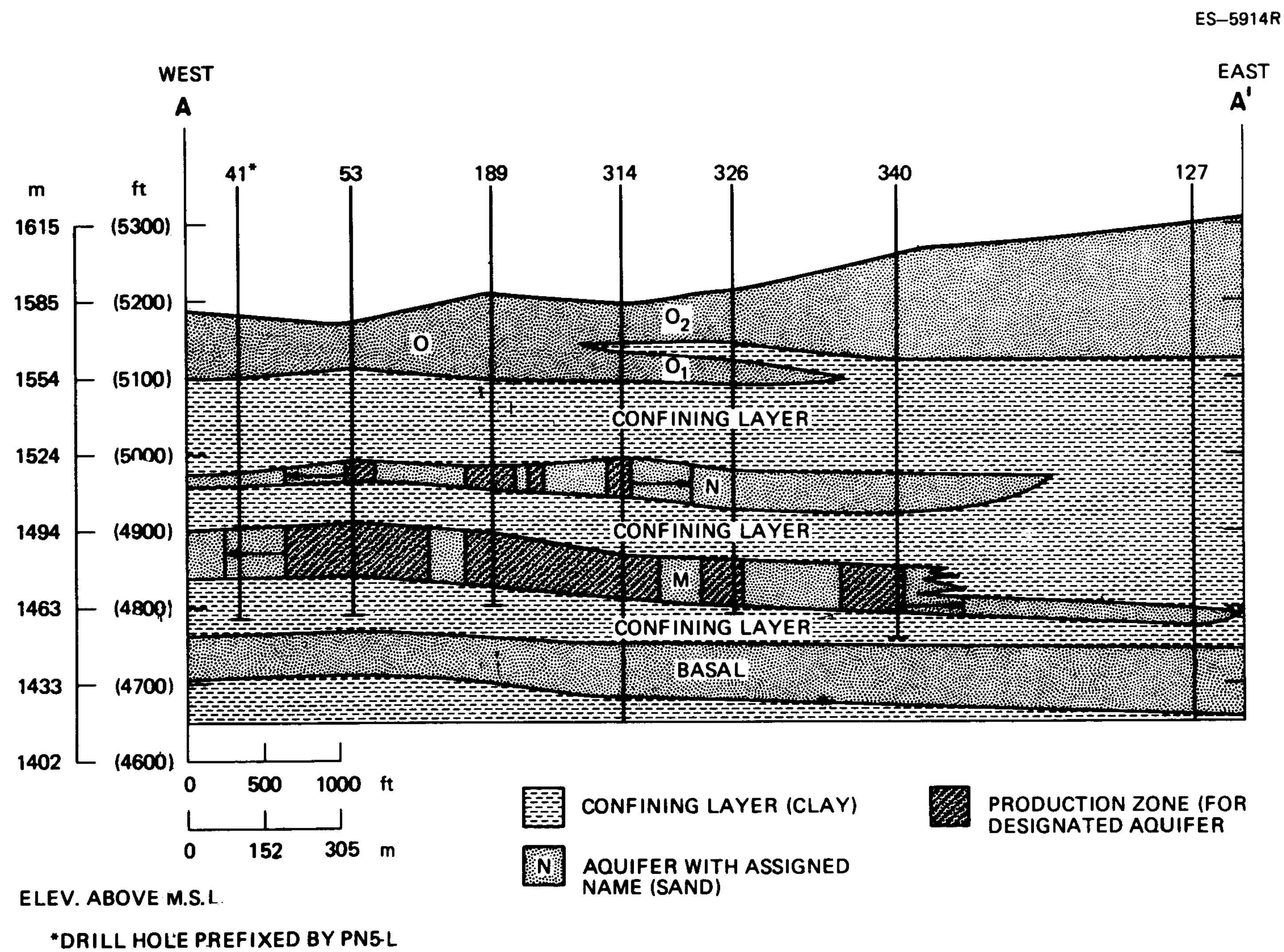

Fig. 3.11. Geologic cross section A-A' (see Fig. 3.10). Source: Adapted from ER, Fig. 2-8.

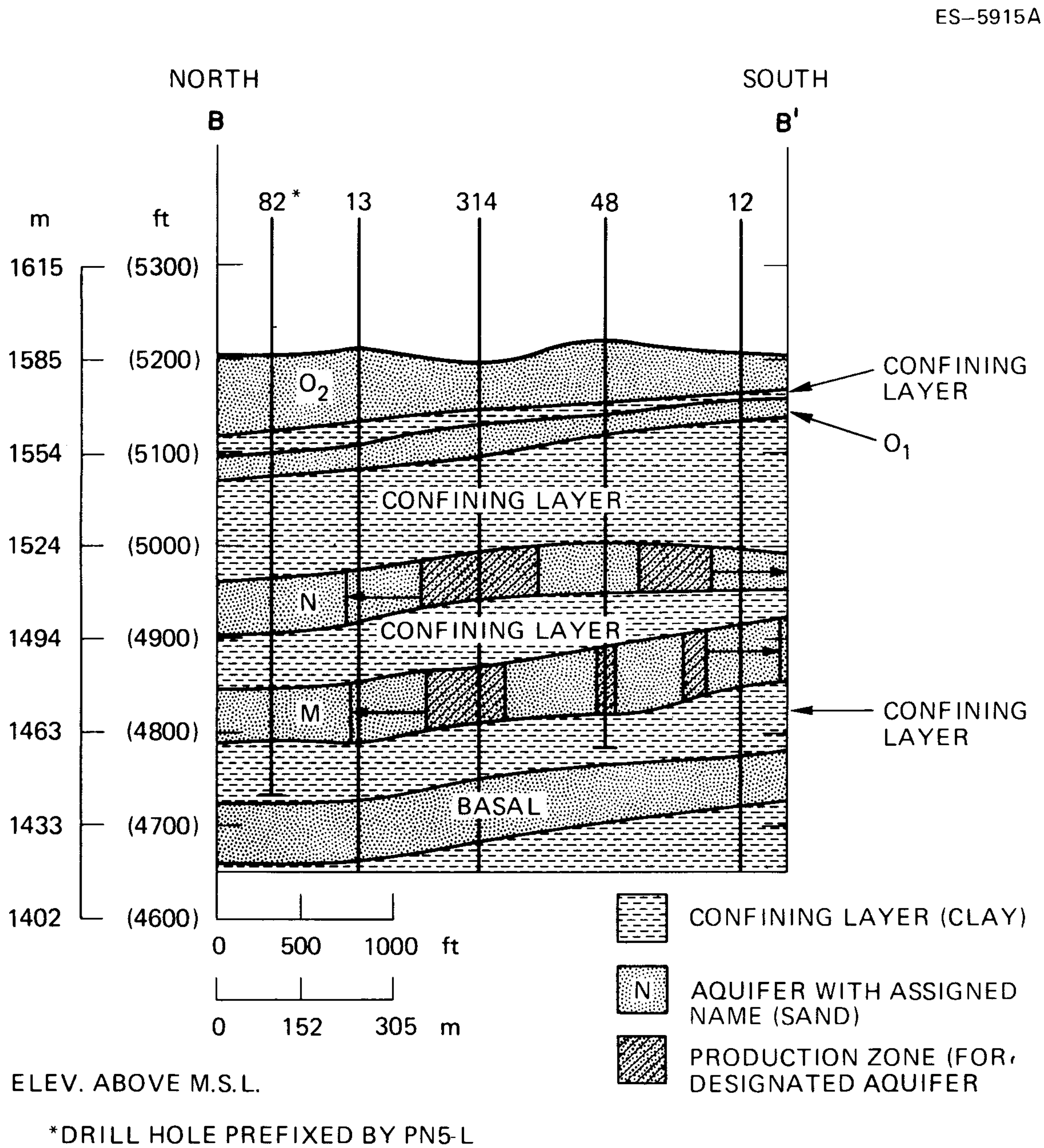

Fig. 3.12. Geologic cross section B-B'. Source: Adapted from ER, Fig. 2-8.

3.7.2 Mineral resources

3.7.2.1 Uranium

Uranium occurrences for the Powder River Basin were first reported in the Pumpkin Buttes area about 80.5 km (50 miles) north of the Leuenberger site by Love in 1952. Since the mid-1960s, when uranium was discovered at depth, drilling has defined many large ore bodies extending from the Pumpkin Buttes area southward into central Converse County. Most of these deposits occur in the Fort Union and Wasatch formations of Early Tertiary age.[24]

Converse County ranked first in uranium production in Wyoming in 1981, producing 1.3 million tons of uranium ore which accounted for 3% of the total mineral production valuation for the year. This production is a decrease of 400,000 tons from 1980. The Bear Creek Uranium Mine is the only currently active facility in the County.[26] Uranium mining areas in Converse County are shown in Fig. 3.2.

3.7.2.2 Oil and gas

In 1981, Converse County accounted for 6% of Wyoming's total crude oil production with 6,588,690 bbl produced, a decrease of over 500,000 bbl from the previous year. Oil accounted for 59% of the county's 1981 total mineral valuation.[26]

The production of natural gas in Converse County in 1981 decreased by 51,156 million m^3 $(2.0 \times 10^5\ ft^3)$ over 1980's production to 3,444,183 million m^3 $(1.2 \times 10^8\ ft^3)$. Natural gas production in Converse County equaled 3.5% of Wyoming's total and accounted for 8% of the county's total mineral production valuation.[26]

Almost all oil and gas production in Converse County is from Cretaceous sandstones and siltstones a few thousand meters below the base of the Fort Union formation.[24]

3.7.2.3 Coal

In 1981, 3,219,000 tons of coal was produced in Converse County by Pacific Power and Light to fuel their Dave Johnston Power Plant. This figure will stabilize at 3.5 to 4 million tons per year by 1985. Coal production in Converse County in 1981 equaled 3.3% of Wyoming's total coal production and 5% of the county's total mineral production valuation.[26]

Most of the thick coal beds mined in the Powder River Basin are within the Fort Union and Wasatch formations; the Fort Union formation contains thick and widespread coal beds throughout the southern portion of the basin.[24] However, within the uranium-bearing units beneath the Leuenberger site are found scattered stringers of lignite to subbituminous coal 0.5 mm (0.02 in.) to 10 cm (4 in.) thick (ER, p. 36).

3.7.3 Seismicity

The area of East Central Wyoming where the Teton-Nedco solution-mining project is located lies in a relatively quiet seismic region of the United States.[27] Although distant earthquakes may produce shocks strong enough to be felt in the Powder River Basin, the region is considered to be one of minor seismic risk (Fig. 3.13). The last earthquake strong enough to cause significant damage in the region of the project site (Intensity VII on the modified Mercalli scale) occurred near Casper, Wyoming, in 1897.[24]

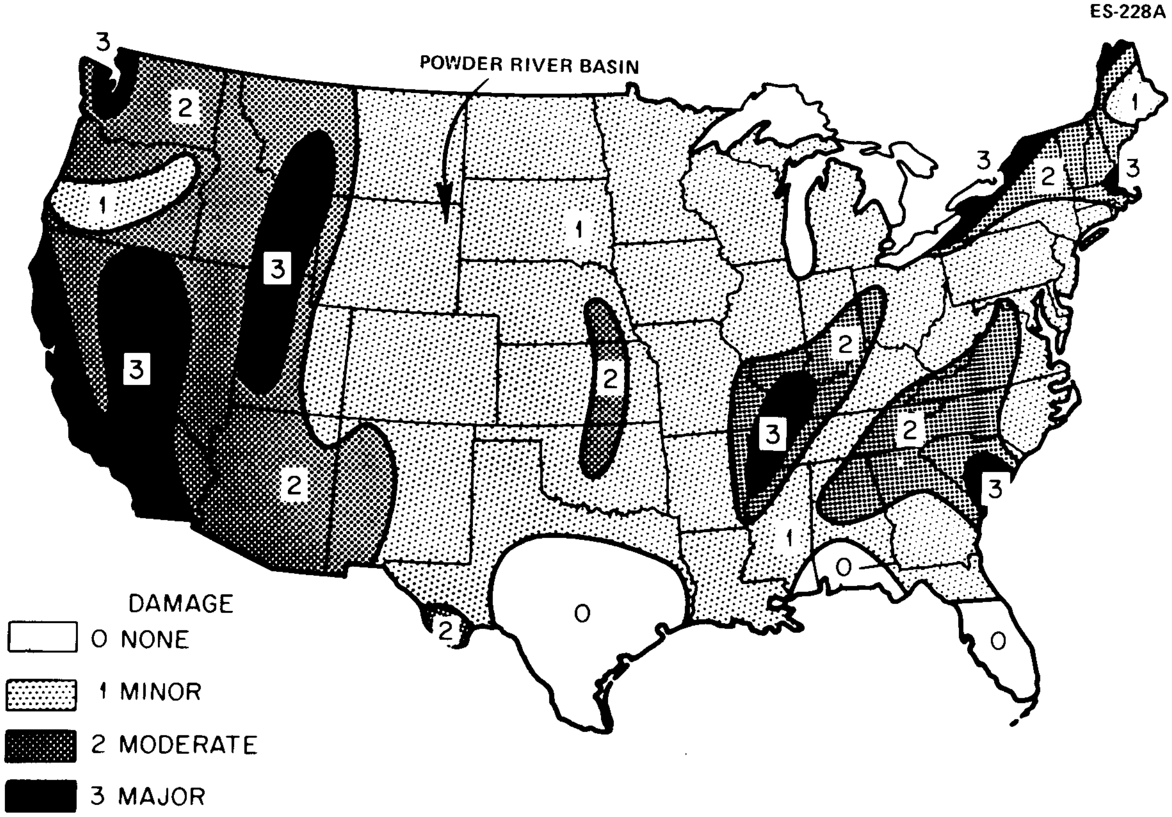

Fig. 3.13. Seismic risk map of the United States. Source: S. T. Algermissen, *United States Earthquakes*, Fig. 2.4, U.S. Government Printing Office, Washington, D.C., 1968.

The seismically active region closest to the site is the western U.S. Intermountain Seismic Belt, which runs in a northerly direction from Arizona to British Columbia. It is characterized by shallow earthquake foci 16 to 40 km (10 to 25 miles) in depth and by normal faulting. Part of this seismic belt extends along the Wyoming-Idaho border, more than 200 km (124 miles) west of the Powder River Basin, and would be the most probable source of earthquakes affecting the project area.

A recent probabilistic acceleration map of the contiguous United States (Fig. 3.14) indicates that the horizontal acceleration at the project site, with 90% probability of not being exceeded in 50 years, is less than 0.04 gravities, which will produce only a small earthquake. On the basis of the historic seismicity record and the tectonic framework of the region, it is highly unlikely that a large-magnitude earthquake will affect the project site during its projected life.[25]

3.8 SOILS

About 14 different soil types have been identified on the permit area (see ER, Appendix D-7, especially Fig. D-7.1). All soils except shingle clay loam, which occurs in several relatively small areas on the site, are rated by the U.S. Soil Conservation Service as good for topsoiling purposes to depths ranging to 1.5 m (60 in.). Most soils in the permit area have high erosion potential and can withstand only light disturbance (e.g., only several vehicular passes to and from a drill site).

3.9 BIOTA

3.9.1 Terrestrial biota

3.9.1.1 Vegetation

Vegetation data for the Teton site were collected from May through September 1979 (ER, Appendix D-8). Vegetation was randomly sampled for cover and productivity in control areas that will be unaffected by the project and in other areas that will be affected. Vegetation on the site is similar to that in surrounding areas (ER, Fig. D-8.3) and appears to have no unique features.

Two types of plant communities occur on the site: grassland and sagebrush. The sagebrush community was defined by the presence of sagebrush cover of at least 30%. Woody vegetation of the site consisted almost entirely of sagebrush (*Artemisia* spp.).

Of the 308 ha (760 acres) on the site, the sagebrush community covers about 178 ha (440 acres), primarily in the eastern one-third, the southern one-third, and the northwestern corner area of the site. The grassland community covers the remainder of the site — about 130 ha (320 acres). A list of the vascular plant species recorded in the permit area is given in ER, Table D-8.2. The following description of plant communities is based on vegetation sampling done in the area to be affected by the project. In the grassland community, the following species occurred in decreasing order of abundance: western wheatgrass, blue grama, big sagebrush, needle-and-thread, prairie junegrass, and threadleaf sedge. Vegetation cover in the grasslands averaged 77%. Litter and rock averaged 5%, and bare ground averaged 19%. In the sagebrush community, the dominant species in decreasing order of abundance were big sagebrush,

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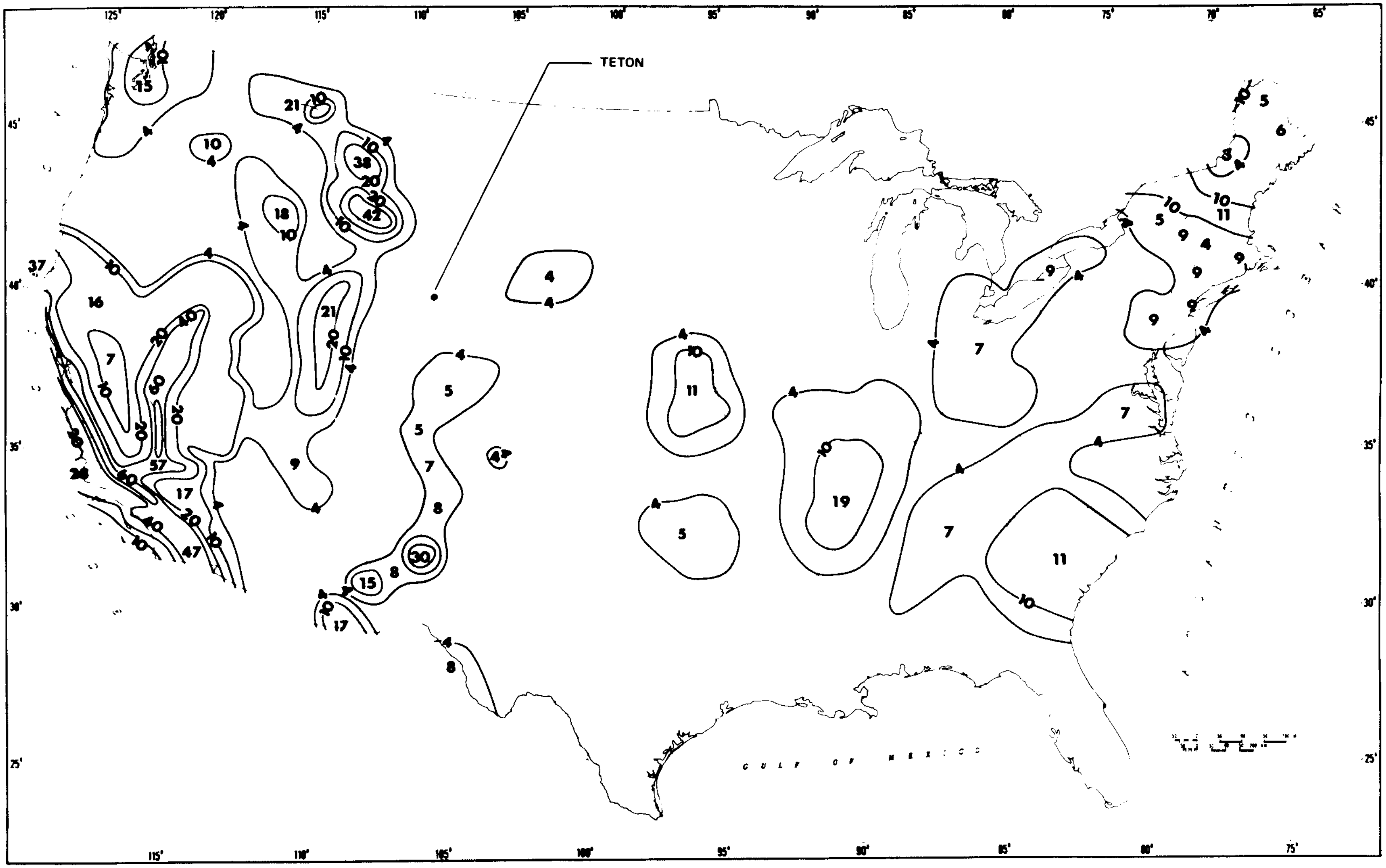

Fig. 3.14. Preliminary map of horizontal acceleration (expressed as percent of gravity) in rock with 90% probability of not being exceeded in 50 years. Source: S. T. Algermissen and D. M. Perkins, *A Probabilistic Estimate of Maximum Acceleration in Rock in the Contiguous United States*, Open File Report 76-416, U.S. Geological Survey, 1976.

blue grama, threadleaf sedge, prairie junegrass, needle-and-thread, and the wheatgrasses. Vegetation cover in the sagebrush community averaged 75%, litter and rock 6%, and bare ground 19%. Estimated standing crops in the grassland and sagebrush communities were 2567 and 2555 kg/ha (2290 and 2280 lb/acre), respectively.

3.9.1.2 Wildlife

Wildlife data were collected formally on the site from April 1979 through January 1980. Casual observations by Teton staff have also been made since that time. Wildlife habitat on the site is generally similar to the extensive areas of habitats in the surrounding areas. Important habitat features for wildlife on the site are the drainage tributaries to Little Sand Creek and a stock pond fed by a windmill on one of these tributaries. The streams are intermittent, but the pond holds water permanently.

Lists of wildlife species observed on the site are presented in the ER, Appendix D-9. The most abundant birds inhabiting the site from May through August were lark buntings, meadowlarks, Brewer's sparrows, vesper sparrows, and sage sparrows. Raptors occurring regularly in the region include great horned owl, golden eagle, red-tailed hawk, rough-legged hawk, sparrow hawk, and prairie falcon. Game birds are not abundant in the area. A few waterfowl visit the ponds on the site during spring and fall migration, and a brood of mallards was raised in 1980. Mourning doves occur regularly during spring and summer. Only lone individuals of sage grouse are usually encountered on the site. No sage grouse strutting grounds were observed in the area.

The most regularly observed mammals on the site and in the vicinity were pronghorn antelope, white-tailed jackrabbits, desert cottontails, coyotes, mule deer, and deer mice. While the mule deer is rarely seen in the permit area itself, the number of pronghorn on the site is generally between 12 and 18. Research and development activities on the site did not appear to greatly alter the habits of this resident herd. Pronghorn antelope appear to be very common in most of the region surrounding the site.

3.9.1.3 Endangered species

The U.S. Fish and Wildlife Service has determined that the endangered black-footed ferret (*Mustela nigripes*), bald eagle (*Haligeetus leucocephalus*), and peregrine falcon (*Falco peregrinus*) may be present in the project area.[28] No endangered plant or animal species were observed on the site, and only the bald eagle is known to occur regularly in the region surrounding the site. A biological assessment for endangered species is presented in Sect. 4.5.6.1. The U.S. Fish and Wildlife Service has reviewed the biological assessment and has determined that the proposed project will not imperil the black-footed ferret, bald eagle, or peregrine falcon.[29]

3.9.2 Aquatic ecology

All waterways draining the region north of the North Platte River in the vicinity of the Teton-Nedco solution mine are ephemeral. Consequently, little aquatic life is to be found, even during the infrequent periods of rainfall. A phytoplankton sample taken from Sand Creek near Glenrock in March of 1978 contained only two genera, *Ankistrodesmus* and *Chlamydomonas*, both at low densities.[22] Habitat for fish does not exist in Sand Creek or in its tributary, Little Sand Creek, on the mine site, with the possible exception of a small stock pond fed by the Smith windmill. No biological data are available for this pond, however.

The North Platte River, into which Sand Creek flows, is classified by the state of Wyoming as a fishery of regional importance.[30] A spillway across the river at the Dave Johnston power plant, 1.6 km (1 mile) upstream from the point at which Sand Creek enters, creates a barrier to upstream movement of fish. Between the spillway and the city of Douglas, approximately 50 river km (30 river miles) downstream, the dominant species is rainbow trout (*Salmo gairdneri*) followed by channel catfish (*Ictalurus punctatus*), brown trout (*Salmo trutta*), and a few cutthroat trout (*Salmo clarki*) and walleye (*Stizostedion vitreum vitreum*).[31] While resident walleye are usually uncommon immediately below the power plant, there is a sizeable seasonal population resulting from the spring migration out of Glendo Reservoir, some 83 river km (50 river miles) downstream.

Below the city of Douglas, walleye increase gradually in number and, with yellow perch (*Perca flavescens*), become the dominant species in Glendo Reservoir. Rainbow trout rank next in abundance, followed by channel catfish, which are numerous near the headwaters of Glendo Reservoir and in certain areas within the reservoir. Brown and cutthroat trout are scarce within the reservoir, and it is possible that cutthroat are entirely absent.

Nongame fish abound in the lower North Platte River,[31] the most prevalent species being carp (*Cyprinus carpio*), common white sucker (*Catostomus commersoni*), and longnose sucker (*Catostomus catostomus*). Also present are the river carpsucker (*Carpiodes carpio*), northern redhorse sucker (*Moxostoma macrolepidotum*), northern creek chub (*Semotilus atromaculatus*), flathead chub (*Hybopsis gracilis*), longnose dace (*Rhinichthys cataractae*), red shiner (*Notropis lutrensis*), common shiner (*Notropis cornutus*), and gizzard shad (*Dorosoma cepedianum*). Incidental occurrences of several centrarchid species have been recorded for this portion of the river, but their importance is minimal.

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29. R. Ballou, U.S. Fish and Wildlife Service, Billings, Montana, personal communication to R. Scarano, U.S. Nuclear Regulatory Commission, Jan. 4, 1982. Docket No. 40-8781.

30. Wyoming Game and Fish Department, *Wyoming Stream Fishery Classification*, Cheyenne, Wyo., 1977.

31. Kevin Thompson, Wyoming Game and Fish Department, Casper, personal communication to C. D. Powers, ORNL, August 1981.

4. ENVIRONMENTAL CONSEQUENCES

4.1 INTRODUCTION

The discussion of energy alternatives (Sect. 1) concludes that there is no other alternative that is a direct replacement for uranium recovery at this site. The staff then considered in detail the applicant's proposal and other alternatives, assuming the uranium ore on the site will be mined and refined (Sect. 2). Section 4 compares the environmental impacts of the present proposal with those of the possible alternatives and forms the scientific and analytic basis for staff conclusions given in Sect. 2.

4.2 AMENABILITY OF THE ORE DEPOSIT TO IN SITU LEACHING

Amenability of the ore deposit at the Leuenberger site to in situ solution mining was first demonstrated by the applicant in April and May of 1979 using two single-hole push-pull tests with sodium bicarbonate/carbonate lixiviant. The tests were performed on each of two uranium ore zones occurring at different depths. Data from these tests indicated that the leaching technique used was feasible for extracting uranium from each ore zone (ER, pp. 4 and 5).

A more extensive and detailed demonstration has been completed. Under Source Material License Number SUA-1373, research and development solution mining operations began on January 22, 1980, on a 3.7-ha (9-acre) site located centrally within the proposed well field area. Initially one test pattern was constructed within each of two separate 0.28-ha (0.69-acre) well field areas, one area designated for each ore zone (Fig. 4.1). Each test pattern was a five-spot configuration consisting of four injection wells placed approximately 15 m (50 ft) apart surrounding a central recovery well. Eventually two additional patterns were completed in each well field area, but in the N well field area they were never placed into service. The total area occupied by test patterns within both well field areas is approximately 0.14 ha (0.35 acres). The process plant design circulation capacity for the R&D facility was 545 m^3/d (100 gpm); however, average test circulation rates were 469 m^3/d (86 gpm).

Five lateral excursion monitor wells surrounded each well field area about 61 m (200 ft) from the well field boundaries. Additionally, one well is completed in each well field area (570 and 304, see Fig. 4.1), to monitor excursions into the overlying O aquifer and one well (314, see Fig. 4.1) to monitor vertical excursions into the underlying basal aquifer (ER, p. D-6.325).

The lixiviant used in the R&D operation was sodium carbonate/bicarbonate; hydrogen peroxide was used as the oxidant until August 26, 1980, when the applicant changed to oxygen. Leaching terminated in the N well field area on June 1, 1980, and in the M well field area on February 17, 1981 (ER, pp. 5 and D-6.323).

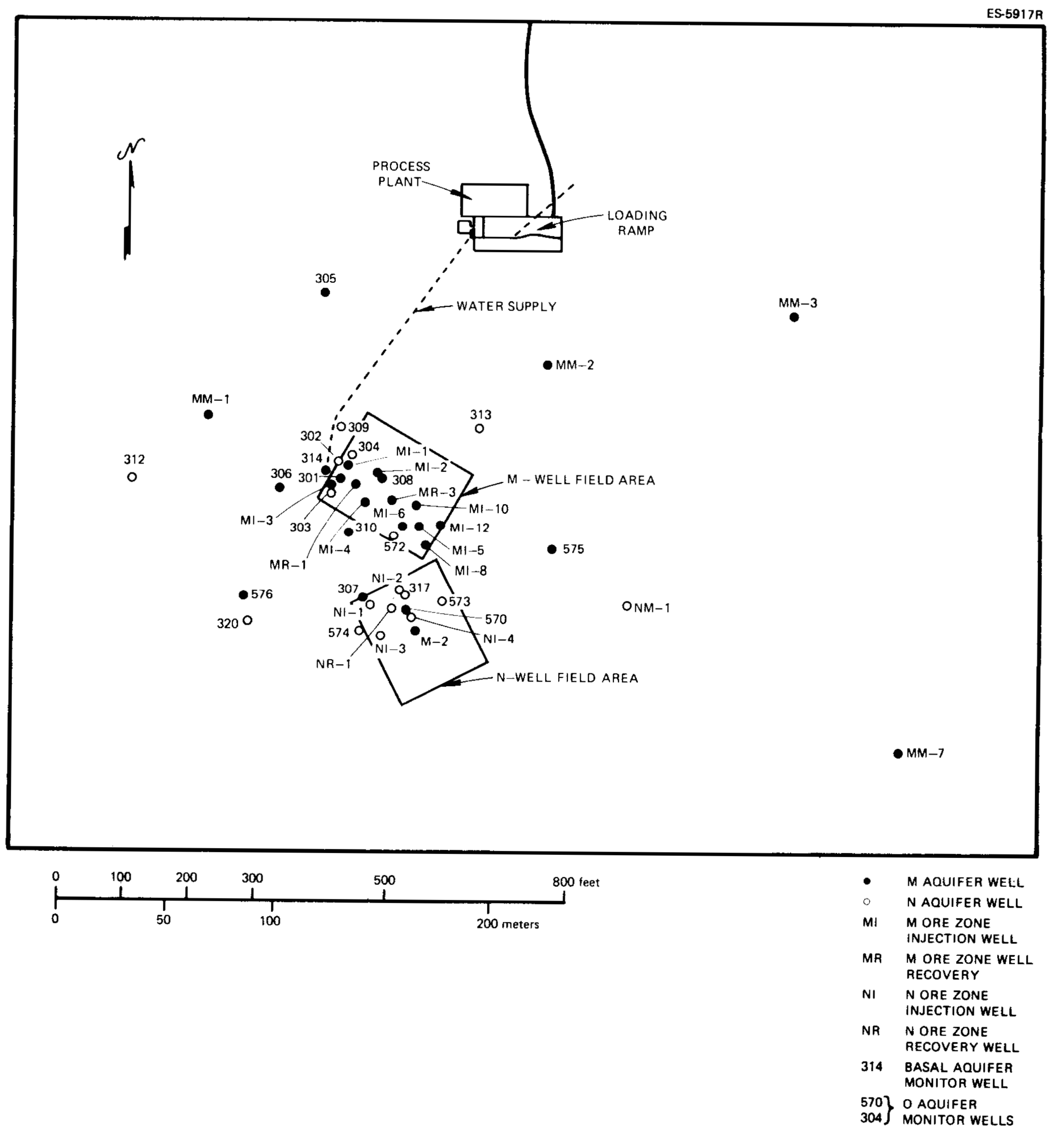

Fig. 4.1. Research and development (R&D) well field layout.

During the 13-month mining period, about 6122 kg (13,500 lb) of uranium (as U_3O_8) were recovered from the ore zones. The average uranium concentration of the recovered production fluid was approximately 52 mg/L, and the average fluid circulation rate was 469 m^3/d (86 gpm). About 47 pore volumes (6.2 x 10^6 gal) were circulated through the test pattern in the N well field area; 1.3 pore volumes (1.7 x 10^5 gal), representing a net bleed of 2.8%, were discharged to the evaporation ponds during the four months the N ore zone was mined.[1] For the 6-1/2 months of M ore zone mining, about 29 pore volumes (27 x 10^6 gal) of mining fluid were circulated through the three M well field test patterns to extract 63% of the total recoverable uranium. Approximately 1 pore volume (9 x 10^5 gal) was discharged to the evaporation ponds representing an over recovery (net bleed) of 3%.[2]

Hydrogeologic information plus the lack of lateral or vertical excursions of mining fluids during R&D operation indicate that the mining unit I ore body is amenable to in situ leaching and that injected fluids should remain confined to the ore body. The staff believes that the favorable characteristics of the unit I ore body probably exist in the remainder of the proposed mine area as well. To substantiate these views, the applicant proposes to obtain and submit for NRC approval detailed hydrogeologic data confirming individual mining unit suitability to in situ leaching before mining in unit I and in each successive unit. These data will include the following:

1. Geologic cross sections constructed from geophysical logs obtained during well field installation for the mining unit at a density of at least one section parallel to and one section normal to the ore trend direction for every 2 ha (5 acres) of well field within a mining unit. Copies of geophysical logs will be provided.

2. A detailed potentiometric surface map for the M and N aquifer which covers the area of the mining unit to be placed in production and the area of immediately adjoining mining units that have not previously been mapped. The scale of these maps will be 2.54 cm = 15 m (1 in. = 50 ft) and contours spaced at 3-cm (0.1-ft) intervals. Water-level measurements used to construct these maps will be collected from the monitor and production wells completed for the mining unit and adjacent mining units.

3. The results of a pump test conducted in the ore zone aquifer within the mining unit. These tests will be designed (with NRC approval) to evaluate ore-zone confinement and hydraulic characteristics. To minimize possible effects from nearby production, the aquifer tests will be conducted in the two mining units adjacent to mining unit I prior to starting production in mining unit I. Subsequent aquifer tests will be conducted with at least one inactive mining unit between the test unit and active units. Active units will be operated so as to minimize interference with aquifer testing.

4.3 AQUIFER RESTORATION

The applicant's proposed aquifer restoration program is presented in Sect. 2.3.10. Alternative aquifer restoration methods are discussed in Sect. 2.3.9.

This section is limited to the staff criteria used for the evaluation of this project, pertinent details of the applicant's pilot-scale aquifer-restoration program, and the conclusions reached by the staff.

4.3.1 Restoration

Restoration is defined as the returning of affected groundwater to a condition consistent with premining use or potential use upon completion of leaching activities.

Restoration is intended to reduce the concentration of toxic contaminants remaining in the groundwater to acceptable levels. Although restoration technology is still in the developmental stage, test results indicate that satisfactory levels of restoration can be achieved.

4.3.1.1 Restoration criteria

The staff's evaluation of the applicant's proposed restoration procedure is based on the requirement that any affected groundwater must be returned to a chemical condition consistent with its potential premining use.

The staff recognizes two water quality zones within the ore-bearing aquifers. The zones are defined as follows.

1. Mining zone — the area within the mineralized (ore deposit) portions of the aquifers. The perimeter of this zone is defined as one well spacing [about 15.2 m (50 ft)] either beyond the outer injection/recovery wells or the limit of the ore deposit to be mined. At the Leuenberger site, groundwater (as determined from average concentrations in mining unit 1 wells and the R&D restoration baseline data) within this zone naturally contain concentrations of radium-226 and manganese that exceed drinking water standards (186 vs 5 pCi/L, 0.08 vs 0.05 mg/L respectively); otherwise, the quality of the groundwater in the N and M aquifers meets domestic standards. Groundwater within this zone will be affected by the in situ leaching operations.

2. Containment zone — the area in the ore-bearing aquifer from the perimeter of the mining zone to the nearest monitor well. The perimeter of this zone is defined by a line connecting the monitor wells surrounding the well field. At the Leuenberger site groundwater quality in this zone is generally similar to that in the mining

zone and although less radioactive, the concentration of radium-226 is still above the drinking water standard (see Table 4.5). It is anticipated that water quality may be degraded in portions of this zone during solution mining operations.

The staff objective for restoration is that the groundwater quality be returned to its highest potential premining use — specifically that each constituent be returned to baseline levels when such constituents exceed applicable standards, that is, for drinking water or for the use of wildlife and livestock (Table 4.1). Where the premining quality of the groundwater constituents meet one of these standards, the appropriate established state or federal criteria will be used to establish maximum permissible chemical concentrations for restoration purposes.

Based on existing baseline water quality data for mining unit I (Table 4.1), the applicant has proposed restoring the groundwater in mining unit I to baseline levels, except for several parameters occurring naturally at concentrations below drinking water standards, that will be returned to levels meeting drinking water standards. These restoration target values (Table 4.1) are concurred with by the Wyoming Department of Environmental Quality and the Nuclear Regulatory Commission (NRC) staff. However, based on R&D restoration, the staff expects uranium to be restored to levels significantly lower than the proposed 5.0 mg/L restoration target. As proposed by the applicant, additional premining water quality sampling will be performed in mining unit I and in all subsequent mining units by sampling a specified set of injection and recovery wells spaced evenly throughout the mining unit(s) at a minimum density of one well per two acres. This new data will be used to establish more representative baseline values for each mining unit (see Sect. 4.4.1.1). The same wells will be sampled as part of the postmining and postrestoration sampling programs (see Sect. 4.4.2.5).

The applicant defined baseline for individual mining units as the average value obtained for each indicator parameter, excluding outliers, obtained from three rounds of sampling of all baseline monitoring wells within a mining unit.

The NRC staff considers the applicant's proposals adequate for sampling and defining baseline within individual mining units. However, because there is uncertainty regarding the mobility of radioisotopes lead-210 and polonium-210 once lixiviant is introduced into the ore zone, lead-210 and polonium-210 have been added to the groundwater baseline parameter list proposed by the applicant; and the applicant will be required to restore them to baseline concentrations. Upon the completion of restoration, the average of each parameter for each round of restoration verification samples should be equal to or less than the restoration target.

In the event significant variation in water quality is indicated during baseline sampling or during restoration verification sampling, the NRC reserves the option to require well-by-well restoration determination.

Table 4.1. Restoration goals for mining unit I

(All values in mg/L unless otherwise indicated)

Parameter	Baseline average[c]	Livestock criteria[b]	Domestic criteria[b]	Target restoration values[c]
HCO_3^-	211			Baseline
CO_3	0			Baseline
Cl	6.6	2000	250	20[d]
SO_4	162		250	Baseline
Ca	75.9			Baseline
Mg	21.6			Baseline
Na	26.7			150[d]
K	8.9			Baseline
ΣTDS	512.7	5000	500	Baseline
pH	7.8	6.5–8.5	6.5–8.5	6.5–9[a]
U	<0.10	5.0	5.0	5[d]
Al	0.11			Baseline
NH_4	0.30		0.5	Baseline
As	0.006	0.2	0.05	0.05[d]
Ba	<0.50		1.0	Baseline
B	<0.25	5.0	0.75	Baseline
Cd	<0.05	0.05	0.01	Baseline
Cr	<0.10	0.05	0.05	Baseline
Cu	<0.09	0.50	1.0	Baseline
F	0.49		1.4–2.4	Baseline
Fe	0.35		0.30	Baseline
Pb	<0.05	0.10	0.05	Baseline
Mn	0.08		0.05	Baseline
Hg	0.0013	0.00005	0.002	Baseline
Mo	<0.50			Baseline
Ni	<0.10			Baseline
NO_2/NO_3	0.15	1/10	1/10	Baseline
Se	<0.01	0.05	0.01	0.01[d]
V	<1.0			1.0
Zn	<0.05	25	5.0	Baseline
Radium-226 pCi/L	186.5	5.0	5.0	Baseline
Thorium-230 pCi/L	2.38			Baseline
Lead-210 p/Ci/L				Baseline[e]
Polonium-210 p/Ci/L				Baseline[e]

[a]Based on existing data collected from six wells completed in the mineralized portion of the ore zone aquifer (wells PN5-L 301, 306, 307, 308, 575, and 576).

[b]Criteria are based on water quality standards of resented in the *Wyoming Water Quality Rules and Regulations,* Chapter 8, Table 1, April 9, 1980. A blank space signifies that no criteria have been established.

[c]Baseline is defined for each parameter for a given mining unit as the mean value obtained from three rounds of baseline sampling collected from the restoration sampling wells within the mining unit. Baseline values presented here will be recalculated as additional restoration baseline monitor wells are completed and sampled prior to injection.

[d]The restoration value is higher than the expected baseline concentration.

[e]Parameters not included in original baseline parameter set.

4.3.2 Applicant's restoration test

On June 1, 1980, the applicant commenced a five-step groundwater restoration program of the N well field. Groundwater samples were collected and analyzed at the end of each step. Restoration sampling data, along with volumes of groundwater recovered, injected, and discharged to the solar evaporation ponds at the end of each restoration step are shown in Table 4.2 (ER, p. D-6.323).

Table 4.2. Analytical trends for N zone restoration 1980

(Units in mg/L except as noted)

	June 1, end of chemical addition	Aug. 9, step 1	Aug 18, step 2	Sept. 19, step 3	Oct. 21, step 4	Nov 6, step 5
			2	3		
U_3O_8	28.4	6.8	3.9	3.2	3.0	2.9
Cl^-	52	44	26	15	16	10
HCO_3^-	1,342	936	672	444	432	312
$SO_4^=$	461	391	316	266	286	292
COND (μsiemens/cm)	2,010	1,480	1,135	875	1,040	885
TDS	2,500		1,066			585
Gallons, recovery	6,218,640	1,860,927	601,770	1,501,192	862,481	691,699
(Pore volume recovered)[a]	(47.71)	(14.28)	(4.62)	(11.52)	(6.62)	(5.31)
Gallons, injected	6,045,630	1,785,289	589,200			
(Pore volume injected)	(46.39)	(13.70)	(4.52)			
Gallons bleed	173,100	75,638	12,570	1,501,192	862,481	691,699
(Pore volume bleed)	(1.32)	(0.58)	(0.10)	(11.52)	(6.62)	(5.31)

Total recovery during restoration	5,518,069 gal	= 42.34 pore volumes
Total injected during restoration	2,374,489	= 18.22 pore volumes
Net sweep	3,143,580	= 24.12 pore volumes
Total recovery during mining	6,218,640	= 47.71 pore volumes
Total injected during mining	6,045,630	= 46.39 pore volumes
Net bleed, 2.78%	173,010	= 1.32 pore volumes

[a] 1 pore volume = 0.4 acre-ft = 130,332 gal.

Step 1 (6-1-80 to 7-12-80) consisted of circulating contaminated groundwater (without the addition of lixiviant or oxidant) through the process plant to remove residual uranium. The commingling of fresh groundwater from the M well field area in an effort to dilute concentrations of N zone chemicals occurred in step 2 (8-10-80 to 8-18-80). Step 3 (8-21-80 to 9-17-80) was a groundwater sweep consisting of pumping production well NR-1 at approximately 218 m^3/d (40 gpm) and discharging the water directly to the solar evaporation ponds. Step 4 (9-26-80 to 10-21-80) and step 5 (10-21-80 to 11-1-80) continued the groundwater sweeping by pumping one at a time injection wells NI-3 and NI-1. All water was discharged to the solar evaporation ponds (ER, pp. D-6.323-326).

Average values for the final round of restoration sampling of all N zone restoration monitor wells along with the average post-restoration sampling data for 2 and 14 months after completion of restoration are shown in Table 4.3. Considering that no special treatment methods were employed during restoration (RO, IX, ED, etc.) the test, in most cases, demonstrates that staff objectives for restoration of the N zone can be realized.

As shown in Table 4.3, the average restored concentrations of major ionic constituents [those contributing most to the total dissolved solids (TDS) concentration] exceeding baseline average concentrations are bicarbonate, sodium, sulfate, and magnesium. In the worst case of sodium, the average restored concentration exceeds the baseline average by less than 30%. Because the ore body was mined with a sodium carbonate/bicarbonate lixiviant, sodium and bicarbonate concentrations were severely elevated during the mining process and have not been restored to baseline. However, there are no standards for these parameters, and their contribution to restored TDS concentrations is not enough to raise TDS levels significantly beyond the baseline range. The baseline average TDS concentration (530 ppm) is above the Wyoming DEQ class I (domestic) standard. Although the average restored sulfate concentration marginally exceeds the class I (domestic) standard (266 ppm vs 250 ppm), it is restored to within the baseline range of values, as is magnesium for which there is no standard. Of the trace elements, only restored concentrations of radium-226 and iron exceed the class I standard, however the baseline average for radium-226 (185 pCi/L) is well over the 5 pCi/L class I standard. Restored iron concentrations were reduced dramatically after Teton initiated the practice of filtering samples. Fourteen months after completion of restoration, stability data show no significant increases in the concentrations of any groundwater constituent (Table 4.3).

The applicant calculated 24.12 pore volumes (3.14×10^6 gal) of groundwater consumption during N well field restoration. All of this water was untreated discharge to the solar evaporation ponds during the groundwater sweep phases of restoration.

On February 25, 1981, the applicant began restoration activities in the M well field area. Details of the staff's evaluation of the applicant's M ore zone restoration test, including a discussion of the restoration

Table 4.3. N ore zone groundwater restoration-test water quality data

(All data in mg/L except as noted)

	Pretesting water quality Mean Std[c]	Livestock criteria[a]	Domestic criteria[a]	Posttesting water quality: November 1980 Mean Std[c]	January 1981 Mean Std[c]	January 1982 Mean Std[c]
pH (units)	8.0±0.38	6.5−8.5	6.5−8.5	7.9±0.1	7.4±0.4	7.3±0.1
Ammonia (NH_3 as N)	0.27±0.41			0.11±0.03	0.17±0.08	0.11±.13
Total NO_2/NO_3 (as N)	0.46±0.76	1/10	1/10	0.18±0.03	<0.1±0	0.25±.20
Bicarbonate (HCO_3)	172.5±34.2			207.8±30.7	213.8±33.5	237±32
Carbonate (CO_3)	1.7±3.8			0±0	0±0	0
Calcium (Ca)	93±28			93±4.7	94±1.7	103±5.7
Chloride (Cl)	23.9±28.2	2000	250	6±2.12	6±1.2	4±2.3
Boron (B)	0.02±0.02	500	0.75	<0.25±0	<0.25±0	<0.01
Fluoride (F)	0.46±0.11		1.4−2.4	0.37±0.08	0.31±0.13	0.42±0.07
Magnesium (Mg)	18.6±8.7			23.4±5.03	21.9±1.6	21.0±3.0
Potassium (K)	30.9±36.4			13.1±1.7	12±2.1	12±1.1
Sodium (Na)	33.6±6.6			43.8±9.6	43.2±13.9	50±9.4
Sulfate (SO_4)	246.4±33.9	3000	250	266.2±8.7	264.2±8.3	259±13.2
Aluminum (Al)	0.07±0.04	5.0		<0.05±0.01	<0.05±0	<.05
Arsenic (As)	0.01±0	0.2	0.05	<0.005±0	0.006±0.002	<.005
Barium (Ba)	0.05±0.02		1.0	<0.1±0	0.13±0.05	<.03
Cadmium (Cd)	0.01±0.02	0.05	0.01	<0.01±0	<0.01±0	<.002
Chromium (Cr)	0.03±0.02	0.05	0.05	<0.05±0	<0.05±0	<.01
Copper (Cu)	0.02±0.02	0.50	1.0	<0.05±0	<0.05±0	<.01
Iron (Fe)[b]	0.20±0.23		0.30	0.62±0.57[b]	0.48±0.36[b]	<.01
Lead (Pb)	0.02±0.02	0.10	0.05	0.05±0.01	0.05±0.004	<.01
Manganese (Mn)	0.04±0.02		0.05	0.06±0.01	0.21±0.33	0.03±.02
Mercury (Hg)	0.01±0.02	0.00005	0.002	<0.001±0	<0.001±0	<.0005
Molybdenum (Mo)	0.07±0.02			<0.1±0	<0.1±0	<.05
Nickel (Ni)	0.03±0.01			<0.05±0	<0.05±0	<.02
Radium-226, (Ra), pCi/L	185±242	5.0	5.0	252.42±318	346±140	368±77
Selenium (Se)	0.01±0	0.05	0.01	0.008±0.006	<0.005±0	<.005
Uranium (U)	0.54±0.76	5.0	5.0	0.64±0.53	0.52±0.39	0.50±.39
Vanadium (V)	0.14±0.20	0.10		<0.1±0	<0.1±0	<.05
Zinc (Zn)	0.02±0.02	25	5	<0.05±0	<0.05±0	<.05
TDS	530±39			577±36	582±34	608±23.6

[a]Criteria are based on water quality standards given in the Wyoming Water Quality Rules and Regulations, Chapter 8, Table 1, Apr. 9, 1980. A blank space signifies that no criteria have been established.

[b]Unfiltered sample.

[c]Standard deviation.

technology and pertinent restoration and stability data, are presented in Appendix F. Based on its evaluation, the staff concludes that Teton Exploration drilling has adequately restored the groundwater in the three M ore zone test patterns. All groundwater constituents excluding bicarbonate, sodium, and radium-226 are returned to no worse than having their average restored concentration below either the baseline average concentration or the Wyoming DEQ class I (domestic) standard. The average baseline concentration of radium-226 however, is considerably above the drinking water standard (236 vs 5 pCi/L) and restored values are consistently within the range of baseline values. There are no standards for bicarbonate and sodium and their contribution to total dissolved solids (TDS) concentrations was small enough to keep TDS within the 500 ppm class I standard.

The M zone restoration test demonstrated that groundwater consumption could be substantially reduced during restoration by adding electrodialysis (ED) treatment to the restoration circuit. By the conclusion of restoration, 46% (10.5×10^6 gal) of the total contaminated groundwater recovered (22.6×10^6 gal) was sent to the ED unit for futher treatment, and less than 8% (1.7×10^6 gal) was ponded as waste water in the form of concentrated ED brines. The 54% not treated by ED was mixed with the ED "purified" product and reinjected to improve overall groundwater quality. Based on the total area affected by the three M ore zone test patterns, the applicant calculates that 1.76 pore volumes (1.7×10^6 gal) of groundwater were consumed during M zone restoration.[2] Compared to the 24.12 pore volumes consumed to restore the N ore zone using no special treatment. Thus, restoration using electrodialysis proved to be better than 90% more effective than using no treatment in conserving groundwater.

4.3.3 Staff conclusions

In the opinion of the staff, the applicant has demonstrated that restoration of the ore zone aquifers to their original potential use condition is achievable.

The applicant proposes, and the staff agrees, that mining be performed sequentially, as described in Sect. 2.3.10.3, commencing restoration of each mined-out area as soon as feasible before mining the next unit. Sequential mining will be a condition of the license; the applicant shall not mine in other than mining units I, II, and III until the ability to achieve restoration in mining unit I has been favorably determined by the NRC. A similar procedure shall be followed throughout the sequence of mining.

The staff's conclusion is that this proposed operation is state-of-the-art and, with monitoring and proposed mitigation measures, will pose no major risk to the environment.

4.4 MONITORING PROGRAMS AND MITIGATING MEASURES

4.4.1 Preoperational monitoring

4.4.1.1 Hydrological

Surface-water baseline

Relatively little monitoring of surface waters has been accomplished at the Teton-Nedco site because of the absence of runoff for the past two years. The only samples available during this period were obtained from a stock pond supplied with windmill-pumped water near the southwest corner of the permit area. The results of five analyses, commencing in May 1980, are given in Table 3.19.

The applicant is committed to sampling Little Sand Creek quarterly or when surface water is flowing at three locations on the property: (1) immediately upstream from the permit area, (2) at a point within the permit area upstream of the windmill, and (3) downstream from the windmill at the aforementioned stock pond. Samples will be analyzed for the parameters shown in Table 3.19.

Groundwater baseline

In addition to the existing baseline water quality for mining unit I, the applicant proposes to establish baseline water quality specifically for restoration and excursion monitoring of mining unit I in the M, N, O, and basal aquifers by sampling the wells shown in Fig. 4.2. Each well will be sampled at least three times with a minimum of 10 d between sampling events. Each sample will be analyzed for the list of parameters shown in *Guideline 8* published by the Wyoming DEQ, plus the radionuclides lead-210 and polonium-210 (Table 4.4).[3] Samples will be collected after field pH and conductivity of the water has stabilized or at least one casing volume has been displaced. The same procedure will be followed in taking groundwater baseline samples for all other mining unit monitor wells.

To ensure that groundwater is not contaminated by mining fluids prior to baseline sampling, the applicant proposes determining baseline groundwater quality for a mining unit before any chemicals are injected into the production zone aquifer within that unit or any adjacent mining unit(s).

The water level in each well used to obtain baseline data will be measured just before it is pumped for sample collection.

The staff considers the applicant's plans for establishing baseline to be acceptable and in conformance with Staff Technical Position Paper

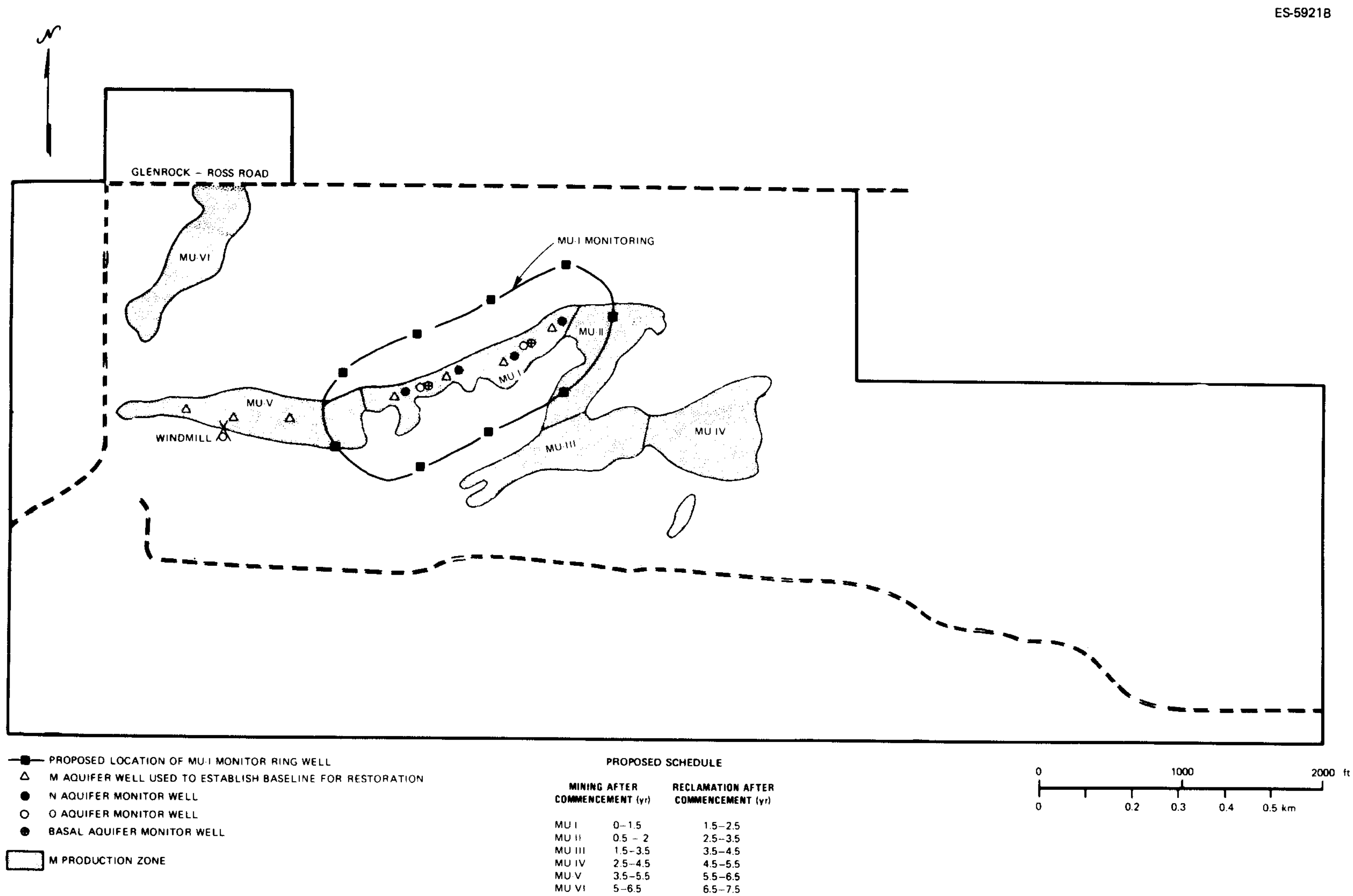

Fig. 4.2. Map of Teton project area showing locations of mining unit I restoration baseline and excursion monitor wells.

Table 4.4. Baseline water quality parameters

Field measurements

pH (reported to nearest 0.1 pH units)
Temperature (C)
Conductivity (siemens/cm corrected to 25 C)
Alkalinity

Laboratory measurements

Ammonia (NH_3^+)
Nitrate (NO_3^-) as N or
Total nitrate ($NO_2^=$)/nitrate (NO_3^-) as N
Bicarbonate (HCO_3^-)
Carbonate ($CO_3^=$)
Calcium (Ca^{++})
Chloride (Cl^-)
Boron (B)
Fluoride (F^-)
Aluminum (Al)
Arsenic (As)
Barium (Ba)
Cadmium (Cd)
Chromium (Cr)
Copper (Cu)
Iron (Fe)
Magnesium (Mg^{++})
Potassium (K^+)
Sodium (Na^+)
Sulfate ($SO_4^=$)
Total Dissolved Solids (TDS)
Lead (Pb)
Manganese (Mn)
Mercury (Hg)
Molybdenum (Mo)
Nickel (Ni)
Selenium (Se)
Zinc (Zn)
Vanadium (V)
Uranium (U)
Radium (Ra-226)
Lead (Pb-210)[a]
Polonium (Po-210)[a]

[a]Included by the NRC.

Source: Wyoming Department of Environmental Quality, *Land Quality Division Guideline No. 8*, Appendix 2, "Water Quality Parameters."

WM-8102, "Groundwater Monitoring at Uranium In Situ Solution Mines." In addition, the applicant will be required to submit all baseline water quality data and water level measurements from each mining unit to the Wyoming DEQ and the NRC for review as soon as they are received and compiled.

Baseline water quality for evaporation pond monitor wells, if their construction is deemed necessary after completion of the NRC evaporation pond review, will be established using the procedures described above.

The applicant will be required by license condition to have an NRC-approved quality assurance program established before commencement of commercial-scale mining.

4.4.1.2 Air-quality monitoring (nonradiological)

Only particulates were monitored at the site. High volume sampling was conducted usually for 23 to 24 h once every six days. This sampling schedule was designed according to regulations of the Air Quality Division of the Wyoming Department of Environmental Quality (DEQ). The sampling was conducted during the last quarter of 1979 and the first two quarters of 1980. Mean particulate concentrations for these three periods are 19 ± 14 SD, 11 ± 2 SD, and 29 ± 12 SD $\mu g/m^3$ respectively. These are well below the standards for the state (Table 3.3).

4.4.1.3 Terrestrial ecology monitoring

Soils on the site were surveyed by personnel of the Soil Conservation Service Office in Douglas, Wyoming. Detailed sampling of soil profiles was conducted by a private consultant and Teton-Nedco personnel at locations that were representative of the soil types where topsoils will be removed for storage elsewhere.

The distribution of the two plant community types on the site (sagebrush and grassland) was determined with aerial photographs. Plant species composition of the two communities was determined by field sampling and collection of specimens from May through late September of 1979. The cover and annual production of vegetation were sampled in the two community types, both in areas to be affected by the project and in control areas that will not be affected. The vegetation sampling was designed to meet Wyoming DEQ guidelines.

Wildlife surveys on the site were conducted periodically from April 1979 to January 1980. The abundance of bird species was sampled on 12 transects, each several hundred yards long. Rabbit populations were surveyed by spot-lighting at night and by daytime observations on four days between August 1 and October 19, 1979. Small mammals were trapped at four

trapping sites, and big game mammals on the site were counted 14 times from vehicles and on foot during the wildlife survey period.

4.4.1.4 Radiological surveys

The applicant has conducted surveys to obtain radiological baseline data (see ER, pp. D-10.1–10.3 for methodology).

Table 4.5 shows a comparison of the concentrations of radioactive elements found inside the M and N production zones with those found outside these zones. The high levels of radium inside the zones is an indication of the ore bodies present.

Table 4.5. Water quality data outside and inside of the M and N production zones

Element	N production zone		M production zone	
	Inside[a]	Outside[b]	Inside[c]	Outside[d]
Radium (pCi/L)	308.71	14.46	319.04	12.71
Selenium (mg/L)	0.02	0.01	0.01	0.01
Thorium (pCi/L)	4.38	1.80	1.71	2.12
Uranium (mg/L)	1.05	0.10	2.88	1.26
Vanadium (mg/L)	0.14	0.15	0.13	0.26

[a]Mean values for 9 wells.
[b]Mean values for 6 wells.
[c]Mean values for 14 wells.
[d]Mean values for 7 wells.

Little Sand Creek and a small tributary are the only stream channels within the permit area. Because these channels are ephemeral, no water has flowed in them for the applicant to sample. Water has been sampled in a pond downstream (Table 3.19).

Total gamma-ray radioactivity was measured with a scintillometer in the vicinity of the well field area. A second survey was done using scintillation monitors and a pressurized ionization chamber. All data obtained were in the normal background range of 13 to 19 μR/h.

Soil samples were taken at eight random locations at the site. These data are presented in Table 4.6. In addition, Teton will be required to obtain soil samples, both surface and subsurface, at the locations of the proposed evaporation ponds and analyze them for radium-226 and lead-210.

Table 4.6. Composite soil samples
(pCi/g)

	Surface soil (0-5 cm deep)	Subsurface soil (5-50 cm deep)	Subsurface soil (50-100 cm deep)
Uranium (as U_3O_8), %	0.0002	0.0003	0.0002
Radium-226 ± counting error[a]	0.6 ± 1.5	0.4 ± 1.3	0.3 ± 1.3
Thorium-230 ± counting error[a]	2.5 ± 0.6	3.4 ± 0.7	1.6 ± 0.5
Lead-210 ± counting error[a]	1.2 ± 0.5	1.3 ± 0.5	0.8 ± 0.5

[a]Variability of the radioactive disintegration process (counting error) at the 95% confidence level, 1.96σ.

The applicant obtained limited pre-operational data on air particulates from January 1 to March 31, 1982 at a site downwind from the process plant. Samples were collected once every six days for a 24 hour period and composited. Results were Ra-226 - 2.59 ± 0.82 x 10^{-16} μCi/ml, Th-230 - 1.61 ± 0.23 x 10^{-15} μCi/ml, Pb-210 - 3.22 ± 0.25 x 10^{-14} μCi/ml, and U-nat - 1.45 x 10^{-15} μCi/ml.

Prior to initiation of mining, the applicant will be required to submit air particulate (for U, Th-230, Ra-226, and Pb-210) and radon baseline data for a 6-12 month period for upwind and downwind site boundary locations and at the nearest residence.

4.4.2 Operational monitoring

4.4.2.1 Surface water

No surface discharge is planned for the Leuenberger operation. In the absence of an accidental spill, surface water monitoring from runoff, other than that attempted quarterly when surface water is available, should not be necessary. If significant accidental releases occur onsite, Little Sand Creek should be sampled after each rainfall or snowmelt until runoff is determined to be free of chemical and/or radiological contamination. Parameters to be sampled will include those listed in Table 3.19.

4.4.2.2 Air quality monitoring operational (nonradiological)

Because the types and quantities of the emissions from the types of vehicles and other mobile equipment used on the site are relatively well known (Sect. 2.3.10.4) and expected to be insignificant, the staff does not consider that monitoring of these sources is necessary. However, the applicant must meet applicable EPA and state requirements for air quality and should practice approved methods of dust control.

4.4.2.3 Waste pond monitoring

The North and South Leuenberger evaporation ponds were constructed under research and development license number SUA-1373 and are proposed by the applicant to become incorporated into the commercial-scale project. Each pond has its own leak detection system — a network of perforated pipe located beneath the liner in a sand-and-gravel filter bed. The perforated pipes are connected to a standpipe located at the low point in the system.

Leak detection systems similar to those used in the North and South evaporation ponds will be installed in the larger East and West ponds. However, because of their greater size, three separate systems will be constructed for each pond so that in event of a leak the problem section of the pond can be easily located (ER, pp. 104 and 105). Leak detection systems will be monitored daily.

The staff has not completed its review of the proposed design for the solar evaporation ponds at the Leuenberger site. The design, construction, and monitoring of the leak detection systems will be reviewed utilizing the criteria suggested in Draft Regulatory Guide (MS-146-4), "Design, installation and inspection of seepage control liners at uranium tailings facilities.

The applicant proposes to sample effluent wastes in the ponds at least once per quarter and analyze them for calcium, alkalinity, sodium, sulfate, radium-226, and uranium. Water, if found in the standpipes, will be analyzed for the same parameters to determine if the water is derived from pond leakage. The staff concurs with the applicant's proposal for sampling evaporation pond effluent wastes.

4.4.2.4 Radiological monitoring

The applicant's operational radiological environmental monitoring program, which may be modified by the staff as the radiological data obtained during mining are reviewed, will continue throughout all phases of operation. The operational radiological environmental monitoring schedule away from the plant building is presented in Table 4.7.

4.4.2.5 Well field monitoring

Well field monitoring procedures will define an area of containment for leachate injection during the mining operation. Well field monitoring consists of the surveillance for initiating corrective actions in the event of leachate migration and will be effected primarily by using monitor wells installed by the applicant for production control. The well field monitoring program is specified in the state mine permit application and has been approved by the Wyoming Department of Environmental Quality.

Table 4.7. Operation radiological environmental monitoring schedule[a]

Sample type	Location	Schedule/Frequency	Analysis
Radon	Upwind, site boundary Downwind, nearest residence Downwind, site boundary	Continuous	Radon-222
Air particulate	Upwind, site boundary Downwind, nearest residence Downwind, site boundary	1 week per quarter (Quarterly composite)	Gross alpha natural Uranium Thorium-230 Radium-226 Lead-210
Environmental dosimeter	Upwind, site boundary Downwind, nearest residence Downwind, site boundary	Changed quarterly	Radiation dose

[a]Additional air samples may be taken at selected locations within the permit area to verify that the downwind boundary location provided the highest site boundary airborne radioactivity concentration.

Excursion monitor well location involves surface spacing and subsurface placement to effectively determine the horizontal and vertical containment of the leach solution. To detect horizontal excursions, ore-zone monitor wells will be spaced around the perimeter of the well fields. To detect vertical excursions, monitor wells will be located within the well fields open to the saturated zones above and below the ore zone (N, O, and basal sands for mining unit I).

To minimize environmental impacts caused by excursions, monitor wells must provide rapid detection of any leach solution outside of the production zone. For effective performance, a number of factors must be considered in selecting locations for placement of monitor wells. These include the following:

1. Site geological and hydrological variations must be evaluated including (1) local variations in groundwater flow rates and direction, (2) local variations in permeability or zones of significant hydraulic conductivity, and (3) presence of subsurface geologic features (channels, clay lenses, facies changes, faults, etc.).

2. Monitor wells should be spaced so that their respective zones of influence overlap.

3. Monitor wells should be located at a distance from the well field so as not to intercept normal operating fluid flows. The zone of influence during monitor well sampling must be considered.

Ore-zone monitor wells

The applicant proposes placing an individual ring of ore-zone excursion monitor wells around each mining unit. Wells will be placed no more than 90 m (300 ft) from the perimeter of a mining unit. Spacing between wells will be determined by mining unit shape and hydrologic factors, so that no monitor well ring will have less than six wells. The applicant's proposal for locating ore-zone excursion monitor wells is consistent with the criteria suggested in Staff Technical Position Paper WM-8102, "Groundwater Monitoring at Uranium In Situ Solution Mines."

The specific plan for locating excursion monitor wells for mining unit I is shown in Fig. 4.2. The ore-zone excursion monitor well ring consists of nine wells approximately 180 m (600 ft) apart and no more than 90 m (300 ft) from the mining unit. However, it may become necessary for the applicant to install additional monitor wells in event that additional aquifer testing uncovers local variations in permeability or zones of significant hydraulic conductivity due to subsurface geologic features or anisotropic conditions within the ore zone aquifer.

The applicant proposes to submit for NRC review and approval prior to mining in mining unit I and subsequent mining units a map on a scale of 2.54 cm to 15 m (1 in. to 50 ft) showing the locations of all monitor wells and a table providing well completion intervals for each monitor well.

Shallow and deep monitor wells

The applicant proposes to install wells permitting the monitoring of aquifers below and above both ore zones (basal and O aquifers respectively). These wells will be completed in each aquifer at a uniform density of one well per 2 ha (5 acres) of well field, or no less than one in each aquifer per mining unit. Additionally, the ore zone not being mined will be monitored while mining is occurring in the other ore zone. These wells will be completed at a uniform density of one well per 0.8 ha (2 acres) of well field. For mining unit I, two wells will be completed in each the O and basal aquifers and four in the N ore zone (Fig. 4.2). The applicant's proposal for locating shallow and deep monitor wells for detecting vertical excursions is consistent with the criteria suggested in Staff Technical Position Paper WM-8102, "Groundwater Monitoring at Uranium In Situ Solution Mines."

Monitor well sampling

The applicant proposes sampling all excursion monitor wells (O, basal, N, and M aquifers) every two weeks during recovery and restoration operations, and measuring water levels in each well before sampling. Samples will be analyzed for alkalinity, uranium, chloride, and electrical conductivity; these analyses will serve as excursion parameters to establish the presence of a potential leachate excursion. These indicator excursion parameters were selected by the applicant because (1) a carbonate/bicarbonate lixiviant will be used, (2) chloride will be the elution ion, (3) electrical conductivity is a function of total dissolved solids or overall water quality, and (4) the uranium concentration of formation water should increase greatly during mining. In addition, alkalinity, chloride, and conductivity measurements are easily and quickly determined.

Quarterly sampling of R&D well-field excursion monitor wells, for the extended list of parameters shown in Table 4.4, indicated that beyond slight fluctuations in excursion parameter concentrations above baseline values, overall water quality at these wells remained unaffected by mining. Therefore, checking excursion monitor wells for parameters other than the list of excursion parameters should not be required during commercial mining.

Water quality data from routine sampling of excursion indicator parameters will be regularly submitted to the NRC in a semiannual report.

Upper control limits

An upper control limit (UCL) will be used to indicate a significant deviation in groundwater chemistry from baseline concentrations. This deviation would indicate that migration (excursion) of lixiviant is probably occurring and would initiate appropriate corrective action(s). The applicant has proposed to set upper control limits for excursion indicator parameters in each monitor well for alkalinity, uranium, chloride, and electrical conductivity as follows.

1. Alkalinity and electrical conductance — The UCL will equal 1.2 times the highest representative baseline value.

2. Chloride — The UCL will equal 10 parts per million or milligram per liter (ppm or mg/L) plus the highest representative baseline value.

3. Uranium — The UCL will equal 1.0 ppm (mg/L), or baseline plus 1.0 ppm (mg/L) if baseline is above 1.0 ppm (mg/L). (Baseline for uranium = the mean value of three baseline samples.)

The applicant proposes sampling excursion monitor wells once every two weeks; if any two indicator parameters from a well exceed their respective UCLs, a confirmation sample will be taken within 48 h. If the two parameters remain above their UCLs, an excursion will be detected and verified and the NRC and the Wyoming State Department of Environmental

Quality notified within 24 h; appropriate corrective action will be taken immediately.

The NRC staff finds the applicant's proposal for setting UCLs for uranium and chloride and for determining and confirming excursions to be unacceptable. Preliminary baseline data for mining unit I indicates that groundwater concentrations for uranium with the M aquifer are small (less than 0.2 ppm). Setting the upper control limits for uranium at the arbitrary value of 1.0 ppm for wells with uranium baseline values below 0.2 ppm would require an increase of at least 500% before the uranium UCL is exceeded. Evidence suggests that during excursions, where baseline uranium concentrations are low and carbonate lixiviants are used, uranium rarely exceeds 1.0 ppm in monitor wells at any time throughout the excursion. Generally, it is NRC practice to recommend establishing uranium UCLs in the same manner as for the other excursion parameter UCLs or at 20% above the highest representative baseline value of each well. However, based on the apparently wide variety in average baseline values for uranium from preliminary baseline sampling (0.005 to 0.15 ppm) of the unit I ore zone, the staff concludes that the uranium UCL for all ore zone excursion monitor wells should be set at the highest baseline value measured from all monitor wells (excluding outliers) plus 20%. For vertical excursion monitor wells in over- and underlying aquifers, the uranium UCLs will be determined by adding 20% to the highest baseline value at each well from three representative baseline samples.

At the Leuenberger site, mining unit I preliminary average baseline chloride values are low (less than 10 ppm) and show little variability within individual monitor wells. The applicant's proposal to establish UCLs for chloride by adding 10 ppm to the highest baseline value is likely to produce UCLs for chloride that are an order of magnitude above baseline. Therefore, the staff feels that the UCL for chloride at each excursion monitor well should be set at 20% above the highest representative baseline value.

Staff experience shows that not all of the excursion indicator parameters chosen by the applicant perform equally well during excursions. Alkalinity has been seen to decline during an excursion, possibly due to its complexing with uranium as excursion fluids leave the mining zone. Although electrical conductivity is a function of the total dissolved solids in well water, it may be vulnerable to instrument error and show significant variability within samples from the same well. Chloride, however, appears to be relatively mobile and stable in solution and tends to show little variability within samples from the same wells at the Leuenberger site. Chloride concentrations in groundwater samples are quickly, easily, and accurately determined. Therefore, the NRC staff has determined that chloride will be the leading excursion indicator parameter. If the UCL for chloride alone is exceeded, if the UCL of any single indicator parameter is exceeded by more than 20%, or if the UCLs are exceeded for any two indicator parameters after routine and confirmation sampling, an excursion will have been detected. Confirmation sampling must be performed within 48 h.

After the Wyoming Department of Environmental Quality and the NRC are notified within 24 h of the excursion, a written detailed report will follow within 7 d. During excursion status, the monitor well(s) on excursion will be sampled weekly, and a monthly report will be submitted until recovery from excursion status has been achieved and maintained for a continuous period of at least one month.

Material balance monitoring

During mining operations, the applicant will routinely monitor pressures, flow rates and chemical constituents in plant circuitry, well field injection and recovery trunk lines, and individual wells in use. The purpose of this monitoring is to provide a continuous check on plant and well field operating efficiency by routinely calculating process material balance on injection and recovery solutions. Material balance calculations will also be used to monitor for possible unwanted loss of chemical constituents. If chemical usage indicates a loss of process chemicals which cannot be explained by current operating procedures such as plant bleed, new well field dilution, or normal process reaction, a fluid balance check for leakage will be conducted. If leakage is indicated, the specific problem areas will be identified by comparing the quantitative assay values in injection lines, recovery lines, and individual recovery wells. Once the problem area is isolated, corrective action will be taken.

Corrective actions

A corrective action procedure will ensure the resumption of containment of the leach solution. For maximum effectiveness, the corrective action requires consideration of a number of factors including (1) spacing of monitor wells, (2) relative mobilities of the various contaminants, (3) uniform measurement and reporting procedures, and (4) response measures consistent with the detected excursion.

If an excursion is verified, the plant supervisor will have several alternative methods for containing and correcting the migration of leach solution. The principal corrective action procedures are overpumping, reordering the pumping balance of the well field, reducing or stopping injection, ceasing both injection and recovery pumping, or beginning restoration procedures. These methods may be applied locally to a few wells within a cell, to the entire cell, to several cells, or to the entire well field as the situation dictates. Current corrective action methods are described.

1. Overpumping. This method involves adjusting pumping so that the rate of flow into the injection wells is exceeded by the flow from the recovery wells. The net result is a general inward movement of native water.

2. Reordering. This is a variation of overpumping in that different ratios are applied to different areas in the well field. Hence, the inward movement of native water may be emphasized at one point or at another. Reordering may further include direct pumping from one part of the field to another.

3. Reducing injection. This is the second way to adjust the ratio of recovery flow to injection flow. At the same time, it reduces the amount of leach solution introduced into the production zone in the vicinity of the wells concerned.

4. Ceasing pumping. This method stops both the injection and recovery flows. Exclusive of the effects of natural forces (e.g., natural migration of groundwater), which are orders of magnitude less, this procedure should retard the further migration of leach solution beyond the established boundaries.

5. Drilling and completing additional wells in the affected area. This method increases the rate and extent of cleanup by either producing water from or injecting fresh water into these wells.

6. Beginning restoration. This step can be utilized when all other efforts have failed to halt the migration of leach solution beyond the farthest allowable limits.

As part of the corrective action procedure, the operator may be required to drill a detection well(s) to locate the extent of migration beyond the monitor well.

The applicant will be required to report in writing to the NRC within 7 d after an excursion has been detected and monthly thereafter until recovery from the excursion has been achieved and maintained for a continuous period of at least one month. These reports will describe the corrective actions taken and provide an evaluation of the results achieved. Also, a final report that describes and evaluates the final results will be filed. The applicant will also notify and report to the appropriate Wyoming State agency in accord with state requirements.

Postmining monitoring

The applicant proposes that throughout the restoration period routine well field excursion monitoring will continue as described in Sect. 4.4.2.5. In addition, all representative injection/recovery wells used in the preoperational (baseline) groundwater monitoring program (1 well per 2 acres of mining unit) and any additional ore-zone aquifer wells necessary to accurately assess the effectiveness of the restoration operations will be sampled. For these wells the sampling frequency and parameters analyzed may vary considerably at the discretion of the operator depending upon the stage of restoration and particular problems encountered.

Once restoration appears complete, a round of verification samples will be collected. All monitor wells used to determine restoration baseline water quality and any monitor well previously on excursion status will be sampled for a full suite of parameters outlined in the Wyoming Department of Environmental Quality *Guideline 8* (see Table 4.4).[3] Additional representative wells throughout the well field at a density of one well per half acre of mining unit will be sampled for a reduced list of parameters to include electric conductivity, chloride, sulfate, bicarbonate, uranium, and sodium. Verification data will be submitted to the NRC within 30 d of their receipt by the applicant.

Postrestoration monitoring

After restoration of a mining unit has been achieved, the applicant proposes to continue sampling the restoration baseline monitoring wells, and any monitor well previously on excursion, every 30 d for six months to assess restoration stability. These samples will be analyzed for the full suite of parameters outlined in Wyoming Department of Environmental Quality *Guideline 8* (see Table 4.4). The stabilization period may be extended for an additional six months if data suggest further evaluation of stabilization is required. In this case, two additional quarterly samples, at nine months and one year past the restoration verification date, will be collected and analyzed for a full suite of indicator parameters (see Table 4.4).

The NRC staff finds the applicant's restoration verification and post-restoration plan acceptable at this time and consistent with the criteria presented in the Staff Technical Position Paper WM-8102, "Groundwater Monitoring at Uranium In Situ Solution Mines." However, postmining and postrestoration monitoring will ultimately be determined by the operational history of the project.

Terrestrial ecology monitoring

Teton-Nedco will monitor the cover and productivity of vegetation on reclaimed lands to ensure that reclamation is successful (Sect. 2.3.10.5). Because of the lack of endangered or rare species at the site and because of the relatively low level of ecological impact of the project, no additional monitoring is suggested by the staff.

4.5 DIRECT EFFECTS AND THEIR SIGNIFICANCE

4.5.1 Impacts on air quality

During construction and operation of the project, emissions to the air will include vehicle and drill-rig exhausts, dust from vehicular traffic on gravel or dirt roads, dust from wind erosion of soils, and small amounts of carbon dioxide and hydrogen chloride–hydrogen peroxide (HCl-H_2O_2) from the elution/precipitation circuit in the processing facilities. There will be no combustion-related emissions from the processing facility because electric power will be used. No drying of uranium slurry products will be conducted at the mine site; therefore, particulates will not be emitted. All gaseous and particulate emissions at the site will be subject to a permit that Teton-Nedco must obtain from the Air Quality Division of the Wyoming Department of Environmental Quality.

Emissions from vehicles and other mobile equipment associated with well drilling and maintenance are discussed in Sect. 2.3.10.4. The major sources of emissions will be the diesel-powered drill rigs and water trucks. The emissions from the drill rigs could result in relatively high ground-level concentrations of pollutants adjacent to the rigs. However, these concentrations will be only temporarily located at any one spot because the rigs will move from one well site to another. Also, the pollutants will disperse rapidly over the surrounding region after being emitted. There are no feasible alternative actions that can be taken to significantly reduce equipment emissions.

Because of the relatively small amounts of emissions, impacts on the air quality in the area will not be significant. Proposed new source performance standards for new stationary sources[4] will not apply to the diesel engines used on the site because these engines will have less than 3.42×10^5 cm^3 (560 $in.^3$) of displacement per cylinder,[5] which is the minimum size to be covered by the standards. Airborne dusts from vehicular traffic are not expected to be a problem because of the low traffic volume on the site. However, if necessary, dusts will be minimized by appropriate control procedures such as the application of dust-control chemicals to gravel roads.

Each disturbed area on the site will be revegetated as soon as feasible after the disturbance activity has ceased. On other disturbed areas such as topsoil stockpiles, seeding will occur periodically as needed to maintain good vegetation cover (Sect. 2.3.10.5). Because of these preventative measures, airborne dust resulting from wind erosion will be held to minimal levels and should not have significant impacts on air quality.

4.5.2 Impacts on land use

Predicted project land uses on the site are given in Tables 4.8 and 4.9. The site or permit area occupies 308 ha (760 acres). Of this, about

Table 4.8. Class I surface disturbance[a]

Area description	Size (ha)	Estimated topsoil[b]	
		yd³	m³
Process plant and support facility		4,518	3,454
R&D previous disturbances	0.7		
Commercial additions	0.8		
Fuel storage area	0.1	81	62
Evaporation ponds			
R&D previous disturbances	1.9	6,292	4,810
1st-year commercial	5.3	17,746	13,566
Later additions[c]	7.4	32,992	25,220
Total 1st-year disturbance	8.8	28,637	21,891
Total Class I disturbance	13.3	61,629	47,112

[a]Class I areas will require topsoil removal and storage.

[b]Soil volumes calculated from baseline data using average depth by soil type indicate that enough topsoil will be available to cover all Class I disturbance with 0.3 m (1 ft) of topsoil during final reclamation.

[c]Area not used in first-year calculation for reclamation bond.

Source: Leuenberger Uranium In Situ Mining Project operated by Teton, *In Situ Mining Permit Application* submitted to the Wyoming Department of Environmental Quality, October 1980, Table III, p. 8.01.

Table 4.9. Class II surface disturbance[a]

Area description	Size (ha)
Total well field	32.4
1st-year disturbance	8.1
Outside storage yard	0.3
Trunk lines, storage areas, and R&D well fields	2.8
Total 1st-year disturbance	11.2
Total Class II disturbance	35.5

[a]In Class II areas, topsoils will be left in place.

Source: Leuenberger Uranium In Situ Mining Project operated by Teton, *In Situ Mining Permit Application* submitted to the Wyoming Department of Environmental Quality, October 1980, Table III, p. 8.02.

49 ha (120 acres) will be affected by project facilities and activities. The primary land use in the region, cattle grazing (Sect. 3.5.1), is not permitted on the area to be affected and will not be permitted for the life of the project. Because the site could support about 0.75 head of cattle per hectare during the growing season, the project will cause loss of pasture for about 37 head of cattle for the life of the project. Surface reclamation and decommissioning (Sect. 2.3.10.5) will attempt to restore the land to good-quality range with a productivity equal to premining conditions. Thus, significant permanent loss of productivity should not occur. Although recreational activities (Sect. 3.5.1) will be prohibited on the site, extensive open land areas surrounding the site should remain available.

Because the nearest significant historical sites are at least several kilometers from the Teton site (Sect. 3.5.2), there should be no impacts on historical resources. Four potentially significant archaeological sites that may have subsurface deposits were found on the project site (Sect. 3.5.2). Therefore, to protect the four sites having the potential for subsurface deposits, cultural clearance was granted by the State Historic Preservation Officer (SHPO) provided no surface disturbing activities take place in or around the boundaries of the sites; the sites must be evaluated for NRHP eligibility prior to any future disturbing activities in these areas. If any archaeological materials are discovered, work in the area must halt immediately and the SHPO contacted, and work may not resume until the archaeological materials have been evaluated and measures for their protection taken. In event these stipulations are not followed, clearance will be voided.[6]

Because only a small percentage of the ore body will be removed, potential subsidence is very small and will not have significant impacts on the primary land uses in the region. If fracturing of formation overlying the ore body should occur during project operation, leaching solutions could travel upward through these formations. However, subsidence and excursions of leaching solutions to the surface have not been problems in other in situ uranium mine projects and are not expected to be problems in this project. Therefore, land uses such as grazing will probably not be impacted.

4.5.3 Impacts on water

4.5.3.1 Surface water impacts

Construction and operation of the solution mine could influence surface water quality in two ways: (1) erosion of soil with subsequent sedimentation of Little Sand Creek and (2) contamination of local waterways with toxic substances released during an accidental spill or leached into streambeds by upward migration of lixiviant. Surface disturbances will occur as land is cleared for the plant [0.2 ha (0.6 acres)], two new solar evaporation ponds [11.6 ha (28.6 acres)], a parking lot, fuel and chemical storage areas, pipelines, and access roads [4.4 ha (10.8 acres)]. Though the permit area slopes generally downward from east to west, then

southwest, the specific site of the proposed construction is essentially level and free of vegetation that would require cutting and hauling. One access road already exists. As a result, extensive earth-moving activities will not be required, reducing the likelihood that significant soil erosion will occur. Further, the applicant is committed to conserving and stabilizing topsoil during construction by placing stockpiles away from drainages and windy ridge tops; by applying appropriate grading, mulching, and seeding techniques (ER Sect. 5.7.8.6); and by restricting all traffic to designated areas from which topsoil has been stripped and windrowed.

Using the Basin Characteristics Method,[7] the 10- and 25-year flood peaks for Little Sand Creek were calculated [11.9 and 18.1 m^3/s (420 and 640 ft^3/s) respectively] and the floodplain margins estimated. To avoid excessive damage to the creek channel, the applicant will neither operate heavy equipment nor drill at an elevation below that of the 25-year floodplain. In general, this precaution prohibits operations within 15 m (50 ft) of the center of the stream channel.

To mitigate against possible excursion of lixiviant, the applicant will recover more solution from the ground than is injected, thereby creating a negative hydraulic force toward the well field. Also, monitors in an extensive system of wells outside the production zone will provide early detection of any leach solution excursions by monitoring chloride, uranium, alkalinity, and conductivity.

A greater potential threat to surface water quality is an accidental spill due to failure of a storage tank, pipeline, or evaporation pond. Although chemicals released in this fashion would not be expected to raise a threat to aquatic life in the North Platte River because they should only reach the river during a major storm event which would provide significant dilution.

The process plant is designed to prevent the escape of spilled liquids. All tanks will be manufactured of fiberglass or steel. Each of the three operational units within the plant will be surrounded by a 15.2-cm (6-in.) curb to contain fluids and will be provided with a separate sump into which liquids can flow. A 5% slope to the concrete floor will enhance this transfer. Once filled, sumps will empty into a brine tank from which solutions will ultimately be directed to the brine (solar evaporation) pond.

Other potential spills involving nonradiological chemicals are associated with the various chemical and fuel storage tanks maintained outside the process plant. Caustic solutions to be stored in the tanks and their anticipated volumes are hydrogen peroxide, 15 m^3 (3963 gal); sodium hydroxide, 56 m^3 (14,800 gal); and hydrochloric acid, 52 m^3 (13,740 gal). Each tank will be placed on a concrete pad surrounded by an earthen berm. In the event of a rupture, solutions will be contained by the berm and ultimately transferred to the brine pond.

Should a pipeline rupture outside the plant, the drop in system pressure will be readily apparent. Small breaks can easily be detected visually during routine inspection of the lines. Where a break results in spilled chemicals, all contaminated soil will be removed to the solar evaporation ponds, as prescribed by NRC and the state of Wyoming.

Two new solar evaporation ponds, the East and West Leuenberger evaporation ponds, will contain the highest concentrations of toxic brines derived from mining operations. Two others, the North and South Leuenberger ponds, already in use, will contain many of the same waste chemicals but in lower concentrations (Table 2.11). Should any of these ponds fail and their contents reach the North Platte River, the impacts on water quality, though undesirable, would probably not be serious. It is likely that only TDS would exceed the Wyoming DEQ criteria for wildlife and livestock (5000 mg/L), and then only if dilution by stream water were minimal. Effluent waters in the ponds will be sampled at least once each quarter and analyzed for Na, Ca, Cl, SO_4, Ra, U_3O_8, and alkalinity (ER, p. 123).

The NRC staff will ensure that catastrophic evaporation-pond-embankment failure will be only a very remote possibility. By license condition, the pond design will be required to meet the safety and engineering design standards set forth in U.S. NRC Regulatory Guide 3.11; operational stability surveillance and testing will be required to meet the recommendations of Regulatory Guide 3.11.1. Also, the NRC will require daily visual inspections to be performed and documented by a qualified individual.

The East and West ponds will be substantially larger than those now in use (Table 4.10). Adequate reserve capacity will be maintained in the evaporation pond system to provide for temporary storage of solution from any pond in event of leakage.

Table 4.10. Teton-Nedco solar evaporation ponds and their anticipated capacities

Reservoir	Capacity	
	m^3	(gal)
North Leuenberger	1.2E4[a]	(3.1E6)
South Leuenberger	1.0E4	(2.8E6)
East Leuenberger	10.6E4	(28.1E6)
West Leuenberger	13.5E4	(35.7E6)

[a]Read as 1.2×10^4.

Freeboard requirements will be determined in accordance with NRC guidelines presented in Draft Staff Technical Position Paper WM-8201, "Hydrologic Design Criteria for Tailings Retention Systems." Generally, staff experience indicates that the required freeboard for most small in situ leaching tailings evaporation ponds is determined to be about 0.6 m (2 ft).

Sewage from the expanded operation will be treated in a state-approved sanitation system consisting of a conventional septic tank and leach field.

Considering the negligible precipitation in the area, the presence of only ephemeral streams on and near the site, and the measures proposed to suppress erosion and prevent spills, the staff concludes that mine construction and operation will have no significant impact on area surface water quality.

4.5.3.2 Groundwater

Comparative impacts on groundwater

The two conventional methods for mining uranium deposits — open-pit and underground mining — and the proposed method of solution mining (in situ leaching) could have considerable environmental impacts on groundwater. All three mining methods may either temporarily or permanently affect groundwater in three ways: disrupt flow patterns, degrade quality, and deplete quantities.

In situ leaching does not require removal of consolidated rock or unconsolidated material associated with or overlying the ore deposit. This advantage preserves intact any groundwater system overlying the ore deposit as opposed to surface or deeper mining methods, which may temporarily or permanently alter these systems. During the production stage, an in situ leaching operation may produce slight changes in flow patterns of the ore-bearing aquifer; these changes will be only temporary and local.

Perhaps the most serious objection to in situ leaching is the degradation of water quality in the ore-bearing aquifer. In addition, if vertical excursions occur or well casings leak, water quality in aquifers overlying or underlying the ore-bearing aquifer may be degraded. Results of restoration at the Leuenberger site research and development project indicate that groundwater quality can be returned to baseline water-use standards. If mechanical, chemical, or natural restoration processes prove as successful on a commercial scale, groundwater degradation from commercial-scale activities at the Leuenberger site will be temporary.

Temporary and permanent groundwater degradation may result from surface- and deep-mining methods. Uranium and associated trace elements (vanadium, arsenic, selenium, and molybdenum) in ore deposits usually occur in a reduced form. Upon exposure to the atmosphere or to oxidizing meteoric waters, the reduced forms may become oxidized and, therefore, more

soluble under aqueous conditions. Surface- and deep-mining methods usually produce waste rock and ore piles in which uranium and other elements may become oxidized and leached by rain. These leached elements may infiltrate and degrade both shallow and deep groundwater systems.

Groundwater will be consumed for the in situ leaching of uranium and the restoration of the ore-bearing aquifer. The total amount of groundwater used during in situ leaching is usually small compared with the quantities of groundwater used during the dewatering of an open-pit or deep mine. Ore obtained from surface- or deep-mining operations has to be processed at a mill that uses additional quantities of groundwater.

Groundwater use

Total use of groundwater (net groundwater withdrawal) for both the M and N ore zones of the upper portion of the Fort Union formation resulting from solution mining is estimated by the staff to be about 7.95×10^5 m^3 (645 acre-ft). This net withdrawal of groundwater will occur only from the ore-zone aquifers during the 11-year life of the project and will not significantly or permanently affect the availability of useable groundwater. Ore-zone water, because of its high radium-226 concentration, does not meet drinking or livestock standards and it will eventually be replenished by natural recharge.

Groundwater quality

Local groundwater quality in the M and N aquifers of the upper portion of the Fort Union formation will deteriorate during the in situ leaching of uranium. The M and N aquifers should be the only aquifers significantly affected by in situ leaching, and this impact will be local and temporary.

The applicant has attempted to locate abandoned exploration holes within and adjacent to the Leuenberger site to the extent such information is available and from reasonable inspection of the site property. To the best of the applicant's knowledge, no drill holes were left abandoned in the site area. All holes drilled by the applicant for the purposes of exploration were plugged by the applicant. However, to check for fluid communication between aquifers, monitor wells will be completed in aquifers over and underlying the ore zone aquifers and monitored regularly to detect changes in aquifer pressure and water quality. At least one aquifer pumping test will also be conducted in each mining unit to verify confinement of ore zone aquifers. The staff considers the aquifer pumping tests and monitoring of over- and underlying aquifers sufficient to test confinement and provide early warning so that any degradation of water quality can be mitigated.

4.5.4 Impacts on mineral resources

At this time, uranium is the only economically recoverable mineral resource at this site. The staff believes that the existing ore deposit can only be

recovered economically by the proposed solution-mining process and that this mining activity will not preclude the recovery of other minerals that may be discovered in economic quantities at this site in the future.

4.5.5 Impacts on soils

The amount of soils disturbed at in situ uranium mining sites is generally small (Tables 4.8 and 4.9). The construction and operation plans for the Teton project were made with soil conservation in mind and will limit soil disturbances to a minimal acreage. Vehicular traffic will be restricted to roads that will be established on the site, including roads between the well sites and the processing plant. In certain areas totaling about 13.3 ha (32.9 acres) (Table 4.8), topsoils will be removed and stored for use in reclamation. Topsoil stockpiles will be sloped no greater than 33% and will be seeded with a cover crop to control erosion. The stockpiles will be located in level areas (except ridge tops) or on side slopes away from drainages and windy ridge tops. Reclamation plans are given in Sect. 2.3.10.5.

4.5.6 Impacts on biota

4.5.6.1 Terrestrial environment

Natural habitats will be completely destroyed for the life of the project on about 14 ha (35 acres) where topsoil removal will be required primarily for evaporation ponds (Table 4.8). On an additional 36 ha (89 acres) within the affected area, topsoils will be left in place. A small fraction of this land will be impacted by designated roads, well sites, storage area, and trunk lines (Table 4.9). After operations are completed, the lands will be returned to a productive condition (Sect. 2.3.10.5).

The vegetation and wildlife on the site and in the vicinity are similar to those in the large expanses of open country in the region and do not appear to have any particularly important or unique features (Sect. 3.9.1). Although it is possible for some rare or endangered species to occur in the area, the site is not particularly important to any of these species (Sect. 3.9.1). In view of these observations, the site appears to be satisfactory from the standpoint of vegetation and wildlife.

Destruction of habitat and disturbances associated with operation (e.g., noise) will unavoidably result in a reduction of the present carrying capacity of the land for wildlife. The reduced carrying capacity will exist for the life of the project. Upon completion of operations, the applicant will attempt to bring the carrying capacity back to preproject conditions (Sect. 2.3.10.5). Therefore, reductions in vegetation and wildlife populations will be minimized. (Plant and animal species that will be impacted by the project are listed in Sect. 3.9.1 and in the ER, Appendixes D-8 and D-9.)

The U.S. Fish and Wildlife Service has identified three endangered species that may be present in the Teton-Nedco project area.[8] These are the black-footed ferret (*Mustela nigripes*), bald eagle (*Haliaeetus leucocephalus*), and peregrine falcon (*Falco peregrinus*). The staff has concluded that the continued existence of each species is highly unlikely to be imperiled by the Teton project. The U.S. Fish and Wildlife Service concurs with this opinion.[9]

The black-footed ferret is associated with the prairie dog, its primary prey.[10] During wildlife surveys on the site and in the vicinity, no prairie dogs were observed (ER, Appendix D-9) and no prairie dog colonies are known to be present in the vicinity of the site. There are several early records of ferrets in Converse County to the east and southeast of the site,[10] but no recent records.[11] Although the lack of recent records does not ensure the absence of this elusive animal, the lack of prairie dogs at the site indicates that the ferret is also likely to be absent.

The bald eagle occurs as a migrant and winter visitor in the vicinity of the site. During the winter, eagles often concentrate along the North Platte River.[12] The river, which runs about 6.4 km (4 miles) south of the site, usually freezes over in most places during the winter, and eagles depart from these areas. However, the Dave Johnston Coal Power Plant east of Glenrock (ER, Fig. 2-2) keeps a stretch of the river open during the winter. Here perhaps more than 20 overwintering eagles occur. These eagles often hunt for prey in upland areas and may occur at the site.[12] However, none was observed during wildlife surveys (ER, Appendix D-9). In the winter, eagles also occur in other areas of Wyoming and in most of the other 47 contiguous states. During January 1979, it was estimated that 395 bald eagles were overwintering in Wyoming and 9843 in all of the lower 48 states.[13] Almost all of these eagles nest in Canada and Alaska.

The significance of the Teton site to the bald eagle is likely to be very minimal. Eagles do not nest in this area of Wyoming, and there is no suitable nesting habitat on the site. Although overwintering eagles may often be concentrated along the North Platte River, they are highly dispersed over large land areas when they hunt for prey in uplands. Land areas surrounding the site will most likely provide more than enough hunting range for the eagles in the area. Therefore, the overwintering population in the Glenrock area, as well as the entire species population, will not be imperiled by the proposed project.

The peregrine falcon may occur as a rare migrant in the region. It is not known to nest in eastern Wyoming, although suitable nesting habitat (e.g., cliffs and tall trees) may be present in the Laramie Mountains south of the site.[12] There is no suitable habitat on the site, and no peregrines were observed during raptor surveys (ER, Appendix D-9). Although falcons could occur at the site during migration or winter, the extensive open habitats in the region are just as suitable as those on the site. Therefore, loss of the onsite habitats should not imperil the existence of this rare migrant or winter visitor.

4.5.6.2 Aquatic environment

The only aquatic habitat on or near the site is a stock pond that contains water whenever an upstream windmill is pumping. Although no biological data exist for this pond, apparently only a few species of algae and invertebrates reside therein. The nearest fish-bearing waters are approximately 6.4 km (4 miles) away. Only under unusual circumstances (severe flooding, evaporation pond failure, or both) would sufficient levels of sediments or chemicals extend far enough from the site to adversely affect aquatic life. Even in such an event, pollutants would probably be diluted to harmless levels by the volume of water transporting them downstream, particularly because their concentrations in waste streams from solution mining are relatively low (Sect. 4.5.3.1 and Table 2.11). No discharge of surface water is anticipated. The staff feels that construction and operation of the solution mill will pose, at most, a minor potential threat to the aquatic environment.

4.5.6.3 Comparison with alternatives

Mining and processing alternatives are discussed in Sects. 2.3.3 and 2.3.4, respectively, and are evaluated in Sect. 2.3.5. From the standpoint of impacts on surface waters, unconventional mining techniques (solution mining) are generally preferable to conventional (open pit or underground mining) methods because substantially fewer erosion and waste disposal problems may arise. Depending upon the type of solution mining used, significantly less surface area may be disturbed and tailings piles, mill tailings, and ore and overburden stockpiles are usually not created. In the Teton project, the type of solution mining proposed involves only the underground extraction of uranium. Those steps required for the surface extraction, transportation, storage, crushing and grinding of ore in conventional operations are eliminated, as are environmental problems such as stream sedimentation and surface waterborne transport of toxic substances.

The sodium bicarbonate/carbonate leaching method chosen is not entirely without its potential adverse effects, however. Surface and/or groundwater may be contaminated due to excursions of leach solutions from the mining zones. To prevent this, the applicant is committed to recovering more solution from the ground than is injected, and to operating an extensive system of monitoring wells outside the production zone (Sect. 4.5.3.1).

4.5.7 Radiological impacts

4.5.7.1 Introduction

The primary sources of radiological impact to the environment in the vicinity of the proposed Teton project are naturally occurring cosmic and terrestrial radiation and naturally occurring radon-222 (Sect. 4.4).

The average annual total-body dose rate from natural background radiation to the population in the site vicinity is estimated to be about 174 millirems.[14] Continuous exposure to concentrations of naturally occurring radon-222 in the air, estimated to be between 500 and 1000 pCi/m^3, could result in doses up to 625 millirems per year. Diagnostic medical procedures result in an average dose of 75 millirems per year.[15]

This section describes the results of the staff's analysis of the project-contributed incremental radiological effects on the environment and the population in the vicinity of the Teton solution mining site. Exposure pathways are discussed, as are the estimated radiological impacts resulting from the estimated emissions from facility operations. The impacts to nearby individuals and the entire population within 80 km (50 miles) are estimated. Finally, consideration is given to the potential radiation exposures of project employees and of biota other than man.

Because the proposed operations at the Teton facility do not involve displacement of ore from the ore body or drying and packaging of the yellowcake product, there will be no routine particulate emissions from the facility. This analysis has considered the effects of releases of gaseous radon-222, which is the only projected routine radioactivity release. The estimated annual release of radon is 627 Ci, which was computed based on the calculational methods presented in Appendix C, and the models, data, and assumptions discussed in Appendix D.

4.5.7.2 Exposure pathways

Estimates of the dose commitments to man are based on the proposed plant design, characteristics of the site environs, and the exposure pathways to man. Only exposure pathways resulting from gaseous radon-222 releases to the atmosphere are considered in this analysis. There will be no surface discharge of radioactive fluids, and radioactive materials liberated underground during the leaching process will be confined.

Because there is expected to be no particulate release and radon-222 is the only gaseous radionuclide that will be released from the Teton facilities, the environmental exposure pathway of primary concern is the inhalation of radioactive materials (radon and its decay daughters) in the air. External exposure to radon daughter radionuclides in the air and on the ground and ingestion of contaminated food products (meat and vegetables) are less significant contributors to dose.

4.5.7.3 Radiation dose commitments to individuals

The estimated radiation dose at a reference point depends on the distance and direction of the point with respect to each of the sources, as well as the wind directional frequency toward the receptor from each of the sources. Doses are higher at locations downwind from the plant. (Prevailing winds in the site vicinity are toward the NNW through ENE sectors, as shown in Table D.2.) As radon is transported offsite its daughters

grow in, which potentially results in higher dose commitments farther from the plant until the radioactive plume is further diluted by dispersion.

The closest residence to the Teton site is 0.5 km (0.3 mile) NE of the plant. In addition, there is a residence 0.7 km (0.4 mile) ENE of the plant. Estimated annual dose commitments to individuals at these locations are shown in Table 4.11. For dose estimates at the above locations, it was conservatively assumed that vegetables and meat consumed by the residents were produced locally. Dose estimates are based on a model year, during which one mining unit is mined, one unit is soaking, and one unit is being restored.

4.5.7.4 Radiation dose commitment to the population

The annual dose commitment to the estimated population within 80 km (50 miles) of the plant site is presented in Table 4.12, along with predicted doses to the same population from natural background radiation sources. Population dose commitments resulting from the operation of the Teton project represent no more than 0.01% of the doses from natural background.

4.5.7.5 Evaluation of compliance with regulatory limits

All radiation doses that result from the uranium solution mining operation at the Teton site and that are estimated for the surrounding population are small fractions of those arising from naturally occurring background radiation (Table 4.13).

Calculated 50-year dose commitments for the maximally exposed individual are only small fractions of the current NRC limits for radiation exposure in unrestricted areas (10 CFR Part 20 "Standards for Protection Against Radiation"). Dose commitments to the nearest residents are not compared with the limits specified in the EPA's "Radiation Protection Standards for Normal Operations of the Uranium Fuel Cycle" (40 CFR Part 190), because these limits do not apply to radon-222 or its radioactive daughters. Table 4.14 provides a comparison of calculated air concentrations compared with limits established by the NRC for public protection.

As indicated in Table 4.14, projected radioactivity concentrations near the project site fall well below NRC limits. To ensure that offsite concentrations are maintained below the permissible limits, the staff will require the applicant to monitor radon concentrations at and near the site (see Sect. 4.4).

Table 4.11. Annual dose commitments to individuals from radioactive releases from the Teton project

Location	Exposure pathway	Dose (millirems per year)			
		Whole body	Bone	Lungs	Bronchial epithelium[a]
Nearest residence, 0.5 km NE	Inhalation	6.15E−7[b]	1.91E−5	5.17E−6	7.76E+1
	External ground	6.49E−3	6.49E−3	6.49E−3	6.49E−3
	External cloud	9.62E−3	9.62E−3	9.62E−3	9.62E−3
	Ingestion				
	Vegetable	6.27E−7	1.56E−5	6.27E−7	6.27E−7
	Meat[c]	1.46E−6	3.63E−5	1.46E−6	1.46E−6
	Total	1.61E−2	1.62E−2	1.61E−2	7.76E+1
Nearby residence,[d] 0.7 km ENE	Inhalation	2.25E−6	6.99E−5	1.89E−5	5.62E+1
	External ground	7.03E−3	7.03E−3	7.03E−3	7.03E−3
	External cloud	1.88E−2	1.88E−2	1.88E−2	1.88E−2
	Ingestion				
	Vegetable	2.29E−6	5.70E−5	2.29E−6	2.29E−6
	Meat[c]	1.46E−6	3.63E−5	1.46E−6	1.46E−6
	Total	2.58E−2	2.60E−2	2.59E−2	5.62E+1
Natural background	Total	1.74E+2	2.09E+2	1.75E+2	5.60E+2

[a]Doses to the bronchial epithelium result from the inhalation of short-lived radioactive daughters of radon-222.

[b]Read as 6.15×10^{-7}.

[c]Meat ingestion doses result from ingestion of the meat of cattle grazed 1.0 km east of the mill.

[d]Location of a Teton airborne effluent monitoring station.

Table 4.12. Annual 100-year environmental dose commitments[a] to the population within 80-km (50-miles) of the Teton site

Receptor organ	Dose (person-rems/year)	
	Project effluents	Natural background[b]
Whole body	0.064	13,200
Lungs	0.073	13,300
Bone	0.104	15,800
Bronchial epithelium	3.62	42,500

[a]Based on estimated impacts from one year of radioactive releases integrated over a 100-year period (a discussion of this method is found in Nuclear Regulatory Final Generic Environmental Impact Statement on Uranium Milling, NUREG-0706, vol. III, Appendix G-6.

[b]Based on a projected population, provided by the applicant, of 75,833 and background radiation doses for the Wyoming Basin presented in ref. 14.

Table 4.13. Total 100-year environmental dose commitments[a] to continental populations from the operation of the Teton in situ facility for eight years

	Total environmental dose commitments (EDCs) (person-rems)			
	Whole body	Lungs	Bone	Bronchial epithelium
EDCs received by the population within 80 km of the mill	0.51	0.58	1.47	28.9
EDCs received by the population beyond 80 km of the mill	49.4	11.2	674	314
Total EDCs received by the continental populations	49.9	11.8	675	343
Fraction of background[b]	1.68E−7[c]	3.98E−8	2.27E−6	2.31E−7

[a]Based on estimated impacts from one year of radioactive releases integrated over a 100-year period.

[b]Background values are estimated on the basis of a projected year 1991 continental population of 372 million people, each person receiving 100 millirems/year to the whole body, bone, and lung and 500 millirems/year to the bronchial epithelium (NUREG-0706, September 1980).

[c]Read as 1.68×10^{-7}

Table 4.14. Comparison of air concentrations during solution mining operations with 10 CFR Part 20 limits for unrestricted areas

	Total air concentration (pCi/m^3)			
	Pb-210	Bi-210	Po-210	WL concentration[a]
10 CFR Part 20 limit[b]	4.00	2.00E + 2[c]	7.00	3.33E−2
Restricted area boundary, 0.6 km ENE	1.92E−7[c]	5.57E−11	3.67E−16	9.35E−5
Fraction of limit	4.81E−8	2.79E−13	5.25E−17	2.81E−3
Restricted area boundary,[d] 0.8 km E	5.43E−7	2.34E−10	2.89E−15	8.17E−5
Fraction of limit	1.36E−7	1.17E−12	4.13E−16	2.45E−3

[a]WL denotes "working level." A one-WL concentration is defined to be any combination of air concentrations of the short-lived Rn-222 daughters, Po-218, Pb-214, Bi-214, and Po-214 that, in one liter of air, will yield a total of 1.3×10^5 MeV of alpha-particle energy in their complete decay to Pb-210. Predicted values given for outdoor air are those calculated on the basis of actual ingrowth from released Rn-222.

[b]Values given are from 10 CFR Part 20, Appendix B, Table II, column I.

[c]Read as 1.92×10^{-7}

[d]Location of a Teton airborne effluent monitoring station.

4.5.7.6 Occupational dose

A potential exposure of solution mining project employees is that attributable to radioactive materials associated with handling of the yellowcake slurry. Where any spillage occurs and the yellowcake becomes dry, some airborne radioactivity may result. However, this operation will be designed to minimize the releases of radioactive contamination to the room air. Even at uranium mills, where drying and barreling of powdered yellowcake is routinely performed, studies at selected mills have shown that few exposures exceed 25% of the specified NRC limits for such exposures averaged over the year.[16,17] The limit of exposure to airborne natural uranium in the chemical forms encountered in the drying and packaging operations is not a radiation exposure limit; rather, this limit is based on the chemical toxicity of uranium.

Worker inhalation of radon and its daughters is another potential exposure condition. The ventilation system in the recovery plant will minimize this type of exposure, and employee exposures should not exceed 10% of the annual limit specified by the NRC (according to a study of comparable employee exposures at existing uranium mills).[17]

Exposure to external radiation is expected to be far below the maximum limits permitted by NRC regulations because of the nature of the material and the operations. However, the applicant will be required to perform periodic gamma radiation surveys to ensure that in-plant radium buildup does not result in excessive radiation exposure (see Sect. 4.4).

4.5.7.7 Radiological impact on biota other than man

Although no guidelines concerning acceptable limits of radiation exposure have been established for the protection of species other than man, it is generally agreed that the limits for humans are also conservative for those species.[18-26] Doses from gaseous effluents to terrestrial biota (such as birds and mammals) are quite similar to those calculated for man and arise from the same dispersion pathways and considerations. Because the effluents of the facility will be monitored and maintained within safe radiological protection limits for man, no adverse radiological impact is expected for resident animals.

4.5.7.8 Summary

An independent assessment of the radiological impacts of the Teton project was conducted by the staff. The maximum dose to individuals is 77.6 millirems/year to the bronchial epithelium, which is less than 14% of the estimated dose to individuals from natural background radiation. The maximum exposure to the population within 80 km (50 miles) is 3.62 person-rem/year to the bronchial epithelium, which is a fraction of only 8.52×10^{-5} of background radiation. These dose estimates represent the annual dose commitments during operation of the Teton facility. After mining has been completed and the site has been fully reclaimed and restored, no further radiological impacts will occur.

4.6 INDIRECT EFFECTS AND THEIR SIGNIFICANCE

4.6.1 Socioeconomic effects

4.6.1.1 Summary

Although conventional (open-pit and underground) mining methods and conventional milling processes have relatively high manpower requirements, the proposed solution-mining project does not. Therefore, despite the historically low unemployment rates in local labor markets unemployment is increasing (Sect. 3.4.3), and the staff is of the opinion that the majority of the project-related employment opportunities will be filled by workers from local labor pools. Because few in-migrants will be needed, population-induced impacts should be minimal. Consequently, the socioeconomic impacts associated with the project will be minimal.

4.6.1.2 Employment

According to the applicant (ER, Sect. 7.6.1.2), the Leuenberger operation will require an onsite work force of approximately 50 employees. The staff estimates that from approximately 60 to 93 additional "indirect" or secondary jobs will be induced by facility operations (see Appendix E for the assumptions utilized to calculate employment impacts). These secondary jobs will be generated via the multiplier effects caused by incremental increases in expenditures in the local economics by Teton-Nedco (for equipment and supplies) and by their onsite employees. Therefore, it is estimated that between approximately 110 and 143 employment opportunities will be generated by the in situ operation (Table 4.15). Based on the sizes of the labor forces in the region, unemployment statistics, and industrial employment patterns, the staff has concluded that from approximately 80 to 95 of the 110 to 143 facility-induced openings will be filled by workers residing in the two-county labor market (Converse and Natrona counties). That is, it is estimated that only about 30 to 50 of the facility-related jobs will have to be filled by hiring nonlocal workers.

4.6.1.3 Population

Assuming (see also Appendix E) that (1) all of the nonlocal, facility-induced workers will in-migrate into the region (that is, assuming that all of the nonlocal employees will move from outside to inside the two-county region to accept local jobs) and (2) none of the direct and secondary workers will be from the same family, the staff estimates that the total facility-generated in-region population influx will be between approximately 90 and 140 (Table 4.15). From an analysis of local community infrastructures and their proximities to the site, the staff has concluded that the vast majority of in-migrating workers will probably settle either within or near Glenrock and Casper, with a small percentage choosing to reside in the Douglas area (Table 4.15). It is estimated

Table 4.15. Estimated incremental impacts on employment, population, and housing caused by operation of the Teton-Nedco uranium in situ leaching project[a]

	Total regional impacts[b]		Converse County				Natrona County	
			Glenrock area		Douglas area		Casper area	
	Low	High	Low	High	Low	High	Low	High
Employment opportunities[c]	110	143						
Population influx	89–100	116–139	16–20	46–59	8	10–12	51–55	79–90
Families	23–26	30–36	5	12–15	3	3	15	23–26
School-age children	21–23	27–32	5	11–13	3	3	12	19
Housing demands	31–34	40–48	7	15–20	3	5	18	27–31

[a]Impacts based on an operation work force of ~50 employees (ER, p. 150); for other assumptions see Appendix E.
[b]The impacted region consists of Converse and Natrona counties.
[c]Includes "direct" or "basic" operation jobs plus induced or "secondary" jobs.

that, as an upper limit, about 60 persons will reside in Glenrock and that, at most, about 90 persons will reside in Casper. According to the 1980 decennial census tabulation (Table 3.4), Glenrock's population was 2,736, Casper's population was 51,005, and Douglas's 1980 population was 6,030. Therefore, operation of the Teton-Nedco facility will increase the populations of the affected urban areas by only a very small fraction.

4.6.1.4 Housing

Assuming a worst-case scenario [that is, if (1) none of the basic and secondary workers are from the same family and (2) each unmarried in-migrant will require a separate residence], from approximately 30 to 50 housing units may be needed to house in-migrating project-related employees and their dependents (Table 4.15 and Appendix E). The staff anticipates that most of the project-related housing demand will occur in Glenrock and Casper. From present tendencies and preferred demands (Sect. 3.4.2), it is expected that most of the housing demand will be for privately owned single-family units and mobile homes. Also, from past and present housing stocks and vacancy rates, local housing markets should be able to assimilate the increase in housing demand caused by the project; however, high purchase costs may force some in-migrants to reside in "second choice" housing, such as rental properties.

4.6.1.5 School enrollment

The staff estimates that only about 20 to 35 additional students will enroll in local school systems (Table 4.15). Most of these students will probably enroll in the Glenrock and Casper school systems. These estimated facility-induced enrollment increases are a very small fraction

of total enrollments in the local school systems (Sect. 3.4.4.4); therefore, the staff is of the opinion that the in situ operation will minimally impact the school systems.

4.6.1.6 Personal income

The staff estimates that the project will generate from approximately $3.6 to $4.0 million (1979 dollars) during each year of operation (see Appendix E for the assumptions utilized to derive these income estimates).* For comparative purposes, the total personal income in Converse and Natrona counties was estimated by the staff to have been approximately $840 million in 1978.

4.6.1.7 Public services and facilities

Since the proposed project will not be labor intensive and in-migration of project-related workers will be limited, the public services and facilities supplied by the counties and municipalities in the region near the site will be minimally impacted.

Health and public safety services

Health services and facilities are sufficient to accommodate increased demands (Sect. 3.4.4.4), and additional fire and police protection requirements will be minimal.

Water and sewage

From the facility-induced population-increase estimates (Table 4.15) and current water usage statistics, the staff estimates that the project will cause an aggregate increase in *peak* water demand on the area's systems to an upper limit of between approximately 1.4×10^5 L/d (3.6×10^4 gpd) and 1.6×10^5 L/d (4.3×10^4 gpd). This increased demand will be apportioned among the Glenrock, Casper, and Douglas water systems; therefore, the impacts on any single system will be minimal. Local sewage and solid waste disposal systems are also adequate to process the additional facility-related demand increases (see Sect. 3.4.4.4 for a description of local sewage and solid waste systems).

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*The income estimates do not include the additional incomes from incremental markups induced by increased commodity demands, local expenditures for project-related supplies, nor interest charges for credit purchases.

Roads and traffic

Highway 95, the primary access to the site (see Fig. 3.2) will bear the brunt of project-related traffic. The increased traffic will consist of workers commuting to and from work and vehicles traveling to and from the site transporting supplies and uranium oxide products. Traffic will be heaviest when the applicant's employees move to and from the site and, because of this increased traffic, there will be a slightly higher potential for traffic and wildlife fatalities. However, because the work force will be small (approximately 50 workers), these adverse impacts should be minimal.

4.6.1.8 Public sector finances

Because very few of the project-generated employment opportunities will have to be filled by nonlocal workers, public sector finances will be minimally impacted by the project. Some additional funds may have to be expended to accommodate in-migrants; however, the project will generate — via payment of property, sales, and severance taxes — sufficient funds to cover additional public sector expenditures.

4.6.1.9 Aesthetics

Because the project site is near a public highway, views of activities from Highway 95 are very probable. However, because in situ leaching will be utilized for uranium extraction, there will be no unsightly surface mines, ore and overburden stockpiles, or mill tailings disposal areas, and the aesthetic impacts should be minimal.

4.6.2 Potential effects of accidents

Accidents during the operation of the Teton project will be minimized through (1) the proper design, construction, and operation of the process equipment; (2) adherence to adopted solution-mining and radiation safety procedures; and (3) incorporation of a quality assurance program designed to establish and maintain safe operations. The NRC will maintain surveillance over the facility and its individual safety system by conducting periodic inspections and by requiring reports of effluent releases and significant deviations from normal operations.

Accidents involving the release of radioactive materials or chemicals have occurred in operations similar to those proposed by the applicant. Therefore, in this assessment, accidents that might occur during operation have been postulated and their potential environmental impacts evaluated.

Solution mining of uranium is a still-developing technology. Because operating experience is limited, the application of probabilities of occurrence for most types of accidents is restricted. Where actual data were lacking, conservative assumptions were used to assess environmental impacts resulting from accidents. Thus the actual effects of such accidents may be less than the potential effects estimated by this assessment.

4.6.2.1 Surface accidents

Surface-pipe failures

All piping at the site will be surface piping flush with the ground to permit ready detection and repair of leaks. The applicant indicates that fiberglass, high-density polyethylene and/or polyvinyl chloride (PVC) will be used. To prevent freezing of solutions in the pipeline, the applicant will insulate all aboveground piping.

The main pipelines will lie in utility corridors from the processing plant and will be at generally safe distances from service roads. Within the well fields, personnel and vehicles may inadvertently break smaller injection or production distribution lines; however, only small fluid losses would result.

Occasionally, leaks can be expected in normal operations as a result of defective materials, construction practice, chemical degradation, vibration, or stress. The applicant will be required to report all pipe breaks or ruptures. A report of the nature of the event and corrective actions taken will be made available to NRC inspectors.

Flow meters will be installed at critical locations in all pipelines for process control, and flow rates will be monitored. Plant personnel will be given strict instructions to report any discrepancies in pipeline flow rates. This procedure will provide early warning of pipeline breaks so that immediate action can be taken. Check valves and manual valves will allow isolation of the system where a break occurs, thus preventing drainage of solution tanks and long sections of pipelines.

A 1-h major rupture in the trunk lines transporting either pregnant solution or lixiviant between the processing plant and the well field could potentially release 340,000 L (90,000 gal) of solution to the adjacent environment. The probability of such a release is extremely low. Smaller, low-volume leaks are more probable. The estimated composition of the lixiviant solutions is shown in Table 4.16.

Soil immediately adjacent to a pipeline rupture will be saturated by the lixiviant solution during the initial stages of a leak. The vertical seepage rate into the ground will be rapid during the long dry periods but will be low during or shortly after thunderstorms in the well field and plant area. Solutions would tend to flow downslope along the surface toward Little Sand Creek. It is unlikely that even the postulated

Table 4.16. Estimated concentrations of principal radionuclides and other constituents in injected solutions

Constituent	Concentration
SO_4, mg/L	364
Chlorine, mg/L	62
Sodium, mg/L	420
Manganese, mg/L	<1
Uranium (as U_3O_8), mg/L	<1
HCO_3^-, mg/L	1550
Th-230, pCi/L	≈4[a]
Ra-226, pCi/L	1540

[a]Staff estimate.

340,000-L (90,000-gal) spill would leave the site because, evenly distributed, it would cover only 5.1 ha (12.5 acres) to a depth of 0.64 cm (0.25 in.) without infiltration. Conceivable leakage from evaporation ponds would be of similar magnitude and would not be expected to have serious environmental effects, if repaired immediately after detection.

In the unlikely event of a spill reaching Little Sand Creek, the applicant would be required to clean it up. However, contaminated materials, whether collected onsite or offsite, would be disposed of in the evaporation reservoir or in an offsite licensed disposal facility.

Contact with the soil should decrease the oxidation potential of the lixiviant. Vegetation in the vicinity of the spill may be harmed as a direct effect of the initial high-oxidation potential of the spilled liquid. The high sodium chloride content in the spilled solutions may cause toxic effects in plant life over the short term. Trace elements are not present in sufficient quantities to be toxic to most plants.

For the postulated leak of 340,000 L (90,000 gal), up to 0.001 mCi of thorium-230, approximately 0.525 mCi of radium-226, and 0.091 mCi of uranium-238 could be released. Evaporation of spilled solutions would cause precipitation of these radionuclides on the native soils. The NRC license will require that all such spills be promptly reported.

In conventional uranium milling operations, pipeline failures would result in similar problems. Tailings dam failures could produce substantially greater impacts.

Failure of chemical and fuel storage tanks

At the Teton project, chemical storage facilities will be maintained outside the plant building. Chemical and fuel storage facilities will

include surge tanks for lixiviant and eluant solutions and a number of small tanks for yellowcake precipitation and water treatment. The probability of a chemical spill will be minimized through proper design and operating procedures.

Tanks located inside the plant building will be equipped with sensing alarms and valving to minimize the probability of an overflow. Overflows or leaks from these inside tanks will drain to the building sump and be returned to the process. Each external process chemical and fuel storage tank will be surrounded by an earthen dike capable of containing the capacity of the tank.

Releases from gas tanks could result in fire or explosion. However, because of the rapid dispersion of the gases, the explosive concentration limits would be exceeded for only a short period of time following tank failure. Releases from the fuel oil tanks, located remotely from the plant, could result in a fire but would not pose any danger to the facility. The tanks carrying hydrogen peroxide will be vented to prevent excessive buildup of pressure. Similar accidents can occur in conventional milling facilities.

Fire in the solvent extraction circuit

Because the applicant proposes to operate with ion exchange columns and aqueous processing, there is no solvent extraction circuit.

Tornadoes

The probability of a tornado in the 1° square in which the Teton site is located is low. From the closest available data, the probability is approximately 3×10^{-4} per year.[27] The area is categorized as region 3 in relative tornado intensity.[28] For this category, the wind speed of the design tornado is 386 km/h (240 mph), of which 306 km/h (190 mph) is rotational and 80 km/h (50 mph) is translational. None of the structures are designed to withstand a tornado of such intensity.

The nature of the operation is such that little more could be done to secure the facility with advance warning than without it. Accordingly, a no-warning tornado was postulated. Because the yellowcake product has the highest specific activity of any material handled at the recovery plant and because as much as 19 t (21 tons) (approximately one truckload) of the product may be accumulated before shipment, the tornado was assumed to be capable of lifting 1588 kg (3500 lb) of yellowcake.

Because the yellowcake is in slurry form, no dispersion as powder can occur. Therefore, the environmental effects would be much less than if dispersed as dry powder. Assuming dry U_3O_8 powder and a conservative model (i.e., all the yellowcake is in respirable form for the dispersion analysis,[29] and all the material was entrained as the vortex passed over

the site), one can conclude that the material will be dispersed by the trailing winds as the vortex dissipates upon reaching the site boundary.

The material was deemed to be in a source representative of the velocities of the tornado and to be dispersed through a 90° arc containing the maximum population density in the vicinity of the site. Because of the small particle size assumed, the settling velocities were considered to be negligible.

On the basis of this model, the maximum exposure would occur at a distance of about 4 km (2.5 miles) from the recovery plant, where a dose to the lungs of 4.6×10^{-5} millirems would result. The 50-year lung dose as a function of distance is plotted in Fig. 4.3.

A similar accident can occur in conventional milling facilities.

Transportation accidents

Shipments of yellowcake. Because the applicant will ship yellowcake as slurry, the yellowcake dryer and its associated emissions are eliminated. The product dewatering centrifuge will reduce the yellowcake water content to 50% by weight. The slurry will be bulk loaded in a type-B tank truck or in approved drums for shipment. The staff estimates that approximately seven tank truck shipments will be required annually. The yellowcake slurry will be shipped to the Kerr-McGee Nuclear Corporation hexafluoride plant in Gore, Oklahoma, for further processing.

From published accident statistics,[30-32] the probability of a truck accident ranges from 1.0×10^{-6} to 1.6×10^{-6} per kilometer (1.6×10^{-6} to 2.6×10^{-6} per mile). Truck accident statistics include three categories of traffic accidents: collision, noncollision, and other events. *Collisions* involve interactions of the transport vehicle with other objects, whether moving vehicles or fixed objects. *Noncollisions* occur when the transport vehicle leaves the transport path or deviates from normal operation in some way, such as by rolling over on its top and/or side. Accidents classified as *other events* include injuries suffered by persons when in a vehicle, when falling from a vehicle, or when being thrown against a standing vehicle; vehicle theft; and fires occurring on a standing vehicle. The probability of a truck shipment of yellowcake slurry from the Teton site being involved in an accident of any type during a one-year period ranges from 0.011 to 0.018.

The following analysis has been made for an accident involving dried yellowcake for which potential health risks are much greater than for the transportation accidents involving yellowcake slurry.

The ability of the materials and structures in the shipping package to resist the combined physical forces arising from impact, puncture, crush, vibration, and fire depends on the magnitude of the forces.[32] These magnitudes vary, as does the frequency with which they occur, with the severity of the accident. A generalized evaluation of accident

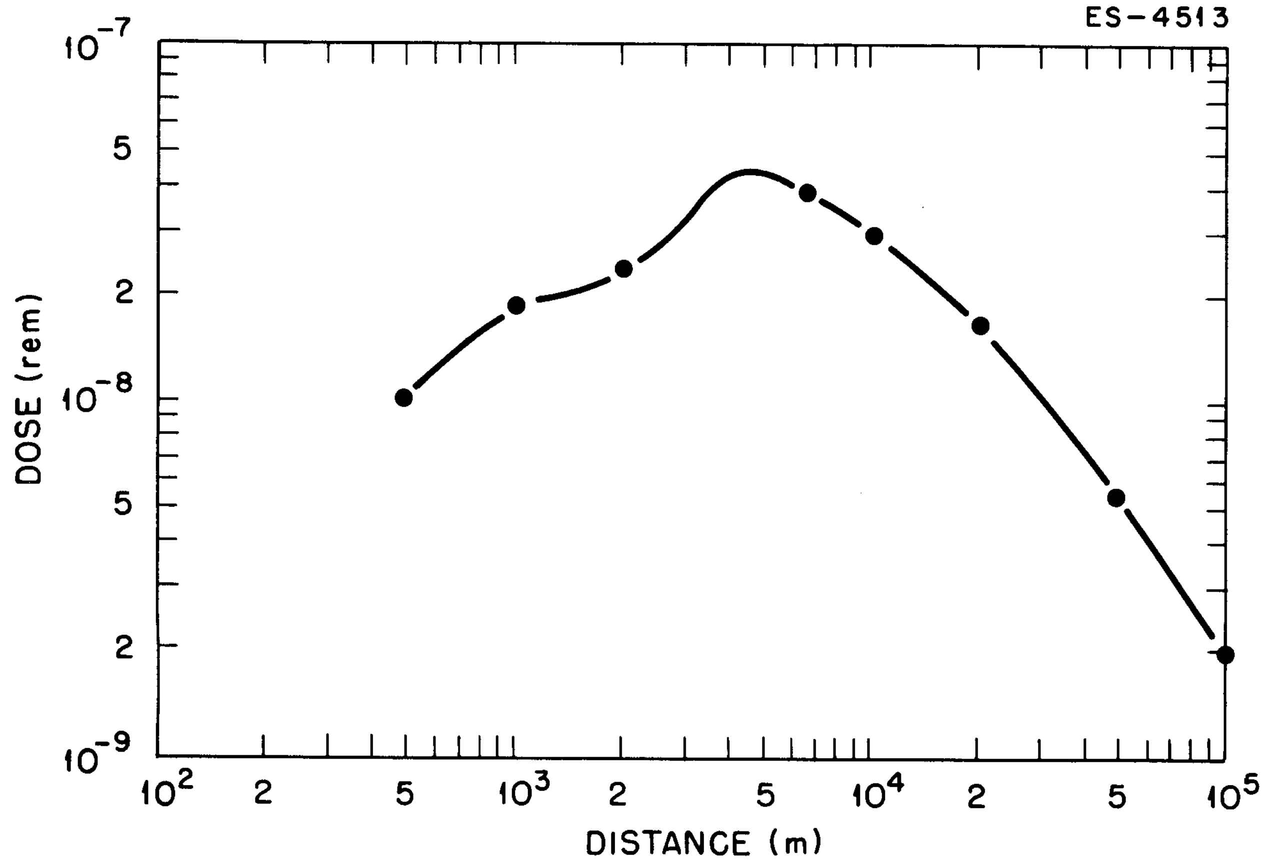

Fig. 4.3. Fifty-year lung dose commitment as a function of distance.

risks by NRC classifies accidents into eight categories, depending upon the combined stresses of impact, puncture, crush, vibration, and fire. On the basis of this classification scheme, conditional probabilities (i.e., given an accident, the probability that the accident is of a certain magnitude) of the occurrence of the eight accident severities were developed. These fractional probabilities of occurrence for truck accidents are given in column 2 of Table 4.17. To assess the risk of a transportation accident, it is necessary to know the fraction of radioactive material released when involved in an accident of a given severity. Two models are postulated for this analysis — Model I, which assumes complete loss of the drum contents, and Model II, which assumes partial loss of the drum contents (Table 4.17). The packaging is assumed to be type-A drums containing low specific activity (LSA) radioactive materials. Considering the fractional occurrence and the release fractions (loss) for Models I and II, the expected fractional release in any given accident is approximately 0.45 and 0.03, respectively.

Table 4.17. Fractional probabilities of occurrence and corresponding package release fractions for each of the release models of low specific activity (LSA) and type-A containers involved in truck accidents

Accident severity category	Fractional occurrence of accident	Model I	Model II
I	0.55	0.0	0.0
II	0.36	1.0	0.01
III	0.07	1.0	0.1
IV	0.016	1.0	1.0
V	0.0028	1.0	1.0
VI	0.0011	1.0	1.0
VII	8.5E–5	1.0	1.0
VIII	1.5E–5	1.0	1.0

Source: U.S. Nuclear Regulatory Commission, *Final Environmental Statement on the Transportation of Radioactive Materials by Air and Other Models*, Report NUREG-0170, Office of Standards Development, February 1977.

For Models I and II, the quantity of yellowcake released to the atmosphere in the event of a truck accident is estimated to be about 7348 kg (16,200 lb) and 499 kg (1100 lb), respectively. Most of the yellowcake released from the container would be deposited directly on the ground in the immediate vicinity of the accident. However, some fraction of the released material would be dispersed to the atmosphere. Expressions for the dispersal of similar material to the environment based on actual laboratory and field measurements have been developed.[31]

The following empirical expression was derived from the dispersal of the material to the environment through the air following an accident involving a release from the container:

$$f = 0.001 + (4.6 \times 10^{-4})[1 - \exp(-0.15ut)]u^{1.78}$$

where

f = the fractional airborne release,
u = the wind speed at 15.2 m (50 ft) expressed in meters per second,
t = the duration of the release in hours.

In this expression, the first term represents the initial puff immediately airborne when the container ruptures in an accident. Assuming that the wind speed is 5 m/s (10 mph) and that 24 h are available for the release, the environmental release fraction is estimated to be 9×10^{-3}. If insoluble uranium (all particles of which are in the respirable size range) is assumed and a population density of 62 people per square kilometer (160 people per square mile) (which is characteristic of the eastern United States) is supposed,[33] the consequences of a truck accident involving a shipment of yellowcake from the mill would be a 50-year dose* to the general population of approximately 13 and 0.9 man-rems to the lungs for Models I and II, respectively. Exposures would be greatly reduced because the product would be in a slurry form, instead of dry powder.

In a recent accident (September 1977), a commercial truck carrying 50 steel drums of uranium concentrate overturned and spilled an estimated 6800 kg (15,000 lb) of concentrate on the ground and in the truck trailer. Approximately 3 h after the accident, the material was covered with plastic to prevent further release to the atmosphere. Using the above formula and values of wind speed for a fractional airborne release for this 3-h duration of release, approximately 56 kg (123 lb) of U_3O_8 would be released to the atmosphere. The consequence of this accident would be a 50-year dose to the general population of 11 man-rems for a population density of 62 people per square kilometer (160 people per square mile). This dose can be compared to a 50-year integrated lung dose of 1427 man-rems from natural background. All U_3O_8 production sources risk this shipping accident; risks are minimized when yellowcake is shipped in slurry form.

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*Doses integrated over a 50-year period following exposure.

Shipments of chemicals to the site. Truck shipments of process chemicals to the Teton plant, if involved in a severe accident, could conceivably result in a local environmental impact. Small quantities of analytical reagents will be transported to the site. A list of process chemicals and fuels used onsite follows:

Shipped as solids	Shipped as liquids
NaCl	HCl
$NaHCO_3$	H_2O_2
Na_2CO_3	CO_2
NaOH	O_2
	Diesel oil
	Bottled gases
	LPG

Most U_3O_8 production facilities have the potential for a similar accident.

4.6.2.2 Subsurface accidents

These accidents and their remedies are discussed in Sect. 4.4.

Evaporation pond leakage

If waste pond leakage is detected (Sect. 4.4.2.3), the ponded liquid will be pumped to an adjacent pond, and the liner will be repaired. The consequences would be similar to storage tank or pipeline failures but would be more difficult to clean up. If the leakage is considered significant, cleanup operations will be required after repair is effected.

Accidents involving evaporation pond failure are discussed in Sect. 4.5.3.1 (Surface water impacts).

Conclusion

The staff opinion is that any potential accident postulated for this project will not result in permanent damage to the environment.

4.6.3 Final waste disposal

The estimated annual volume of waste solids from construction, drilling, production, and restoration is tabulated below.

Activity	Nonradioactive, m^3 (yd^3)	Radioactive, m^3 (yd^3)
Construction	720 (943)	0 (0)
Drilling	2150 (2800)	79 (104)
Evaporation ponds and other residue[a]		687 (900)
Production	Included in construction	3.0-4.7 (4-6)[b]

[a]Average over eight years. These figures include contaminated pond liners residue, materials trapped by the injection-line filter system, sediments periodically cleaned out of surge tanks, spent ion exchange resin, and contaminated worn equipment.

[b]Most equipment will be decontaminated and recycled.

All radioactive wastes will be disposed of offsite at licensed disposal facilities. The applicant will provide surety that funds will be available for final waste disposal.

4.6.4 Lack of resource development

If uranium is not extracted from this site, other sources must eventually be explored; expansion of U_3O_8 production is necessary to meet projected needs (Sect. 2.2.1).

4.6.5 Possible conflicts between the proposed action and the objectives of federal, state, regional, and local plans and policies

There is no apparent conflict as long as monitoring and mitigation measures are specified to protect the environment and public health and safety. National policy is to replace oil by increasing the use of energy from uranium and coal. The state of Wyoming encourages uranium production under proper environmental safeguards. Because the local region is heavily dependent on uranium extraction to support the local economy, the region has planned for expansion.

4.6.6 Effects on urban quality, historical and cultural resources, and society

The size of the project in terms of the number of workers is too small to cause any appreciable impacts on urban quality or any type of societal services. No indirect effects on offiste historical and cultural resources are expected. Direct effects on onsite resources are addressed in Sect. 4.5.2.

4.7 ENERGY REQUIREMENT AND CONSERVATION POTENTIAL

The project is estimated to use less than 1% of the potential electrical energy available from the U_3O_8 produced. No direct or indirect conservation potential exists for the project except that the proposed mining method requires less energy per pound of U_3O_8 produced than do other mining methods.

4.8 UNAVOIDABLE ADVERSE ENVIRONMENTAL IMPACTS

4.8.1 Air quality

The impacts on air quality addressed in Sect. 4.5.1 are unavoidable because all are associated with necessary project activities for which there are no practicable alternatives. These impacts involve emissions from gasoline- and diesel-fired equipment and vehicles, dust from vehicular traffic and wind erosion, and small amounts of chemical emissions from the processing plant and the evaporation ponds. All of these unavoidable impacts are considered minimal (Sect. 4.5.1); therefore, there will be no significant impacts on land use, biota, or inanimate objects.

4.8.2 Land use

No offsite impacts are expected. On the 308-ha site, various land uses that are adverse to soils and biota are necessary and unavoidable. However, the magnitude of these effects will be held to minimum practicable levels. Also, after the completion of project operations, the applicant will attempt to restore the land to its preproject productivity. Thus, the impacts on productivity of the land should be temporary and should not prevent return to preproject land uses.

4.8.3 Water

4.8.3.1 Surface water

Construction activities at the site may contribute a small amount of sediment to local waterways, all of which are ephemeral. Any effect on water quality during the infrequent periods of runoff is expected to be temporary.

4.8.3.2 Groundwater

Approximately 7.96×10^5 m^3 (645 acre-ft) of groundwater will be permanently removed from the aquifer, mostly during restoration activities. Some short-term project-induced degradation of groundwater quality may occur. Restoration tests indicate, however, that the water can be restored to a quality equal to or better than baseline.

4.8.4 Soils

Unavoidable adverse impacts on soils will involve topsoil removal and stockpiling and soil compaction by vehicular traffic. Soils will be removed from about 14 ha (35 acres) and stored. Soils on a small fraction of a 36-ha (89-acre) area will be compacted by vehicular traffic and activities at well fields, trunk lines, and storage areas. Reclamation plans involve attempting to return and restore soils on all disturbed lands to preproject conditions. Overall impacts on soils should be minimal and temporary.

4.8.5 Ecological

4.8.5.1 Terrestrial

Plant and animal habitats within a 49-ha (120-acre) area will be unavoidably impacted during the life of the project (Sect. 4.5.6.1). Habitats on about 14 ha (35 acres) from which topsoils will be removed and stored will be completely destroyed, primarily for evaporation ponds. A small fraction of the remaining 34 ha (85 acres) will also be impacted, although topsoils will be left in place. Thus, there will be a small but unavoidable reduction in plant and animal populations in the region including the site. No rare or endangered species will be jeopardized. Reclamation on the site is expected to restore the site to good wildlife habitat.

4.8.5.2 Aquatic

Sedimentation, resulting from construction activities, may have minor and temporary impacts on aquatic systems downstream on those rare occasions when local channels carry water.

4.8.6 Radiological

Except for radon-222, only small radioactive emissions will result from solution mining. The local environment will continue to be shielded by earth materials overlying the radioactive ore deposits. However, some small increase in the level of radioactivity is expected from emissions from the recovery plant and well-field facilities.

4.8.7 Socioeconomic

No unavoidable adverse socioeconomic impacts on the local community are expected.

4.9 RELATIONSHIP BETWEEN SHORT-TERM USES OF THE ENVIRONMENT AND LONG-TERM PRODUCTIVITY

4.9.1 The environment

4.9.1.1 Surface elements

The short-term increases in suspended particulates and chemical emissions associated with project activities are expected to have no effect upon the long-term quality of the atmosphere in the project area.

Project operations will cause a short-term reduction in carrying capacity of the local grazing resource and some reduction in hunting opportunities.

Well field development facilities will result in a loss of not over 49 ha (120 acres) of vegetative cover during the limited operation proposed by the applicant.

Waste ponds, pipelines, access roads, and plant buildings will occupy only 4% [13.3 ha (33 acres)] of the site.

Proposed monitoring and mitigating measures will ensure that only minimal short-term effects from project operations will occur.

After reclamation, there should be no long-term effects on surface productivity.

4.9.1.2 Underground effects

The extraction of uranium (short-term usage) will not preclude extracting other minerals of current or future economic importance at a later date.

The short-term extraction of groundwater at up to 7.95×10^5 m^3 (645 acre-ft) during the limited operation, mostly during well field restoration, should not adversely affect later use of the aquifer.

Restoration of the mined aquifer region to the available level of use prior to mining has been demonstrated. The staff expects similar results on a commercial scale, and sequential restoration of mining units will be required. If unsuccessful on a larger scale, the mined aquifer region (mining zone) would be unavailable for irrigation or stock water wells. This zone is currently contaminated because of natural radioactivity. With the addition of contaminants from solution mining, however, this contamination would represent a long-term impact for about 12 ha (30 acres) of aquifer area. All existing stock wells are in the aquifer above the mined aquifer region.

4.9.2 Society

Because the project will not be a large factor in the local economy, no significant short-term or long-term impacts on the local communities can be expected from this project.

4.10 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

4.10.1 Land and mineral resources

After reclamation, no land resources are considered lost.

The uranium produced is irreversibly and irretrievably lost when used to produce power from a nuclear reactor.

4.10.2 Water and air resources

Water used in the project, primarily during aquifer restoration, is recycled to the atmosphere for distribution elsewhere. The aquifer will eventually become recharged from natural sources. The air is self-cleaning of pollutants at the low concentrations expected. The displacement of these resources is small in comparison with the benefits derived from the mined uranium.

4.10.3 Vegetation and wildlife

These resources are renewable; while some irreversible and irretrievable commitment is required, the commitment is relatively minor. Reclamation will require a commitment of human and financial resources.

4.10.4 Material resources

Irreversible and irretrievable commitments of construction materials will be made for well completions, plant buildings, and other activities.

Chemicals and reagents used during solution mining will also not be recoverable for reuse. The fuels used for vehicles, heating, and plant processing will also be irretrievably committed.

These materials are not in short supply and are common to many industrial processes.

4.11 NRC BENEFIT-COST SUMMARY

4.11.1 General

The general need for uranium is for replenishment of that consumed in the operation of nuclear power reactors. In reactor-licensing evaluations the benefits of the energy produced are weighed against related environmental costs, including a prorated share of the environmental costs of the uranium fuel cycle. These incremental impacts in the fuel cycle are justified in terms of the benefits of energy generation. However, it is appropriate to review the specific site-related benefits and costs of an individual fuel-cycle facility such as the Teton project.

4.11.2 Quantifiable economic impacts

Monetary benefits accrue to the community from the presence of the project, such as local expenditures of operating funds and the state and local taxes paid by the project. Against these monetary benefits are monetary costs to the communities involved, such as those for new or expanded schools and other community services. It is not possible to arrive at an exact numerical balance between these benefits and costs for any one community unit, or for the project, because of the ability of the community and possibly the project to alter the benefits and costs. For example, the community can use various taxing powers to redress any perceived imbalance in favor of the project. The project, on the other hand, may create larger revenues through increased product price to redress any imbalance it suffers through direct or indirect taxation.

4.11.3 The benefit-cost summary

The benefit-cost summary for a fuel-cycle facility such as the Teton project involves comparing the societal benefit of an ensured U_3O_8 supply (ultimately providing energy) against local environmental costs for which there is no directly related compensation. For the project, there are basically three of these uncompensated environmental costs: groundwater impact, radiological impact, and disturbance of the land. The radiological impacts of the project are small, and eventually radioactive wastes will be disposed of offsite (Sect. 4.5.7). The disturbance of the land is also a small environmental impact. All of the disturbed land will be reclaimed after the project is decommissioned and will become available for previous uses. Complete restoration of an aquifer contaminated by a commercial-scale project has not yet been demonstrated, although the staff considers that, in view of the applicant's pilot-scale demonstration, restoration to baseline is feasible. The benefit of the production up to 1.04×10^5 kg (2.3×10^5 lb) of U_3O_8 is considered to offset the risk that the groundwater quality underlying a portion of the 32-ha (80-acre) mining zone will not be completely restorable.

4.11.4 Staff assessment

The staff concludes that the adverse environmental impacts and costs are such that the use of the mitigating measures suggested by the applicant and the regulatory agencies involved would reduce the short- and long-term adverse impacts associated with the project to acceptable levels.

In considering the energy value of the U_3O_8 produced, minimal radiological impacts, minimal disturbance of land, and mitigable nature of the societal impacts, the staff has concluded that the overall benefit-cost balance for the Teton project is favorable, that control of the well fields to minimize groundwater contamination is possible, and that the indicated action is that of granting a license for this solution-mining project with at least the conditions specified in the Summary and Conclusions.

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21. *Eniwetok Radiological Survey,* USAEC Report NVO-140, Nevada Operations Office, Las Vegas, Nevada, 1973.

22. N. A. Frigerio, K. F. Eckerman, and R. S. Stowe, "Background Radiation as a Carcinogenic Hazard," *Rad. Res.* 63: 599 (1975).

23. A. H. Sparrow et al., "Chromosomes and Cellular Radiosensitivity," *Rad. Res.* 32: 915 (1967).

24. *Radioactivity in the Marine Environment,* Report of the Committee on Oceanography, National Academy of Science-National Research Council, Washington, D.C., 1971.

25. R. J. Garner, "Transfer of Radioactive Materials from the Terrestrial Environment to Animals and Man," *Environ. Control* 2: 337-85 (1971).

26. S. E. Thompson, *Concentration Factors of Chemical Elements in Edible Aquatic Organisms,* USAEC Report UCRL-50564, Rev. 1, October 1972.

27. H. C. S. Thom, "Tornado Probabilities," *Mon. Weather Rev.* 91: 730-737 (October-December 1963).

28. E. H. Markee, Jr., and J. G. Beckerley, *Technical Basis for Interim Regional Tornado Criteria,* U.S. Atomic Energy Commission Report WASH-1300, May 1970.

29. F. C. Kornegay, Ed., *Condensed Proceedings of the Symposium of the Dispersion of Particulate Matter by Natural Vortices,* Argonne National Laboratory, Argonne, Ill., August 1976.

30. Directorate of Regulatory Standards, U.S. Atomic Energy Commission, *Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Plants,* Report WASH-1238, December 1972.

31. Battelle Northwest Laboratories, *An Assessment of the Risk of Transporting Plutonium Oxide and Liquid Plutonium Nitrate by Truck,* Report BNWL-1846, Richland, Wash., August 1975.

32. U.S. Nuclear Regulatory Commission, *Final Environmental Statement on Transportation of Radioactive Materials by Air and Other Modes,* Report NUREG-0170, Washington, D.C., December 1977.

33. U.S. Bureau of the Census, *Statistical Abstract of the United States: 1976,* 97th ed., Washington, D.C., 1976.

5. PROFESSIONAL QUALIFICATIONS OF THE TETON-NEDCO PROJECT FES TASK GROUP

The following individuals were responsible for independent analysis of information provided by the applicant in the ER and in responses to questions subsequently submitted requesting new information or clarification of material in the original ER. This interdisciplinary group obtained information from federal, state, and local sources to supplement material provided by the applicant and also participated in the scoping process. There are no known relationships between the individuals or the organization that prepared this statement with industries regulated by the NRC and suppliers thereof that might give rise to an apparent or actual conflict of interest regarding the work described in this proposal.

A review of pertinent literature sources was also done to ensure that potential environmental consequences would be fully assessed and that the final recommendations made by the staff would be in conformance with the state of the art and with the interest of the National Environmental Policy Act.

The qualifications of each individual are listed so that primary responsibility for information in particular sections is apparent. Because much of the Environmental Statement represents joint efforts by the staff, it is impractical to provide a separate listing of contributors to many subsections.

Roger L. Kroodsma
Environmental Sciences Division
Oak Ridge National Laboratory

Roger Kroodsma, a terrestrial ecologist, specializes in wildlife ecology and avian community ecology. While at ORNL, he has conducted research on the edge effect and avian community ecology of power-line corridors. He has written 18 scientific publications. Major issues he has addressed in environmental impact statements include power-line impacts on waterfowl, eagles, and natural areas; relationships of wildlife to agricultural and industrial land use; cooling tower impacts on vegetation; erosion control plans; and air pollution effects on biota. He has served as a task group leader for several impact statements and has participated in the preparation of more than 20 environmental assessment documents. He has appeared as an expert witness at several Atomic Safety and Licensing Board hearings.

Education:

- Received a B.A. degree in biology from Hope College, Holland, Michigan, in 1966.

- Received an M.S. degree in zoology from North Dakota State University in 1968.
- Received a Ph.D. degree in zoology from North Dakota State University in 1970.

Affiliations:

- Holds membership in the Wildlife Society, the American Ornithologists' Union, and the Ecological Society of America.

Samuel C. Martin
Science Applications, Inc.*
Oak Ridge, Tennessee

Samuel Martin is an economist specializing in econometrics, environmental impact assessment, program planning, and power system voltage and loading distribution problems. He has been responsible for the preparation of alternative sections for six uranium milling and mining environmental impact statements. In addition, Martin was responsible for updating the socioeconomic sections of the Programmatic Environmental Impact Statement for the Department of Energy's Strategic Petroleum Reserve Program. His duties have also involved the preparation of guidelines to determine unit operations for the High-Temperature Gas-Cooled Reactor Recycle Facility at Oak Ridge National Laboratory.

Education:

- Received a B.S. degree in electrical engineering from Clemson University in 1967.
- Received an M.S. degree in industrial management from Clemson University in 1968.
- Received an M.A. degree in economics from the University of Tennessee in 1977.
- Is working toward a Ph.D. degree in economics from the University of Tennessee.

Affiliations:

- Holds membership in the Southern Economic Association, Mid-Continent Regional Science Association, South Carolina Academy of Sciences, and Phi Kappa Phi.
- Is a registered engineer-in-training in South Carolina.

---

*Current address: Middle South Utilities, New Orleans, La.

Richard B. McLean
Energy Division
Oak Ridge National Laboratory

Richard McLean is a research staff member in the Energy Division. His technical training is in marine biology with an emphasis in the behavioral components of a marine benthic faunal community. He has authored or coauthored 26 scientific papers dealing mainly with community interaction of selected marine biota and freshwater fish. Previous technical experience includes research at Florida State University and Lerner Marine Laboratory, Bimini, Bahamas, investigating movements, migrations, and orientation of spiny lobsters.

He has participated in ecological surveys of shorelines and reefs at several sites in Florida and the Bahamas. Most recently his research effort has been directed at fish predator-prey dynamics in southeastern reservoirs. Other responsibilities have included being leader of the Environmental Analysis and Assessments Project and being the lead ecologist evaluating environmental impacts on a number of proposed nuclear power plants. He has also testified as an expert witness at a number of Atomic Safety and Licensing Board hearings.

Education:

- Received a B.A. degree in biology from Florida State University in 1968.
- Received a Ph.D. degree in marine biology from Florida State University in 1975.

Affiliations:

- Holds membership in the American Institute of Biological Sciences, the American Society of Zoologists, the Animal Behavior Society, and the Society of the Sigma Xi.

Susan E. Pantell
Division of Waste Management
U.S. Nuclear Regulatory Commission

Susan Pantell is a project manager for the Uranium Recovery Licensing Branch of the Division of Waste Management. Her technical training is in mathematics, and she is involved in performing analyses of the radiological impacts from the airborne effluents from uranium milling facilities. She also provides support to other project managers on the staff for licensing actions related to various uranium recovery operations.

Education:

- Received a B.A. degree in mathematics from Brown University in 1981.

C. Donald Powers
Environmental Sciences Division
Oak Ridge National Laboratory

Don Powers, of the Aquatic Ecology Section and the Environmental Impacts Program, has contributed to assessments of uranium mine and milling projects and of geothermal steam field development. Prior to joining ORNL in 1979, he supervised the microbiology laboratory in the Marine Sciences Research Center at the State University of New York at Stony Brook. His main research efforts were directed at describing the effects of certain waterborne pollutants on estuarine microbial communities. Working primarily with chlorinated hydrocarbons, he has most recently concentrated on the influence of polychlorinated biphenyls on plankton primary productivity and community structure.

Education:

- Received a B.S. degree in microbiology from Michigan State University in 1961.
- Received an M.S. degree in microbiology from Michigan State University in 1965.
- Received a Ph.D. degree in epidemiologic science from the University of Michigan in 1969.

Affiliations:

- Holds membership in the American Society of Microbiology, the Ecological Society of America, the Linnaean Society of New York, the Society of Environmental Toxicology and Chemistry, and Sigma Xi.

Frederick W. Ross
Uranium Recovery Field Office
U.S. Nuclear Regulatory Commission

Frederick W. Ross is a project manager for the Licensing Branch I of the Uranium Recovery Field Office. His technical background is in geology and hydrogeology. As a project manager, Ross oversees the licensing of new uranium in situ extraction facilities as well as initiating licensing actions at operating in situ solution mines. In addition, he provides other project managers with technical assistance in the area of groundwater geology. His experience with industry includes

duties as a prospecting geologist at a Florida phosphate mine operated by the Occidental Chemical Company and as a hydrogeologist with the State of Florida, where he performed studies related to the hydrologic impacts of intensive agricultural groundwater use. While with the NRC, Ross has arranged for the licensing renewal of an existing in situ extraction facility and has reviewed hydrogeologic conditions and proposed licensing actions at several other uranium solution mines.

Education:

- Received a B.A. degree in geology from the University of South Florida in 1972.

- Received an M.A. degree in geology from the University of South Florida in 1975.

In addition, the Final Environmental Statement was reviewed by cognizant members of the Nuclear Regulatory Commission staff and the NRC legal staff for conformance with NRC policy and regulatory guides.

The NRC Environmental Project Manager who has primary responsibility for all aspects of the proposed project is

Frederick W. Ross
Uranium Recovery Field Office
P.O. Box 25325
Denver, Colorado 80225

6. LIST OF AGENCIES RECEIVING FINAL ENVIRONMENTAL STATEMENT

The following federal, state, and local agencies have been sent copies of the Final Environmental Statement:

Department of Agriculture
Department of the Army
Department of Health and Human Services
Department of Housing and Urban Development
Environmental Protection Agency
Department of the Interior
The Geological Survey of Wyoming
Wyoming Commissioner of Public Lands and Farm Loans
Wyoming Department of Environmental Quality
Wyoming Executive Department
Wyoming Game and Fish Department
Wyoming Recreation Commission
Wyoming State Engineers Office
Powder River Basin Resource Council

Appendices

Appendix A

COMMENTS ON THE DRAFT ENVIRONMENTAL STATEMENT AND NRC RESPONSES

In this appendix, the letters of comment on the Draft Environmental Statement pertaining to the Teton project are reproduced in full. The staff responses are printed conveniently close to each comment. Specific comments and responses are keyed by numbers in the margins of the letters and at the beginnings of the corresponding responses. In addition, changes in the text have been made where needed.

Letters of comment were received from the following groups and/or individuals and are reproduced on the page indicated.

U.S. Department of Agriculture, Economic Research Service A-3
U.S. Department of Agriculture, Forest Service A-4
U.S. Department of Agriculture, Soil Conservation Service A-5
Department of the Army A-6
Department of Health and Human Services A-9
U.S. Department of Housing and Urban Development A-11
U.S. Environmental Protection Agency A-12
U.S. Department of the Interior A-17
The Geological Survey of Wyoming A-19
Wyoming Commissioner of Public Lands and Farm Loans A-21
Wyoming Department of Environmental Quality,
Water Quality Division A-22
Wyoming Executive Department A-23
Wyoming Game and Fish Department A-24
Wyoming Recreation Commission, State Historic
Preservation Office A-26
Wyoming Recreation Commission, State Parks Division A-27
Wyoming state Engineer's Office A-28
Wyoming State Highway Department A-29
Wyoming State Historic Preservation Office . . . .
The Pennsylvania State University A-31
Powder River Basin Resource Council A-33

United States Department of Agriculture

Economic Research Service

Washington, D.C. 20250

July 15, 1982

Mr. Ross A. Scarano, Chief
Uranium Recovery Licensing Branch
Division of Waste Management
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Scarano:

Thank you for forwarding the information relating to the issuance of a source and byproduct material license for Teton Exploration Drilling, Inc., located in Converse County, Wyoming.

We have reviewed Docket No. 40-8781 and have no comments.

Sincerely,

Velmar W. Davis

VELMAR W. DAVIS
Associate Director
Natural Resource
Economics Division

No response required.

United States Department of Agriculture
Forest Service
Rocky Mountain Region
11177 West 8th Avenue
P.O. Box 25127
Lakewood, CO 80225

1950
(WS&MAM)
July 19, 1982

Ross A. Scarano, Chief
Uranium Recovery Licensing Branch
Division of Waste Management
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Ross:

We appreciate your sending us the Draft Environmental Statement on Teton Exploration Drilling, Inc.-Teton Project.

Since the project is not on and does not affect National Forest System lands, we have no substantive comments to make. However, much of the data you folks present in the draft statement is extremely useful to us, for a variety of reasons. We appreciate it.

No response required.

Best personal regards,

THOMAS E. SCHESSLER, Director
Watershed, Soils, and Minerals Area Management

FS-6200-11(8-80)

United States Department of Agriculture
Soil Conservation Service
P.O. Box 2440
Casper, Wyoming
82602

July 26, 1982

Ross A. Scarano, Chief
Uranium Recovery Licensing Branch
Division of Waste Management
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Scarano:

SUBJECT: Draft EIS Related to the Operation of the Teton Project, Converse County, Wyoming

We have reviewed the subject document and have no comments.

No response required.

Sincerely,

Frank S. Dickson
State Conservationist

cc: Peter C. Myers, Chief, SCS, Washington, D.C.

The Soil Conservation Service is an agency of the Department of Agriculture

DEPARTMENT OF THE ARMY
OMAHA DISTRICT CORPS OF ENGINEERS
6014 U S POST OFFICE AND COURTHOUSE
OMAHA NEBRASKA 68102

REPLY TO
ATTENTION OF
MROPD-M

18 August 1982

Mr. Ross A. Scarano
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Scarano:

We have reviewed the Draft Environmental Statement related to the operation of the Teton Project, Docket No. 40-8781, in Converse County, Wyoming.

The Final Environmental Statement should include a discussion of a possible need for a Department of the Army permit(s) pursuant to Section 404 of the Clean Water Act. Discussion of such permit requirements is included in the inclosed comments.

Our inclosed comments also raise questions regarding cultural resources. Our review of the project raises no flood plain management concerns at this time.

We look forward to receiving the final report as it is available. Thank you for this review opportunity.

Sincerely,

RICHARD D. GORTON, Chief
Environmental Analysis Branch
Planning Division

1 Incl
As stated

CORPS COMMENTS ON THE TETON PROJECT,
U.S. NUCLEAR REGULATORY COMMISSION

Permits

(1) Section 404 regulates the discharge of dredged or fill material in our Nation's waterways, lakes, and wetlands. Such activities must be authorized under the nationwide permit or permitted by an individual Department of the Army permit.

The document indicates (item 2.3.1 - page 2-15) the proposed activity involves a contiguous tract of land within Township 34 North, Range 74 West of the Six Principle Meridian, Converse County, WY. Surface waters (item 3.6.1 - page 3-25) draining the mine site (elevation 1575m (5200 ft) flow by means of Little Sand Creek and its unnamed tributary to Sand Creek, thence to the North Platte, entering about 8.3 km (5 miles) east of Glenrock, WY city limits (elevation 1524 m (5000 ft). Sand Creek at the project site has an average annual flow of 5 cubic feet per second (c.f.s.) or greater.

Individual or Nationwide permits will be required for filling activities on waterways where the average annual flow is <u>greater</u> than 5 cubic feet per second (c.f.s.) Filling activities on waterways having an average annual flow of <u>less</u> than 5 cubic feet per second (c.f.s.) will generally be considered under the Nationwide concept.

Although no wetland areas are mentioned in the document, it should be noted that individual or Nationwide permits would be required for filling activities associated with wetlands. These actions would be evaluated on a case by case basis.

Cultural Resources

(2a-d) A copy of the Environmental Report should have accompanied the DES in order to demonstrate the adequacy of the cultural resource inventory. A copy of the ER requested from the NRC in Washington was not received by the time the DES review was completed. The DES indicates that coordination was implemented between the NRC and the Wyoming State Historic Preservation Office. Several questions were raised (Section 3.5.2) which cannot be answered from the information supplied in the DES.

a. Was the rationale for determining potential significance of the four archeological sites based solely on their subsurface contents?

b. Is the above also the reason used for excluding the four surface sites?

1. <u>Permits</u>: While USGS records (Water Resources Data for Wyoming, vol. 1, Missouri River Basin) indicate that Sand Creek transports no water most of the year, it is agreed that the average annual flow near the site exceeds 5 ft^3/s (as opposed to the flow of Little Sand Creek). Therefore, Corps Individual or Nationwide Permits are required if dredged or fill material is to be discharged into waterways, lakes, or wetlands. Neither dredging nor filling of Leuenberger waterways are contemplated, however, and no wetlands exist within many miles of the site.

2a-d. Four archaeological sites were considered as potentially significant by Wyoming because they might have subsurface deposits. The Office of the Wyoming State Archaeologist (OWSA) stated that these sites would require further work to determine their actual significance if they might be disturbed by the proposed project (ER, Appendix D). Four other sites were determined by the OWSA to be surface sites with no subsurface deposits. The OWSA examined these surface sites and determined that the sites were not highly significant and that no further work was necessary at these sites (ER, Appendix D). The three isolated artifacts that were found were apparently of no significance in affecting the status of the archaeological sites. The applicant will contact the OWSA to further study the four potential subsurface sites if project design changes are made that would affect these sites (Sect. 4.5.2). Section 4.6.6 has been modified to make it consistent with Sect. 4.5.2.

c. Are there any discernable relationships between the eight sites and the three isolated finds to change their status?

d. Section 4.6.6 states, "No areas of historical archeological interest were identified at the site; thus no impacts in the areas are expected." Why does this statement run counter to the results of the cultural resource inventory in Section 3.5.2, Historical archaeological, and scenic values?

2a-d. contd The applicant shall not conduct surface disturbing activities in or around the four sites discussed in Sect. 4.5.2 having potential for subsurface archaeological deposits. Before any future disturbing activities in these site areas, the sites must be evaluated for National Register of Historic Places eligibility.

If any archaeological materials are discovered during construction, work in the area must halt immediately and the SHPO office contacted. Work in the area must not resume until the archaeological materials have been evaluated and adequate measures for their protection taken.

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

Food and Drug Administration
Rockville MD 20857

AUG 2 0 1982

Mr. Ross A. Scarano
Uranium Recovery Licensing
Division of Waste Management
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Scarano:

The Bureau of Radiological Health staff have reviewed the Draft Environmental Statement (DES) related to the operation of the Teton Project, NUREG-0925, dated June 1982, Docket No. 40-8781, and have the following comments to offer:

1. The solution mining operation and waste management systems proposed by Teton Exploration Drilling in their application for a Source and Byproduct Material License provides adequate assurance that the radon-222 in the gaseous effluents will be controlled to levels as low as reasonably achievable (ALARA). It appears that the calculated doses to individuals and the population resulting from radioactive releases from the Teton project are within current radiation protection standards. It is recognized that there will be (1) routine particulate emissions, and (2) surface discharge of radioactive fluids from the facility.

2. The only environmental pathway identified in Section 4.5.7.2 is the radon-222 releases to the atmosphere. Other pathways are not addressed in this DES since there are no planned emissions that would impact on such pathways. The dose calculation methods, models and assumptions (Appendix C and D) used in the estimation of radiation doses to individuals and to populations within 80 km. of the plant have provided the means to make reasonable estimates of the doses resulting from normal operations at the facility. Results of these calculations are shown in Tables 4.11, 4.12, 4.13 and 4.14. These results confirm that the calculated doses meet the 10 CFR 20 regulatory limits. However, in examining Table 4.12, we find that superscript a states that a discussion of the method for calculating the annual 100-year dose commitment is included in Appendix D, Section D.3. Appendix D in this copy of the DES contains only Tables D.1 and D.2. We would appreciate receiving the Sections that appear to be missing from Appendix D.

3. The discussion in Section 4.6.2 on the potential effects of accidents considered to be an adequate assessment of the environment and health impact from tornadoes or transportation accidents. However, the surface-pipe failures discussion could assess the health impact of thorium-230, radium-226 and uranium-238 reaching Little Sand Creek from an accidental release of 340,000 liters (90,000 gal.) of either pregnant solution or lixiviant between the processing plant and the well field. In addition to the requirement for reporting and cleaning up accidental releases, the NRC should require the applicant to prepare an emergency plan that would address measures for mitigating the consequences of such accidents. It should also include provisions for coordinating the emergency response with the State of Wyoming.

(Typo corrected by the NRC staff after contacting the Department of Health and Human Services.)

1. No response required.

2. Only exposure pathways resulting from gaseous radon-222 releases to the atmosphere are considered in this analysis. There will be no surface discharge of radioactive fluids, and radioactive materials liberated underground during the leaching process will be confined.

The footnote *a* to table 4.12 is incorrect. A discussion of the methodology may be found in Appendix G-6 of NUREG-0706* and Regulatory Guide 3.5.1.*

3. See response to State of Wyoming Game and Fish Department, Comments 1 and 2. An evaluation of potential accidents indicates that there would not be any on the scale that would warrant specially prepared emergency planning. Any necessary clean up would be coordinated with the State of Wyoming.

*U.S. Nuclear Regulatory Commission, *Generic Environmental Impact Statement on Uranium Milling (draft)*, Appendix G.6, NUREG-0706, Vol. III, Sept. 1981; and U.S. Regulatory Commission, *Calculational Models for Estimating Radiation Dose to Man from Airborne Radioactive Materials Resulting from Uranium Milling Operations*, Regulatory Guide 3.5.1 (March 1982).

(4.) The monitoring programs and mitigating measures, as presented in Section 4.4, appear to provide adequate air, water and soil samples at critical locations to measure the potential emissions from the facility. The radiological survey (Section 4.4.1.4) has provided baseline data, but does not indicate if a plan exists, for the operational phase, to conduct periodic resurveys to determine if there is any environmental impact as a result of facility operations.

(5) The operational radiological environmental program (Section 4.4.2.4) has not been defined except for airborne effluent monitoring. It would be helpful if this section could be expanded to identify the specific monitoring programs that may be modified as the radiological data obtained during mining are reviewed by the NRC.

We note that licensing conditions in 5 a. and 5 m. (Summary and Conclusions) require the applicant to take additional measures to implement the monitoring program described in Section 4.4. We agree with this requirement since it supports our comments made above.

Thank you for the opportunity to review and comment on this Draft Environmental Statement.

Sincerely yours,

John C. Villforth
Director
Bureau of Radiological Health

4. The operational environmental radiological monitoring program is presented in Table 4.7. No impact is expected outside the site boundary, and at the time of decommissioning a resurvey will be conducted onsite. As stated in Sect. 4.4.2.4, the operational monitoring program may be modified as the radiological data obtained during the mining operation are reviewed.

5. Radon gas is the only expected effluent. Should the air particulate samplers indicate any potential buildup of radioactive materials additional environmental samples, such as in soils and on vegetation, will be collected. Of course, as pointed out in Sect. 4.4.2.5, water quality data from routine monitoring wells will also be submitted to the NRC for review.

U.S. Department of Housing and Urban Development
Denver Regional/Area Office, Region VIII
Executive Tower Building
1405 Curtis Street
Denver, Colorado 80202

August 2, 1982

Mr. Ross A. Scarano
Chief
Uranium Recovery Licensing Branch
Division of Waste Management
Washington, D.C. 20555

Dear Mr. Scarano:

Thank you for the opportunity to review and comment on the Draft Environmental Impact Statement (DEIS), on Teton Exploration Drilling, Inc. - Teton Project, Converse County, Wyoming.

Your DEIS has been reviewed with specific consideration for the areas of responsibility assigned to the Department of Housing and Urban Development (HUD). The review considered the proposal's compatibility with local and regional comprehensive planning and impacts on urbanized areas. Within these parameters we find this document adequate for our purposes.

No response required.

If you have any questions regarding these comments, please contact Mr. Carroll F. Goodwin, Area Environmental Officer at FTS 327-3102.

Sincerely,

Robert J. Matuschek
Director
Office of Regional Community
Planning and Development, 8C

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VIII
1860 LINCOLN STREET
DENVER, COLORADO 80295-0699

AUG 30 1982

Ref: 8AW-RC

Mr. Ross A. Scarano, Chief
Uranium Recovery Licensing Branch
Division of Waste Management
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Scarano:

In fulfillment of our responsibilities under Section 309 of the Clean Air Act, the Environmental Protection Agency has reviewed the Draft Environmental Statement (DES) related to the operation of the Teton Project (NUREG 0925). Our detailed comments are attached.

Some of our concerns, about the project, as expressed in a letter to you of September 14, 1981, have been resolved. Our review of the DES disclosed a variety of apparent discrepancies and omissions with respect to information on water balance, well construction and monitoring data and plans. We have been assured by your staff that aquifer restoration will be addressed for both ore zones in the Final Environmental Statement.

In accordance with the procedures EPA has adopted to rate environmental statements NUREG-0925 has been rated ER-2. This means that EPA has reservations concerning the environmental effects of certain aspects of the proposed action and needs additional data as indicated by the enclosed comments.

Should you have any questions concerning these comments, please feel free to contact Mr. John Giedt at FTS 327-6008.

Sincerely yours,

Steven J. Durham
Regional Administrator

Attachment

USEPA Specific Comments on the Draft Environmental Statement (DES) for the Teton Project (NUREG 0925)

1. Page 1-5. The validity of the data used to support the need for this project is questionable. The DOE report which asserts that 39 percent of new generating plants between 1970 and 1988 will be nuclear was published in 1970. These data are obsolete. The cancellation of orders and the slowdown in completion of plants under construction has exacerbated the current uranium market glut. The price of uranium is less than half of what it was a couple years ago. As a result, several uranium mines and mills, many in Wyoming, have been forced to close. The availability of less expensive Canadian and Australian yellowcake suggests the U.S. producers will not soon see their market return, unless tariffs or import quotas are imposed. The NRC staff concluded in the DES, "It is evident that there is and will be <u>more</u> production capability for U_3O_8 than will be needed during the 1980 decade (item 2, page 1-5, emphasis added). Furthermore, various uncertainties in projecting uranium needs "preclude rational forcasts past 1988" (DES, top paragraph, page 1-5). Hence, available information indicates that for the foreseeable future, no uranium, beyond what is already stored or what can be produced by a fraction of existing facilities, will be needed.

The information in the DES does not support the conclusion that there is a need for this project. Does NRC have further information which does confirm a need for this uranium?

2. Page 2-30. There may need to be clarification concerning the amount of water pumped to the evaporation pond during the restoration process. On page 2-30, bottom paragraph, the projected amount is 645 acre-feet which is over 90 percent of the total effected volume of 700 acre-feet reported on page 2-30. On page 2-50, the third paragraph states that 20 percent will be sent to the brine pond for evaporation.

3. Page 2-36. Does the discussion of injection pressure and hydraulic fractures in the first paragraph refer to the injection zone or confining zone? What site-specific evidence is there to suggest that an injection pressure of 100 psi will not fracture the confining zones? The operator may have to produce such evidence to obtain a VIC permit.

4. Page 2-41. This page displays a schematic of an injection and recovery well but the document does not display a schematic of an observation well. As the groundwater monitoring program is critical to the project would not a schematic of an observation well be appropriate?

5. Page 2-41. What is the purpose of the weep hole on Figure 2-5? Is it located in the tubing or casing? If located in the tubing then the injection pressure will be transmitted to the monitoring annulus and any annulus pressure will only be monitoring injection pressure. If the weep hole is in the casing and the packer fails the lixiviant will migrate through the weep hole into zones above the ore zone.

1. The 1979 DOE projections have been updated to 1981 and are included in the text. It is not the purpose of NEPA to justify or establish an economic need for a project. NEPA requires that the statement shall briefly specify the underlying purpose and need to which the agency is responding in evaluating the alternatives, including the proposed action. The need to which the NRC is responding is the licensing of a uranium solution mine. If licensed, the economics will play a major role in determining if the mine will be built or operated.

2. The two volumes (645 acre-ft of wastewater discharged to the ponds and the 700 acre-ft of affected aquifer) are unrelated. The 645 acre-ft of liquid that is estimated will be discharged to the evaporation ponds during mining and restoration represents the 20% of the treated water containing the concentrated brines from electrodialysis. The total effected volume (700 acre-ft) represents the total volume of pore space contained with the portion of the aquifer being mined and is equal to the amount of groundwater in the wellfield.

3. The discussion of injection pressures refers to the injection zone. Conditions in the Summary and Conclusions section require limiting the injection pressure to 0.63 psi per foot of well depth. The staff has calculated that this pressure will not cause fracturing of the confining zones and the R&D data at the Luenberger site support this conclusion. The measured permeabilities, planned well spacings, and planned flow rates are consistent with this restriction.

In addition, the applicant has stated that injection pressures will be no greater than 100 psi at the well-head in any event. The staff will also require that injection pressures not exceed the pressure to which new wells are packer-tested, which will be much lower than the injection pressure limit based on the potential for formation fracture. All requirements for a UIC permit will be met by the applicant.

4. The construction of an observation well will be similar to an injection or recovery well except that an observation well will be screened through the thickness of the aquifer being monitored. Casing above the screens will be grouted and sealed so that only water from the monitored interval will be sampled.

5. The weep hole shown in Fig. 2.5 is one method of directing the cement from the well casing out into the annular space between the casing and the bore hole wall during well completion. If weep holes were used for cementing injection and recovery wells, they would be located at the bottom of the casing that projects down into the production zone sands. Therefore, the introduction of lixiviant through a weep hole would not contaminate additional geologic strata. Well installation for production wells at the Leuenberger site will not employ the use of weep holes as originally stated.

6.) Page 2-47. Figures 2.7 displays a flow sheet in which the recovery wells take in 7.5 gpm more than the injection wells, thus 7.5 gpm builds up in the system. However, only 5.84 gpm are shown going to the evaporation ponds. How is the missing 1.66 gpm, 2390 gallons per day, accounted for?

7.) Page 2-53. Figure 2.8 suggests the evaporation ponds will evaporate 26 gpm, yet we could find no evidence in the document supporting this rate. How large are the evaporation ponds? Does the pond design consider the low evaporation rate during the winter? A table or summary of potential evaporation rates for the site area should accompany the document.

8.) Page 2-54. Is the evaporation rate for the waste fluids 0.81 m/year in this area or is that the rate for pure water? This could have a marked effect upon how quickly the planned evaporation ponds' capacity is exhausted.

9.) Page 2-57. As in our previous review, we suggest some type of monitoring of the borehole cuttings in the mud pits. Our opinion would be that there should be no 15-cm thick layer of earth containing greater than 15 pci/g of Ra-226. We suspect values much lower will be achieved by the mixing which occurs during the drilling process however, it should be confirmed. The NRC disposal criteria for uranium and thorium wastes (46 FR 52061, October 23, 1981) may apply to the drill cuttings and muds as well.

10.) Page 2-58. Has the applicant found a licensed tailing facility which will accept the solid waste from the evaporation ponds?

11.) Page 3-2. If one assumes 20 ug/m^3 of particulate load in air for the period in 1982 (see pages 3-2 and 4-15) when the air sample was collected, it follows that the airborne particulates contain 13 pCi/g of Ra-226, 80 pCi/g of Th-230, 1610 pCi/g of Pb-210, and 7300 pCi/g of U-nat. These values are erroneously high and the procedures should be checked. We suggest the filter material background may not have been subtracted, among other problems.

12.) Page 3-35. As both Total Dissolved Concentrations of the M-Zone, 330 mg/l (page 3-35) and N-Zone, 530 mg/l (page 408) are less than 10,000 mg/l these zones will require aquifer exemptions under the UIC program, when it becomes effective, in order for the injection operation to be in compliance with UIC regulations.

13.) Page 4-10. The DES requires only the determination of <u>total</u> parameter concentrations in surface water, not dissolved and suspended concentrations. The collection and analysis of bottom sediment samples from surface water drainages are not required.

We feel the monitoring program should be upgraded to include bottom sediment sample collection and comprehensive analysis of water samples (i.e., dissolved and suspended concentration data for each parameter as opposed to the total concentration).

6. Figure 2.7 shows 5.84 gpm going to evaporation ponds and 1.86 gpm to the process serge tank for a total of 7.7 gpm. The process serge water will be ponded for future process (thus the dashed line) or will be reinjected during restoration. The total amount reinjected has been corrected from 1492.5 to 1492.3 gpm.

7. The evaporation rate for the Converse County area is approximately 44 in. per year; an average rainfall of about 12 in. yields a net evaporation of 32 in. per year (Weather Atlas of the United States, United States Department of Commerce, 1968 – Reprinted 1975). This evaporation rate over 14.8 acres is equal to 39.5 acre/ft/year or 24.5 gpm. Figure 2.8 has been corrected to show an evaporation rate of 24.5 instead of 26 gpm.

8. The evaporation rate of 0.81 m/year is lake or reservoir evaporation, and the staff knows of no reason why evaporation from the waste ponds should not be similar. However, an evaporation rate less than expected would necessitate a cutback in production or construction of additional ponds and would not result in additional environmental impacts.

9. The staff concluded that this method of disposal of drill cuttings is acceptable because (1) the radiation level of 8.4 pCi/g is well below the standard for subsurface soils (15 pCi/g above background), (2) is within twice the range of background radiation levels found in mineralized areas of the West, and (3) the drill cuttings will be covered with several feet of soil. Although the value of 8.4 pCi/g is an estimated average, and it is realized that the radium-226 will not be uniformly distributed, the staff does not feel verification sampling is necessary because the standard allows averaging over an area of 100 m^2.

10. UNC Teton has used the Exxon licensed tailing facility, approximately 16 miles to the northeast of the UNC Teton site, for solid waste disposal during the R&D operation and its decommissioning. Exxon or another licensed facility will be used for the operational phase as required by license.

11. It cannot be assumed that the particulate load is only from naturally occurring radioactive material. Regardless, the values on page 4-15 for airborne radioactivity are still orders or magnitude below the maximum permissible limits for unrestricted areas (10 CFR 20 Appendix B).

12. The proposed solution mining operation cannot commence until the State of Wyoming, which will implement the UIC program, has issued a mining permit.

13. The staff considers it unnecessary to require the applicant to analyze bottom sediment samples and dissolved and suspended concentrations of each parameter because Little Sand Creek carries water so infrequently and is located several hundred feet from the evaporation ponds. As stated in Sect. 4.4.1.1 (p. 4-10), runoff had been entirely absent from the stream channel during the two years preceding the preparation of the DES. There would presumably be little or no sediment to analyze. The sampling regimen given in the DES should, in our opinion, be adequate.

14. Page 4-10. The DES does not require the measurement of lead-210 and polonium 210 in groundwater. We recommend the establishment of baseline levels for these two radionuclides as well as uranium, thorium, and radium-226.

15. Page 4-14. Table 4.5 displays data from uranium and its decay products which should be in equilibrium except for solubility differences. A large variation is shown; most notable, the thorium outside the N production zone is shown to be 50 times the concentration shown for inside the ore zone. The data is questionable. Perhaps the "outside" value is high by two orders of magnitude. In paragraph 5, we suggest thorium-230 be added for analysis. In Table 4.6 and the paragraph including air results, the isotopic ratios for uranium daughters are not in equilibrium.

16. Page 4-15. As indicated in our previous review comment on the ER, the surface water sampling program should include bottom sediment samples and analysis of water samples for dissolved and suspended parameter concentrations.

17. Page 4-16. We feel that thorium would be a more valuable analysis for the waste pond solution. The waste solution should be low in uranium and should have been low in radium when delivered from the wells.

18. Page 4-16, Table 4.7. Our concern remains that three air monitoring locations (one upwind and two downwind) may not be adequate for monitoring the overall dispersion of radon-222 released to the environs from the process building. The DES should contain the justification for such a limited number of sampling locations.

Airborne particulate sampling at the closest inhabitant in the predominant wind direction is prudent. Radon sampling at that station, however, may not be prudent. The higher wind velocities indicate that unstable atmospheric conditions will exist and substantially reduce the radon concentrations (i.e., vertical dilution). The meteorological pattern for the site should be studied to determine the wind direction under stable atmospheric conditions when radon concentrations will be the highest. The desired radon sampling location may not be the same as for airborne particulate sampling.

19. Page 4-20. The top paragraph on page 4-20 states that due to the variation in baseline uranium values in the ore zone, the uranium UCL should be set at 20 percent above the highest baseline measured at any of the monitor wells. Page 4-19 (top paragraph) states that beyond slight fluctuations in excursion parameter concentrations, water quality in the R&D well field excursion monitor wells was unaffected by mining. These somewhat contradictory statements suggest that the expected natural variation in the wells will mask, if not obliterate, any small changes due to mining. Is this the case in fact, or have insufficient data on the baseline concentrations in the ore zone been obtained to adequately characterize the fluctuations at each monitor well? If each well's fluctuations were better defined, perhaps a set of UCL's could be developed for each well, providing a more sensitive criterion by which an excursion could be defined.

14. The NRC staff agrees; Polonium-210 and lead-210 will be baselined by the applicant (see revised sections 4.3.1.1 and 4.4.1.1).

15. The sample results have been reviewed and a value three orders of magnitude higher than the other wells was found at well 320. We assume this to be in error and have deleted this value from Table 4.5.

Based on the composite soil sample data provided in Table 4.6, it appears that the activity of uranium, radium-226, thorium, and lead-210 occur in fairly uniform ratios over the site. Therefore, the staff does not think it necessary to require additional soil samples be analyzed for more than uranium and lead-210. Regarding the isotopic equilibrium of uranium and its daughters, it is very common to see the amount of disequilibrium shown by this data.

16. See response to EPA response 13.

17. The purpose of the waste pond sampling is to compare the analysis with that for water found in the standpipe to verify the source of the standpipe water. Therefore the proposed is acceptable.

18. The staff feels that initially the three radon-222 sampling locations, shown in Table 4.7, plus the nonroutine sampling program at selected locations should be adequate to monitor the radon-222 concentrations to which the maximum exposed individual will be subjected. Figure 3.1 indicates a predominant wind direction that obviates the need for numerous monitoring stations except for stations upwind and downwind. Because the impact on the individual is the most important parameter to be determined, the sampler at the nearest residence is the correct location for that sampler. As pointed out, a review of the sampling results will be used to change the routine monitoring program as required.

19. The staff agrees that natural variation could mask small changes in water quality because of mining. However, it is impossible to distinguish between the two types of change. The purpose of the UCL is to determine when the parameters measured have definitely exceeded natural variation. Each monitoring well has a unique set of UCLs (except for uranium). High natural variations in uranium concentrations between wells requires that UCLS be based on the highest baseline values of all ore zone monitor wells (see Sect. 4.4.2.5). Staff experience has shown that a UCL 20% above baseline is comparable to a UCL that is two standard deviations above the mean based on Student's T test.

What is the scientific basis for choosing the UCL (page 4-20) for uranium and cloride to be 20 percent above the highest representative baseline value? Why not 15 or 25 percent? Would it not be more appropriate to use a statistical basis such as a Student's test with a certain level of significance?

20. Page 4-34. We are not sure how this radon dose was developed or to what organs it applies. Perhaps the statement is not needed.

21. Page 4-43. Will property, severance and sales tax be paid in time to avoid a cash flow problem as local authorities handle the additional public sector expenditures caused by the in-migrants.

22. Page 4-44. In the event of a surface pipe failure, will the contaminated soil be removed immediately? Where will it be placed? The section on pipe failures states only that the licensee will report all such spills promptly.

23. Appendix B. The discussion of the aquifer test in Appendix B does not state whether the wells recovered (i.e., whether the static water level after pumping returned to the pre-pumping level). If the wells did not recover then the N and M zones may be limited aquifers. If they are limited aquifers then the impact of water depletion due to in-site mining should be assessed.

Values of T and S were calculated from recovery data but the duration of recovery measurements was not discussed in Appendix B. How long was recovery measured?

20. The staffs radiological dose determination is based on models, data, and assumptions discussed in Regulatory Guide 3.5.1, March 1982. A reference to this document is in Sect. 4.5.7.2 and previously given in this report. The organs considered in the dose from radon-222 and its decay daughters are for bronchial epithelium.

21. Recent lay-offs of mining personnel in Converse County has resulted in some unemployment. It is expected that local workers will fill the majority of the available positions.

22. Any contaminated soil will be analyzed for radioactivity and if necessary will be immediately removed and placed in a licensed disposal area.

23. For the four ore zone aquifer pumping tests, recovery measurements were made for the same period of times as the pumping period. Recovery measurements for the pump tests showed that the water levels recovered to essentially the same as pretest levels, which indicated that the aquifers are not limited.

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

ER-82/1158

AUG 16 1982

Mr. Ross A. Scarano, Chief
Uranium Recovery Licensing Branch
Division of Waste Management
Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Scarano:

We have reviewed the draft environmental statement for the operation of the Teton Project in Converse County, Wyoming, sent to us June 30, 1982.

The DES acknowledges several areas where the company's proposal is not fully accepted or where the pilot study is believed to be inadequate. In these cases, the DES is mute on the differences or inadequately resolves them. This leaves the reader unable to fully evaluate the potential impacts of the proposed project due to inadequate information regarding the areas of discrepancy between the staff and the company. Specific examples are presented below.

1 In appendix B-5, pages B-5 through B-6, Staff Independent Evaluation, several questions regarding the adequacy and appropriateness of the company's aquifer tests are raised. It is noted that: (1) the M No. 1 study was not conducted meticulously enough to yield more than rough approximations of aquifer transmissibility and storage and that the results should not be used to evaluate the degree of aquifer confinement; (2) tests indicate the N aquifer to be a leaky aquifer; and (3) the tests were poorly designed to accurately determine aquifer anisotrophy. As a result, required additional testing by the company as a part of the license is being proposed.

2 On the other hand, the conclusion in section 4.3.3. regarding the aquifer restoration proposal of the company indicates that it is believed that the company has adequately demonstrated that restoration of the ore zone aquifers to their original potential use condition is achievable. Since the restoration demonstration utilizes the aquifer test data found to be questionable, an apparent discrepancy exists between the two conclusions. We suggest that the statement be expanded to include a more detailed rationale for the conclusion that the restoration plan is achievable. We also suggest that the discussion of the inadequacies of the aquifer testing program address the rationale for requiring more testing, including the worst case scenario which would result from that faulty data and assumptions and an estimate of the probability of such an occurrence.

1-2. Conclusions concerning the applicants ability to restore the aquifers to their original potential use condition were based on the actual pilot aquifer restoration tests and not on the aquifer pump tests (see final version of Sect. 4.3.2, and Appendix F). The inadequacies of the applicants aquifer testing program relate more to the verticle confinement of mining fluids within the ore deposit rather than attainment of restoration goals. Prior to mining in each 4-ha (10-acre) mining unit, the applicant will be required to conduct aquifer pumping tests as necessary to demonstrate that the ore zone aquifer is adequately confined from the upper and lower aquifers. The worst-case scenario, should pump tests not be conducted, would be the contamination of the upper and lower aquifers in one 4-ha (10-acre) mine unit. Therefore, the occurrence of a worst-case scenario is highly unlikely. Based on the pilot scale tests conducted in Mining Unit I, where there were no vertical excursions, aquifer confinement probably exists between O, M, N, and the basal aquifers within Mining Unit I.

(3) The problem of releases of other heavy metals by the lixiviant process is mentioned but not addressed. On page 2-46, the DES specifically mentions the possibility of mobilizing such contaminants as arsenic, barium, fluoride, lead, selenium, vanadium, and zinc in the leaching process. However, the discussion suggests that such mobilization would be minimal, and the evaluation remains mute on the subject. In addition, the removal of potential contamination by heavy metals and other ions is not addressed in the discussion of the elution precipitation circuit on page 2-48, nor in the sections on groundwater restoration.

(4) In view of other testing discrepancies discussed above, we believe that the FES should specifically address the issueof mobilized contaminants. Such a discussion should include an evaluation of the potential for contamination, the efficacy of groundwater restoration procedures for removing this type of contamination, the adequacy ofthe leaching and precipitation circuit for removing any contamination which occurs, and the disposal of contaminants removed from the system.

The discussions suggested above are necessary to provide the reader an independent means of evaluating the efficacy of the proposed processes and evaluating the potential impacts.

We appreciate the opportunity to review your statement.

Sincerely,

Bruce Blanchard, Director
Environmental Project Review

3. The lixiviant process will mobilize many elements but these will be contained within the Mining Unit. During the restoration process, the RO units will remove contaminants and pump the "cleaned" water back into the aquifer until the concentration of each water quality indicator cited in Table 4.1 is reduced to baseline concentrations or drinking water quality standards.

4. The ore zone aquifers are confined and any communication with other aquifers will be prevented as was demonstrated by the R&D operation where there were no vertical excursions. Restoration of the ore zone aquifers will be accomplished by pulling noncontaminated water into the ore zone and removing contaminants with reverse osmosis (RO) units. RO will remove contaminants and restore the aquifer to the same level of water quality that existed prior to mining. The applicant has demonstrated through R&D testing that this level of restoration is achievable (see Sect. 4.3.2 and Appendix F). Radioactive contaminated residules will be deposited at a mill tailings site or other NRC-licensed disposal site.

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AUG 11 1982

August 9, 1982

Dick Hartman
State Planning Coordinator
Wyoming State Clearinghouse
2320 Capitol Avenue
Cheyenne, Wyoming 82002

Dear Mr. Hartman:

Ray Harris, Staff Minerals Geologist, has reviewed the draft E.I.S. for the Operation of the Teton Project--Teton Exploration Drilling, Inc. (State I.D. No. 82-134) and his comments are attached.

If you need further information on any of the comments, please let me know.

Sincerely,

James C. Case

James C. Case
Staff Environmental Geologist

JCC/nb
Encl.

Geology--Interpreting the past to provide for the future

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MEMORANDUM

TO Jim Case

FROM Ray E. Harris

COMMENTS Teton Project DES by the US NRC.

In general this DES is well thought-out and suited to the project. I have three comments on details in the report.

Section 2.3.10.4, p. 2-51.

(1) The NRC assumes all ^{222}Rn is released from solution. However, ^{222}Rn dissolved in water is a prospecting tool. Therefore, not all ^{222}Rn is released from solution during the 3.8 day half-life of the isotope.

The NRC should review its calculations (appendix C) and substitute a precentage release based upon the amount of ^{222}Rn remaining the the lixiviant, determined from calculated or measured ^{222}Rn solubility.

Section 3.7.1.2., p. 3-38, Site Geology.

(2) The geology of the site is well reported and agrees with published work by others. However, extending the term "Lebo" (member of the Fort Union Formation) to this area from southern Montana may be questioned. In northern Wyoming, near Ranchester in the Wolf Mountains, the Fort Union Formation is divided into the upper sandy Tongue River member, the middle shaly Lebo member, and the lower sandy Tullock member. Without direct fossil evidence, and from the stratigraphic column (Figure 3.9), the uranium may be in the Tongue River member. The zone is probably best described as occurring in the upper part of the Fort Union Formation, undivided.

Section 4.4.2.5., Well Monitoring, p. 4-19, Upper control limits

(3) The NRC upper control limits of 20% over baseline are below the natural variability of the amount of these substances in water, for these relatively small concentrations. Local variability from the same well and spring over time often results in values of 2 to 10 times more or less than the first measurement, which is near the range set by Teton. The NRC should be aware of this natural variation occurring in ground water. Teton's limits of 10 ppm chloride, 1.0 ppm uranium, and 1.2 x the alkalinity and conductance baselines seem quite reasonable, and allow for natural variation. Setting the low values proposed by the NRC can only lead to needless alarms over excursions that are not, in fact, occurring. Such may occur with Tetons limits, but less frequently, yet a real excursion will be detected in time to control it.

Geology: Interpreting the past to provide for the future

1. The NRC recognizes that not all of the radon-222 dissolved in the mining solutions will be released to the atmosphere as they are circulated through the plant. However, as they are allowed to reach equilibrium with the atmosphere, a large percentage of the radon-222 will be released. Because the exact percentage remaining in solution is unknown, and to be conservative in its estimates, the NRC assumes 100% of the soluable radon-222 is released to the atmosphere. In addition, the NRC assumes that only 20% of the radon-222 contained in the ore body is eminated to the groundwater.

2. Thank you for your comment. The text has been amended by describing the ore body as occurring in the upper portion of the Fort Union Formation. All references to the Lebo Member have been deleted.

3. The NRC believes that by calculating separate upper control limits for each excursion monitor well based on no less than three samples from each well, excluding outliers, spacial-temporal differences in groundwater quality are generally accounted for. In addition, in the course of working with the R&D project and the commercial application, the NRC has evaluated hundreds of groundwater samples from numerous wells within the aquifers at the Leuenberger site and has obtained extensive knowledge of local variations in groundwater quality.

THE STATE OF WYOMING

Commissioner of Public Lands and Farm Loans

2424 PIONEER AVENUE
PIONEER BUILDING

CHEYENNE, WYOMING 82002

July 19, 1982

PLEASE ADDRESS REPLY
TO THE COMMISSIONER

U. S. Nuclear Regulatory Commission
ATTN: Uranium Recovery Licensing Branch
Washington, DC 20555

Gentlemen:

Reference Docket No. 40-8781 DES Teton Project in Converse County, Wyoming, this comment is offered:

(1) Page 3-20: Add this sentence at the end of the 2nd paragraph under Fire & police protection for Converse County: "The Converse County Rural Fire Control Association maintains over 30 mobile fire units located on ranches and in settlements."

Thank you for the opportunity to comment.

Very truly yours,

CARL E. JOHNSON
STATE FORESTER

By: Bryce E. Lundell
Bryce E. Lundell
Asst State Forester

BEL:eb

1. The text has been amended.

THE STATE OF WYOMING

ED HERSCHLER
GOVERNOR

Department of Environmental Quality

Water Quality Division

1111 EAST LINCOLNWAY CHEYENNE, WYOMING 82002 TELEPHONE 307 777-7781

MEMORANDUM

TO: Robert E. Sundin, Director, DEQ

THROUGH: William L. Garland, Administrator, WQD

FROM: A.J. Mancini, Groundwater Supervisor, WQD

DATE: July 15, 1982

SUBJECT: Comments on Draft ES Related to the Operation of the Teton Project, NUREG-0925 (NRC Docket No. 40-8781

(1) Comments are not provided because the DEQ has already permitted the ISL operation, and WQD has permitted pond construction.

Even though DEQ permits have been issued, Teton has opted not to commence "mining" at this time. When and if Teton does want to begin the ISL operation, Teton will have to receive prior DEQ approval.

1. All pertinent permits will be acquired by the applicant prior to mining.

WYOMING
EXECUTIVE DEPARTMENT
CHEYENNE

ED HERSCHLER
GOVERNOR

August 26, 1982

Mr. Ross A. Scarano, Chief
Uranium Recovery Licensing Branch
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Scarano:

The draft environmental statement related to the operation of the Teton Uranium Project in Converse County, Wyoming (Docket No. 40-8781) has been circulated for state agency review. Copies of agency comments are enclosed for your consideration and use.

(1) The environmental analysis supports the issuance of a combined Source and Byproduct Material License, subject to specific licensing conditions and conformity with other local, state and federal standards and regulations. Several of the necessary state permits have already been issued. However, since Teton has opted not to commence "mining" at this time, these permits may require extension or re-approval by the time the operation begins. The applicant should keep the pertinent state agencies abreast of the actual development and operation plans, to avoid unnecessary delay in starting up the project.

Thank you for the opportunity to review and comment on this document. Please keep me informed of the progress in this effort.

Yours sincerely,

Ed Herschler

EH:pcl
Enclosures

1. Proper permits will be obtained by the applicant, and the pertinent state agencies will be advised of development and operation plans.

THE STATE OF WYOMING

ED HERSCHLER
GOVERNOR

Game and Fish Department

CHEYENNE, WYOMING 82002

EARL M. THOMAS
DIRECTOR

July 23, 1982

EIS 801/L3 USNRC
Teton Project Docket No. 40-8781
Converse County

Mr. Dick Hartman
State Planning Coordinator
2320 Capitol Avenue
Cheyenne, Wyoming 82002

Dear Dick:

In our letter of June 18, 1981 relating to the scoping of this project we recommended that two issues be addressed prior to approval of the proposed project.

1. Impacts on North Platte River.

2. Relationship between the proposed monitoring plan and plans to correct any potential problems or impacts to fish and wildlife.

Though these issues were addressed, fish and wildlife concerns were only covered in a perfunctory manner.

(1) P. 4-27, 4-28 stated that if a pond fails and the contents reach the North Platte River, the impacts on water quality would "probably" not be serious. It further states that only TDS would likely exceed the Wyoming DEQ criteria for wildlife and livestock (5,000 mg/L). Since more definite impacts on water quality are not known (it is dependent on soil conditions and weather), maybe there should be some mention of the impacts on the fish and wildlife of the river if the worst possible water quality alterations were to occur.

(2) P. 4-45. The draft states that if a spill reached Little Sand Creek, the applicant would be required to clean up the contaminated materials and dispose of them in the evaporation reservoir or in an off-site licensed disposal facility.

1-3. Pond failure: During the dry conditions that prevail most of the year at the site, any pond leakage would be gradual, localized, and detected quickly because of the pond leak detection system. Mitigating action would be taken immediately after discovery of any leak. Because the streambeds between the site and the North Platte River, some 4 miles away, would be dry, there would be no transport of contaminants to the North Platte. Contaminated soil from the streambeds on the site would be cleaned up and deposited in an off-site disposal facility (pg. 4-45).

The only situation in which spilled pond contents could reach the North Platte River would be during a period of extremely heavy rainfall. Freeboard requirements will protect against a 6-hour probable maximum precipitation event and wind induced waves. Nevertheless, should a pond overflow, the contents would be well diluted by the rainfall both before and after escaping the pond. The cause of the problem would also serve as its solution.

In the extremely unlikely event that heavy rains caused one of the ponds to develop a major break and release all of its contents within a few hours, dilution may again be considered a mitigating factor. Using the largest of the four ponds (West Leuenberger) as an example, one might visualize its contents (135,000 m^3) escaping on May 18, 1978, the day on which Sand Creek registered its highest rate of discharge (7.9 m^3/s) for the Water Year at a USGS station 2.2 miles upstream from the North Platte. At that rate, 11,340 m^3 of water would flow past the gauge in one day. If the entire capacity of the West Pond were released in a single pulse at that point, it would be diluted by a factor of 11. Considering that the waterway would collect runoff for another 2 miles before joining the North Platte, one might estimate a further 11-fold dilution, or a total dilution factor of 121. Contaminants would then be further diluted upon entering the larger water body with its storm-increased flow. The staff feels that the concentrations of chemicals in the ponds (Table 2.11) would be sufficiently reduced under these conditions to alleviate any severe impacts on fish and wildlife using the river.

Mr. Dick Hartman
July 22, 1982
Page 2, EIS 801/L3

This would evidently involve considerable ground and soil disturbance to Little Sand Creek itself and to its drainage basin. The occurrence of a runoff event could cause considerable increase in erosion of the drainage basin and a subsequent increased sediment load to the North Platte River. The possible impact this could have to the fisheries of the North Platte River should be addressed. To cover the possibility of such an event, plans are needed for immediate revegetation and stabilization of the watershed.

(3) P. 4-10. The applicant is committed to sampling Little Sand Creek quarterly, or when surface water is flowing, at three locations: (1) Upstream from the permit area, (2) within the permit area upstream of the windmill, and (3) downstream from the windmill at the stock pond. Since the waters of Little Sand Creek would eventually flow to the North Platte River, there should be some mitigating measure in the event it is found that the creek is being contaminated by the operation. The present draft contains no cleanup plan or corrective measure, but only a plan for sampling of the creek.

Comments are offered to help make the final EIS more complete and accurate in considering the wildlife resources. Please contact us if we may be of further help.

Sincerely,

W. DONALD DEXTER, DIRECTOR,
WYOMING GAME AND FISH DEPARTMENT

WDD:HBM:mlr

cc: Game Division
cc: Fish Division

1-3. contd <u>Spill cleanup and its effects</u>: Contrary to the Wyoming Game and Fish Department's comments regarding p. 4-10, the applicant is committed to cleaning up after a spill in Little Sand Creek, as stated on p. 4-45. We agree, however, that such cleanup activities would temporarily disturb soil in and around the creek bed and, perhaps, in its small drainage area. It is conceivable that a subsequent runoff event would increase the sediment load to the North Platte River. Elevated sediment concentrations would reduce productivity through light reduction and partial burial of benthic organisms. Certain species of fish that require clear water might suffer adverse effects due to gill clogging. In addition, the water might be somewhat less palatable to terrestrial wildlife. The staff, nevertheless, feels that such effects would be minor and only temporary because of the infrequency of substantial rainfall in the region.

THE STATE OF WYOMING

ED HERSCHLER
GOVERNOR

Wyoming Recreation Commission

1920 THOMES CHEYENNE, WYOMING 82002

JAN L. WILSON
Director
777-7695

July 16, 1982

Mr. Dick Hartman
State Planning Coordinator
2320 Capitol Avenue
Cheyenne, Wyoming 82002

Dear Mr. Hartman:

The Draft ES related to the Operation of the Teton Project was received in this office on July 13, 1982. Thank you for giving us the opportunity to review the report.

(1) Enclosed is a memorandum from our staff archeologist who reviewed the materials. He indicates that provision must be made for cultural resources. Therefore, the Wyoming State Historic Preservation Officer (SHPO) recommends cultural clearance for the purposes of applicable state and federal laws only if the archeologist's recommendations are followed. In the event that his recommendations are not followed, clearance will be void.

If you have any questions concerning these recommendations please contact the appropriate member of our staff.

Sincerely,

Mark Junge, Deputy
State Historic Preservation Officer

FOR:

Jan L. Wilson, Director and
State Historic Preservation Officer

MGJ:klm
Encls.

1. The staff and applicant recognize the necessity of protecting cultural responses. The applicant shall not conduct surface disturbing activities in or around the four sites discussed in Sect. 4.5.2 having potential for subsurface archaeological deposits. Before any future disturbing activities in these site areas, the sites must be evaluated for National Register of Historic Places eligibility.

If any archaeological materials are discovered during construction, work in the area must halt immediately and the SHPO office contacted. Work in the area must not resume until the archaeological materials have been evaluated and adequate measures for their protection taken.

THE STATE OF WYOMING

ED HERSCHLER
GOVERNOR

Wyoming Recreation Commission

1920 THOMES CHEYENNE, WYOMING 82002

JAN L. WILSON
Director
777-7695

August 6, 1982

U.S. Nuclear Regulatory Commission
Attn: Recovery Licensing Branch
Washington, D. C. 20555

RE: 40-8781

Dear Sirs:

The Draft Environmental Statement related to the issuance of a Source and Byproduct Material License for Teton Exploration Drilling, Inc. - Teton Project was received in this office July 22, 1982. Thank you for giving us the opportunity to review the report.

The major concern of the Wyoming Recreation Commission (WRC) would be the possible impacts on the recreation resource in Converse and Natrona counties However, because the work force will be small (appro imately 50 workers) and the proposed project area wil not be located near any identified high value recreation lands, these adverse impacts should be minimal. The WRC recommends clearance for this project as it currently stands.

If you have any questions concerning this recommendation, please contact this office.

Sincerely,

Alvin F. Bastron

Alvin F. Bastron, P.E.
Chief, State Parks Division

AFB/lr

No response required.

THE STATE OF WYOMING ED HERSCHLER GOVERNOR

State Engineer's Office

BARRETT BUILDING CHEYENNE, WYOMING 82002

MEMORANDUM

August 4, 1982

TO: State Planning Coordinator

FROM: Richard G. Stockdale, Ground Water Geologist, State Engineer's Office

SUBJECT: Review of Draft Environmental Statement for Teton Project, Teton Exploration Drilling, Inc. (State Identifier No. 82-134)

A review of the subject Environmental Statement has revealed the following:

(1) It appears that appropriate permits have been obtained through the State Engineer's Office for the Water facilities. It was noted, however, that some permits expire at the end of 1983. Extensions of time may be needed if the project is not completed by the expiration date of the permits.

(2) The report indicates that approximately 645 ac-ft of water will be utilized during the life of the project. The report is unclear, however, as to whether additional water would be needed for aquifer restoration in addition to the 645 ac-ft.

(3) It should be noted that the necessity for protecting existing water rights, or the compensation and/or the providing of an alternate water supply if there is injury, must be considered.

1. Proper permits will be obtained by the applicant.

2. The 645 acre-ft of water includes restoration.

3. All water rights have been research by the applicant. The staff believes that sufficient precautions have and will be taken to protect existing water supplies.

THE STATE OF WYOMING

Ed Herschler, Governor
Lane Mengum, Superintendent and Chief Engineer

Wyoming State Highway Department

P. O. BOX 1708 CHEYENNE, WYOMING 82002-9019

July 16, 1982

EIS Comments
Teton Project
State ID 82-134

Mr. Dick Hartman
State Planning Coordinator
Wyoming State Clearinghouse
2320 Capitol Avenue
Cheyenne, WY 82002

Dear Mr. Hartman:

We have reviewed the Draft EIS for the Teton project and offer the following comments.

1. There should be little or not impact on traffic operation of State Highways in the area.

2. There is not sufficient information to determine if there are likely to be other impacts. More information is needed to determine whether there is likely to be subsidence along or near the road; or whether leaks, spills or other drainage could affect the highway roadside. A good site location map would, perhaps, answer most of these questions.

Very truly yours,

William P. King, P. E.
Environmental Services Engineer

WPK/mg

1. No response required.

2. Gradual removal of 645 acre-ft over the life of the mining and restoration process will not result in subsidence because no rock matrix is removed and water will be recharged from the aquifer in the large surrounding area. Figure 2.6 shows the access roads in relation to the well fields, reservoirs, and process plant. Leaks or spills should have little potential to affect highway roadsides.

WYOMING RECREATION COMMISSION

STATE HISTORIC PRESERVATION OFFICE

REVIEW AND COMPLIANCE

Interdisciplinary Staff Comments

Archeology • History • Historical Architecture • Recreation Planning

TO: **Mark Junge, Chief**

FROM: **Richard Bryant, Archeological Compliance Officer** RB

DATE: **July 16, 1982 (district #7)**

RE: **Draft ES related to the Operation of the Teton Projects (NW of Douglas) A-95/82-134**

The Draft EA incorporates the concerns of the Wyoming SHPO and makes provision for protection of the cultural resources in the project area. If the stipulations for cultural resource site protection are fulfilled, we have no objections to the project and recommend cultural resource clearance.

No response required.

THE PENNSYLVANIA STATE UNIVERSITY
104 DAVEY LABORATORY
UNIVERSITY PARK, PENNSYLVANIA 16802

College of Science
Department of Physics

Area Code 814

19 August 1982

Uranium Recovery Licensing Branch
U.S. Nuclear Regulatory Commission
Washington, D.C., 20555

Dear NRC:

Enclosed are my comments on the Draft Environmental Statement related to the operation of the Teton Project, NUREG-0925. Please note that the information presented here are my own, and not necessarily those of the Pennsylvania State University.

I hope that these comments are useful in developing the Final Environmental Statement. Would you please also send me a copy of that Final EIS when it is available.

Sincerely,

William A. Lochstet

Wm. A. Lochstet, Ph.D.

Some Long Term Health Consequences of
Teton Project

by
William A. Lochstet
The Pennsylvania State University*

August 1982

The Nuclear Regulatory Commission has attempted to evaluate the health consequences of operation of the Teton Project solution mining operation in its Draft, NUREG-0925.

(1) In section 2.2.1.5 there is a comparison of the coal and nuclear fuel cycles based on NUREG-0332. NUREG-0332 was issued as a draft for public comment in September 1977. A final version, reflecting public comments was never prepared. Furthermore, this report (Draft) is based on a mixture of deep mines and pit mines. This is inappropriate for a solution mining operation.

(2) The analysis presented in these drafts (NUREG-0332 and NUREG-0925) is incorrect because they ignore the long term effects from radon generated by the radioactive decay of uranium-238 thru several steps to radon-222. This impact was recognized by the NRC in GESMO (NUREG-0002), and can also be found in the final NUREG-0564 at pages B-33 to B-38. The result is that the major environmental impact arises from the depleted uranium from the enrichment process. The decay of this uranium-238 thru several steps, to radon-222 is the largest and most important health impact. The impact of the fuel cycle to support one 1000 Mwe plant for one year is 400,000 deaths.

It is noted that the radon emissions for solution mining are less than for either open pit or shaft mining.

* The information presented here does not necessarily reflect the position of the Pennsylvania State University, which affiliation is given here for identification purposes only.

1. The staff feels that a comparison of health effects of the nuclear fuel cycle with that of the coal cycle in NUREG-0332 is valid because the findings of the study were not found to be faulty upon review. While solution mining in particular was not included in the nuclear fuel cycle cited, if it were included rather than the conventional types of mines (deep and pit) with their associated milling operations, the health effects for the nuclear fuel cycle would actually be less because the process selectively puts uranium into solution and leaves the other daughters of the chain in the ore body.

2. While the stored depleted uranium resulting from uranium-235 enrichment contains radionuclides with a very long half-life, and disposal methods that can control the radon from reaching the atmosphere are already a proven reality.

   As calculated by Gotchy,* the mortality rate for the nuclear fuel cycle per GWe-year is 0.2 (this would be approximately doubled if occupational risks were included).

*R. L. Gotchy "Health Risks from the Nuclear Fuel Cycle," in *Health Risks of Energy Technologies*, C. C. Travis and E. L. Etnier, editors, Westview Press, Boulder, Colorado, pp. 35-75 (to be published November 1982).

Powder River Basin Resource Council

48 North Main Sheridan, Wyo. 82801 (307) 672-5809

23 August 1982

U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
ATTN: Uranium Recovery Licensing Branch

RE: Comments on Draft Environmental Statement related to the operation of the Teton Project, Docket No. 40-8781

To Whom It May Concern:

(1) The Powder River Basin Resource Council is a non-profit, membership organization dedicated to preservation of Wyoming's agricultural economy and unique way of life. We would like to submit the following comments on the above Draft Environmental Statement.

Section 2.2.1.4 (Uranium fuel requirements, available resources, domestic production capabilities, and comparison of uranium resources and production capabilities with uranium requirements):

Generally, this section overrates the need for uranium and underestimates the potential contributions of renewable sources of energy. On the one hand, the text states that "The considerable uncertainty inherent in forecasting electricty demand, the unpredictable path of government nuclear-related policies and programs (breeder reactors, spent fuel reprocessing, etc.), and the availability and economic competition of alternative conventional and unconventional energy sources preclude rational forecasts past 1988." (p. 2-5). On the other, the text states that "It is evident that there is and will be more production capability for U_3O_8 that will be needed during the 1980 decade." If the need for nuclear generation cannot be accurately predicted past 1988, and it is already known that excess productive capacity for uranium exists, it is something of a leap of faith to assert that additional productive capacity will be needed to meet increasing demand in the 1990s and beyond.

Further, although the DES admits that "timely development" of alternative sources such as solar will require "a favorable market as well as government incentives" (p. 2-11) and that energy conservation is "the cleanest and cheapest way to relieve the energy shortage" (p. 2-14), there is no discussion of the effect of reallocating the government's subsidies of nuclear power to alternative sources. If solar and conservation were given the same amount of federal financial attention as nuclear, it could very well be that a "need" for the Teton Project would not exist.

The NRC staff did not avail itself of the latest materials in discussion projected electrical demand growth (and consequently the need for additional nuclear generation). The statement on page 2-14 that "...in the case of electrical energy, demand is expected to increase (during the next decade) at a rate about twice as great as that for total energy" is taken from the Project Independence document, dated 1974. Since that time, growth in electrical demand has dipped sharply - even rural electric systems, which are the fastest-growing in the nation, experienced their lowest load growth ever last year at 1%.

1. Section 2.2 of the FES has been updated. The staff believes that economics will dictate the success or failure of the project. It is not the intent of NEPA to justify a project on the basis of economics (see response 1, USEPA). Thus, a discussion of the use and need for uranium in Sect. 2.2 is simply to give the public background information on the current use of uranium compared with fossil fuels and other energy sources and to make the point that increased uranium production will be needed in the future as additional nuclear units under construction now come on line in this decade.

(2) The PRBRC questions the statement on page 2-46 - "The pilot test was operated with sodium bicarbonate concentrations, apparently at about 2 g/L, and the commercial plant is expected to operate in the same range." What concentrations did the pilot plant employ? If the commercial plant does not operate in the same range, will that affect the success of restoration efforts?

(3) On page 2-55, it is noted that the applicant may "run out of pond capacity by the ninth year of operation," and that an area has been designated for construction of "contingency ponds." It might be a good idea to require the construction of at least one contingency pond well before the ninth year, to avoid any problems that may occur if adequate pond capacity is not available (for example, if an excursion occurs and pumping is recommended as a control method, and there is not sufficient pond capacity available, the applicant might be forced to discharge contaminated groundwater into a surface drainage.)

(4) On page 3-31, the DES states that potentiometric elevations in wells penetrating the O_2, N, and M aquifers were monitored "periodically" since the autumn of 1979. How often is "periodically"? Since this information was apparently used to construct the potentiometric maps which in turn indicate the direction of groundwater flow - and, to some degree, the separation of the aquifers involved - it would be interesting to know how much data the maps are based on.

(5) The determination of pre-mining groundwater quality is critical to the evaluation of restoration success. On page 3-36, it says that "Groundwater in the M and N ore zone sand of mining unit I does not meet drinking water standards because of its high radium-226 levels, which exceed the drinking water standard of 5 pCi/L. However, baseline averages for the other indicator parameters are within or very close to meeting drinking water standards." On page 4-4, it says that "At the Leuenberger site, groundwater (as determined from average concentrations in mining unit 1 wells and the R&D restoration baseline data) within this zone naturally contains concentrations of radium-226 that exceed drinking water standards (186 vs 5 pCi/L). The quality of the groundwater in the N and M aquifers is such that the water does not meet either domestic or livestock standards; however, with the exception of radium-226, the groundwater quality meets or exceeds livestock-use criteria."

Does the water meet drinking water standards, or not? If it doesn't, how close is it? Will the NRC require restoration to drinking standards? On page 2-15, the text states that "Individual groundwater parameters than can not be returned to baseline by reasonable efforts will at least be returned to levels commensurate with the groundwater's highest potential premining use based on Wyoming drinking water and livestock standards." What constitutes a "reasonable effort"?

(6) Monitor wells will be placed in the ore zone not being mined while mining is occurring in the other zone (page 4-18). Will a migration into the inactive ore zone be considered an excursion?

The PRBRC prefers the stricter UCLs advocated by the NRC on pp. 4-19 and 4-20.

2. The pilot plant used 0.5-2.0 g/liter sodium bicarbonate concentrations. The commercial plant is not expected to operate above 2.0 g/liter. Thus, the restoration success will not be adversely affected.

3. The NRC has evaluated the water balance for the commercial project, and based on the R&D operation and excursion experience at other sites, has determined that adequate pond capacity exists for the first several years of operation. As the operation progresses, we will obtain actual water balance data for this site as well as a better indication as to how much pond capacity would be needed to handle emergencies such as excursions and leaks. Based on this operating data, we will determine when additional ponds are needed.

4. Periodic water level elevations taken from the various wells used to describe and monitor hydrologic conditions in the aquifers involved in the UNC Teton Project refer to a large volume of data collected from the time a well was installed through the end of the R&D project. These periodic measurements include the initial elevation taken when the well was first drilled. Measurements taken thereafter were quarterly, monthly, weekly, and in some cases, daily, depending upon the need for data to evaluate the effects of various operating procedures. The potentiometric surface maps presented in the Environmental Report for the O, N, and M aquifers were prepared from the periodic 1980 data as described above. The maps are intended to give a general flow and gradient of the aquifers depicted and attempt to present a general picture of these aquifers in a natural static state at a given time. The maps are not intended to show an average aquifer condition over a long period of time. Aquifer water levels are affected from day to day by natural conditions such as barometric pressure changes and from one year to the next because of natural recharge variations. Prior to mining in each mining unit, the applicant will be required to submit detailed potentiometric maps.

5. The water in the M and N ore zones meets drinking water standards except for concentrations of radium-226 and manganese and the text has been amended to clarify this. A reasonable effort is defined as that effort demonstrated in the R&D operation that returned the constituents in the water to baseline conditions or drinking water standards (see final version of Sect. 4.3.2 and Appendix F which has been added to the FES).

6. The migration of leachate into any inactive ore zone will be considered an excursion. Monitor wells located in an inactive ore zone will be subject to the same conditions given in Sect. 4.4.2.5 as those monitor wells located outside the ore zone.

Comments on DES related to the Teton Project
Powder River Basin Resource Council
23 August 1982

(7) Please check the statement on page 4-20, "If its UCL alone is exceeded, if the UCL of any single indicator parameter is exceeded by more than 20%, or if the UCLs are exceeded for any two indicator parameters after routine and confirmation sampling, an excursion will have been detected." Should the second mention of the term "UCL" actually be the word "baseline"?

(8) Some definitive standard should be established for surface reclamation. The assurance that the applicant "will attempt" to restore the land to good-quality range gives little guidance for reclamation evaluation purposes.

(9) It would be a good idea to require the applicant to monitor offsite radioactivity concentrations at the nearest residence to ensure that these concentrations are maintained below permissible limits where it most matters (p. 4-35).

(10) The statement that a maximum dose of 77.6 millirems/year to the bronchial epithelium is less than 14% of the estimated dose to individuals from natural background radiation says nothing about the consequence to a particular individual of increasing his/her exposure by this amount. More information should be provided as to the potential health effects of this exposure and on protecting affected individuals (p. 4-39).

(11) Generally, the PRBRC takes a dim view of the NRC's "test-as-you-go" attitude for issuing mining permits. The NRC's evaluation of the applicant's aquifer tests (p. B-5) indicates that the applicant has not always conducted quality work, and in fact there is some doubt as to the confinement of the N and M ore zones ("...the test results are, to some degree, inconclusive with respect to ore zone confinement..." - p. B-6). The NRC plans to remedy this deficiency by requiring the applicant to perform additional aquifer tests in each mining unit before actual mining takes place. Why not obtain that information prior to issuing a permit? Once the applicant establishes a mining operation, it will be difficult to terminate operations if additional tests reveal conditions unsuitable for in situ mining. It would be better to take every possible step to anticipate problems and establish the facts prior to mining than to discover them after excursions or other difficulties occur.

Thank you for this opportunity to comment.

Sincerely,

Sarah Gorin Jones

Sarah Gorin Jones
staff, for the
Powder River Basin Resource Council

7. The text has been revised to read, "If the UCL for chloride alone is exceeded, ..."

8. Under bonding requirements established with Teton-Nedco, the Wyoming Department of Environmental Quality (DEQ) will inspect and determine the adequacy of surface reclamation at the site (Sect. 2.3.10.5). The Reclamation Performance Bond filed by Teton-Nedco with the Wyoming DEQ will ensure the availability of funds to adequately restore and reclaim the project site. Plans for reclamation are discussed in Sect. 2.3.10.5. The NRC staff considers that these reclamation plans and the associated bonding requirements will provide for adequate surface reclamation.

9. The staff agrees. See radiological monitoring program on p. 4-16 and in Table 4.7.

10. Based on the somatic risk (CGEJS, NUREG G-0706 PG-58, Appendix G-7) of 72 premature deaths/lifetime/10^6 manrems and the incremental dose of 77.6 mrem/year for the 11-year life of the plant, the increased risk of premature deaths is 6.2×10^{-5}.

11. Even if the applicants aquifer tests were conducted to the complete satisfaction of the NRC staff, total confinement between the aquifers over the entire ore body could not be guaranteed with absolute assurance. With this in mind, the NRC staff will require that aquifer tests be performed in each individual mining unit before operations begin in that unit. Even though the tests were conducted less than ideally, they still provide useful information. Initial pump tests and the R&D demonstration indicate that there are no natural or manmade pathways (fault, fractures, abandoned boreholes, etc.) through the confining units for significant amounts of fluid to migrate between aquifers and there is probably adequate ore zone confinement in Mining Unit I. At other sites, mining operations have been suspended by the NRC when conditions were believed to be unsuitable for in situ mining. The NRC does not require tests on all mining units be made before licensing because it would be an unreasonable economic burden for the applicant.

Appendix B

REVIEW AND ANALYSIS OF AQUIFER TESTS

A detailed discussion of the applicant's ore zone aquifer tests is presented below. Specific information on each test, including dates, well locations, pumping rates, well design, and aquifer characteristics calculated by the applicant are presented in Sects. B.1 through B.4. The staff's independent evaluation and conclusions regarding the tests are presented in Sects. B.5 and B.6.

Hydrologic properties of the N and M sands (ore zone aquifers) in the project area were established by the applicant based from data obtained from four separate aquifer tests. Three aquifer tests were conducted in the M ore zone: in the western portion of the ore zone (mining unit IV) on July 21, 1980; in the central portion (mining unit I) on February 21, 1979; and in the eastern portion (mining unit IV) on July 29, 1980. The remaining aquifer test was conducted in the N ore zone sand (mining unit VII) on June 26, 1979. The locations of the wells used for the aquifer tests are shown in Fig. 3.4.

The applicant used the Theis nonequilibrium method to calculate the transmissivity and storage coefficients of the aquifers. As a check, transmissivity and storage were also calculated by the Cooper-Jacob and recovery straight-line approximations. To determine if the ore zone aquifers exhibited properties of leakance, time drawdown curves were compared to type curves of the Modified Hantush Method (1960). Major assumptions inherent in these methods are:

1. The aquifer is confined and homogeneous within the radius of influence of the test. The assumption that the aquifers are confined is based on geophysical well logs and water-level elevations and is verified by the water-level responses measured during all four tests. The Theis equation assumes no leakance; all water pumped during the test is derived from storage in the aquifer. The Modified Hantush equation assumes that the aquifer is leaky and that a portion of the water is developed from storage in the aquiclude(s). The applicant has determined from his analyses of the four tests that the N and M ore zone aquifers exist under nonleaky conditions and that consistent values of transmissivity at respective observation wells within each ore zone indicate that the aquifers are homogeneous and isotropic.

2. The pumped well fully penetrates the entire thickness of the aquifer and monitor wells are fully screened across the aquifer. Well completion data submitted by the applicant indicate that all pumped wells are fully penetrating and all monitor wells are screened fully across their respective aquifers.

B.1 AQUIFER TEST N #1

Aquifer test N #1 was conducted in the central portion of the project area in N ore zone mining unit VII on June 26, 1979. Water was withdrawn from pumping well 317 at an average discharge rate of 2.72 L/s (43.1 gpm) for 36.5 h while water-level responses in the N aquifer were measured at six monitor wells: 313, 319, 320, 572, 573, and 574. Water-level responses in the overlying O aquifer were monitored in well 570 and in the underlying M aquifer in well 307.

The top of the N aquifer in the test area is approximately 61 to 64 m (200 to 210 ft) below land surface; the wells used in the test are completed from 79 to 85 m (260 to 280 ft) and fully penetrated the 15-m-thick (50-ft) aquifer.

Table B.1 is a summary of the applicant's four aquifer tests. The average transmissivity and hydraulic conductivity calculated by the applicant for the N aquifer are 8.66 m^2/d (697.5 gpd/ft) and 0.58 m/d (13.95 gpd/ft^2), respectively.

The applicant's analyses of the drawdown data using the Cooper-Jacob straight-line method indicate the possible existence of a barrier boundary coinciding with the thinning of the N sand southeast of the aquifer testing area. The applicant has determined that the N aquifer is nonleaky and contains no discontinuities in permeability within the radius of influence of the aquifer test.

B.2 AQUIFER TEST M #1

M aquifer test #1 was conducted in the central portion of the M ore zone in mining unit I on February 21, 1979. Water was withdrawn from pumping well 301 at an average discharge rate of 2.78 L/s (44 gpm) for 48 h, and water-level responses in the M aquifer were measured at four monitor wells: 305, 306, 307, and 308. Water-level responses in the overlying N aquifer and underlying basal aquifer were monitored at wells 302 and 314, respectively.

The top of the M aquifer in the test area is approximately 104 m (304 ft) below land surface; the wells used in the test are completed from 117 to 122 m (385 to 400 ft) and fully penetrated the 18-m-thick (60-ft) aquifer.

The average transmissivity and hydraulic conductivity calculated by the applicant for the M aquifer in the area of aquifer test M #1 are 5.12 m^2/d (412 gpd/ft) and 0.34 m/d (6.87 gpd/ft^2) (Table B.1).

The applicant has determined that the M aquifer is nonleaky and contains no discontinuities in permeability within the radius of influence of the M #1 aquifer test.

Table B.1. Summary of pumping test results

Well No.	Distance (r) to pumped well (ft)	Method: Theis nonequilibrium T (gpd/ft)	Theis nonequilibrium S	Cooper-Jacob T (gpd/ft)	Cooper-Jacob S	Recovery T (gpd/ft)	Summary
				N AQUIFER TEST #1			
313	295.4	610	6.4×10^{-5}	599	6.2×10^{-5}	600	T avg. = 697 gpd/ft (~700 gpd/ft)
317	0.42 (pumping well)	823		948		896	S avg. = 8.3×10^{-5}
319	297.9	659	7.4×10^{-5}	593	8.6×10^{-5}	610	b = 50 ft
320	248.8	677	8.5×10^{-5}	609	1.0×10^{-4}	640	k = T/b = 14.0 gpd/ft^2 = 1.9 ft/day
572	98.3	810	1.7×10^{-5}	711	4.3×10^{-5}	760	$r_e = (0.3Tt/S)^{1/2}$
573	67.5	706	7.0×10^{-5}	650	9.8×10^{-5}	680	$= [0.3(700)(1.52)/8.3 \times 10^{-5}]^{1/2}$
574	81.1	726	2.1×10^{-5}	643	3.1×10^{-4}	680	= 1961 ft or 2000 ft (rounded)
Mean		716	5.52×10^{-5}	679	1.1×10^{-4}	695	
				M AQUIFER TEST #1			
301	0.36 (pumping well)	348		407		320	T avg. = 412 gpd/ft (~410 gpd/ft)
305	297.2	348	1.5×10^{-4}	407	7.2×10^{-4}	430	S avg. = 2.6×10^{-4}
306	95.2	420	1.4×10^{-4}	408	1.2×10^{-4}	412	b = 60 ft
307	196.8	548	5.4×10^{-5}	490	6.3×10^{-5}	433	k = 6.83 gpd/ft^2 = 0.9 ft/day
308	57.1	360	4.1×10^{-4}	357	3.8×10^{-4}	394	$r_e = (0.3Tt/S)^{1/2}$
							$= [0.3(410)(2)/2.6 \times 10^{-4}]^{1/2}$
Mean		419	1.9×10^{-4}	416	3.2×10^{-4}	398	= 973 ft or 1000 (rounded)
				M AQUIFER TEST #2			
MM6	0.42 (pumping well)	296		246		260	T avg. = 292 gpd/ft (~290 gpd/ft)
MM8	499.7	356	5.3×10^{-5}	291	4.9×10^{-5}	309	S avg. = 6.5×10^{-5}
MM9	246.1	285	8.3×10^{-5}	303	7.5×10^{-5}	279	b = 65 ft
Mean		312	6.8×10^{-5}	280	6.2×10^{-5}	283	k = T/b = 4.5 gpd/ft^2 = 0.6 ft/d
							$r_e = (0.3Tt/S)^{1/2}$
							$= [0.3(290)(4)/6.5 \times 10^{-5}]^{1/2}$ = 2314 ft
							= 2300 (rounded)
				M AQUIFER TEST #3			
MM3	793.9	324	8.3×10^{-5}				T avg. = 261 gpd/ft (~260 gpd/ft)
MM4	40.2	232	4.6×10^{-4}	228	4.4×10^{-4}	239	S avg. = 2.6×10^{-4}
MM7	642.5	279	5.1×10^{-5}	247	6.0×10^{-5}	227	b = 60 ft
MM10	0.42 (pumping well)	342		255		272	k = T/b = 4.3 gpd/ft^2 = 0.6 ft/d
Mean		294	2.6×10^{-4}	243	2.5×10^{-4}	246	$r_e = (0.3Tt/S)^{1/2}$
							$= [0.3(260)(4)/2.6 \times 10^{-4}]$ = 1095 ft
							= 1100 ft (rounded)

T Transmissivity in gallons per day pe

S = Storage coefficient.

b = Aquifer thickness.

k = Hydraulic conductivity.

t = Duration of pumping test.

r_e = Effective radius or zone of influence of pumping test.

B.3 AQUIFER TEST M #2

M aquifer test #2 was conducted in the western portion of the M ore zone in mining unit VI on July 21, 1980. Water was withdrawn from pumping well MM6 at an average discharge rate of 1.88 L/s (29.8 gpm) for 96 h, and water-level responses in the M aquifer were measured at two monitor wells: MM8 and MM9. Water-level responses in the overlying N aquifer and underlying basal aquifer were monitored at wells NM3 and BM2, respectively.

The top of the M aquifer in the test area is approximately 94 m (310 ft) below land surface; wells used in the test were completed from 109 to 118 m (359 to 387 ft) and fully penetrated the 20-m-thick (65-ft) aquifer.

The average transmissivity and hydraulic conductivity calculated by the applicant for the M aquifer in the area of aquifer test M #2 are 3.63 m^2/d (292 gpd/ft) and 0.18 m/d (4.49 gpd/ft^2) (Table B.1).

The applicant has determined that the M aquifer is nonleaky and contains no discontinuities in permeability within the radius of influence of the M #2 aquifer test.

B.4 AQUIFER TEST M #3

M aquifer test #3 was conducted in the eastern portion of the M ore zone in mining unit IV on July 29, 1980. Water was withdrawn from pumping well MM10 at an average discharge rate of 1.66 L/s (26.3 gpm) for 96 h, and water-level responses in the M aquifer were measured at three monitor wells: MM3, MM4, and MM7. Water-level responses in the overlying N aquifer and underlying basal aquifer were monitored at wells NM4 and BM1, respectively.

The top of the M aquifer in the test area is approximately 107 m (350 ft) below land surface; the wells used in the tests are completed from 118 to 126 m (387 to 412 ft) and fully penetrated the 18-m-thick (60-ft) aquifer.

The average transmissivity and hydraulic conductivity calculated by the applicant for the M aquifer in the area of aquifer test M #3 are 3.24 m^2/d (262 gpd/ft) and 0.18 m^2/d (4.39 gpd/ft^2), respectively (Table B.1).

The applicant's analyses of the drawdown data using the Cooper-Jacob straight-line method indicate the possible existence of a barrier boundary coinciding with the thinning of the M aquifer east of mining unit IV. The applicant has determined that the M aquifer is nonleaky and contains no discontinuities in permeability with the radius of influence of the M #3 aquifer test.

B.5 STAFF INDEPENDENT EVALUATION

Equations for modeling aquifer behavior are for radial flow into wells having constant drawdown or constant discharge. If basic assumptions about the nature of the aquifer are correct, solutions to the equations can be considered accurate only after every attempt has been made to satisfy the conditions for which the equations are suited. Data derived from aquifer tests where the discharge from the pumping well is not maintained at a reasonably constant rate will deviate significantly from the type curve representing an accurate solution to the flow equation.

Discharge data submitted by the applicant for aquifer test M #1 show that the pumping rate varied significantly during the test from a high of 4.20 L/s (66.5 gpm) through the first 6 min of the test, declining steadily to 2.52 L/s (40 gpm) near the conclusion of the pumping period; after 139 min, the pump was turned off for 8 min. These pumping rate variations appear as numerous aberrations in the drawdown data from the theoretical type curve used by the applicant to determine aquifer characteristics. Therefore, the NRC staff has determined that the M #1 aquifer test was not conducted meticulously enough to yield other than rough approximations of aquifer transmissivity and storage and that the results should not be used to evaluate the degree of aquifer confinement.

After comparing all drawdown data to the type curves for the Modified Hantush leaky-aquifer solution, the applicant determined that no vertical connections existed between aquifers at the project site. However, the NRC staff feels that drawdown curves for the observation wells of the N #1 aquifer test exhibit a reasonably close degree of fit to type curves of the Modified Hantush, indicating that not all water withdrawn during the test was from storage within the N aquifer. The Modified Hantush solution for leaky aquifers takes into account storage of water in the semipervious confining bed(s); however, when two semipervious confining beds are involved, as in the case of the N aquifer, it is impossible to determine the hydraulic properties of individual confining units. Modified Hantush solutions can give values for aquifer transmissivity and storage that are many times smaller than the values given when the Theis solution is applied to the same data.[1] Values of N aquifer transmissivity and storage calculated by the NRC staff using the Modified Hantush method are approximately one-half those calculated by the applicant using the Theis solution (Table B.2) and nearly equal to those of the M aquifer.

Drawdown data from the M #2 and M #3 aquifer tests can be fitted to type curves of the Modified Hantush solution with much less certainty, indicating that the M aquifer exhibits a greater degree of confinement.

Water-level responses in respective over- and underlying aquifers to pumping during the four aquifer tests were limited to fluctuations of less than 0.2 m and were only slightly greater than recorded changes in barometric pressure. However, water yielded by a leaky artesian aquifer

Table B.2. Comparison of N #1 aquifer test results using the Theis Method vs the Modified Hantush Method

Well No.	Theis Transmissivity m^2/d	Theis Transmissivity gpd/ft	Theis Storage	Modified Hantush Transmissivity m^2/d	Modified Hantush Transmissivity gpd/ft	Modified Hantush Storage
317 (pumping well)	10.22	823				
313	7.58	610	6.4×10^{-5}			
319	8.19	659	7.4×10^{-5}	2.92	235	2.0×10^{-5}
320	8.41	677	8.5×10^{-5}	3.07	247	1.7×10^{-5}
572	10.06	810	1.7×10^{-5}	3.84	309	2.4×10^{-6}
573	8.77	706	7.0×10^{-5}	4.70	378	4.4×10^{-5}
574	9.02	726	2.1×10^{-5}	3.40	274	3.1×10^{-5}

may be derived largely, if not entirely, from storage in the confining units(s).[1] Therefore, small fluctuation in water levels in over- and underlying aquifers occurring during aquifer pumping tests of relatively short duration cannot be used as conclusive evidence that the system is nonleaky.

Although the applicant's calculations show the aquifers to have no major direction of transmissivity, the tests, with respect to the number and placement of observation wells, were poorly designed for accurately determining aquifer anisotropy.

B.6 CONCLUSIONS

Although there are some problems with the applicant's aquifer tests and data analysis, some basic information about the ore zone aquifers is apparent. It appears that the N and M aquifers have similar hydraulic properties with approximately equal transmissivities and the storage coefficients [3.7 m^2/d (300 gpd/ft) and 1 x 10^{-4}]; however, the N aquifer apparently exhibits a somewhat lesser degree of confinement. There also appears to be no natural of manmade pathways (faults, fractures, abandoned boreholes, etc.) through the confining units for significant amounts of fluid to migrate between aquifers.

On the basis of the results of the aquifer tests conducted by the applicant, and because there is no history of vertical excursions at the applicant's R&D solution mining facility, the staff concludes that there is probably adequate confinement of the ore bodies within the project area. However, because the aquifer tests were not well suited for determining aquifer anisotropy and because the test results are, to some degree, inconclusive with respect to ore zone confinement, the NRC staff

concurs with and will require as a license condition the applicant's proposal to perform an additional aquifer test in each mining unit as described in Sect. 4.2 to verify ore zone confinement. These tests will be designed, with NRC approval, to supply data for evaluating anistropic properties of the ore zone aquifers and hydraulic characteristics of the confining units.

REFERENCE FOR APPENDIX B

1. S. W. Lohman, *Groundwater Hydraulics*, U.S. Geological Survey Professional Paper 708, 1972.

Appendix C

RADON RELEASES FROM IN SITU OPERATIONS

This appendix describes the assumptions, data, and equations used to estimate the annual radon-222 released from the solution-mining and restoration processes. The parameters used in the radon release calculations were based on the data submitted by the applicant.[1,2] (Where different values for the two ore zones were provided, averages are based on percentage of usage.) The principal parameters are listed below:

Average acres to be mined per year	10
Average production flow rate, gpm	1500
Average restoration flow rate, gpm	200
Operating days per year	365
Formation porosity, %	26
Average ore thickness, ft	12.5
Rock density, g/cm^3	1.84
Residence time for production solution, d	7
Equilibrium value for radon for 7 d, %	69
Residence time for restoration solution, d	14
Equilibrium value for radon for 14 d, %	87

The staff assumed for this analysis that one mining unit will be mined, one unit soaked, and one unit restored during the course of a calendar year. This scenario was chosen to represent the worst-case annual emissions.

C.1 RADON RELEASE FROM MINING AND SOAKING

For uranium-238 in equilibrium with all its daughters, an ore-body concentration of 246.8 pCi/g of radon is estimated for an average ore grade of 0.087%. One cubic foot of ore contains

$$28{,}300\ cm^3/ft^3 \times 1.84\ g/cm^3 \times (1 - 0.26) \times 246.8\ pCi/g$$

$$\times 1 \times 10^{-12}\ Ci/pCi = 9.51 \times 10^{-6}\ Ci/ft^3\ .$$

The radon activity in the pore water is based on an emanation coefficient of 0.20 of radon into the ore pore space[3] (26% of the ore). Thus, the pore water contains:

$$\frac{9.51 \times 10^{-6}\ Ci/ft^3}{0.26} \times 0.20 = 7.32 \times 10^{-6}\ Ci/ft^3$$

of radon at equilibrium. The radon release from a production flow of 1500 gpm is calculated as

$$1500 \text{ gal/min} \times 8 \text{ lb/gal} \times \frac{1}{62.4 \text{ lb/ft}^3} \times 1440 \text{ min/d} \times 365 \text{ d/year}$$

$$\times 7.32 \times 10^{-6} \text{ Ci/ft}^3 = 740 \text{ Ci/year},$$

where 365 d/year is the number of days of annual operation.

For the pregnant leach solution, it is estimated that approximately 69% of the radon-222 remains undecayed at the time the leach solution is depressurized by release into the production fluid surge tanks before processing for uranium removal. The annual radon release per mining unit is then calculated to be

$$740 \text{ Ci/year} \times 0.69 = 511 \text{ Ci/year} .$$

In addition to the release of radon from the production solution, it is estimated that one pore volume of nonproduction water will be removed as each 10 acres of mining unit is put into service over the 10 acres. The radon release from a nonproductive source resulting from this start-up procedure is as follows:

$$10 \text{ acres/year} \times 43{,}560 \text{ ft}^2\text{/acre} \times 12.5 \text{ ft} \times 0.26 \times 7.32 \times 10^{-6} \text{ Ci/ft}^3$$

$$= 10 \text{ Ci/year},$$

where 12.5 ft is the average thickness of the ore bodies and 0.26 is the assumed formation porosity.

For the mining unit that will be soaked during the year, it is assumed that one pore volume of mining solution will be removed when the lixiviant is added. Thus an additional 10 Ci/year is released from soaking.

The total release of radon from mining and soaking operations is:

Start-up solution	10 Ci/year
Production	511 Ci/year
Soaking solution	10 Ci/year
Total	531 Ci/year

C.2 RADON RELEASE FROM RESTORATION

The applicant proposes to start restoration of the aquifer during the second year of operation at a pumping rate of 200 gpm. For the restoration procedure, the radon release is calculated to be

$$200 \text{ gal/min} \times 8 \text{ lb/gal} \times \frac{1}{62.4 \text{ lb/ft}^3} \times 1440 \text{ min/d} \times 365 \text{ d/year}$$

$$\times 7.32 \times 10^{-6} \text{ Ci/ft}^3 \times 0.87 = 86 \text{ Ci/year},$$

where 0.87 is the estimated degree of radon equilibrium.

In addition it is assumed that one pore volume of solution will be removed before restoration begins. The total release of radon from restoration procedures is:

Start-up solution	10 Ci/year
Restoration solution	86 Ci/year
Total from restoration	96 Ci/year

C.3 RADON RELEASE FROM THE LEUENBERGER PONDS

Radium solids are not leached in sufficient quantities to produce significant amounts of radon in the waste liquids; therefore radon emission from the Leuenberger ponds is negligible.

C.4 SUMMARY

The total radon release from the Teton in-situ facility for a model year, when one mining unit is mined, one unit soaked, and one unit restored is as follows:

Release from production	531 Ci/year
Release from restoration	96 Ci/year
Maximum release	627 Ci/year

REFERENCES FOR APPENDIX C

1. UNC Teton Exploration Drilling Company and NEDCO Power Company, *Source Material License Application for Uranium In Situ Leaching*, Leuenberger Site, Converse County, Wyoming, Docket No. 40-8781, October 1980. Docket No. 40-8781

2. United Nuclear Corporation Teton Exploration Drilling, Inc., *NRC Review Comment for the Source Material License at the Leuenberger Site*, Docket No. 40-8781, August 1981.

3. C. M. Jensen, K. K. Nielson, R. F. Overmyer, K. M. Putzig, V. C. Rogers, and B. W. Sermon, Argonne National Laboratory and Ford, Bacon and Davis Utah, Inc., "Characterization of Uranium Tailings Cover Materials for Radon Flux Reduction," USNRC Report NUREG/CR-1081, March 1980.

Appendix D

DETAILED BASIS FOR RADIOLOGICAL ASSESSMENT

The staff's radiological impacts assessment is based on site-specific data provided by the applicant[1,2] (Table D.1) and on the models, data, and assumptions discussed in "Calculational Models for Estimating Radioactive Materials Resulting from Uranium Milling Operations," (Regulatory Guide 3.5.1, March 1982). The prediction of offsite air concentrations of radioactive materials is based on joint relative frequency data gathered from the National Weather Service Station at Casper, Wyoming over the period 1967 through 1971 (Table D.2).

Table D.1. Some parameters and conditions used in the radiological assessment of the solution-mining project

Parameter	Value
Average ore grade (U_3O_8), %	0.087
Ore activity, pCi/g	246.8
Average production flow rate, L/min (gpm)	5678 (1500)
Average restoration flow rate, L/min (gpm)	757 (200)
Stack effluent height, m	6
Mixing height (annual average), m	529.52
Land use and grazing of cattle	
Hectarage required to graze one animal unit (450 kg) for one month (AUM), ha	1.35
Fraction of year spent grazing locally, %	50
Fraction of stored feed grown locally, %	100

Table D.2. Joint relative frequency meteorological data

MPH	N	NNE	NE	ENE	E	ESE	SE	SSE
Stability Class 1								
1.5	0.0069	0.0240	0.0103	0.0240	0.0171	0.0103	0.0069	0.0411
5.5	0.0137	0.0274	0.0206	0.0069	0.0137	0.0206	0.0137	0.0617
10.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
21.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
28.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
All	0.0206	0.0514	0.0309	0.0309	0.0308	0.0309	0.0206	0.1028
Stability Class 2								
1.5	0.0554	0.0507	0.0374	0.0421	0.0960	0.0424	0.0665	0.0651
5.5	0.0959	0.1233	0.0685	0.0411	0.1233	0.1165	0.1302	0.1165
10.0	0.0685	0.0617	0.0685	0.0411	0.0617	0.0206	0.0548	0.0274
15.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
21.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
28.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
All	0.2198	0.2357	0.1744	0.1243	0.2810	0.1795	0.2515	0.2090
Stability Class 3								
1.5	0.0186	0.0133	0.0115	0.0118	0.0366	0.0186	0.0127	0.0037
5.5	0.0959	0.1370	0.0959	0.1028	0.1781	0.0959	0.1233	0.0822
10.0	0.2535	0.1850	0.1576	0.1713	0.2329	0.1918	0.1233	0.0822
15.5	0.0274	0.0137	0.0137	0.0137	0.0343	0.0343	0.0137	0.0000
21.5	0.0000	0.0069	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
28.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
All	0.3954	0.3559	0.2787	0.2996	0.4819	0.3406	0.2730	0.1681
Stability Class 4								
1.5	0.0792	0.1053	0.0854	0.0741	0.0598	0.0592	0.0548	0.0268
5.5	0.5412	0.5823	0.4453	0.3220	0.4110	0.3220	0.1918	0.1302
10.0	1.1440	1.4249	1.0207	0.8768	0.9248	0.4932	0.3014	0.1370
15.5	1.1097	1.4865	1.0275	0.6508	1.0001	0.5480	0.1987	0.0548
21.5	0.2809	0.3768	0.1713	0.0617	0.2261	0.0822	0.0411	0.0137
28.0	0.1028	0.1028	0.0274	0.0000	0.0137	0.0069	0.0000	0.0000
All	3.2578	4.0786	2.7776	1.9854	2.6355	1.5115	0.7878	0.3625
Stability Class 5								
1.5	0.3723	0.1668	0.1431	0.1104	0.1608	0.1124	0.0635	0.0583
5.5	1.1098	0.8974	0.6439	0.5480	0.6234	0.3563	0.3083	0.1919
10.0	0.3425	0.3014	0.2809	0.2877	0.4042	0.3083	0.1165	0.0480
15.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
21.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
28.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
All	1.8246	1.3656	1.0679	0.9461	1.1884	0.7770	0.4883	0.2982
Stability Class 6								
1.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
21.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
28.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
All	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
All	5.7182	6.0872	4.3295	3.3863	4.6176	2.8395	1.8212	1.1406

Table D.2. Joint relative frequency meteorological data (Cont'd.)

S	SSW	SW	WSW	W	WNW	NW	NNW	Totals
0.0137	0.0206	0.0240	0.0240	0.0377	0.0171	0.0206	0.0103	0.3086
0.0069	0.0206	0.0069	0.0274	0.0548	0.0343	0.0000	0.0206	0.3498
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0206	0.0412	0.0309	0.0514	0.0925	0.0514	0.0206	0.0309	0.6584
0.0977	0.0410	0.0618	0.0445	0.1126	0.0402	0.0208	0.0644	0.9386
0.2124	0.1028	0.1576	0.1370	0.1370	0.0959	0.0548	0.1096	1.8224
0.0548	0.0685	0.0822	0.1096	0.1781	0.0685	0.0754	0.0822	1.1236
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.3649	0.2123	0.3016	0.2911	0.4277	0.2046	0.1510	0.2562	3.8846
0.0282	0.0186	0.0186	0.0292	0.0179	0.0273	0.0320	0.0028	0.3014
0.1507	0.0959	0.0959	0.1713	0.2398	0.1302	0.0754	0.0617	1.9320
0.1233	0.1987	0.3699	0.6439	0.4727	0.2261	0.1644	0.1576	3.7542
0.0343	0.0959	0.2055	0.1713	0.1918	0.0343	0.0411	0.0685	0.9935
0.0137	0.0069	0.0343	0.0343	0.0411	0.0206	0.0000	0.0000	0.1578
0.0000	0.0000	0.0069	0.0137	0.0069	0.0000	0.0000	0.0000	0.0275
0.3502	0.4160	0.7311	1.0637	0.9702	0.4385	0.3129	0.2906	7.1664
0.0548	0.0336	0.0411	0.0530	0.0679	0.0816	0.0430	0.1009	1.0205
0.1918	0.1233	0.2055	0.3357	0.3357	0.2398	0.1439	0.4521	4.9736
0.2124	0.6302	1.4180	2.1304	1.7468	0.5412	0.5206	0.5001	14.0225
0.3699	3.0826	6.5420	5.1993	1.9318	0.9453	0.5891	0.4042	25.1403
0.1781	2.6716	5.0075	2.2126	0.9248	0.4042	0.2398	0.1028	12.9952
0.0411	1.4797	2.2469	0.9727	0.5206	0.1165	0.0411	0.0343	5.7065
1.0481	8.0210	15.4610	10.9037	5.5276	2.3286	1.5775	1.5944	63.8586
0.1221	0.1124	0.1448	0.2996	0.5746	0.2607	0.2023	0.2606	3.1647
0.3014	0.3152	0.5275	1.2741	2.0140	0.9865	0.9042	0.9933	11.9952
0.0548	0.4042	1.0892	2.8223	1.9044	0.4042	0.2466	0.2603	9.2755
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.4783	0.8318	1.7615	4.3960	4.4930	1.6514	1.3531	1.5142	24.4354
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.2621	9.5223	18.2861	16.7059	11.5110	4.6745	3.4151	3.6863	100.0034

REFERENCES FOR APPENDIX D

1. United Nuclear Corporation (UNC) Teton Exploration Drilling, Inc., *NRC Review Comment for the Source Material License Application at the Leuenberger Site*, Docket No. 40-8781, August 1981.

2. UNC Teton Exploration Drilling Company and NEDCO Power Company, *Source Material License Application for Uranium In-Situ Leaching, Leuenberger Site, Converse County, Wyoming*, Docket No. 40-8781, October 1980.

Appendix E

ASSUMPTIONS UTILIZED FOR THE SOCIOECONOMIC IMPACT ASSESSMENTS

E.1 INTRODUCTION

The staff combined information collected from a literature survey and from personal and written communications with the applicant, planners, and other authorities in the Converse/Natrona County area to develop a set of assumptions useful for analyzing the socioeconomic impacts of the proposed uranium solution-mining project. The socioeconomic environment in the affected region has, because of energy-related developments, been very dynamic; and, because of the relatively small sizes of the communities near the project site (Casper being an exception), the local economics are very sensitive to both inflow and outflow of industrial activities. Accordingly, because any of the assumptions utilized for the analyses could be erroneous in both the short and long terms, the impact assessments in Sect. 4.3.1, when quantified, should be read with caution. To account for reasonably potential variabilities, the staff calculated, when feasible, high and low ranges for quantifiable impacts. Also, although it is obvious that the proposed mining project will not exist in isolation but will combine with other energy-related developments to impact local communities, a detailed independent analysis incorporating synergistic impacts is beyond the scope of this DES.

E.2 ASSUMPTIONS

1. The staff assumed that Glenrock and Douglas in Campbell County and Casper in Natrona County, the most well-established communities within reasonable commuting distance of the project site, will absorb the vast majority of the project-induced socioeconomic impacts.

2. According to the applicant (ER, p. 150), the onsite work force will consist of approximately 50 employees. To account for feasible potentialities, it was assumed that, at most, up to 50% (25) of these employees will have to be hired from nonlocal labor pools. ("Local" labor markets were assumed to consist of the labor forces in Natrona and Converse counties.) This assumption was considered to be a worst case assumption; that is, it is possible that only a very few employees will be nonlocal. The number of workers that will be hired locally will, of course, depend on labor market conditions when the applicant needs additional employees. If the local labor markets are very tight — as has been the case in recent years when unemployment rates have been as low as 1.5% (Sect. 3.4.3) — then the applicant may have to import workers to fill job vacancies. If unemployment rates are relatively high — as was the case in 1981 because of the slumping yellowcake market — then the applicant will have to import few, if any, workers to meet employee requirements.

3. To further ensure conservatism, some of the assessments were based on two additional worst case assumptions: (a) that none of the basic workers and none of the project-induced secondary workers would come from the same family, and (b) that all unmarried in-migrating workers would require separate residences.

4. It was estimated that each operation job will induce approximately 1.2 to 1.85 secondary jobs. The 1.2 multiplier was taken from ref. 1; the 1.85 multiplier was calculated from economic base theory[2-5] and county business patterns.

5. It was assumed that, at most, 10 to 25% of the secondary workers will be nonlocal. On the bases of the sizes of the local labor pools, the composition of the work forces, and unemployment statistics, this assumption appears to be reasonable.[6,7]

6. It was assumed that all (basic and secondary) of the married in-migrating workers will bring their families with them.[8]

7. It was assumed that 25% of the in-migrating workers will be unmarried.[8]

8. It was assumed that the family size for all married in-migrating workers will average approximately 3.5 (2 adults and 1.5 children) and that approximately 60% of the in-migrating children will be school age.[8]

9. To determine settlement patterns, it was assumed that all of the in-migrating onsite employees and all of the in-migrating secondary workers will choose to reside in and near Glenrock and Douglas in Converse County and in and near Casper in Natrona County. Considering (1) the distances of these communities from the project site and (2) their relative sizes (comparative populations) and utilizing a population "gravity" model,[8,9] the staff estimated that approximately 13 to 30% of the in-migrating onsite (basic) workers will choose to reside in the Glenrock area, approximately 10% in the Douglas area, and approximately 61 to 77% in the Casper area. Similarly, the staff estimated that approximately 42 to 56% of the in-migrating secondary (project-induced) workers will choose to reside in Glenrock, approximately 6 to 8% in the Douglas area, and approximately 38 to 50% in the Casper area.

10. To determine facility-induced personal income, the staff utilized payroll estimates provided by the applicant, basic economic consumption theory, and the results of payroll and consumption research on similar projects.[1,8] The staff estimates that each dollar of operation payroll will generate approximately $1.25 to $1.50 of income in the local economics.

11. The water usage estimates were based on estimated project-induced population inflows and the assumption that peak per capita water usage will range from approximately 948 L/d (250 gpd) to 1100 L/d (300 gpd).

REFERENCES FOR APPENDIX E

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2. E. J. Stenehjem and J. E. Metzger, *A Framework for Protecting Employment and Population Changes Accompanying Energy Development,* Report ANL/AA-14, Argonne National Laboratory, Argonne, Ill., May 1980.

3. G. E. Thompson, "An Investigation of the Local Employment Multiplier," *Rev. Econ. Stat.* 41: 61-67 (1959).

4. G. H. Hildebrand and A. Mare, Jr., "The Employment Multiplier in an Expanding Industrial Market: Los Angeles County, 1940-47," *Rev. Econ. Stat.* 32: 241-249 (1950).

5. K. Sasaki, "Military Expenditures and the Employment Multiplier in Hawaii," *Rev. Econ. Stat.* 45: 298-304 (1963).

6. Wyoming Employment Security Commission, Research and Analysis Section, "Wyoming Annual Average Labor Force, 1970-79," Casper, Wyo., undated.

7. Wyoming Employment Security Commission, Research and Analysis Section, "Wyoming Covered Employment and Wage Data by Industry and County, 1977-1979," Casper, Wyo., undated.

8. Mountain West Research, Inc., *Construction Worker Profile: Final Report,* Washington, D.C., December 1975.

9. F. L. Leistritz and S. H. Murdock, "Research Methodology Applicable to Community Adjustment to Public Land Use Alternatives," presented at the Forum on the Economics of Public Land Use in the West, Reno, Nev., March 1977.

Appendix F

EVALUATION OF APPLICANT'S M ORE ZONE RESTORATION TEST

F.1 INTRODUCTION

Under Source Material License SUA-1373, covering the research and development activities at the Leuenberger Site, the applicant is required to submit a final M ore zone well field restoration report for NRC staff evaluation. The purpose of the report is to demonstrate that groundwater quality in the M well field area is restored to its premining use condition — that each groundwater constituent is returned to its baseline concentration or to within the Wyoming Department of Environmental Quality (WDEQ) class I (domestic) water quality standard (premining use as determined by the WDEQ-Water Quality Division) using best existing technology.

This evaluation is based on data submitted by the applicant in their Leuenberger R&D Project final M ore zone restoration report and in quarterly reports submitted to the NRC as required by Source Material License SUA-1373, covering the periods July-September and October-December, 1982.[1,2] When Teton determined restoration was complete, they were required by license to sample nine M well field wells, representative of the three M ore zone test patterns, for a full set of water quality indicators to verify that restoration was achieved. This sampling was followed by six monthly samples and two successive quarterly samples to determine the stability of well field water quality. Wells sampled were MR-1, MR-3, MR-5, MI-1, MI-6, MI-10, 302, 306, and 308. Wells MI-2, MI-3, MI-4, MI-8, and MI-12 were included in the final restoration stability sampling schedule to ensure that no affected areas remained that were not completely restored. Locations of the wells relative to their positions within the M well field are shown in Fig. 4.1 (see Sect. 4.2 — AMENABILITY OF THE ORE DEPOSIT TO IN SITU LEACHING).

F.2 RESTORATION PROCESSES

Restoring the M well field began immediately upon terminating injection of lixiviant on February 25, 1981, and continued until December 20, 1981. The restoration verification sample was taken on January 8, 1982. To restore the three test pattern well fields, Teton employed a directional sweep approach designed to be effective at recapturing solutions from affected areas beyond the well field along the major axis of ore-zone-aquifer transmissivity. The technology applied to restoring the M well field also incorporated the following processes: (1) filtration of recovered solutions, (2) ion exchange (IX) to lower residual uranium concentrations, (3) reversing polarity electrodialysis (ED) to concentrate constituents

from a portion of the IX effluent into a reduced volume and to dilute concentrations in the untreated IX effluent with the "purified" ED product, and (4) reinjection of diluted solution into the well field area to improve overall groundwater quality.

During restoration contaminated groundwater was removed from the well field and passed through IX at an average rate of 197 L/min (52 gpm) of which 95 L/min (25 gpm) were sent to the ED unit for further treatment. The ED unit successfully concentrated 89.4% of the dissolved solids into a brine that was transferred to the evaporation ponds at a rate of 15.2 L/min (4 gpm). The 79 L/min (21 gpm) treated ED product was mixed with the remaining 102 L/min (27 gpm) of untreated water and reinjected. At the conclusion of restoration, 8.54×10^4 m^3 (22.6×10^6 gal) or 23.3 pore volumes of contaminated groundwater were recovered, of which 46% or 3.97×10^4 m^3 (10.5×10^6 gal) were treated by the ED unit, 6.43×10^3 m^3 (1.7×10^6 gal) or 1.8 pore volumes were ponded as waste water, and 7.76×10^4 m^3 (20.5×10^6 gal) or 21.5 pore volumes of improved water were reinjected. The overall restoration technique was better than 90% effective in conserving groundwater.

F.3 RESTORATION DATA EVALUATION

All restoration and postrestoration stability monitoring data for each round of samples have been reviewed to determine the degree of restoration and stability of water quality. Peak and average concentrations of each indicator were compared with peak and average baseline concentrations as well as to Wyoming DEQ class I (domestic) water quality standards. Tables F.1–F.3 are a compilation of pertinent water quality data for the M ore zone restoration monitoring wells showing water quality of the M well field at the completion of restoration (Table F.1), six months into postrestoration (Table F.2), and one year after restoration (Table F.3). Based on the staff's review of all data submitted by Teton, the following water quality indicators are considered adequately restored because their concentrations have consistantly remained (1) below detection limits (detection limits were always below the Class I standard or baseline, whichever is lower), (2) below average baseline concentrations, or (3) below the WDEQ class I (domestic) standards.

chloride[a]	boron[a,b]	nickle[c]
sulfate[a,b]	cadmium[c]	nitrogen[a,b]
calcium[b]	chromium[c]	selenium[c]
magnesium[b]	copper[c]	vanadium[c]
potassium[b]	fluoride[a,b]	zinc[c]
uranium[a]	lead[c]	aluminum[c]
ammonium[a,b]	mercury[c]	iron[b]
barium[c]	molybdenum[c]	TDS[a]

[a]Restored concentrations consistently below WDEQ class I (domestic) standard.

[b]Restored concentrations consistently below average baseline concentration.

[c]Restored concentrations below detection limits.

Table F.1. Water quality data from representative M well field ore zone wells at the completion of restoration, January 8, 1982

Parameter sampled	Well number									Mean	Baseline mean
	MI-1	MI-6	MI-10	MR-1	MR-3	MR-5	301	306	308		
HCO_3^- mg/L	93	240	236	244	268	268	211	281	211	228 ± 56.2	223 ± 27.9
$CO_3^=$ mg/L	0	0	0	0	0	0	0	0	0	0 ± 0	0 ± 0
Cl mg/L	NA*	8	6	7	8	9	6	8	NA*	5.8 ± 3.4	5.7 ± 2.0
$SO_4^=$ mg/L	28	77	82	82	82	82	84	135	280	103.6 ± 71.4	128.9 ± 65.5
Anion eq.	2.11	5.76	5.74	5.91	6.34	6.36	5.38	7.50	9.28	6.04 ± 1.90	6.50 ± 1.32
Ca^{++} mg/L	15	54	44	40	42	43	45	85	123	54.6 ± 31.4	70.5 ± 13.4
Mg^{++} mg/L	3	4	10	11	10	10	6	20	20	10.4 ± 6.1	18.6 ± 7.3
Na^+ mg/L	23.0	59	61	64	74	72	57	32	32	52.7 ± 18.8	27.0 ± 1.9
K^+ mg/L	2	5	5	5	6	6	5	7	9	5.6 ± 1.9	8.9 ± 1.1
Cation eq.	2.14	5.72	5.80	5.81	6.29	6.25	5.35	7.45	9.40	6.02 ± 1.91	6.47 ± 1.30
−/+ balance	98.60	100.70	98.97	101.72	100.95	101.76	100.56	100.67	98.72	100.25 ± 1.23	100.47 ± 1.35
Sum TDS	166	447	444	453	490	490	414	568	675	460.8 ± 136.3	482.6 ± 85.2
Cond μm/cm	240	500	490	500	540	550	470	600	750	515.6 ± 133.7	538 ± 102
TDS mg/L	119	328	324	339	358	364	311	428	569	348.9 ± 117.5	381 ± 108
pH unit	7.44	7.17	7.32	7.02	7.12	7.02	7.45	7.84	7.88	7.36 ± 0.32	7.6 ± 0.2
U mg/L	0.007	0.036	0.015	0.007	0.002	0.005	0.008	0.093	0.004	0.020 ± 0.029	<0.10
Alk mg/L	77	197	193	200	220	220	173	230	173	187 ± 45.9	182.8
Al mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.14 ± 0.18
NH_4^+ mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.24 ± 0.35
As mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.009 ± 0.010
Ba mg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.50
B mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.25
Cd mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.05
Cr mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.10
Cu mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05
F mg/L	0.27	0.30	0.30	0.30	0.33	0.27	0.30	0.57	0.65	0.37 ± 0.14	0.49 ± 0.05
Fe mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.60 ± 0.56
Pb mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04 ± 0.05
Mn mg/L	0.01	0.01	0.01	0.02	0.03	0.02	0.02	<0.01	0.02	0.016 ± 0.008	0.08 ± 0.04
Hg mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.001 ± 0.0005
Mo mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.50
Ni mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05
NO_2/NO_3 mg/L	<0.05	0.30	0.10	0.10	0.10	<0.05	0.10	<0.05	<0.05	0.10 ± 0.08	0.20 ± 0.12
Se mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.006 ± 0.004
V mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<1.0
Zn mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.092 ± 0.110
Ra^{226} pCi/L	75 ± 5	326 ± 10	199 ± 8	391 ± 11	18.6 ± 2.4	215 ± 8	709 ± 15	1229 ± 20	13.1 ± 2.1	352.9 ± 394.3	235.96 ± 335.4

*Not available.

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Table F.2. Water quality data from representative M well field ore zone wells six months after the completion of restoration, June 1982

Parameter sampled	Well number									Mean	Baseline mean
	MI-1	MI-6	MI-10	MR-1	MR-3	MR-5	301	306	308		
HCO_3^- mg/L	202.3	246.7	250.1	278.2	274.0	272.1	219.6	305.5	211.8	251.1 ± 34.6	223
$CO_3^=$ mg/L	0	0	0	0	0	0	0	7.2	9.8	1.9 ± 3.8	0
Cl mg/L	6.1	8.1	8.3	8.3	9.2	10.0	7.4	8.1	2.3	7.5 ± 2.2	5.7
$SO_4^=$ mg/L	58.5	82.9	84.9	96.6	88.8	94.6	97.6	122.9	304.4	114.6 ± 73.1	128.9
Anion eq.	4.71	6.00	6.10	6.81	6.60	6.71	5.84	8.04	10.21	6.78	6.50
Ca^{++} mg/L	39	48	47	54	47	48	47	92	127	61 ± 29	70.5
Mg^{++} mg/L	7.3	11.9	11.4	11.9	10.3	11.4	11.6	22.1	26.0	13.8 ± 6.1	18.6
Na^+ mg/L	47.6	58.9	64.2	67.2	72.5	74.8	52.2	28.0	25.0	54.5 ± 18.2	27.0
K^+ mg/L	5.6	5.8	5.9	6.8	7.6	7.6	6.4	8.3	10.2	7.1 ± 1.5	8.9
Cation eq.	4.77	6.10	6.24	6.79	6.56	6.80	5.75	7.87	9.87	6.75	6.47
−/+balance	98.65	98.34	97.76	100.29	100.70	98.77	101.60	102.10	103.45	100.40	100.47
Sum TDS	366	462	472	523	509	519	442	594	717	512	482.6
Cond μm/cm	484	582	583	652	621	638	564	725	898	639 ± 118	538
TDS mg/L	292	344	338	378	360	376	338	442	622	388 ± 97	381
pH unit	7.70	7.52	7.62	7.46	7.55	7.48	7.58	8.24	8.26	7.71 ± 0.31	7.6
U mg/L	0.49	0.35	0.29	0.23	0.07	0.16	0.42	1.25	0.06	0.37 ± 0.36	<0.10
Alk mg/L	165.8	202.2	205.0	228.0	224.6	223.0	180.0	262.4	190.0	209 ± 29.1	182.8
Al mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.14
NH_4^+ mg/L											0.24
As mg/L	0.006	0.048	0.017	0.053	<0.005	0.021	0.029	0.007	<0.005	≤0.021 ± 0.019	0.009
Ba mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.50
B mg/L	0.19	0.17	0.28	0.10	0.06	0.19	0.14	0.07	0.14	0.15 ± 0.07	<0.25
Cd mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05
Cr mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.10
Cu mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
F mg/L	0.27	0.30	0.24	0.27	0.22	0.24	0.36	0.45	0.74	0.34 ± 0.17	0.49
Fe mg/L	<0.05	0.15	0.10	0.47	<0.05	<0.05	0.22	<0.05	<0.05	≤0.13 ± 0.14	0.60
Pb mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05
Mn mg/L	0.06	0.10	0.10	0.14	0.08	0.09	0.08	0.08	0.09	0.09 ± 0.02	0.08
Hg mg/L	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0011
Mo mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.50
Ni mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
NO_2/NO_3 mg/L	0.10	0.10	<0.05	<0.05	0.15	0.08	<0.05	0.08	<0.05	0.08 ± 0.03	0.20
Se mg/L	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	≤0.0012 ± 0.0007	0.006
V mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<1.0
Zn mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.092
Ra^{226} pCi/L	124 ± 6	257 ± 9	109 ± 8	132 ± 12	16 ± 2	175 ± 8	564 ± 14	748 ± 16	37 ± 4	240 ± 250	236

Table F.3. Water quality data from all M well field ore zone wells 12 months from the completion of restoration, December 20–21, 1982

Parameter sampled	Well number							
	MI-1	MI-2	MI-3	MI-4	MI-6	MI-8	MI-10	MI-12
HCO_3^- mg/L	264	269	281	271	248	287	202	287
$CO_3^=$ mg/L	8.9	0	0	0	0	0	5.3	0
Cl mg/L	8.5	7.1	8.9	10.2	7.9	7.3	7.3	9.3
$SO_4^=$ mg/L	91	187	88	93	105	119	249	101
Anion eq.	6.76	8.51	6.69	6.67	6.48	7.39	8.74	7.07
Ca^{++} mg/L	53.9	68.2	48.4	48.7	53.9	82.5	102.3	57.2
Mg^{++} mg/L	12.6	15.9	11.2	12.0	14.1	22.9	24.6	14.5
Na^+ mg/L	71.4	84.0	79.8	75.6	58.8	30.8	31.9	69.3
K^+ mg/L	6.3	7.7	7.2	6.9	6.2	8.1	9.1	9.6
Cation eq.	7.01	8.58	7.01	6.90	6.59	7.58	8.79	7.33
−/+balance	96.42%	99.08%	95.48%	96.65%	98.34%	97.49%	99.49%	96.50%
Sum TDS	517	639	525	517	434	558	627	548
Cond μm/cm	642	804	637	648	624	689	804	654
TDS mg/L	372	492	354	368	364	416	542	336
pH unit	8.34	7.99	8.00	7.64	7.67	8.01	8.09	7.73
U mg/L	0.03	0.31	0.10	0.23	1.41	1.15	0.20	1.00
U fl. mg/L	0.029	0.314	0.087	0.220	1.526	1.187	0.061	1.187
Al mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.06
NH_4^+ mg/L	0.11	<0.05	<0.05	0.12	0.12	<0.05	<0.05	<0.05
As mg/L	0.006-<0.001	0.060-0.058	0.012-0.012	0.031-0.023	0.031-0.022	<0.005-<0.001	<0.005-<0.001	<0.005-<0.001
Ba mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
B mg/L	0.29	0.18	0.26	0.24	0.16	0.10	0.08	0.12
Cd mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cr mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cu mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
F mg/L	0.22	0.22	0.22	0.27	0.27	0.40	0.51	0.20
Fe mg/L	<0.05	0.63	<0.05	0.19	0.29	<0.05	<0.05	<0.05
Pb mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Mn mg/L	<0.05-0.03	0.20-0.19	0.06-0.04	0.07-0.04	0.07-0.05	0.06-0.03	<0.05-0.03	<0.05-0.03
Hg mg/L	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Mo mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Ni mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
NO_2/NO_3 mg/L	0.03	0.02	0.05	0.01	0.01	0.01	0.01	0.03
Se mg/L	<0.005-0.002	<0.005-0.004	<0.005	<0.005-0.003	<0.005-0.001	<0.005-<0.001	<0.005-<0.001	<0.005-<0.001
V mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Zn mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ra^{226} pCi/L	206 ± 8	706 ± 26	27 ± 5	93 ± 10	673 ± 26	832 ± 29	12.4 ± 3.5	91 ± 9
Alk mg/L	231	221	230	222	203	235	174	235

*Not available.

Table F.3. continued

Parameter sample	Well number						Mean	One standard deviation
	MR-1	MR-3	MR-5	301	306	308		
HCO_3^- mg/L	188	203	166	235	279	232	243.7	±40.1
$CO_3^=$ mg/L	0	0	0	0	0	0	1.0	±2.7
Cl mg/L	1.7	8.5	4.5	7.7	8.3	8.3	7.5	±2.1
$SO_4^=$ mg/L	308	148	56	82	104	82	129.5	±71.5
Anion eq.	9.55	6.65	4.01	5.78	7.00	5.75	6.93	NA*
Ca^{++} mg/L	108.9	57.2	30.8	44.0	52.8	44.0	60.9	±22.4
Mg^{++} mg/L	28.5	14.5	7.9	11.4	13.4	11.3	15.3	±5.9
Na^+ mg/L	35.7	60.9	44.0	60.9	73.5	62.7	60.0	±17.8
K^+ mg/L	7.5	5.5	3.5	5.7	6.9	5.6	6.8	±1.6
Cation eq.	9.61	6.86	4.20	5.94	7.13	6.01	7.10	NA*
−/+balance	99.86%	96.99%	95.57%	97.21%	98.23%	95.58%	97.60	NA*
Sum TDS	679	498	313	447	539	446	520.3	±94.1
Cond μm/cm	877	648	405	467	666	553	651	±125
TDS mg/L	572	366	198	310	376	308	383.9	±97.4
pH unit	7.90	7.58	7.50	7.62	7.92	7.59	7.83	±0.24
U mg/L	0.92	1.95	0.25	0.31	0.03	0.19	0.58	±0.60
U fl. mg/L	1.039	2.162	0.271	0.365	0.044	0.178		
Al mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	≤0.051	±0.003
NH_4^+ mg/L	0.11	0.12	0.17	0.15	0.13	0.18	≤0.104	±0.047
As mg/L	0.012-0.015	0.026-0.015	0.082-0.032	0.078-0.034	0.014-0.012	0.095-0.010	≤0.033	±0.032
Ba mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	≤0.10	NA*
B mg/L	0.25	0.24	0.38	0.27	0.27	0.25	0.22	±0.08
Cd mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	≤0.01	NA*
Cr mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NA*
Cu mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05	NA*
F mg/L	0.24	0.22	0.17	0.20	0.20	0.20	0.25	±0.09
Fe mg/L	0.09	0.57	0.51	0.30	<0.05	0.43	≤0.24	±0.22
Pb mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NA*
Mn mg/L	<0.05-0.04	0.07-0.03	0.13-0.09	<0.05-0.02	0.07-0.06	0.06-0.04	≤0.07	±0.04
Hg mg/L	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	NA*
Mo mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.1	NA*
Ni mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05	NA*
NO_2/NO_3 mg/L	0.08	0.05	0.05	0.11	0.03	0.01	<0.036	±0.030
Se mg/L	<0.005-<0.001	<0.005-<0.001	<0.0005-<0.001	<0.005-<0.001	<0.005-<0.001	<0.005-<0.001	<0.005	NA*
V mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	NA*
Zn mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	NA*
Ra^{226} pCi/L	436 ± 20	58 ± 21	265 ± 15	177 ± 13	126 ± 11	212 ± 14	280	±273
Alk mg/L	154	166	136	192	229	190	201.3	±33.1

Although iron concentrations reported in the last round of postrestoration sampling exceed the class I standard at several wells, it should be noted that the baseline average concentration also exceeds the standard, and the average restored iron concentration (0.24 ppm) is below the class I standard (0.30 ppm). Water quality indicators chloride, total dissolved solids (TDS), and uranium are restored to concentrations above baseline average, and in the case of uranium above baseline range; however, all are returned to concentrations below the class I standard.

F.3.1 Paramaters Requiring Further Explanation

Of the major groundwater constituents (those contributing most greatly to the TDS concentration), bicarbonate and sodium are not returned to concentrations below average baseline; sodium is above baseline range. Because the ore body was mined with a sodium carbonate/bicarbonate lixiviant, sodium and bicarbonate concentrations were severely elevated during the mining process. However, because there are no quality standards for these parameters, and their concentrations are restored to levels at which their contributions to TDS are sufficiently low to keep TDS under the 500 ppm class I standard, bicarbonate and sodium are considered restored.

Manganese concentrations during the 12-month stability monitoring period have occasionally been reported at levels exceeding both the class I standard (0.05 ppm) and the baseline average concentration (0.08 ppm). However, at last sampling the baseline average was exceeded at only 2 of the 14 wells tested. Because (1) the average restored concentration (0.07 ppm) is below the baseline average concentration, (2) the baseline average concentration exceeds the class I (domestic) standard, and (3) the peak restored concentration (0.20 ppm) meets the class II (agricultural) standard (0.20 ppm), manganese is considered restored.

At last sampling, restored arsenic levels exceeded the class I (domestic) standard (0.05 ppm) at 4 of the 14 wells tested and the baseline average concentration (0.01 ppm) at 8 wells. However, because (1) the average restored concentration at last sampling (0.033 ppm) is below the class I (domestic) standard; (2) the peak restored concentration is less than 0.1 ppm, which is below the 0.20 ppm class III (livestock) standard (next most stringent standard); and (3) in light of the overall level of restoration, arsenic is considered restored.

The average restored radium-226 concentration at last sampling (280 pCi/L) is 19% above the 236 pCi/L baseline average. However, the baseline average concentration greatly exceeds the 5 pCi/L class I standard, and restored radium-226 values reported for the year-long stability period were usually within the baseline range of values (2.4-920 pCi/L). Therefore, radium-226 is considered restored.

F.5 CONCLUSIONS

The NRC staff concludes that the applicant has adequately restored the M ore zone well field area by returning the groundwater to its highest potential premining use. Excluding bicarbonate, sodium, and radium-226, at last sampling all groundwater constituents are restored to no worse than having their average restored concentrations below either WDEQ class I (domestic) standards or baseline average concentrations. Bicarbonate and sodium are considered restored because they have no standards, and their contributions to restored TDS concentrations were small enough to keep TDS within the 500 ppm class I standard. For radium-226, the baseline average concentration greatly exceeds the class I standard and restored values were consistently within the baseline range of values.

REFERENCES FOR APPENDIX F

1. Teton-Nedco Joint Venture, Quarterly Reports for the Leuenberger Research and Development In Situ Uranium Project, April 1980 through December 1982. Docket No. 40-8728.

2. Teton-Nedco Joint Ventura, M-Zone Restoration Report for the Leuenberger Research and Development In Situ Uranium Project, August 9, 1982. Docket No. 40-8781.

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Pertains to Docket no. 40-8781

16. ABSTRACT *(200 words or less)*

This Final Environmental Impact Statement is issued by the U.S. Nuclear Regulatory Commission in response to the request by Teton Exploration Drilling, Inc. for the issuance of an NRC Source and Byproduct Material License authorizing operation of the proposed Teton Project to mine uranium in situ by injecting a carbonate/bicarbonate lixiviant into the ore body. The statement considers: (1) alternative of no licensing action, (2) alternative energy sources, and (3) alternatives if uranium ore is mined and refined on the site. The proposed action is to grant a Source and Byproduct Material License to the applicant subject to the stipulated license condition.

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